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THE MANAGEMENT OF APPLE POWDERY MILDEW: A DISEASE ASSESSMENT METHOD FOR GROWERS

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Summary Recent improvements in spray programmes and prospects for supervised control are considered for apple mildew. Details are given of a simple method whereby growers can assess and monitor secondary infections on foliage. Sampling studies are described which led to rules for selecting trees and shoots: four shoots per tree, trees in two parallel lines. By restricting observations to a zone of five young leaves assessments are relevant to immediate control decisions. The relation between mean number of colonies per leaf and the prevalence (%) of mildewed leaves is given and the latter is preferred. Two methods of measuring prevalence are presented. Decision guidelines for supervised control in British orchards are currently based on mildew thresholds of 8 and 20% infected leaves by this method.

Résumé De récents perfectionnements apportés aux programmes de pulvérisation ainsi que la perspective du contrôle de la lutte contra l'oidium du pommier sont considérés. Une méthode simple grâce à laquelle les cultivateurs peuvent évaluer et contrôler les infections secondaires des feuilles est décrite. Les études d'essais présentées aboutissent aux directives pour la sélection des arbres et des pousses: 4 pousses/arbre, arbres en deux lignes parallèles. Les lectures sont applicables aux décisions de lutte immédiates si les observations sont limitées à une zone de cinq jeunes feuilles. La relation entre le nombre moyen de colonies par feuilles et la prédominance (%) des feuilles oidiées est établie, la préférence allant à cette dernièr. Deux méthodes sont prèsentées par lesquelles on peut évaluer la prédominance. Dans ces méthodes les directives à partir desquelles on prend une décision concernant le contrôle de la lutte dans les vergers britanniques sont fondées actuellement sur les seuils d'oidium de 8% et 20% des feuilles contaminées.

TRENDS TOWARD RATIONAL CONTROL

There are more chemicals to control apple mildew today than ever before and many English fruit growers use two or more a year. Early in the season, for example, a fungicide is chosen to suppress primary mildew. During blossom, control is sustained but with a fungicide which minimises harming fruit-setting processes. The post-blossom fungicide is chosen to control secondary infections without russeting fruit skins. Burchill & Butt (1975) and Butt & Burchill (1976) describe such programmes.

In western Europe the winters are rarely cold enough to ensure a reliable winterkill of mildew and so the goal of spray programmes in the growing season is to keep newly-formed buds healthy. There are crucial periods in the season when fruit buds and terminal buds are in special need of protection (Butt, 1971, 1972) and this knowledge, combined with the appropriate choice of chemicals, has led to the rational planning of intensive programmes in accordance with seasonal changes in control needs and proneness to spray damage.

PROSPECTS FOR SUPERVISED CONTROL

Certain general characteristics of powdery mildews and perennial hosts explain why apple mildew is often hard to control:

a) The habit of perennating inside buds ensures a source of primary inoculum resident in orchards.

b) The conidia germinate in the absence of liquid water and so infections occur almost daily during the vegetative season.

c) Foliage develops over a long growing season and so trees stay susceptible for several months; also, it is difficult to maintain adequate doses of chemical to protect these rapidly growing leaves.

It is naive to expect that, with the known fungicides, apple mildew can be successfully controlled with a few, critically-timed applications in regions where the disease is annually severe. This approach is especially fallible with dinocap and binapacryl because of their brief persistence (Tew & Warman, 1972). A more realistic way to lower both costs and undesirable side-effects is to match the amount of chemical per application and/or the inter-spray interval to the level of epidemic activity, whilst accepting the need, in general, for a long spray programme. This approach acknowledges the continuous infection pressure experienced by the host and the potential of the pathogen to multiply rapidly, but seeks savings when the epidemic allows.

Supervised (and integrated) control programmes commit growers to collect information and make decisions. The authors are convinced that disease assessment is essential to the management of apple mildew. First, in England the incidence of the disease varies greatly from orchard to orchard, even on the same farm (Butt, 1977). Second, for many foliar diseases the key determinants of infection frequency are meteorological parameters such as rainfall and surface wetness, which are fairly easy to measure and use in crop protection schemes. With powdery mildews, however, the amount of inoculum is the key determinant of the amount of infection (Butt, 1978). A method for measuring leaf infections easily and quickly has been produced (Butt, 1979); details are given below. By this method managers can match control inputs to the activity of the epidemic of secondary infections at each site and can take tactical action in accordance with seasonal changes in potential spore production.

SAMPLING STUDIES

Tree selection Surveys on scattered orchards in Kent (Table 1A) provided information on spatial patterns of mildew distribution. A grid of squares,

Table 1A

Details of commercial, sprayed apple orchards surveyed once in 1977

Farm and orchard	Area (ha)	Tree details			
		Cultivar	Number	Spacing (m)	Height (m)
A	3.2	Bramley	1689	2.5 x 7.0	4.0
B1	0.7	Cox	2320*	1.5 x 2.5	4.0
B2	0.8	Bramley	191	6.5 x 7.0	5.0
C1	1.3	Bramley	312	6.5 x 7.5	5.0
C2	2.7	Bramley	773	6.0 x 7.0	3.0
C3	1.6	Bramley	1000*	2.5 x 5.0	3.0
C4	2.0	Cox	829	5.0 x 6.0	4.0
D1	1.5	Cox	1015	4.0 x 6.5	2.0
D2	0.8	Cox	726	4.0 x 6.5	2.0
D3	1.4	Bramley	286	6.0 x 7.5	3.0
D4	2.2	Bramley	363	6.0 x 7.5	3.0
E1	4.0	Cox	4050*	2.0 x 3.0	2.5
E2	1.0	Cox	1012	2.5 x 5.0	3.0

* approximate number.

alligned with the rows of the planting plan, made easy the sampling of trees spaced about 12 m apart over the whole of each orchard. (The exact distance between sampled trees depended on planting distances.) Five leaves on each of four shoots were selected on each sampled tree by the rules described under Assessment Method (paragraphs 6-10). The leaves were examined for mildew. The percentage of leaves with mildew along and across the rows of the grid did not indicate systematic gradients of disease across any of these orchards; rather, the distribution was continuous and irregular.

The information from the grid survey was used to examine various practical ways of sampling orchards. The mean percentage of mildewed leaves given by two lines of trees across the orchard from edge to edge was close to the 'grid' figure, whether arranged as a cross (+) or in parallel. To avoid over-sampling the centre area parallel lines are better, and are easier to record.

Lines which follow other paths (e.g. diagonal, X, W) are suited to field crops (Lin et al., 1979), but not plantations.

It was decided to stipulate the size of the sample according to orchard area and so make the number independent of orchard shape. This was done on the basis of the expected number of trees, 12 m apart, in two parallel lines across square orchards (see paragraph 1 under Assessment Method). Using this rule to select a sample of trees appropriate to the area of each orchard in the survey, mildew assessments were close to the percentages given by the grid, with deviations from the latter in the range -5.3 to +4.2 (Table 1B). (With a single-line sample the deviations increased to the range -17.2 to +5.8.)

Table 1B

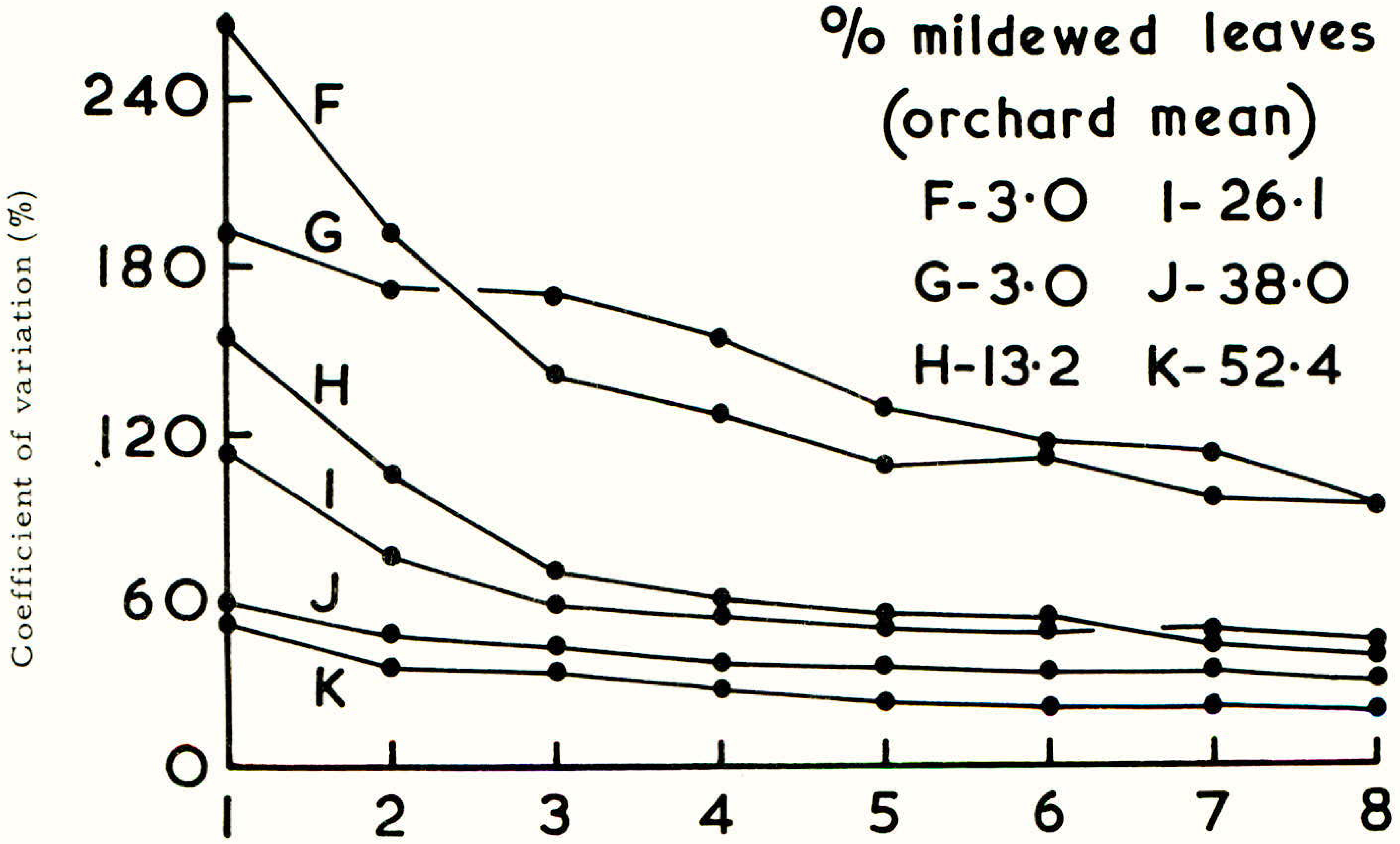
Evaluation of the proposed tree-selection method for measuring mildew incidence (1977 survey)

	Tree selection method			
	12 m grid		2 parallel lines*	
Farm and orchard	Trees in sample (no.)	Leaves mildewed (%)	Trees in sample (no.)	Leaves mildewed (%)
A	109	33.5	30	36.5
B1	64	59.2	16	58.0
B2	41	71.8	16	72.8
C1	65	47.4	20	51.6
C2	162	43.8	30	45.2
C3	242	33.9	20	28.8
C4	84	46.2	23	42.6
D1	169	3.6	20	3.3
D2	167	3.2	15	3.3
D3	59	42.7	20	39.3
D4	68	44.9	23	50.2
E1	162	19.7	35	18.4
E2	67	42.5	14	39.8

* The proposed method; the number of trees is determined by the area of the orchard (paragraph 1 under Assessment Method).

Shoot selection In 1978, six sprayed commercial orchards in Kent were used to study between-shoot variation in mildew incidence on trees selected in accordance with paragraphs 1-2 (see Assessment Method). Shoots and leaves were selected by the methods described in paragraphs 6-10 below, except that two shoots (not one) were selected on each face, giving eight (not four) per tree. Coefficients of variation were calculated for samples of 1-8 shoots per tree and meaned for the 2-8 recorders at each orchard (Fig. 1). (Shoot records were selected at random for inclusion in samples of less than 8.)

Fig. 1. Relationship between coefficient of variation of mildewed leaves and number of shoots sampled per tree on six orchards, 1978



Number of shoots

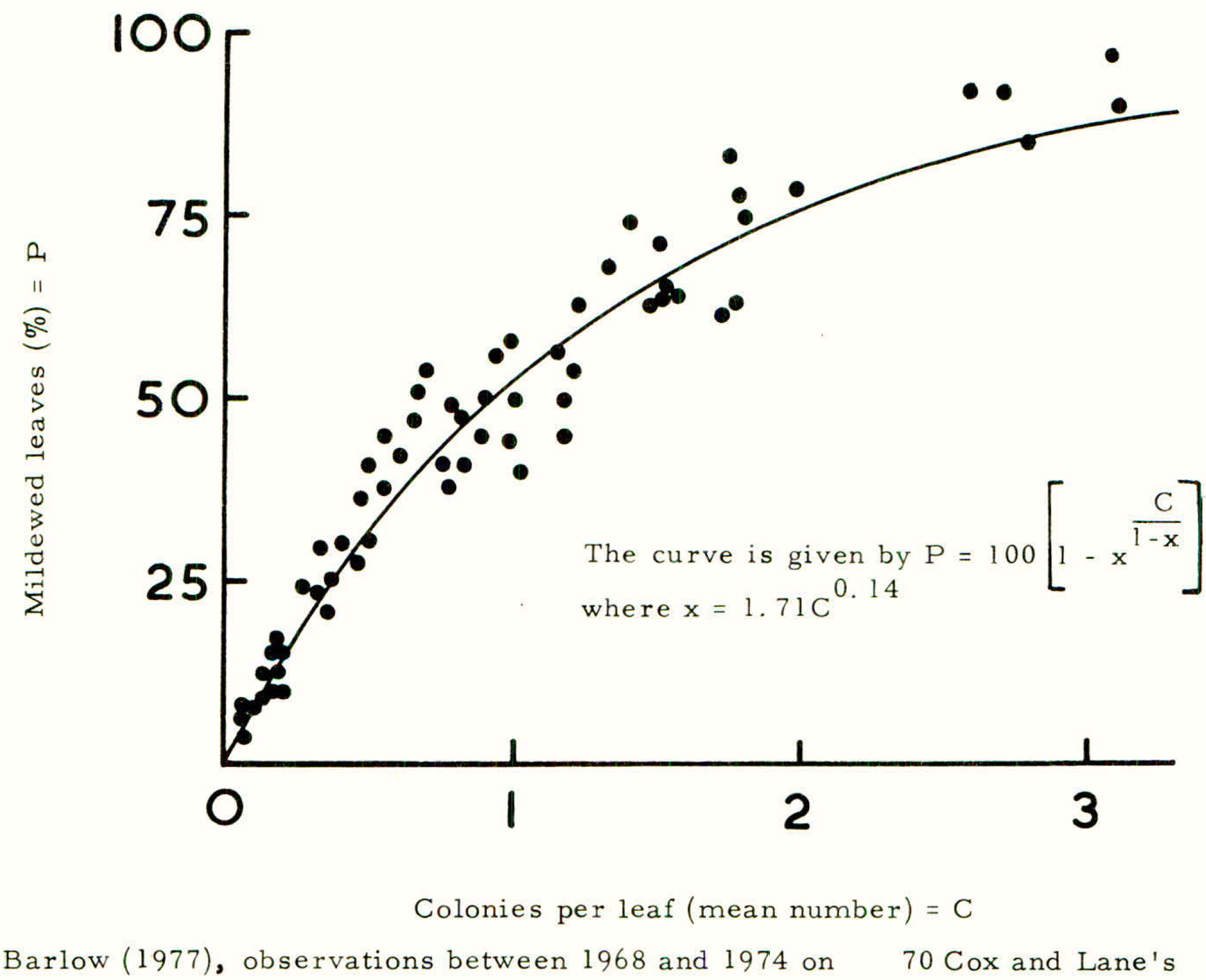
On the evidence of Fig. 1, four shoots per tree is considered about optimal when using the described tree selection method. Furthermore, in three orchards in the 1977 survey there was a statistically significant difference ($P < 0.05$-$P < 0.001$) in the incidence of mildew between the four faces of the tree. Accordingly, the four shoots are systematically sited on the four faces, as in paragraph 6 below.

Leaf selection Assessments are restricted to unrolled leaves near the shoot tip (see paragraphs 8-9 below). First, mildew colonies on older leaves can be difficult to recognise. Second, mildew on these immature, expanding leaves provides the earliest visible measure of recent infections. Third, sporulation declines with leaf age and observations suggest a low sporulation rate on leaves below about the fifth node below the youngest unrolled leaf (reference leaf). Assessments on the five leaves below the reference leaf are, therefore, reliable and of epidemiological significance.

Mildew measurement The prevalence (incidence) of secondary mildew is the proportion of infected leaves, often expressed as a percentage of the number examined. Intensity (sometimes called severity) is often expressed as the proportion of the leaf area mildewed and integrates the number and size of colonies. Clearly, prevalence is simpler for growers to assess because only the presence or absence of mildew has to be recorded.

The distribution of colonies among leaves fits the negative binomial distribution better than the Poisson (Barlow, 1977); this was determined by calculation using 1974 shoot data (23-32 leaves/tree) from 16 trees of cv. Cox's Orange Pippin, each sprayed with dinocap or binapacryl. Further support for the negative binomial was obtained with shoot data (43-138 leaves/tree) collected between 1968 and 1974 on 34 Cox and 37 Lane's Prince Albert trees each sprayed with any one of five fungicides: the mean and variance of the number of colonies per leaf were related in the manner suggested by Taylor's Law (Taylor, 1961). On this basis the expected percentage of mildewed leaves was calculated for various mean numbers of colony per leaf (Fig. 2). As reported by

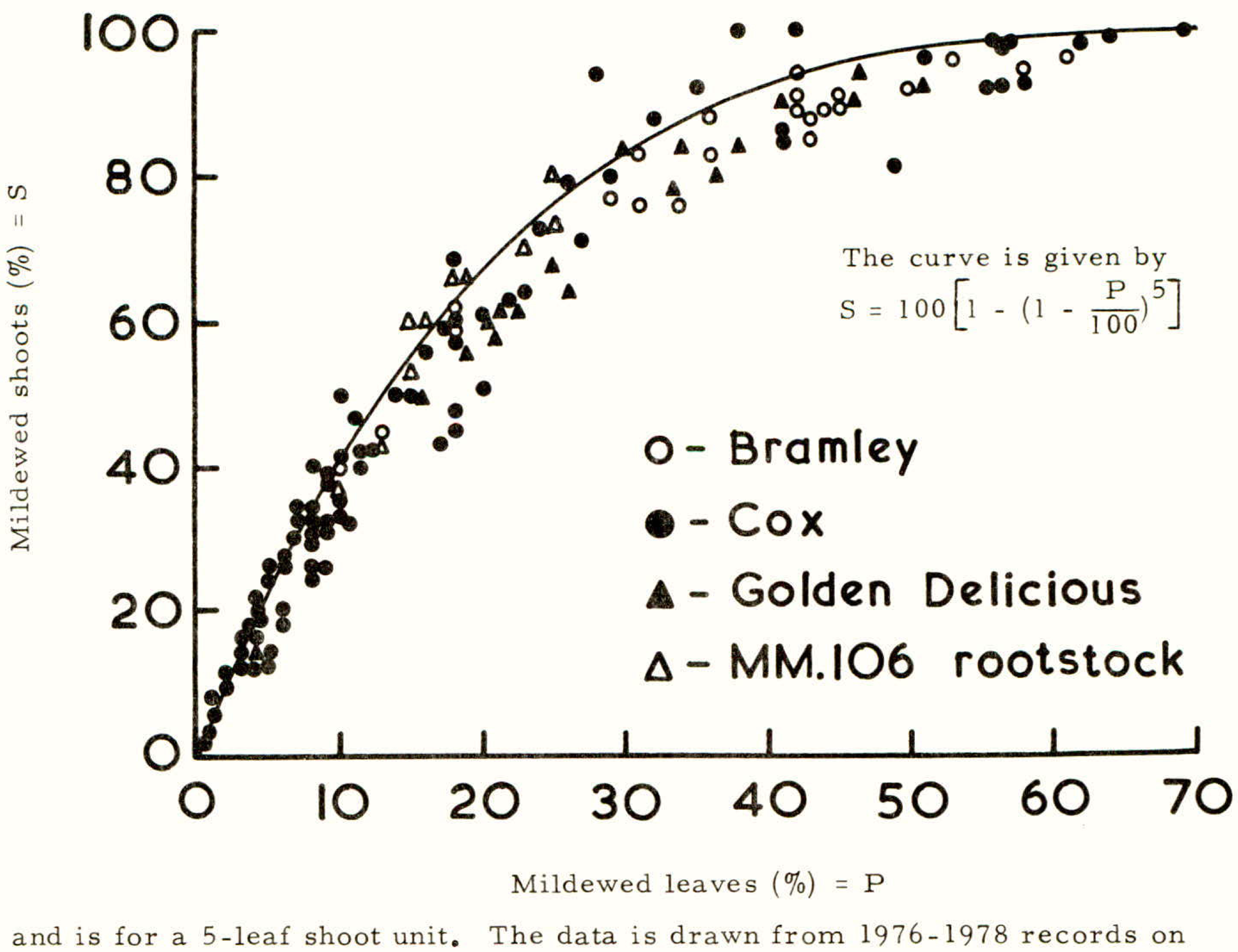
Fig. 2. Predicted relation between the percentage of mildewed leaves and the mean number of colonies per leaf, based on Taylor's power law and the negative binomial distribution



Barlow (1977), observations between 1968 and 1974 on 70 Cox and Lane's trees, each sprayed with any one of six fungicides, lie close to the curve in Fig. 2 and accordingly it seems that there is little advantage in counting colonies below about 35% mildewed leaves, and the simple inspection of leaves for mildew presence is an adequate and speedy method of sampling in the surveys and monitoring needed in mildew management programmes.

Mildew prevalence can be measured by inspecting either single leaves or units of groups of leaves; Fig. 3 shows the relationship between these methods

Fig. 3. Observed and predicted relation between percentage mildewed leaves and percentage mildewed shoots (units of five leaves) on sprayed apple trees



and is for a 5-leaf shoot unit. The data is drawn from 1976-1978 records on variously sprayed trees in commercial orchards and research station plots. The observations lie close to the expected curve. Clearly, when the prevalence is low, assessment on the 5-leaf unit is a sensitive alternative to assessing all five leaves individually.

DESCRIPTION OF THE ASSESSMENT METHOD

1. The number of trees to sample in each orchard is:

Area not more than: (ha)	Trees to sample	Area not more than: (ha)	Trees to sample
$\frac{1}{2}$	10	$2\frac{1}{2}$	25
1	15	$3\frac{1}{2}$	30
$1\frac{1}{2}$	20	4	35

Orchards larger than 4 ha are treated as two or more smaller areas.

2. These trees lie evenly spaced in at least two straight parallel lines (traverses) that divide the orchard into approximately equal areas.

3. Mark these trees so that repeated assessments are on the same plants. Fill in an office record sheet. (For an example see Butt, 1979.)

4. Sample the main cultivar. In "mixed" orchards sample the most susceptible cultivar (e.g. Idared, Jonathan), or the mixture.

5. The first assessment is made when extension shoots have six unrolled leaves (about late May in England), and is repeated every 2 to 3 weeks until extension growth stops. Fewer records will, nevertheless, provide useful information: in England, June is a crucial month for monitoring the progress of epidemics.

6. At the time of each assessment select at random four extension shoots on each tree, one on each alley face of its canopy and one on each in-row face. In hedgerow plantations it may be more convenient to share these shoots between two adjacent trees on opposite sides of the alley. Shoots need not be labelled.

7. Select actively growing extension shoots at varying but reachable heights in the outer zone of the canopy. Avoid shoots with primary mildew or otherwise totally mildewed and shoots that project far from the face of the canopy.

8. Identify the youngest unrolled leaf (i.e. without a "funnel" or upturned margin where the lamina joins the petiole) as the reference leaf.

9. Examine the five leaves below the reference leaf.

10. A leaf is counted as mildewed only if mycelium is visible on the lower surface without the aid of a magnifying glass; a flexed leaf margin or a pale yellow spot on the upper surface are not conclusive symptoms. Avoid wet foliage.

11. If possible one person should take all records.

12. On the selected shoots record on a counter the number of either

(a) mildewed leaves, by examining all five leaves on each shoot, or

(b) mildewed shoots, by counting the shoot as mildewed if the disease occurs on any of its five leaves.

Note this number after each traverse and whether leaves (L) or shoots (S).

13. The five leaves are examined in sequence, beginning with the youngest. The shoot count (12b) is faster because as soon as mildew is seen on any of the five leaves the recorder selects the next shoot.

14. The leaf count (12a) is used for the first assessment of the season. Subsequently, when monitoring in orchards with less than 20% mildewed leaves the shoot count is a sensitive and faster alternative. The shoot method is adequate and very fast in orchards with more than 60% mildewed leaves! To

monitor seasonal changes in the range 20-60% mildewed leaves, continue with the leaf method.

15. For each traverse and for the orchard as a whole, calculate the percentage of mildewed leaves or shoots. Use the curve in Fig. 3 to convert shoot records into leaf percentages.

GUIDELINES FOR SUPERVISED CONTROL

The method was developed to help growers gather information about epidemics of secondary infections. With this method, orchards (or trial plots) are compared, disease progress is monitored and the information is used to appraise the situation. The consequent decisions channel control resources according to needs, thereby "tuning the spray programme to the problem".

Current guidelines for using the information obtained with the assessment method are based on three ratings (Table 2).

Table 2

Current guidelines for the supervised control of apple mildew in Britain based on summer disease ratings

Disease rating	Mildewed leaves (%)	Action after petal-fall*
light	<8	In cool weather with prolonged rainy spells, or when shoot growth is very slow, economise by using less fungicide each application or by extending spray intervals.
moderate	8-20	Maintain control. Consider improving the programme by shortening spray intervals or using more fungicide each application in showery or rainless, warm but humid weather, especially when dew is frequent and when shoot growth is rapid.
potentially severe	>20	Improve control immediately if shoots are growing, irrespective of weather: shorten spray intervals, use more fungicide each application, perhaps increase spray volume. Consider a change of fungicide. CHECK SPRAY MACHINERY.

* Before petal-fall use a routine control programme.

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References

BARLOW, G.P. (1977) Sampling and variation. East Malling Research Station Annual Report for 1976, 68.

BURCHILL, R.T.; BUTT, D.J. (1975) Apple spray programmes used at East Malling to control scab and mildew. East Malling Research Station Annual Report for 1974 (Growers' Bulletin), 161-165.

BUTT, D.J. (1971) The role of the apple spray programme in the protection of fruit buds from powdery mildew. Annals of Applied Biology 68, 149-157.

BUTT, D.J. (1972) The timing of sprays for the protection of terminal buds on apple shoots from powdery mildew. Annals of Applied Biology 72, 239-248.

BUTT, D.J. (1977) The role of disease surveys in the management of apple mildew. East Malling Research Station Annual Report for 1976 (Growers' Bulletin), 191-193.

BUTT, D.J. (1978) Epidemiology of powdery mildews. In: SPENCER, D.M. (Ed.). The Powdery Mildews. London; Academic Press. p. 51-81. ISBN 0 12 656850 2.

BUTT, D.J. (1979) An apple mildew assessment method for use in supervised control. East Malling Research Station Annual Report for 1978 (Growers' Bulletin), 211-214.

BUTT, D.J.; BURCHILL, R.T. (1976) Apple spray programmes used at East Malling to control scab and mildew, 1975. East Malling Research Station Annual Report for 1975 (Growers' Bulletin), 161-164.

LIN, C.S.; POUSHINSKY, G.; MAUER, M. (1979) An examination of five sampling methods under random and clustered disease distributions using simulation. Canadian Journal of Plant Science 59, 121-130.

TAYLOR, L.R. (1961) Aggregation, variance and the mean. Nature 189, 732-735.

TEW, R.P.; WARMAN, T.M. (1972) Apple powdery mildew. East Malling Research Station Annual Report for 1971, 137-138.

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CONTROL OF VARIOUS STORAGE FUNGI OF APPLES AND PEACHES BY POST-HARVEST DIPPING IN IPRODIONE OR ALUMINIUM TRIS(ETHYL PHOSPHONATE)

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Summary In laboratory studies, treatment with iprodione (Rovral ®), applied as a post-harvest dip, protected fresh wounds on apple fruits from rots caused by post-treatment inoculation with strains of *Botrytis cinerea* and *Penicillium expansum* tolerant to benzimidazoles. Similarly, this fungicide protected apples from *Rhizopus nigricans*.

With peaches, post-harvest dipping in iprodione effectively controlled rots of *R.nigricans* and *Monilia fructigena* which arose from natural field infections. The activity of iprodione against established *R.nigricans* infections was greatly improved when peaches were treated by immersion for 15 minutes at 51.5°C; sprinkling a warm solution is proposed as a possible practical technique to be tested.

Aluminium tris(ethyl phosphonate) (Aliette ®) as a post-harvest dip protected stored apples from post-treatment inoculations of *Phytophthora cactorum* and retarded the development of *R.nigricans*. There may be a role for this fungicide as a prophylactic orchard spray, before harvest.

Resumé Dans des essais de laboratoire, l'iprodione (Rovral ®) utilise en trempage des fruits après récolte, a protégé les blessures fraichement faites sur des pommes et inoculées après le traitement, avec des souches de *Botrytis cinerea* et *Penicillium expansum* resistants aux benzimidazoles. Ce fongicide a aussi été efficace sur pommes contre *Rhizopus nigricans*.

Sur pêches, un traitement par trempage après la récolte avec de l'iprodione a controlé de facon efficace les pourritures dues à *R.nigricans* et *Monilia fructigena* dans le cas d'infections naturelles. L 'activite curatif d'iprodione contre *R.nigricans* a été nettement supérieure lorsque les pêches étaient traitées par immersion pendant 15 minutes à 51.5 degres C. L'aspersion d'une solution chaude comme moyen pratique de traitement sera à experimenter.

L'aluminium tris(ethyl phosphonate) (Aliette ®) utilise en trempage des fruits après récolte, a protégé des pommes stockées contre les inoculées de *Phytophthora cactorum* faites après traitement et a retardé le developpement de *R.nigricans*. Il peut y avoir aussi un interêt a utiliser ce fongicide au verger en pulverisation avant récolte.

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INTRODUCTION

The chemical control of storage rots of top fruit is usually practiced by applying fungicides in the orchard, sometimes supplemented, where approved, by post-harvest treatments.

Obviously, the general hygiene of fruit depots is important in reducing the level of inoculum because it is sufficient for only a few spores, perhaps a single propagule, of Botrytis, Penicillium or Rhizopus to land on a fresh wound to cause a rot. Techniques are available to treat crops immediately after handling operations which cause mechanical damage have ended. It is important to apply such post-harvest treatments soon after the crop is picked, for in many trials the inoculation of fresh wounds, before treatment with fungicide, has always resulted in serious rotting.

To reinforce this means of protection two chemicals of low mammalian toxicity have been laboratory tested against various rots of apple and peach. Iprodione is very active against B.cinerea and is widely used to control grey mould in several crops, for example vine, tomato, lettuce and flowers. Trials were undertaken to examine iprodione for the control of B.cinerea, P.expansum and R.nigricans on stored apples and R.nigricans and M.fructigena on stored peaches.

Aluminium tris(ethyl phosphonate) (coded LS 74783) is primarily active against Phycomycetes (Bertrand et al 1977; Williams et al 1977). Its anti-fungal properties are extremely specific because whereas at low doses (5-50 ppm) it inhibits sporogenesis of, for example, Phytophthora palmivora, P.capsici and P.cactorum and zoospore germination of P.capsici (100 ppm), it does not affect the mycelial growth of these species at 250 ppm. To inhibit growth in vivo a concentration of 1000 ppm or more is required (Bompeix 1979).

The manner of action of LS 74783 is two-fold, the one being direct, as described, and the other indirect by stimulating the defence mechanisms of the host (Vo et al 1979). Trials were undertaken with apples to determine the efficacy of LS 74783 as a post-harvest dip to control damage by P.cactorum.

METHODS AND MATERIALS

Healthy fruit was used in all but one trial. Healthy fruits were wounded and artificially inoculated with strains of various fungi cultivated in the laboratory on media. In trial 5, however, naturally infected fruits were used. All fruit were stored in boxes with the fruit touching during the various periods of storage used.

Storage conditions and details of wounding, inoculation and treatment are described with the results.

RESULTS AND DISCUSSION

Trials with iprodione

Two trials (1 and 2) were carried out with apples (cv. Golden Delicious) inoculated with a strain of B.cinerea tolerant to benzimidazoles.

In trial 1, 50 fruits were used for each treatment. Every apple was wounded twice with a 6mm diam. punch to a depth of 0.5-1.0mm and then dipped immediately. When the fruits were dry, approximately 2h later, each fruit received 10 µl of a spore suspension (10^5 spores/ml). Results after storage at 20°C and 98% r.h. are given in Table 1.

Table 1

Efficacy of iprodione as a protectant dip to control
*Botrytis cinerea** rots of apple fruits stored at 20°C, 98% r.h.

Dip treatment	Concn (ppm)	Infected wounds (%) Days after treatment 4	7	9
distilled water		32	48	54
thiabendazole	1000	10	16	26
iprodione	250	0	0	0
iprodione	500	0	0	0
iprodione	1000	0	0	0
iprodione	2000	0	0	0

(* A strain of *B.cinerea* tolerant to benzimidazoles)

In trial 2, 60 fruits were used for each treatment. Every apple was wounded once with a 6mm diam. punch to a depth of 0.5-1.0mm and then immediately dipped. When dry, 2h later, each fruit received 10 µl of a spore suspension (10^6 spores/ml). Results after storage at 1°C and 95% r.h. are in Table 2.

Tables 1 and 2 compare the effects of iprodione and thiabendazole against a benzimidazole-resistant strain of *B.cinerea*; iprodione was effective for 9 days at 250 ppm in protecting damaged apples stored at 20°C, 98% r.h. In cold storage (1°C, 98% r.h.) a 70% reduction in rots was recorded 7 weeks after treatment with iprodione at 1000 ppm, by which time undipped apples (which had been inoculated) had a rot on every wound.

Table 2

Efficacy of iprodione as a protectant dip to control
*Botrytis cinerea** rots of apple fruits stored at 1°C, 95% r.h.

Dip treatment	Concn (ppm)	Infected wounds (%) Weeks after treatment 3	7
distilled water		0	100
thiabendazole	1000	0	77
iprodione	1000	0	30

(* A strain of *B.cinerea* tolerant to benzimidazoles)

Trials 3 and 4 measured the comparative efficacy of iprodione against a strain of *Penicillium expansum* (tolerant to benzimidazoles) on apple (cv. Golden Delicious).

In trial 3, 100 fruits were used for each treatment. Every apple was wounded once using a 6mm diam. punch to a depth of 0.5-1mm and then dipped immediately. After 2h, when the fruits were dry, each fruit received 10 µl of spore suspension (10^6 spores/ml). Results after storage at 22°C and 100% r.h. are in Table 3.

Table 3

Efficacy of iprodione as a protectant dip to control Penicillium expansum* rots of apple fruits stored at 22°C, 100% r.h.

Dip treatment	Concn (ppm)	Infected wounds (%) Days after treatment 4	8
distilled water		90	96
thiabendazole	1000	88	99
carbendazim	500	77	96
iprodione	1000	5	21

(* A strain of P.expansum tolerant to benzimidazoles)

In trial 4, 60 fruits were used for each treatment. Every apple was wounded once with a 6mm diam. punch to a depth of 0.5-1.0mm and then dipped immediately. After 2h, when the fruits were dry, each fruit received 10 µl of a spore suspension (10^6 spore/ml). Results after storage at 1°C and 95% r.h. are in Table 4.

Table 4

Efficacy of iprodione as a protectant dip to control Penicillium expansum* rots of apple fruits stored at 1°C, 95% r.h.

Dip treatment	Concn (ppm)	Infected wounds (%) Weeks after treatment 3	7
distilled water		44	80
thiabendazole	1000	13	63
iprodione	1000	0	5

(* A strain of P.expansum tolerant to benzimidazoles)

Iprodione at 1000 ppm was providing, under the conditions of these experiments, excellent protection against P.expansum after 7 weeks in cold storage and after short term storage at higher temperature.

One of the more valuable uses of iprodione is for the control of R.nigricans on peach and apple, especially as in France dicloran is banned on peaches. Compared with numerous other fungicides, iprodione has proved to be one of the few chemicals capable of impeding the development of rots caused by Rhizopus (Bompeix et al 1979). In trial 5, therefore, a study was made with peaches (cv. Rubidon) to test the comparative efficacy of iprodione as a pre-storage treatment. In this trial, 88 fruits were used for each treatment (except 176 for control), the fruits having natural field infections. Before storage at c.25°C and 98% r.h. the fruits were dipped. Records were taken of R.nigricans and Monilia fructigena after 5 days, the usual pre-marketing delay (Table 5). It is notable that at 1000 ppm a post-harvest iprodione dip gave good control of both Rhizopus and Monilia arising from natural field infections.

In trial 6, apples (cv. Golden Delicious) were used to measure the duration of protection against R.nigricans; 88 fruits were used for each treatment. Every apple was wounded with a 6mm punch to a depth of 0.5-1.00mm, treated immediately, and when dry 2h later, each fruit was inoculated by each fruit receiving 10 µl of a 10^6 spore/ml suspension. The apples were stored at 22°C and 98% r.h. for 11 days and then at 4°C and 98% r.h. until the 45th day.

Although the apples were at 22°C and 98% r.h. for the early period of storage, iprodione at 2000 ppm gave good protection which led to a useful degree of control after 45 days (Table 6). Only a slight improvement in performance was detected at 4000 ppm.

Table 5

Efficacy of iprodione as a post-harvest dip to control natural Rhizopus and Monilia infections of peaches stored for 5 days at 25°C, 98% r.h.

Dip treatment	Concn (ppm)	Infected fruit (%) R.nigricans	Infected fruit (%) M.fructigena
dry control		26	13
distilled water		51	14
captafol + carbendazim	1000 + 250	7	0
thiabendazole	1000	38	0
captan	1000	37	8
iprodione	1000	2	1
iprodione	250	11	3

Table 6

Efficacy of iprodione as a protectant dip to control Rhizopus nigricans rots of stored apple fruits

		Infected wounds (%)				
		Days after treatment				
Dip treatment	Concn (ppm)	3	5	8	11	45
distilled water		48	77	88	97	-
iprodione	2000	0	1	2	16	39
iprodione	4000	0	0	0	15	23

In a final study with Rhizopus (trial 7), the effect of immersing peaches (cv. Rubidon) in a warm solution of iprodione was investigated. Twenty-five fruits (10 only for the warm-water controls) were used for each treatment. Every fruit was wounded with a scalpel and simultaneously inoculated at four positions; the inoculum was introduced on a scalpel dipped in a spore suspension (1.5×10^6 spores/ml). Dip treatments were applied 24h later, fruits being immersed in the 'warm' bath (51.5°C) for 15 min. Results are given in Table 7 from storage at 20°C and 98% r.h.

Table 7

Efficacy of iprodione against Rhizopus rots of peaches : comparison of 'cold' dip and 'warm' bath treatments applied 24h after inoculation

		Infected wounds (%)		
		Days after treatment		
Treatment	Concn (ppm)	1	3	7
dry control		100	100	100
distilled water - 'cold'		100	100	100
iprodione - 'cold'	1000	0	96	100
iprodione - 'cold'	250	40	100	100
iprodione - 'warm'	100	0	0	5
distilled water - 'warm'		0	32	100

In trial 7, using curative treatments, iprodione at 1000 ppm delayed the appearance of *Rhizopus* rots for less than 3 days when applied as a 'cold' dip (solution at ambient temperature). The effect improved, however, where the 'warm' bath was used, so that at 100 ppm only 5% of wounds were visibly infected after 7 days compared with 100% rotting following a 'cold' dip at 1000 ppm. It should be stressed that the peaches were over-ripe and therefore very susceptible to rots.

Trials with aluminium tris(ethyl phosphonate)

In trials 8 and 9, apples (cv. Golden Delicious) were used to investigate the efficacy of LS 74783 against *Phytophthora cactorum*.

In trial 8, 100 fruits were used for each treatment. Ten days after applying treatments zoospores of *P.cactorum* were sprayed as a suspension onto the surface of every fruit (Bompeix & Mourichon 1977). The apples were stored at 22°C and 98% r.h. Results are given in Table 8.

Table 8

Efficacy of LS 74783 as a protectant dip to control *Phytophthora cactorum* rots of apple fruits stored at 22°C, 98% r.h.

Dip treatment	Concn (ppm)	Infected fruit (%) 30 days after inoculation
distilled water		32
LS 74783	1000	4
LS 74783	2000	3
tolyfluanide	1000	14
captan	1000	10

Under these conditions LS 74783 gave good protection. Other trials (not reported here) with *P.cactorum* and *P.syringae* confirmed the excellent protection given by LS 74783 against *Phytophthora* rots of apples.

When the dip treatments were applied 3 days after inoculation by a spore spray (trial 9), poor results were obtained, even at 5000 ppm (Table 9).

Table 9

Efficacy of LS 74783 as dip treatment applied 3 days after inoculation with *Phytophthora cactorum* to apples stored at 22°C, 100% r.h.

Dip treatment	Concn (ppm)	Infected fruit (%) Days after treatment 3	4	6	11
distilled water		0	32	44	68
LS 74783	2000	0	25	32	54
LS 74783	5000	0	21	30	54

It seems probable that in trial 9 the storage conditions (22°C, 100% r.h.) were conducive to rapid colonization of the internal tissues before the treatment was applied 3 days later, by which time the fungus escaped contact with the fungicide (Mourichon & Bompeix, 1979). The results of trial 9 are in accordance with experience with various anti-Penicillium treatments which, when applied 24-48 h after inoculation are totally ineffective (Laville et al, 1978). In commercial practice infection occurs during harvesting, transport and handling at the depot; taking Table 8 into account, preventative use of this material in apple orchards may provide valuable control of Phytophthora rots.

It is noteworthy that LS 74783 has also been found to inhibit the development of R.nigricans on apples, but less so than iprodione.

CONCLUSIONS

Iprodione is particularly valuable for the post-harvest treatment of apples and peaches because it is active against the four major storage fungi of fruit grown in France, namely M.fructigena, R.nigricans, B.cinerea and P.expansum.

Under the conditions of these trials iprodione prevented or delayed apple rots caused by B.cinerea (250-1000 ppm) and P.expansum (1000 ppm). In both cases iprodione was effective in protecting fresh wounds from a strain tolerant to benzimidazoles. Iprodione was also effective in protecting fresh wounds on apples from R.nigricans (2000-4000 ppm).

When peaches with natural field infections of R.nigricans and M.fructigena were given a post-harvest dip in iprodione the treatment was effective against both types of rot (1000 ppm). The curative activity of iprodione on peaches was much improved when fruits were immersed for 15 min at 51.5°C; by this method activity against R.nigricans was recorded at as low as 100 ppm. This latter result suggests that a practical method could be developed to apply a warm solution of iprodione to harvested peaches, possibly by means of sprinklers.

Aluminium tris(ethyl phosphonate) (LS 74783) at 1000-2000 ppm as a dip treatment 10 days prior to inoculation with zoospores was effective in controlling apple rots caused by Phytophthora spp. In an environment which undoubtedly favoured rapid growth of P.cactorum, however, dipping in this fungicide 3 days after inoculation was relatively ineffective, even at 5000 ppm. Clearly LS 74783 merits consideration for use as a prophylactic orchard spray before harvest.

References

BERTRAND, A.; DUCRET, J.; DEBOURGE, J.C.; HORRIÉRE, D. (1977) Etude des propriétés d'une nouvelle famille de fongicides, les monéthyl-phosphites mételliques. Caractéristiques physico-chimiques et propriétés biologiques. Phytiatrie Phytopharmacie 1, 3-17.

BOMPEIX, G. (1979) Personal communication.

BOMPEIX, G.; COEFFIC, M.; GREFFIER, P. (1979) Lutte contre les pourritures des pêches à Monilia spp, Botrytis sp. et Rhizopus sp. Fruits 34, No.8 (In press)

BOMPEIX, G.; MOURICHON, X. (1977) Phytophthora cactorum (L and C) Schroet, P.syringae Kleb, Phytophthora spp. Parasites des pommes et des poires - Compte Rendu Académie d'Agriculture de France, 493-501.

LAVILLE, E.Y.; HARDING, P.; DAGAN, Y.; RAMAT, M.; RIPPON, L.E. (1978) Synthèse des essais entrepris avec l'imazalil sur les pourritures des agrumes après récolte. Fruits. 33 (4), 257-267.

MOURICHON, X.; BOMPEIX, G. (1979) Mise en évidence des voies de pénétration du P.cactorum (L et C) Schroet dans les pommes "Golden Delicious" - Etude réalisée en microscopie électronique à balayage. Fruits (in press).

VO, THI HAI.; BOMPEIX, G.; RAVISÉ, A. (1979) Rôle du tris-o-éthyl phosphonate d'aluminium dans la stimulation des réactions de défense des tissus de tomate contre le Phytophthora capsici - C.R.Acad. Sc Paris, t.288 Seres D. 1171-1174.

WILLIAMS, D.J.; BEACH, B.G.W.; HORRIÉRE, D.; MARECHAL, G. (1977) LS 74783, a new systemic fungicide with activity against Phycomycete diseases. Proceedings 9th British Crop Protection Conference. Pests and Diseases. 565-573.