A rational approach to apple scab control - the role of disease warning systems and curative spraying.

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Summary

The consequences of four approaches to apple scab control using different fungicide programs (viz. (i) protectant, (ii) curative, (iii) mixture of protectant and curative and (iv) strategic, (using either protectant or curative sprays as dictated by infection conditions) were considered by plotting estimated periods of disease control against infection periods determined by an apple scab disease warning system. The study was carried out using data collected by Reuter-Stokes Apple Scab Predictors, at Orange N.S.W. (1983-1987) and at Batlow, N.S.W. (1984-1987).

Although other non-disease factors may also be involved in the selection of a disease control strategy, in the major N.S.W. apple growing districts of Orange and Batlow, it appears that a strategic programme, or a programme involving application of a mixture of a protectant and curative fungicide on a regular basis will provide good disease control. A full protectant programme or a full curative programme may fail to provide control in some seasons. Reliance on a full curative programme may lead to fungicide resistance because of the chemical nature of the fungicides involved.

The role of the disease warning service is to enable the orchardist to make a rational decision on which type of fungicide to use and when to apply it.

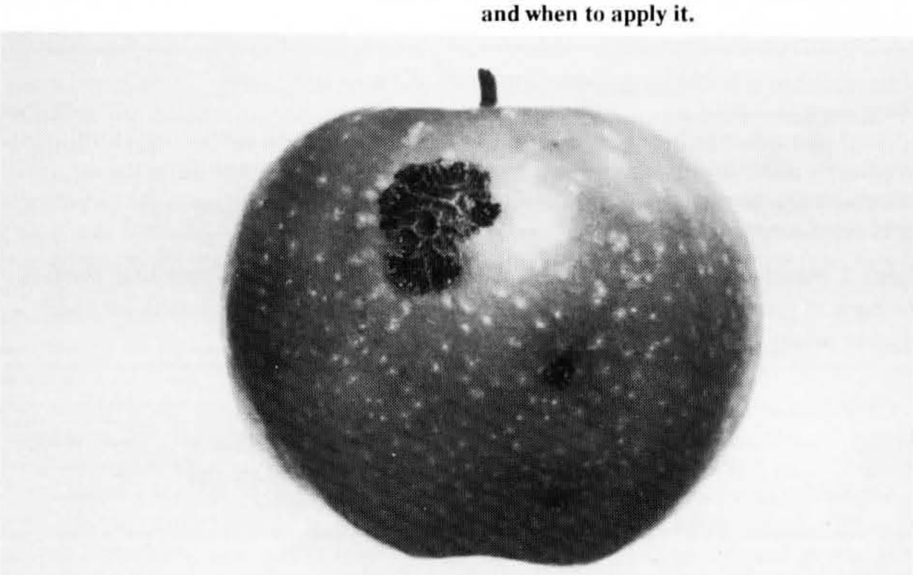

Figure 1. Apple scab on fruit.

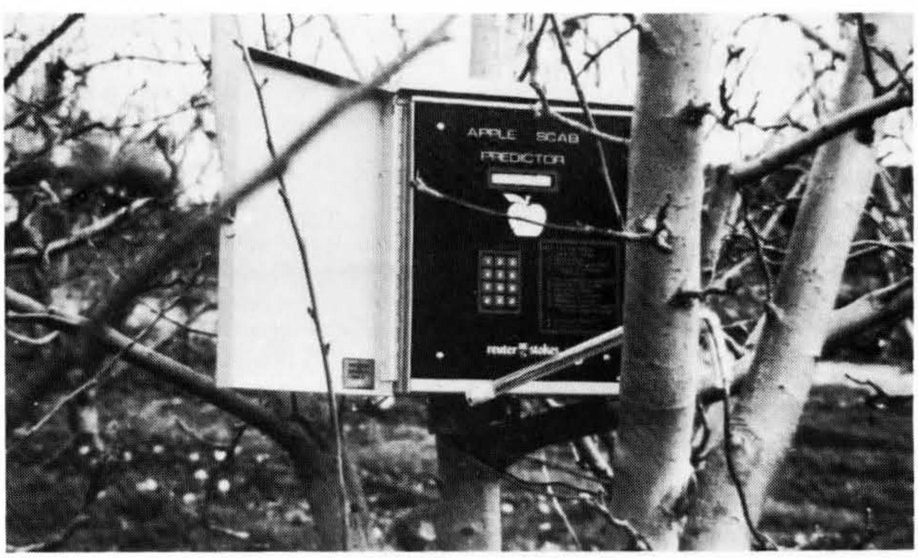

Figure 2. The 'Apple Scab Predictor' provides information on weather conditions favourable for infection.

Introduction

Apple scab caused by the fungus *Venturia inaequalis* (Cke.) Wint. (Fig. 1) is the most important disease of apples in New South Wales and most parts of the world. Initiation of scab infection depends on plant surfaces remaining wet for a period, and the length of this necessary period of wetness is related to temperature (Mills and La Plante 1951). Various systems which detect weather conditions suitable for primary (ascospore) infection have been developed as an aid to apple scab control (Jones *et al.* 1980). Disease warning services are operated in New South Wales at Orange and Batlow, the two major apple producing areas, during the primary infection period, by the NSW Agriculture and Fisheries Department, using electronic weather monitoring devices (Penrose *et al.* 1985). These instruments provide information as to when conditions have been suitable for primary infection to occur. Scab control warning services currently do not operate during the secondary infection period since the biology of the organism (conditions for release of spores and length of wetness period for infection) differ from those pertaining to primary infection. A regular protectant spray programme is required if primary infection control has failed.

Scab control with fungicides can be based on protecting plant surfaces from new infections (protectant), or on killing infections once they have occurred (curative) or a combination of both. The development of curative fungicides with the ability to eradicate established infections up to five days after occurrence has given added impetus to research on control of scab by sprays applied after weather suitable for infection has been detected. Such an approach is promoted as a spray-saving alternative to protectant spraying (Van der Scheer 1975, Ellis, Madden and Wilson 1984, Jones and Fisher 1984) with attendant benefits of reduced costs, and less impact on the environment (Penrose *et al.* 1985). However the fact that infection is dependent on the occurrence of rain to initiate infection means that the suitability of this technique will vary from season to season and with geographic or climatic area. In areas or seasons when the occurrence of rain is frequent or prolonged there may be few chances to save sprays by curative spraying, but the supplementation of a protectant programme with curative sprays (i.e. strategic spraying) or the use of a mixture of protectant and curative fungicides, may be highly desirable.

A study was therefore made of the theoretical consequences of four scab control approaches using infection period data collected over five seasons at Orange, NSW and four seasons at Batlow, NSW to examine the relative merits of these approaches.

Materials and Methods

Infection periods.

Apple scab infection period data were collected from Orange for the five seasons 1983-87 and from Batlow for the four seasons 1984-87, using an RSS-411 Apple Scab Predictor (Fig. 2) (Reuter-Stokes, Inc., Cleveland, Ohio) at each location, and the data modified to take into account the fact that ascospores are released almost solely in daylight hours (Hirst and Stedman 1962, Brooks 1969).

In the assessment for each season greentip (the breaking of dormancy), was assumed to commence on September 13, at which time a copper spray (e.g. copper oxychloride) gave protection in all programmes until the next spray was applied on September 20. Infection periods from this date to November 30 were examined for each season, since this period covers the period of primary or ascosporic infection during which time disease warning services operate and the susceptibility to infection is greatest.

The date of occurrence and length of the infection periods were plotted graphically. The protection period or curative period of four fungicide programmes (see below) were plotted on the same figure (e.g. Fig. 3). It was assumed that (i) spraying could not commence until the end of the infection period because of rain, (ii) that spraying would commence only after daybreak (6 a.m.) and (iii) that spraying could be completed in the 24 hours following the end of the infection period if no further rain fell. No allowance was made for reduction in the length of protectant period caused by rainfall which may reduce fungicide deposits. From these figures the number of sprays applied and any periods where control would not have been obtained due to lack of protectant cover or period of curative activity required, were noted.

Fungicides and Programmes

The fungicides currently recommended for scab control (Johnson *et al.*, 1988) and their various properties are given in Table 1.

Four programmes were examined:

P) Protectant fungicide with no eradicant activity and an assumed protection activity of 10-14 days applied at 10 day intervals till end of October, then at 14 day intervals till end of November. The increase in the length of protection provided is based on the fact that less susceptible tissue is produced as the season progresses e.g. metiram.

C) Curative fungicide applied only after an infection period occurred, the fungicide having an assumed five days curative activity and four days protectant activity e.g. fenarimol.

M) A mixture of protectant and curative fungicides applied as for (P) with an assumed four days curative activity e.g. penconazole plus mancozeb.

S) Strategic - protectant fungicide applied as for (P) but replaced or supplemented with a curative fungicide when control appeared at risk, the fungicides having the properties detailed in (P) and (C).

Table 1. Fungicides recommended for apple scab control in New South Wales after green tip spray[A].

Fungicide	Scab[B] Curative activity (days)[C]	Scab[B] Protectant activity (days)[D]	Powdery[B] mildew	Effect on predatory mites	Resistance risk
Protectant					
dithianon (Delan[R])	0	10-14	no	no	low
mancozeb (Manzate 200[R] Dithane M45[R])	0	7-14	no	yes	low
metiram (Polyram 2000[R])	0	10-14	no	yes	low
metiram plus nitrothal isopropyl (Pallinal[R])	0	10-14	yes	yes	low
thiram (various)	0	10-14	no	no	low
ziram (Fulasin[R])	0	14	no	no	low
Curative/Protectant					
bitertanol (Baycor[R]) plus (Agridex[R])	5	7-10	yes	no	yes
dodine (Melprex[R])	1.5	10	no	no	yes
fenarimol (Rubigan[R])	5	4	yes	no	yes
penconazole (Topas[R]) plus mancozeb	4	7-10	yes	no	yes
triforine (Saprol[R])	3	NR[F]	no	yes	yes

[A] from Deciduous Fruits Spray Calendar 1988-89 (Johnson *et al.*, 1988)
[B] from registered label
[C] Period after infection during which fungicide can eradicate the infection
[D] Period for which fungicide provides a protective covering against new infections
[R] Registered trade name
[F] Not recommended

Table 2. Number of fungicide sprays theoretically applied for apple scab control for each of four schedules, and (in brackets) the number of occasions on which control might have failed.

Location and year	Spray Programme: (i) Protectant	(ii) Curative	(iii) Mixture of protectant and curative	(iv) Strategic
Orange				
1983	7 (2)	6 (0)	7 (0)	7 (0)
1984	7 (0)	4 (0)	7 (0)	6 (0)
1985	7 (1)	7 (0)	7 (0)	7 (0)
1986	7 (1)	5 (0)	7 (0)	7 (0)
1987	7 (1)	6 (0)	7 (0)	9 (0)
Mean	7 (1.0)	5.6 (0)	7.0 (0)	7.2 (0)
Batlow				
1984	7 (2)	6 (0)	7 (0)	7 (0)
1985	7 (1)	7 (1)	7 (0)	7 (0)
1986	7 (2)	7 (0)	7 (0)	8 (0)
1987	7 (0)	4 (0)	7 (0)	7 (0)
Mean	7(1.25)	6.0 (0.25)	7.00 (0)	7.25 (0)
Overall Mean	7 (1.1)	5.8 (0.1)	7.0 (0)	7.2 (0)

Results

The results (Table 2) showed that in most

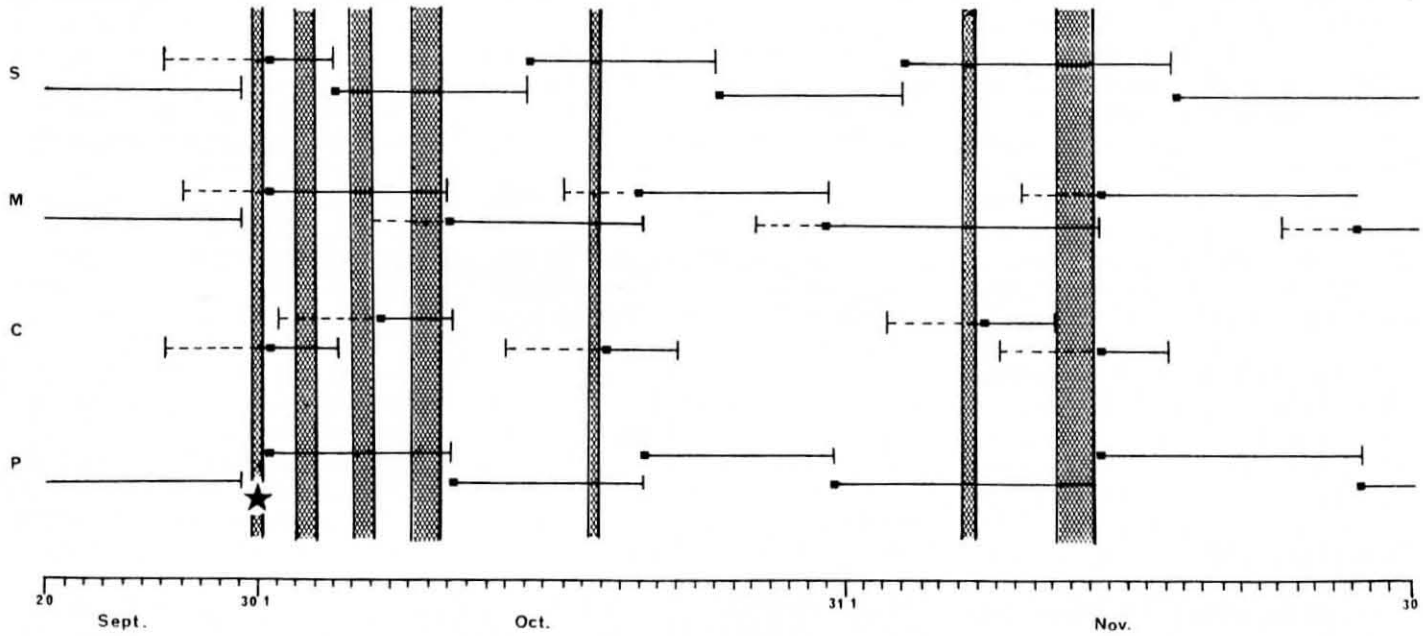

Figure 3. Protectant (—) and curative (--) activity of various fungicide programmes in relation to application date (■) and infection periods (vertical columns) recorded at Orange, NSW in 1986. Failure of control is illustrated thus (*). Fungicide programmes examined are protectant (P), curative (C), mixture of protectant and curative fungicide (M) and strategic (S).

seasons protectant spraying could be expected to fail because an infection period occurred towards the end of or after the protectant period of the fungicide. Where curative spraying saved sprays, this averaged only a little over one spray saved per season, and in four out of the nine situations examined did not result in a spray being saved. Curative sprays could be applied at the appropriate time in all seasons except one where a prolonged infection following a number of previous infection periods would have resulted in a situation where control would probably have failed.

The use of a mixture of both curative and protectant fungicide resulted in completely reliable control and required the same number of applications as the protectant program.

Strategic spraying involving a protectant programme, supplemented with curative sprays when required, required slightly more sprays per season than any other programme, but there was no failure of disease control.

Discussion

Protectant-spraying on the 10-14 day schedule used in this study would have resulted in poor scab control in some seasons. For this reason, it is common for growers to apply several more sprays, reducing the interval between sprays to 7 days early in the season. In most instances, this is at variance with the labelling of the fungicides (Table 1), and results in greater fungicide usage, with attendant chemical and application costs.

Curative spraying has been shown to be an effective means of scab control (Washington 1980, 1981; Ellis and Wilson 1983, Penrose *et al.* 1985). The work reported here shows that in most seasons control will be maintained, with an average saving of about one spray per season when compared with protectant spraying. However, prolonged weather unfavourable for spraying, due either to rain or wind, or water-logged soil conditions making machinery access impossible, may make this approach more risky. Insecticidal and powdery mildew sprays need to be applied regularly, at approximately two weekly intervals (Johnson *et al.* 1988). Therefore it may be more efficient to include a scab fungicide with these sprays, rather than to wait for an infection period to occur, which could mean having to spray again for scab shortly after application of the insecticide or powdery mildew spray. Further, a number of the scab fungicides will also control powdery mildew (Table 1).

The application of mixtures of a protectant fungicide plus a curative fungicide on the same timing as a straight protectant schedule, could be expected to give excellent disease control, and in our work would have suffered from no failures. However, the cost of using two full rate fungicides, whilst not doubling application costs, would result in a considerable cost increase.

Strategic spraying, involving a regular protectant schedule, replaced with a curative fungicide when required had the advantage in this study of no failures, but at the expense of slightly more applications per season than the protectant schedule studied. However, because growers often apply sprays more frequently than the 10-14 day schedule studied here, the total number of sprays applied strategically may be similar to those applied on a protectant schedule in practice.

Schwabe (1980) points out that a protective spray programme is the best means of achieving effective scab control, supplemented in the first half of the season with curative fungicides at critical periods. Jones *et al.* (1984) indicated that in the United States most growers follow a protective spray schedule to control scab. Using information obtained on predicted infections, growers change to a curative fungicide if required. They point out that to rely on curative spraying, the grower must be able to spray his orchard within a very short time. Further, the saving of sprays may be offset by the fact that curative fungicides are generally more expensive.

Fungicide resistance has been reported in *V. inaequalis* to a number of the newer ergosterol biosynthesis (EB) inhibiting fungicides (Stanis and Jones 1985, Thind *et al.* 1986), and for dodine (Gilpatrick and Blowers 1974), which are used for curative control of apple scab. The use of fungicides all with the same mode of action is generally regarded as favouring development of resistance. Of the curative fungicides listed in Table 1, all except dodine have a similar mode of action (EB inhibitors) and therefore their sole use in a curative spray programme may favour the selection of resistant strains.

The choice of fungicide can also be determined by factors other than disease considerations. In New South Wales integrated mite control using predatory mites is recommended (Johnson *et al.* 1988) and widely adopted. Several of the currently available fungicides (Table 1) have deleterious effects on this programme.

The selection of a strategy to control apple scab is not simple. Many factors may be involved, from fungicide resistance, the weather experienced, effects on other diseases or beneficial insects, and cost. Within these limitations it would appear that in New South Wales main apple growing areas, either a mixture of curative and protectant fungicides, applied on a protectant schedule, or a protectant spray programme replaced by curative sprays when required, (i.e. strategic), may give the most reliable disease control.

The role of disease warning services is to enable growers to make a rational decision on the strategy to be followed within the circumstances prevailing in any particular season.

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