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Fire blight risk assessment during bloom in an experimental orchard using BIS (Billing's Integrated System)

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Abstract

The value of BIS for blossom blight risk assessment was studied from data collected in an experimental orchard in south-west France. Trees observed included mature commercial pear and apple trees and some young trees in experimental plots. There was a weather station in the orchard and beehives were present. Field records included flowering times of the pear and apple cultivars studied (mostly Passe-Crassane and Beurré Hardy, Royal Gala and Golden Delicious) and dates when blossom blight was first seen on each cultivar. Between 1980 and 1991, records of blight were available for 25 cases. In most cases, one or more infection risk (IR) days, as defined for BIS, could be found during bloom. DD13 mean sums (sums of degree days above a mean temperature of 13 °C) gave good guidance on times when early signs of blossom blight were present in 14 cases. There was only a slight divergence from BIS guides in a further five cases. Possible reasons for divergence and for non-fit in the remaining six cases are discussed. It is concluded from this study that BIS should give useful guidance on optimal times for protective spray applications and for timing of searches for signs of early blossom blight in south-west of France. Graphical presentations of data provide additional information.

Introduction

In 1979, an experimental orchard was established near Dax, south-west France, in a joint programme between INRA (Institut National de la Recherche Agronomique) and SPV (Service de la Protection des Végétaux) in the framework of European Commission (AGRIMED-CAMAR) projects, aimed at studies on fire blight control. Experimental plots were planted with commercial varieties of pears, apples and ornamental host plants and with new hybrid cultivars. The plots were located in a 40 ha commercial fruit farm where natural outbreaks of fire blight were first seen in 1978. Blossom blight records were available from 1980-1991.

BIS (Billing's Integrated System), Billing (1996), Berrie and Billing (1997) was developed over the period 1992–1995. It incorporates features of earlier approaches to fire blight risk assessment developed by Billing (1980 a,b; 1992) and others (in particular Mills, 1955; Powell, 1965; Thomson et al., 1982; van der Zwet et al., 1988; Steiner, 1990 a, b).

The object of this study was to use the records collected at the Dax orchard for an independant evaluation of BIS in relation to blossom infection risks, for optimal timing of protective spray applications, and to disease development rate estimates, for optimal timing of searches for signs of new disease.

BIS differs from Billing's revised system BRS (Billing, 1992) in the following ways. Temperature values and heat sums are no longer expressed in terms of potential daily doubling (PD) of the pathogen. In BIS, a clear distinction is made between infection risks (IR) for open flowers when weather is warm and widespread blossom blight is possible and blossom or green tissue infection on warm wet (WW) days

Table 1. Infection risk (IR) days. Blossom infection risks (BIR) of general infection risks using WW (warmth/wetness) and scores (2 to 6)

	BIR during bloom when DD18 max. sum > = 17				WW score if rainfall (mm) (on warm day **or** the next day)		
Mean temp °C	dry	fog/ dew	rain > = trace[a]	WW > = 3	3.0	10.0	20.0
13					2	3	4
15		B	B	B	3	4	5
18		B	B	B	4	5	6
20	B[a]	B	B	B	4	5	6

[a] Score B also when maximum temperatures are ≥ 27 °C.

when localised spread of inoculum is possible (Table 1). The WW scores have been simplified. Disease development rate estimate (D-period length) now follow closely the method used in the Maryblyt model (Steiner, 1990 a, b) but the critical sums are different. The graphics have been simplified. The methods are suitable for computerization if desired.

Materials and methods

Field records

Pear and apple cultivars

These included mature trees in the commercial plantation and young trees in experimental plots (Table 2, Figure 1). As the orchard was an experimental site for fire blight where tests on the susceptibility of new pear, apple and ornamental cultivars were made, inoculum levels might sometimes be high near the test plots used in this study.

Table 2. Pear and apple cultivars under observation in the Dax experimental field (1980-1991)

Cultivars	Approx. number	Age[a] (years)	Year(s) of observation
Pear			
Alexandrine Douillard (AL)	30	25	1980
Passe Crassane (PC)	200	20	1980–1981
	800	2	1982–1984
	300	1	1986–1991
Beurré Hardy (BH)	800	20	1980–1988
	400	6	1990
Apple			
Golden Delicious (GD)	4000	20	1980–1987
Royal Gala (RG)	800	4	1985–1990
Canada Gris (CG)	400	4	1990

[a] on the first year of observation.

Flowering records

Plots were visited twice a week for assessment of phenological stages. Blossom periods recorded were 5–10% open flowers to 90% petal fall. There were likely to be some intact open flowers available for colonization and infection by the pathogen for a few days before the start and after the end of the recorded period.

Disease records

Inspections for early signs of blossom blight were mostly made at 3–5 days intervals. If signs of blight were well developed, the most likely time of early signs was estimated.

Weather records

A meteorological station with a standardized shelter was located in a pear plot where Passe-Crassane trees were 20 years old in 1980. Daily temperature and rainfall values were obtained from a thermograph and a rain recorder. Trace rainfall amounts (which we consider to often indicate heavy dewfall) were not recorded after 1983. Heavy dewfall or fog was occasionally recorded but unfortunately daily records were not possible.

Weather analyses

The methods used were those described by Billing (1996) and Berrie and Billing (1998); Billing (BIS methods and evaluation, in preparation). BIS is used to assess field and weather related risks for all hosts throughout the growing season but this paper only

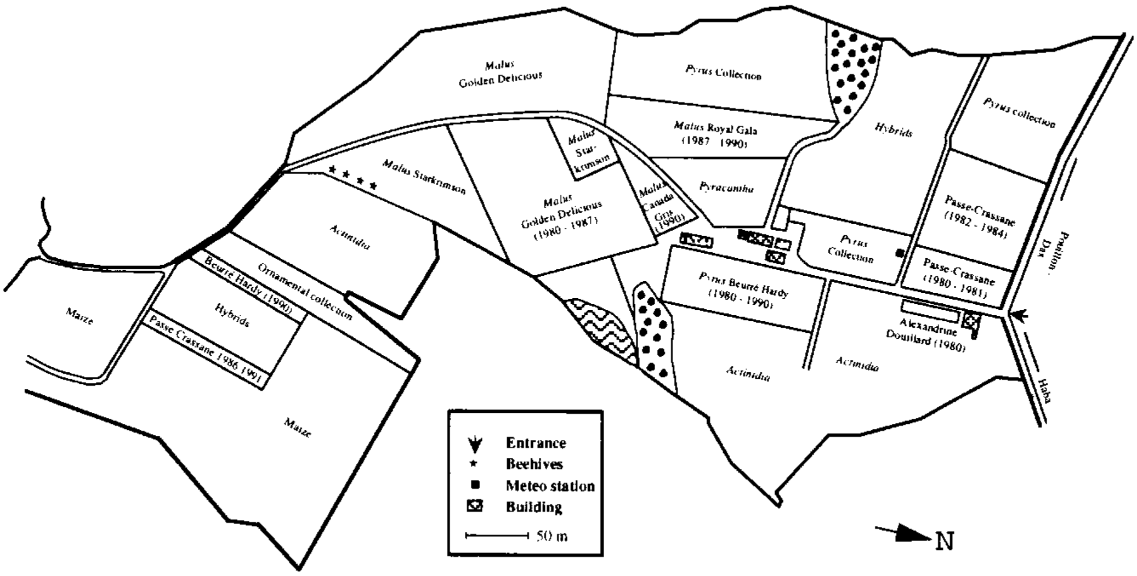

Figure 1. Experimental orchard EC – INRA – SPV (Situation 1991) Mr Dussarat farm. 'Bédat' – Dax – Labatut, Landes, France
Commercial or experimental plots where inspections for early signs of blossom blight were done (1990–1991). Dates indicate the years of observation.

considers risks before and during pear and apple blossom periods. Maximum temperatures never exceeded 32 °C.

Criteria for infection risk (IR) days are summarized in Table 1. Degree days above 18 °C (DD 18 max sums) are used to judge flower colonization and spread risk during bloom. The critical sum for BIR day is >=17; sums >=34 suggest the possibility of high disease incidence (DIN).

The length of the D-period (the time from the day after the IR day of early signs of blight and fresh inoculum production) is estimated using simple degree day sums above a mean temperature of 13.0 °C (DD 13 mean sums). The critical sum is >=17 except in the case of apple blossom blight when it is usually >=47.

Graphics

Field factors need to be considered alongside weather analyses. Graphics (using symbols for concise presentation) allow day-by-day analyses of events including oozing cankers, flowering times, new symptoms, daily temperatures and rainfall and storms. Keys to abbreviations and symbols are given in Table 3.

Optimal timing of protective spray applications and of searches

Weather analyses, in conjunction with full field evidence give guidance during bloom on the optimal timing of protective spray applications (with BIS, usually on the day before a forecast IR day). The end of D-periods following significant infection risks give guidance on optimal timing of searches for signs of new disease. Suggested dates for first spray applications (based on available evidence) are shown in the graphics (Figures 2–6) for each year. Warnings for the first sprays during bloom suggested by firescreens, a commercially available software for fire blight control developed in France (Jacquart-Romon and Paulin, 1991) are also indicated. Firescreens has been shown to provide useful warnings for control of the disease in the Dax area (Lecomte et al., 1997). It differs from BIS in that IR days and D-periods are based on Billing's original system, BOS (Billing, 1980a). A full comparison of the reliability of the two approaches was not possible, so the suggested spray dates only provide broad guidance on differences.

Results

Infection risks

In most cases where early signs of disease were seen, one or more IR days could be identified from early to midbloom which conformed to BIS (Table 1). Characteristics of some of the first IR days during bloom are shown in Tables 4 and 5. In the graphics, IR days

Table 3. Key to abbreviations and symbols

Abbreviations	
Used in text and graphics	
AL, BH, PC	Pear cultivars: Alexandrine Douillard, Beurré Hardy, Passe-Crassane
CG, GD, RG	Apple cultivars: Canada Gris, Golden Delicious, Royal Gala
DD	Degree days and DD sums (18 °C max or 13 °C mean)
D-period	Disease development period following infection (time when early signs of disease likely)
DIN	Disease incidence
IR day	Infection risk day (B or WW score day)
Used in graphics	
Date	1, 2, 3: 10th, 20th, 30th;: , 5th, 15th, 25th
Bloss	Blossom period (- - - - - - - - - - - - - - - - -)
Te	Temperature (max. or mean)
B	Blossom infection risk
WW	Warmth/Wetness score
n	Active cankers
b	Blossom blight
s	Shoot blight
DD18	DD18 max. °C sums *during bloom only* (> = multiples of 17.0)
D-period	Graphical representation of D-period, from start (IR-day) to end.
o	End of D-period on completion of DD13 sum≥17.0 (———) for pears and RG apple, or 47.0 for CG and GD apples (– – – –). When these values are not reached at the likely end of the D-period, the actual value of the DD13 sum is indicated, instead of o.
Spray BIS	Suggested first spray warning during bloom, according to BIS guidance and available evidence.
Spray F.	First spray warning during bloom issued by firescreens .

Symbols (graphics)

Symbol	DD18 sum>=	Max. temp °C>=	Mean temp °C>=	Rainfall (mm)
U Ultra	68	30.0	22.0	>=20.0
X Extra	51	27.0	20.0	10.0
H High	34	24.0	18.0	3.0
m medium	17	21.0	15.0	1.0
• low		18.0	13.0	< 1.0
z				fog or trace
d				heavy dew

(B and WW scores) are shown for prebloom, blossom and postbloom periods. Unusual cases are noted in the comments on the graphics (below).

D-period estimates

There were 25 cases where early signs of blossom blight (or in one case, shoot blight) had been seen. These were divided into three groups. First, 14 cases (Table 4) where the D-period starting on the first most likely IR day ended in 0–3 days of the date when

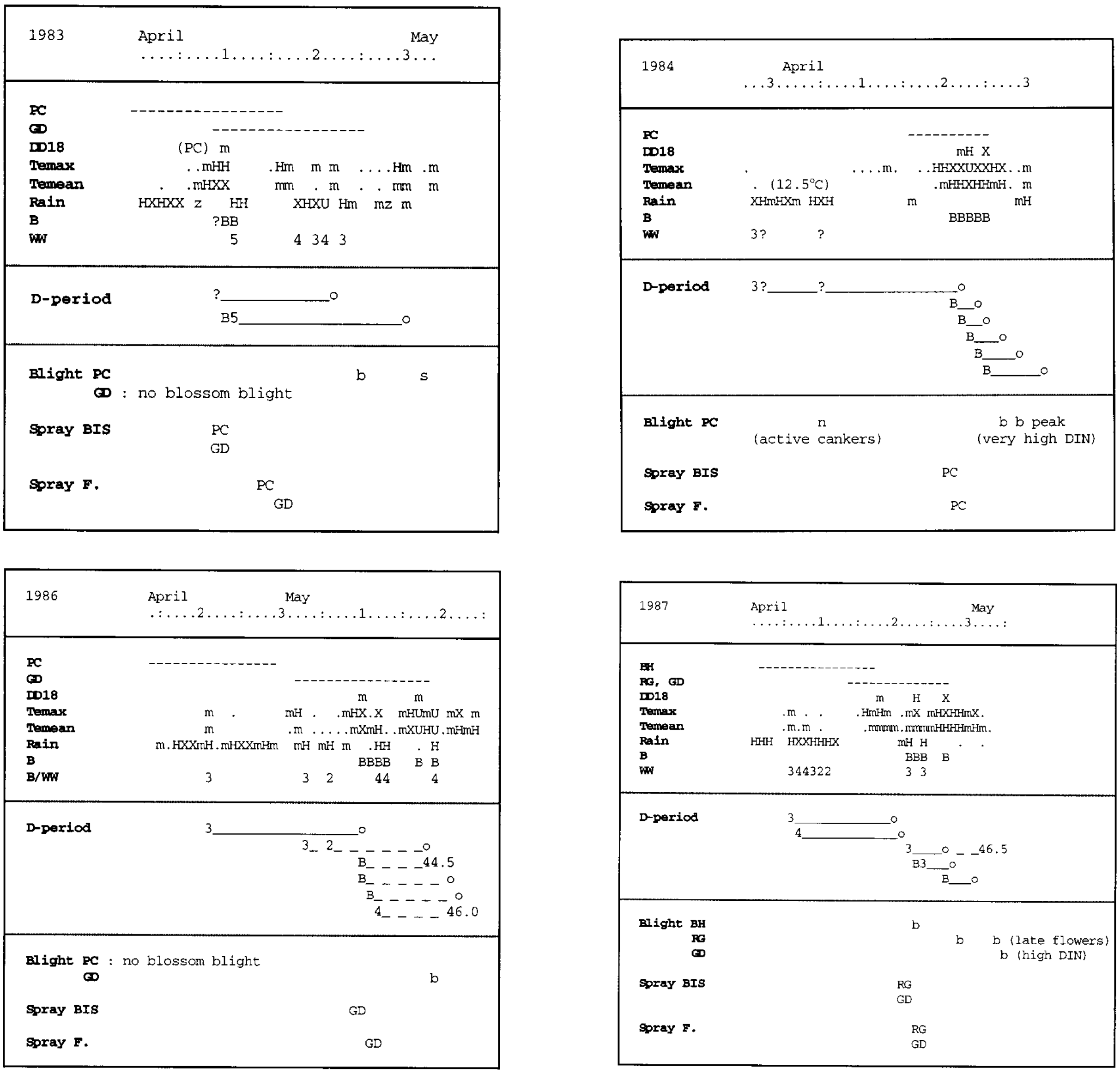

Figure 2–5. Field, weather, fire blight data and spray warnings – 1983, 1984, 1986 and 1989.

early signs of disease were seen. The second group (Table 5) were five cases which did not conform completely with BIS guides but were close to them; in two cases, possible alternatives IR days are shown in both Tables 4 and 5. The five near-fit cases (Table 4) included two, PC (1983) and RG (1988) where the critical DD 13 sum (>=17) was reached one day after early signs of disease were seen. In two other cases, RG (1985) and PC (1991), long cool D-period (19 and 31 days) might have affected DD13 mean sum precision. With BH (1980), mean temperatures dropped below 13.5 °C after the sum of 16.5 had been reached; also, during bloom, the DD18 max sum was split by a sudden drop in temperature on one day to 14.0 °C. With PC (1983), the DD max sum of 15 reached 23 the following day. Two near-fit cases, RG (1985) and (1988) became good-fit cases if there were some open flowers before the 5% blossom record suggests (see graphics).

Five of the six non-fit cases (Table 6, Figure 6) occurred in two years (1989 and 1990) when prebloom

Table 4. Best-fit cases using early signs of disease and DD13 mean sums following likely infection risk (IR) days (14 cases). See also Table 5 and graphics

Host	Cultivar	Year	Likely IR day DD18 >=17 B	Likely IR day DD18 >=17 WW	Likely IR day DD18 <17 WW	Early signs DD13 fit sum	(days)[a]	D-period length (days)
Pear	AL	1980			2	>=17.0	0	6
	PC	1980			4	>=17.0	1	17
		1981	B wet			>=17.0	2	5
		1983	(shoots)		5	>=17.0	3	22
		1984	B dry			>=17.0	3	3
	BH	1981			5	>=17.0	1	10
		1985	B dry			>=17.0	0	17
		1987			3	>=17.0	3	14
		1988	B wet			>=17.0	2	3
Apple	RG	1987	B wet	3		>=17.0	1	5
		1987	B dry (late flowers)			>=17.0	3	4
	GD[b]	1986			3	>=47.0	1	15
		1987	B wet	3		46.5	3	10
	GD[b]	1990	B[c]			>=47.0	0	11

[a] Difference between the end of the D-period (DD13 mean sum >=17.0 or 47.0) and the time (days) when early signs of disease were seen or suspected from degree of symptom development (inspection intervals 2-5 days).
[b] For alternative IR days. See Table 5.
[c] If there was dewfall on the day before rain.

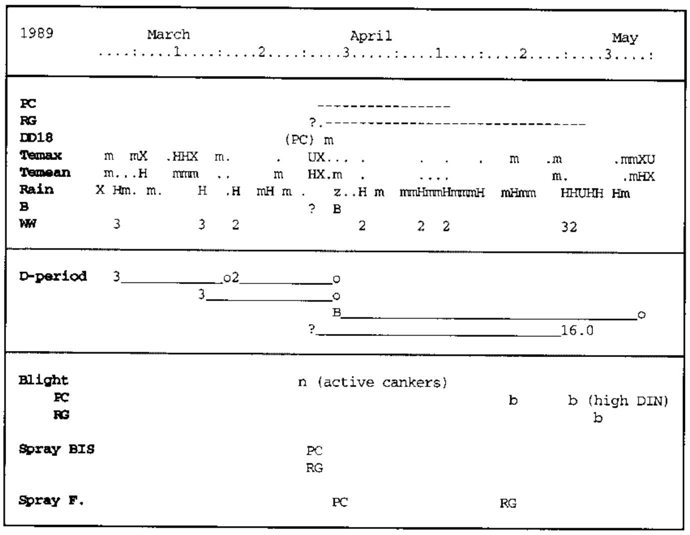

Figure 6. Field, wheater, fire blight data and spray warnings – 1989.

temperatures were unusually high. There were also prebloom frosts in those years.

Blossom blight incidence

Available disease records did not allow a full study of relationships between infection risks during bloom (BIR) and the incidence of blossom blight. However, an unusually high incidence on pears (PC) in 1984 and apples (CG) in 1990 and many blighted flowers on apples (RG and GD) in 1987 were associated with high DD 18 max sums (>=34) and >=4 BIR days during bloom. In two years when no blight was seen

Table 5. Near-fit cases (5) and alternative IR days (2). See also Table 4 and graphics

Host	Cultivar	Year	IR day	Lower thresholds DD18 Sum	Lower thresholds DD13 Sum	Fit (days)	D-period length (days)
Pear	PC	1983	?	15	20.0	4	13
		1991	WW3[a]		16.0	0	31
	BH	1980	B?	10 + 7	17.5	4	19
Apple	RG	1985	WW2		15.5	0	19
		1988	B/WW6		15.0	0	10
	GD[b]	1986	B		44.5	0	9
	CG[b]	1990	B/WW4		45.0	0	10

[a] Prebloom IR day.
[b] For alternative IR days see Table 4.

Table 6. Non-fit cases (6). Prebloom weather (see Figure 6 for 1989)

Host	Cultivar	Year	Prebloom max. °C days >= 27.0	Prebloom max. °C days >= 24.0	Prebloom frost °C (days)	Active canker seen
Apple	GD	1980		2	No	No
Pear	PC	1989	2	4	−2.0 (1)	Yes
Apple	RG	1989	2	4	No	No
Pear	PC, BH	1990	2	5	−1.0 (3)	No
Apple	RG	1990	2	5	No	No

on pears, there was only one IR day (WW 3) during bloom (1986) or none (1982).

Further comments using graphics (Figures 2 to 6)

The graphics illustrate concisely points of special interest associated with some of the cases listed in Tables 4 to 6.

1983 (Figure 2). The best fit IR day (?) for pear (PC) was the day before the first typical BIR day. On that day, the mean temperature was >=20 °C but the DD18 max sum was only 15 so this is a near-fit case. The D-period associated with a WW5 day fits well the appearance of shoot blight.

1984 (Figure 3). The pear (PC) blossom period was very warm and dry but there were five consecutive days with temperatures >=27 °C which could act as BIR days (Table 1) and encourage high disease incidence. This was a good-fit case.

1986 (Figure 4). At pear (PC) midbloom, the WW3 day might have led to localized blossom blight near active cankers releasing bacterial inoculum (if present) but no blight was seen. A good fit D-period for the apple GD (DD13 mean sum >=47) started on another WW3 day and blossom blight was likely to be localized at first. More blight was seen soon afterwards and BIR on four consecutive days (two with WW4 scores) would account for this.

1987 (Figure 5). The BH pear blossom period was cool and wet but D-periods following the first two IR days (WW 3 and 4) fitted well the early signs of blossom blight.

The apples RG and GD flowered together and the first BIR day was mid-bloom. Blossom blight was seen on RG soon after the DD13 mean sum was >=17 but it was not seen on GD until the sum was 46.5 (cool weather prevented a further increase in this sum). Late flower infections were seen on RG and were associated with a D-period starting on a BIR day at the end of bloom. Blossom blight risks were high for both apples (DD18 max. sum >=51) and disease incidence on the 20 year old GD trees was high.

1989 (Figure 6) and 1990. These two years with five non-fit cases (Table 6) shared several characteristics: pre-bloom frost days; high temperatures prebloom; prebloom infection risks; two very warm days just prebloom or early bloom; cool, wet blossom periods with early D-periods ending long after signs of blossom blight had been seen on pears (PC, BH) or apple (RG).

Several points merit attention in the 1989 graphic. There was an active canker producing bacterial ooze just before two very warm days at first bloom. Perhaps the 30 °C day was an IR day (labelled: ?), if so, a DD13 mean sum of 16 (not 17) is reasonable for a long, cool, wet D-period. The end coincides with high PC pear blossom blight incidence (but not the first signs of blight) and with the first RG apple blossom blight. These are only near-fit cases if normal BIS guides on IR days are ignored. The 1990 graphic offered no guidance on possible explanations for non fit cases.

Timing of protective spray applications during bloom

Judgements depend on all possible field and weather risks including overwintering canker risks. Such risks are usually judged by the incidence of remaining twig or stem cankers in spring and knowledge of new blossom or shoot or twig infections and progressive stem invasion late in the previous season. Judging by the weather analyses illustrated, protective spray applications might be made slightly earlier when using BIS compared with firescreens recommendations in most cases. The difference in timing was wider in a few cases. The number of recommended spray applications during bloom would probably be similar. There was no evidence available to judge which approach would provide the best protection. Precise guidance on spray timing is outside the scope of this paper.

Discussion

BIS was developed mainly with the use of cases of fire blight in England and some from the USA. Weather records for these cases came, almost exclusively, from national weather stations in the area concerned, not from orchards. The weather and disease records from Dax in south west France were collected by independent workers, before BIS was developed, using an orchard weather station. This seemed to provide an objective approach to BIS testing and evaluation. As is common when testing risk assessment systems, the available records were not always ideal for the purpose but they were adequate.

Results showed that the occurrence of fire blight was closely related to the occurrence of BIS infection risk (IR) days. A high incidence of blossom blight was associated with high DD18 max sums during bloom and four or more IR days (experience elsewhere shows that high disease incidence does not always follow such weather).

When the precision of D-period length estimates was examined using a critical DD13 mean sum of $>=17$ (or$>=47$ for Golden Delicious apple) more than half the cases fitted BIS expectations well. If near-fit cases are included, the proportion rises to 19/25 (76%). This proportion is in accord with good-fit cases observed by Billing with more than 40 other cases. (paper in preparation).

The non-fit cases (Table 6) are of special interest. Lack of trace rainfall or dewfall records was never an explanation for non-fit cases. It was possibly so with one near-fit case (CG 1990) as shown in Tables 4 and 5. It may be noteworthy that for five non-fit cases out of six, temperatures were high in the prebloom period and prebloom infections were a possibility but not the explanation for the times when early signs of blossom blight were seen. Possible explanations for non-fit cases need to be explored at the time of occurrence. An unknown insect risk cannot be predicted, nor can the possibility of indirect infections due to the extension of small twig cankers (Billing et al., 1974, Billing, 1996). Prebloom and indirect infections are not always easy to distinguish from direct early open flower infections; their incidence is only rarely high. Such cases are not well documented but Miller (1929) observed direct flower bud infections on apples and Billing (unpublished) on hawthorns. Miller and two other early workers in the USA and Billing (unpublished) easily produced prebloom infections experimentally on pear and apples. In the absence of insect, frost or storm damage, high doses of inoculum (such as ooze from overwintering cankers) and thorough wetting are usually necessary for such infections.

The graphics have advantages over tabulated data when following events on a day-by-day basis. Prebloom and blossom period risks are easier to assess. Different types of infection risk (including possible storm damage) which might affect subsequent disease incidence stand out and the times of infection in relation to stages of bloom on different pear and apple cultivars is clear.

BIS has some features in common with the maryblyt model (Steiner, 1990a, b) including the use a DD13 mean sums for judging times when early signs of blossom blight are likely. Dax observations confirm that the threshold sum for pear blossom blight is lower than that for most cases of apple blossom blight (Billing, 1996). Van der Zwet (1990) in the USA and Gouk et al. (1996) in New Zealand (using different versions of the maryblyt model) have also found that pear blossom blight symptoms may appear earlier than those on apple. At Dax, the apple cultivar Royal Gala seemed to be an exception to the general rule for apples; a DD13 mean sum of 17.0, not 47.0, was the appropriate threshold. This finding is in contrast to that reported by Gouk et al. (1996); late flowers on Royal Gala behaved like other apples cultivars.

Up to now no comparison between maryblyt, firescreens and BIS is available. These three systems should be used in parallel, in the future, in an area where protective sprays are in regular use, to see which gives the best guidance.

Conclusions

BIS should provide useful guidance in the Dax area for the timing of protective spray applications and for searches for signs of new disease. Some slight divergences from recommended thresholds warn that (like any system) BIS cannot always offer strict rules concerning risks. The user needs to explore anomalies (at the time, because it is not possible with historical records) and pay due attention to field factors that affect risks. There is no doubt that blossom blight symptoms appear more rapidly on pears than on most apple cultivars. The case of the apple cultivar Royal Gala needs further investigation.

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