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Testing electronic warning equipment together with the curative fungicide bitertanol for control of apple scab (*Venturia inaequalis* (Cooke) Winter)

Afprøvning af et elektronisk varslingsudstyr sammen med det kurative fungicid bitertanol til bekæmpelse af æbleskurv (Venturia inaequalis *(Cooke) Winter)*

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Summary

In three years of experiments the control of apple scab (*Venturia inaequalis* (Cooke) Winter) obtained by spraying according to an electronic warning system Berghof Biomat SWG was compared to the control obtained by a protective program with application intervals of seven days. In the warning treatment the curative fungicide bitertanol with 0.25 kg per ha was used. Bitertanol was also used in the protective treatment with 0.25 kg per ha the first two years, and was replaced by 1.5 kg tolylfluanid per ha the last year.

In the trials there was a high risk of infection so the preventive sprayings were applied in rather short intervals (7–10 days). The warning treatment gave under this condition a reduction of the spraying frequency. Applications in accordance with the warning equipment gave a slightly less control of apple scab compared to the protective treatment. The report indicates ways to eliminate the difference. It is concluded that the use of warning equipment together with a curative fungicide gives a sufficiently safe control of apple scab.

Key words: Apple scab, *Venturia inaequalis,* warning equipment, bitertanol.

Resumé

I forsøg over tre år blev virkningen af at bekæmpe æbleskurv (*Venturia inaequaelis* (Cooke) Winter) ved at sprøjte efter et elektronisk varslingsapparat Berghof Biomat SWG sammenlignet med virkningen af et forebyggende sprøjteprogram med sprøjteintervaller på 7 dage. I varslingsledet blev benyttet det kurative fungicid bitertanol med 0,25 kg pr. ha. Bitertanol blev ligeledes benyttet i det forebyggende led de to første år. Det sidste år blev det erstattet med 1,5 kg tolylfluanid pr. ha. I de gennemførte forsøg var der en høj infektionsrisiko, hvorfor de forebyggende sprøjtninger blev udført med ret korte intervaller (7–10 dage). Varslingssystemet gav under disse forhold en reduktion af sprøjtehyppighed. Der blev fun-

det en tendens til en lidt ringere virkning mod både blad- og frugtskurv ved sprøjtning efter varslingsapparatet i forhold til det forebyggende sprøjteprogram. Forskellen var dog meget lille og der angives i beretningen muligheder for at fjerne forskellene. Det konkluderes, at fastlæggelse af sprøjtetidspunkterne efter et elektronisk varslingsapparat kan give en tilstrækkelig sikker bekæmpelse af æbleskurv.

Nøgleord: Æbleskurv, *Venturia inaequalis*, varsling, bitertanol.

Introduction

Apple scab (*Venturia inaequalis* (Cooke) Winter) is a serious disease in apples in Denmark. To control the disease the growers must spray several times during the growth season. The main effect takes place from budburst to about four weeks from petal fall where infection with ascospores is possible (22). If no scab infected flecks are observed at this time the grower will stop spraying until late summer, where the fruits are sprayed for control of among other things storage scab. To increase the efficiency and to decrease the number of applications electronic warning systems based on the scab infection table of *Mills* and *Laplante* (15) have been developed (e.g. 6, 8, 10, 20). The appearance of the ergosterol-biosynthese inhibitor (E.B.I.) fungicides has made the use of warning systems more attractive. The E.B.I. fungicides show a curative effect up to 96 hours after a scab infection and so give a broad time margin from when a warning is registered to the fungicide being applied.

The aim of the investigation has been to establish if application of a curative fungicide in accordance with a commercially available electronic apple scab warning equipment gives sufficient control of apple scab under strong infection pressure, and how the number of the applications could be reduced.

The warning equipment was operated as recommended by the manufacturer. No attempts were made to check the precision of the equipment's meteorological registrations or to improve the warning model.

Materials and methods

The experiments were carried out for three years from 1987 to 1989 and included three treatments: A control to assess the infection pressure, a treatment where the apple scab was controlled by protective sprayings, and a treatment where a curative E.B.I. fungicide was applied according to electronic warning equipment. The electronic fungus warning equipment was a Biomat SWG (Berghof, West Germany). It consists of a sensor unit which is placed in a tree crown, where it record the foliage moisture and the air temperature. The signals are transferred to a central unit which contains a program based on Mills' tabel for the relation between temperature and the minimal period of leaf wetness necessary to give scab infection. It means that the model only registers when the climatic factors give the possibility of apple scab infection. The warning equipment can be set to indicate three levels of infection: Light, medium, or severe.

The experiments were carried out in an experimental plantation in 3 m high 'Golden Delicious' spaced at 2.85 × 4.5 m. The experimental design was systematically placed plots of 4 trees. The number of blocks varied from year to year. It was 6 in 1987, 3 in 1988, and 4 in 1989.

To assure the presence of infectious ascospores a net containing scab infected leaves from the previous year was placed in the canopy of each plot.

The fungicide bitertanol was used in the warning treatments with 0.25 kg per ha (1.0 kg Baycor 25 WP per ha). Bitertanol was considered to have a curative effect of 4 days and a protective effect of at least 3 days. It meant that when the warning equipment indicated a possibility of infection bitertanol was applied up to 96 hours later. The warning equipment was reactivated 3 days after the application. This time scheme gave a minimal interval of 7 days between the applications in the warning treatment. Bitertanol was also used in the protective treatment in 1987 and 1988 with 0.25 kg per ha while it was replaced by the strictly protective fungicide tolylfluanid with 1.5 kg per ha (3.0 kg Euparen-M per ha) in 1989. The aimed

spraying intervals were 7 days until the end of June and thereafter 10–14 days. In warm dry periods the intervals were extended. The control plots were not sprayed at all.

The applications were made with a tractor-mounted air mist blower with 1,0 mm swirvl cone nozzles and an axial blower. The spray volume was 400 l per ha.

In 1987 the first protective spraying was applied and the electronic warning equipment was activated at the mouse-ear stage. In 1988 the start of the two treatments was moved foreward to budburst. In 1989 the procedure was changed, so both in the protective and in the warning treatment a protective spraying with 1.5 kg tolylfluanid per ha was applied at budburst. The warning equipment was activated 10 days later at mouse-ear stage and the treatment was thereafter sprayed with bitertanol as stated above.

In 1987 the warning equipment was set to indicate a light level of infection from the beginning of the season until the growth stage fruit swelling was reached, when it was changed to medium level for the rest of the season. In 1988 the level was set to medium from budburst to petal fall, then it was changed to light level until fruit set and back again to medium level for the rest of the season. In 1989 the level of infection was set to medium the whole season.

The level of scab infection on leaves and fruits was assessed according to the Danish guidelines for testing pesticides for control of apple scab (2). The leaf scab was assessed on 100 leaves per plot according to a scale from 1 to 5 with 1 = no infection and 5 = 10 or more spots per leaf. The fruit scab was assessed on 100 fruits per plot according to a scale from 1 to 4, where 1 = no infected flecks and 4 = the flecks cover more than 1 cm^2. For both leaf and fruit scab the level of infection and the efficiency was calculated according to *Townsend* and *Heuberger* (21) and *Abbott* (1) respectively.

Results

The dates and growth stages of the applications in 1987–1989 are shown in Table 1. The levels of infections of leaf and fruit scab, the efficiency of the treatments to control apple scab, and the number of applications made in 1987–1989 are shown in Table 2.

Infections of apple scab were observed in the control plots every year. There was a lot of rain in 1987 which caused great problems in the timing of the applications. The scab infection did not become severe in 1989 due to very dry weather.

Discussion and conclusion

A tendency was found to a slightly less control of both leaf and fruit scab in the warning treatment compared to the protective treatment even though the difference was significant only in 1989. The difference is very small however and much smaller than for example the difference found in the efficiency between different fungicides approved for control of apple scab (18).

The reduction in the number of applications by using the equipment differed very much from year to year. In 1987 there was a reduction of only one spraying because of the extremely wet season caused frequent warnings. The wet weather also often caused longer periodes between the protective sprayings than intended. In the two following

Table 1. Dates and growth stages of the applications 1987–1989.
Datoer og vækststadier for sprøjtninger 1987–1989.

1987

A. Dato, *dato*	5/5	13/5	19/5	26/5	30/5	9/6	10/6	19/6	30/6	9/7	21/7	22/7	3/8	18/8	20/8	26/8	1/9	9/9		
B. Treatment, *forsøgsled**	2+3	2	3	2	3	3	2	2+3	2+3	2	3	2	2+3	2	3	3	2	2+3		
C. Growth stage, *vækststadium***	C2	D	D	D	G	H	H	I	L	L	L	L	L	L	L	L	L	L		

1988

A.	28/4	5/5	7/5	13/5	19/5	25/5	26/5	2/6	3/6	9/6	11/6	16/6	23/6	27/6	30/6	10/7	12/7	22/7	26/7	2/8	6/8	11/8	18/8	22/8	1/9	6/9	8/9
B.	2	2	3	2	2	3	2	2	3	2	3	2	2	3	2	3	2	2	3	2	3	2	3	2	2	3	2
C.	C1	C2	C2	E	E	G	G	H	H	I	I	I	I	L	L	L	L	L	L	L	L	L	L	L	L	L	L

1989

A.	30/3	13/4	20/4	28/4	8/5	18/5	1/6	8/6	15/6	29/6	1/7	7/7	21/7	3/8	7/8	11/8	16/8	20/8	21/8	30/8	2/9
B.	2+3	2	2	2+3	2	2	2	2+3	2	2	3	2	2+3	3	2	3	2	2	3	2	3
C.	C1	C2	C2	D	E	G	I	I	L	L	L	L	L	L	L	L	L	L	L	L	L

* 2 = preventive treatment, *forebyggende led*, 3 = warning system, *varslingsled*
** C1 = budburst, *grøn spids*, C2 = mouse-ear stage, *museøre*, D = tight cluster, *tæt klynge*, E = pink bud, *ballon*, G = full bloom, *blomstring*, H = petal fall, *afblomstring*, I = fruit set, *dunet frugt*, L = fruit swelling, *glat frugt*

Table 2. The level of infection of leaf and fruit scab and the number of applications in the 3 treatments in 1987–1989. *Infektionen af blad- og frugtskurv og antal sprøjtninger i de 3 forsøgsled i 1987–1989.*

Treatment *Forsøgsled*	No. of applications *Antal sprøjtninger*			Leaf scab *Bladskurv*								Fruit scab *Frugtskurv*		
	1987	1988	1989	1987			1988			1989		1987	1988	1989
				24/6	30/7	31/8	28/7	17/8	13/9	3/8	25/8	22/10	24/10	4/10
				Level of infection *Angrebsgrad*								Level of infection *Angrebsgrad*		
1. Control *Ubehandlet*				72	94	100	32	30	47	21	16	100	55	23
				Efficiency *Virkningsgrad*								Efficiency *Virkningsgrad*		
1. Control *Ubehandlet*	0	0	0	0a*	0a	0a	0a	0a	0a	0a	0a	0a	0a	0a
2. Preventive *Forebyggende*	12	17	16	93b	86b	91b	100b	100b	100b	100b	99b	79b	99b	99c
3. Warning system *Varsling*	11	10	9	87b	80b	90b	100b	100b	100b	90b	97b	73b	94b	92b

* *Numbers followed by the same letter in columns do not differ significantly for P<0,05*
Tal efterfulgt af samme bogstav i søjlerne er ikke signifikant forskellige for P<0,05

years there was a reduction of seven applications each year. The number of sprayings was unrealistic high compared with practical apple growing because of the presence of the scab infected control plots caused an infection pressure throughout the season. This means that the results cannot apply to practical apple growing. An interesting point is however that the reduction in the number of sprayings in the warning treatment was obtained early in the season in the period where the fruit growers carry out their sprayings.

The experimental design was adjusted between the years to incorporate new knowledge. The start of the treatments was moved foreward from the mouse-ear stage to budburst because scab infection can occur at this early stage (12). The humidity conditions inside the unfolded bud at the budburst stage differ from the outside conditions, so the sensor unit of the warning equipment is not able to register the relevant data at the budburst stage (19). Therefore a purely protective spraying was applied at budburst in both treatments in 1989. The warning equipment was first activated at the mouse-ear stage where the humidity conditions are more comparable around the small leaves and the sensor unit.

The adjustment of the warning equipment's level of infection was changed each year. The adjustment to the light level early in the season in 1987 and 1988 was done according to *Scheer* (19) who pointed out that apple trees are most susceptible to ascospore infection at that time. The adjustment to the light level caused on the other hand frequent warnings which gave a very high incidence of sprayings compared with practical apple growing. That is why the level was set at medium throughout 1989. A systematical investigation of which level to be used should be made.

Bitertanol proved to be a very efficient fungicide for control of apple scab when applied in a protective treatment with 7 days intervals as well as when applied in a curative treatment with a minimal interval of 7 days between the applications. These results are in accordance with *Birch et al.* (3), *Brandes et al.* (4), *Dijke et al.* (5), *Gilpatrick et al.* (9), *Kelly* and *Jones* (11), and *Kolbe* (13) but inconsistent with *Palm* (17) who found that the protective effect of bitertanol is negligible. In 1989 bitertanol was replaced by tolylfluanid in the protective treatment. This was done purely to adjust the experimental design to similar experiments going on i Sweden and Norway.

The results of the efficiency show that a better control of leaf scab than of fruit scab was obtained. *Palm* (17) investigated scab control obtained with two curative, local systemic fungicides in 'Golden Delicious'. Two weeks after flowering the efficiency of control of leaf and fruit scab was

the same. Four weeks after flowering the control of fruit scab decreased however control of leaf scab remained the same. *Palm* connected the decrease in the control of fruit scab with a quick increase in fruit volume and a building of a wax layer which happen four weeks after flowering. This explanation might be valid for the present results as bitertanol is a curative local systemic fungicide and the investigation was made in 'Golden Delicious'.

In conclusion it can be stated that determination of the applications of a curative fungicide to control apple scab under high infection pressure by use of an electronic warning equipment is sufficiently efficient under Danish conditions. The investigation gives no conclusive answer to if the warning system can cause a reduction of the number of sprayings in practical apple growing.

The apple scab warning model can be improved by incorporating observations of the start of the ascospore discharge in the spring and of the end in the summer. There is obviously no reason to spray even when the conditions for infection are present if there is no infectious spores avaiable. Assessment of ascospore discharge can be made by visual methods (16, 22) and by use of models for degree day accumulation (7). *MacHardy* and *Gadoury* (14) found a distinct variation in the ascospore discharge per day. These observations should be confirmed for Danish conditions and if present they should be incorporated in the warning model.

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