RELATIONSHIPS BETWEEN AUTUMN BLACK SPOT, LEAF LITTER AND *VENTURIA INAEQUALIS* ASCOSPORE PRODUCTION IN APPLE ORCHARDS

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ABSTRACT

Ascospore production from pseudothecia in apple leaf litter in the spring is a critical step in the disease cycle of *Venturia inaequalis*. Leaf litter management is potentially an important component of an integrated pest and disease management strategy. An orchard study was carried out in Hawke's Bay to investigate the relationships between the incidence of black spot on leaves in autumn, the density of apple leaf litter on the orchard floor in spring and the number of ascospores produced in spring. A total of 22 blocks on eight orchards were surveyed for black spot incidence in autumn 2000. The following spring, remaining leaf litter was measured and ascospore production was quantified using spore traps. Autumn black spot levels and spring litter levels were accurate predictors of spring ascospore production. Management strategies employed on different blocks influenced spring leaf litter and ascospore levels. Blocks with high autumn black spot generally had high spring ascospore production. Management practices that substantially reduced litter levels resulted in reduced *V. inaequalis* inoculum.

Keywords: apple, black spot, *Venturia inaequalis*, leaf litter, ascospores.

INTRODUCTION

Black spot, caused by *Venturia inaequalis* (Cke.) Wint. infection, causes substantial costs and fruit losses to apple industries worldwide (MacHardy 1996). Management of overwintering inoculum on apple leaf litter is likely to become an important component of disease control strategies, especially under integrated fruit production (IFP) and organic production systems. *Venturia inaequalis* depends on apple leaf litter to over-winter and to complete the sexual stage of its life cycle, culminating in the release of ascospores from litter on the orchard floor in the spring. This dependence offers an opportunity for orchardists to break the pathogen life cycle and substantially reduce spring inoculum levels.

Two important factors likely to contribute to *V. inaequalis* inoculum density in spring are the incidence of black spot on leaves prior to leaf fall in the previous autumn and the density of leaf litter remaining in the spring. These two factors are important components of potential ascospore dose (PAD) prediction systems (Gadoury & MacHardy 1986).

The aim of this study was to investigate the relationship between autumn black spot levels, apple leaf litter and spring ascospore production under New Zealand conditions. Ultimately it is intended to incorporate such information into management decision-making tools.

METHODS

Trial sites

Eight Hawke's Bay orchards were selected for the trial. Assessments were made in 22 separate blocks with half the blocks under organic management and half under integrated fruit production (IFP) management.

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Autumn black spot assessment

Prior to leaf fall in autumn (May) 2000, black spot incidence on leaves was assessed in each of the trial blocks, using a system based on that of Gadoury & MacHardy (1986). Initially, ten extension shoots on each of ten trees scattered throughout each block were sampled. All leaves on each of the 100 shoots were carefully examined for presence of black spot lesions. If less than four or more than 20 infected leaves were found on the 100 shoots, sampling was ceased. Otherwise sampling was continued up to 300 shoots by selecting ten shoots/tree from further trees. Autumn black spot level for each block was expressed as mean number of black spot infected leaves per 100 shoots.

Spring leaf litter assessment

Apple leaf litter remaining on the ground was measured in early October at the same time as spring ascospore assessments were carried out. Leaf litter was assessed for each of the eight ascospore-trapped plots (see below) on each of the 22 orchard blocks by recording presence/absence of leaf fragments beneath 100 points on a 25 mm mesh grid through a clear plastic sheet. Leaf litter density was expressed as percentage ground cover.

Spring ascospore assessment

Spring ascospore release was assessed once on each of eight plots measuring 310 x 220 mm on each of the 22 orchard blocks during the peak ascospore release period in early October. Twelve suction traps were used. These traps, designed by Prof. W. MacHardy (University of New Hampshire), were each driven by a hair-drier motor mounted in a 60 mm diameter plastic pipe, and powered from a 12-volt deep cycle battery. Air and spores were sucked in through a 9 x 2 mm aperture in a cap at the bottom end of the pipe, and impacted on a glass microscope slide mounted 2 mm from the aperture. Each trap was held centrally in a clear plastic box measuring 310 x 220 mm and 200 mm high, and placed over the plot to be sampled. The sampling aperture was approximately 50 mm from the ground/leaf litter surface. Air flow rates through the traps were approximately 10 litres/min.

To stimulate and synchronise ascospore release, each plot to be assessed was saturated with 1.0 litre of water using a watering can (equivalent to approximately 10 mm of rainfall on the plot area), and the trap was placed over the plot for 1 h. Slides were removed for counting of ascospores at a later date.

Ascospores were counted by scanning four predetermined 250 µm wide transects across the spore imprint band deposited on each slide, under 400 X magnification. Counts were averaged for each slide to give a mean ascospore count per transect for each plot.

Autumn black spot, litter values and spore count data were log-transformed prior to statistical analyses. Transformed spore counts for each plot were regressed against litter values for each plot and mean autumn black spot leaf values for each orchard block, using Minitab® 12.1 regression analysis. Data from organic and IFP managed orchards were analysed first separately then together. Otherwise, data for different varieties and orchards were pooled.

RESULTS AND DISCUSSION

A wide range of autumn black spot, spring litter and spring ascospore levels were measured in the various blocks (Table 1 and Fig. 1).

Regression analysis of all plots in each block showed that autumn black spot levels and spring litter levels were predictors of spring ascospore levels. Both predictors had a positive ($P < 0.001$) correlation with spring ascospore numbers. For all blocks combined, the regression equation, with an r^2 value of 45.1%, was:

$$\log \text{SpringAscospores} = -1.74 + 0.766(\log \text{AutumnBlackspot}) + 0.761(\log \text{SpringLitter})$$

Autumn black spot numbers and spring litter levels were better predictors of spring ascospore numbers on organic than on IFP orchards. For organic blocks the regression equation, with an r^2 value of 67.5%, was:

$$\log \text{SpringAscospores} = -1.43 + 0.618(\log \text{AutumnBlackspot}) + 1.43(\log \text{SpringLitter}).$$

For IFP blocks, the regression equation, with an r^2 value of 21.2%, was:

$$\log \text{SpringAscospores} = -1.19 + 0.46(\log \text{AutumnBlackspot}) + 0.443(\log \text{SpringLitter})$$

TABLE 1: Summary of autumn black spot incidence (no. infected leaves/100 shoots), mean spring leaf litter (% ground cover) and mean spring ascospore counts¹ for each of 22 Hawke's Bay apple blocks assessed in 2000.

Block	Variety	Management system	Autumn Black spot	Spring leaf litter	Spring spore count ¹
1	Royal Gala	Organic	0	3.4	0
2	Braeburn	Organic	1	1.6	0.6
3	Braeburn	Organic	1	2.1	0.2
4	Braeburn	Organic	3	0.6	0.3
5	Braeburn	Organic	8	1.6	1.5
6	Braeburn	Organic	23	38.1	185.9
7	Pacific Queen	Organic	26	8.8	38.1
8	Gala	Organic	28	5.2	933.5
9	Braeburn	Organic	214	0.4	0.2
10	Royal Gala	Organic	264	12.4	783.4
11	Fuji	Organic	296	4.1	642.5
12	Pacific Rose	IFP	0	27.3	0
13	Granny Smith	IFP	0	38.4	0
14	Royal Gala	IFP	0	19.8	3.0
15	Fuji	IFP	1	15.3	0.06
16	Braeburn	IFP	4	14.3	0.06
17	Braeburn	IFP	8	1.3	2.7
18	Braeburn	IFP	9	23.6	1.5
19	Royal Gala	IFP	24	12.9	37.6
20	Royal Gala	IFP	51	6.0	12.0
21	Fuji	IFP	62	1.1	0.09
22	Braeburn	IFP	85	1.9	0.07

¹Spring ascospore counts expressed as average number of spores per transect across the spore band deposited on a microscope slide using a suction spore trap.

A number of factors may have contributed to the stronger relationship on organic rather than IFP orchards. On IFP orchards DMI (demethylation inhibitor) fungicide use may have masked autumn black spot symptoms on leaves (O'Leary & Sutton 1986). In addition, use of urea on IFP orchards and subsequent interruption of *Venturia* mating during winter (Burchill & Cook 1971) may have further contributed to variability in the data.

FIGURE 1: Autumn black spot incidence, spring leaf litter (% ground covered) and spring ascospore counts for individual plots on each of 22 Hawke's Bay apple blocks assessed in 2000.

In this study low autumn black spot levels (< five infected leaves per 100 shoots) were always followed by relatively low spring ascospore levels, regardless of litter levels. Moderate to high autumn black spot incidence was generally followed by high spring ascospore release, except where litter levels were below about 2% of ground cover.

In some orchards with relatively high autumn black spot levels, low ascospore numbers were released in the spring, due to good management of leaf litter. For example, blocks 21 and 22 had high incidence of black spot in the autumn, but leaf litter levels were below 2% ground cover in the spring. This was probably due to very heavy sheep grazing in these two blocks, causing removal, trampling and enhanced breakdown of leaf material. Resulting spring ascospore release was very low. In contrast, block 19 on the same orchard had moderate autumn black spot levels but was not grazed during winter. Thus, spring litter levels and resulting ascospore numbers were relatively high. This demonstrates the potential for reducing spring ascospore release by good management and removal of leaf litter during winter.

Spring litter levels tended to be relatively low on organic orchards, probably due in part to increased earthworm activity removing leaf litter (Raw 1962). One exception was block 6, an orchard in the first year of organic management. In general, spring leaf litter levels were relatively high on IFP orchards except where intensive sheep grazing had been employed.

Results of this study demonstrate that there is potential for incorporating information on autumn black spot and spring leaf litter into the management decision-making process. Autumn assessments could be particularly useful in identifying blocks where sanitation is either necessary or potentially most beneficial. Modelling packages designed to assist growers in managing black spot infection in the spring should incorporate autumn black spot and spring litter data, on an individual block basis. Future work will investigate the most useful strategies for managing leaf litter, and also attempt to quantify the optimum level of leaf litter for effective inoculum reduction following various autumn black spot levels.

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