Development of a Model for Predicting Flyspeck Risks in Blocks of Apple Trees

Arthur Tuttle, Christopher Bergweiler, James Hall, Lisa Reisner, Steven Christle, Wesley Autio, and Daniel Cooley
University of Massachusetts

For several years, we have been working toward the elimination of summer fungicide applications in apple orchards. The positive economic and environmental impacts of achieving this goal are considerable. Unfortunately, in the absence of fungicides, the severity of flyspeck disease, and to a lesser extent sooty blotch, can be significant. In apple trees which are not sprayed in the summer, flyspeck incidence varies dramatically, from barely existing in some blocks of apple trees to infesting more than half the fruit in others.

How do we decide which trees need spraying and which do not in a given year or month? We know that the flyspeck fungus needs very high relative humidity (97-100 %) to develop. By tracking leaf wetness, rainfall, relative humidity, and temperature we can estimate when specks will first show up in unsprayed trees in or near an orchard. We can also estimate when spray residues will be removed from apple trees by rain, thanks to studies performed by Dave Rosenberger at Cornell University's Hudson Valley Laboratory. It remains a challenge, however, to estimate severity of symptoms at harvest for a given block of trees.

Certain characteristics of blocks of apple trees, such as slope, relative altitude in the orchard, and spacing of rows and alleys are likely to influence air drainage and relative humidity in the blocks. The size and openness of tree canopies will also affect the humidity surrounding an apple. The consensus among plant pathologists working with apples is that the inoculum for flyspeck disease overwinters on the waxy cuticle of alternate host plants like blackberry, oak, grape, and maple in wooded or shrubby borders near the apple trees. Within the orchard block, flyspeck does not colonize apple twigs. Flyspeck that grows on fruit is removed at harvest or decays over the winter on drops. The orchard border is home to over 100 species that maintain waxy cuticle suitable for flyspeck

and sooty blotch over a 12-month period on first year growth.

Many relationships involving the block and the borders seem worthy of investigation. Number and size of borders around a block, distance between a block and its borders, density of alternate host plants in the borders, and density of the fungus on those hosts might all have significant impacts on summer diseases in fruit at harvest. We study these factors and their relationships to flyspeck disease development in order to create a predictive model to help growers safely reduce fungicide inputs.

We reported on the first part of this study in the Spring 1996 issue of *Fruit Notes*. This experiment took place in six orchards over the 1995 and 1996 growing seasons. In each orchard, pairs of similar blocks of apple trees were chosen. Some orchards dedicated as many as 13 pairs of blocks to this experiment. At each orchard, one block received no fungicide after primary scab season (approximately June 15), while the other block was managed according to the grower's preferences using standard first-level IPM. Flyspeck incidence was recorded weekly by examining 200 fruit in each block from late-July through mid-September. For each block, the following orchard site characteristics were evaluated and compared statistically to the flyspeck incidence or severity data: slope of the ground, relative elevation of the block compared to other blocks in the orchard, closeness of shrubby or wooded borders to the apple trees, density of a major alternate host plant in the borders (blackberry), severity of flyspeck infestation on those host plants, and density of apple tree canopies.

Table 1 lists the orchard site factors that had the greatest effects on the flyspeck counts that were done in the in 2-week period leading up to harvest in 1995 and 1996. Unless otherwise noted, analyses for this report were performed on data from the blocks which

Table 1. Characteristics of blocks of apple trees or adjacent wooded or shrubby borders that positively affected the amount of flyspeck on apples: in order of significance.

August 20 through harvest 1995	August 20 through harvest 1996	August 29 through harvest 1995, 1996, 1998, and 1999
1. Lack of slope of block	1. Density of flyspeck on brambles in border	1. Density of flyspeck on border host plants
2. Low relative elevation within the orchard	2. Lack of slope of block	2. Number of borders
3. Height of apple trees		3. Closeness of apples to borders
4. Density of brambles in border		4. Lack of slope of block
5. Closeness of apple trees to a border		

received no summer fungicide. First-level IPM blocks did not have enough flyspeck to analyze. In 1995, there were more flyspeck symptoms in blocks that were relatively flat than in steep-sloped blocks (r^2, or amount of variation explained, was 0.17, or 17%), and the amount of flyspeck was higher in blocks that were relatively low in elevation within the orchard ($r^2 = 0.12$). Other factors that had positive but less significant impacts ($r^2 < 0.03$) were height of apple trees, proximity of apples to border areas, and density of host-plants in the borders.

In 1996, the significant site factors (Table 1) were density of flyspeck on host-plants in borders ($r^2 = 0.13$), lack of slope of the block ($r^2 = 0.05$), and height of the apple trees ($r^2 = 0.04$). The factors which contributed only marginally to explaining the variability in flyspeck incidence ($r^2 < 0.03$) were number of borders adjacent to a block of apple trees and proximity of brambles in the borders to the apples.

In summary, the site factors that were the most important during 1995 and 1996 (explained at least 10% of the variability) were **slope** and relative **elevation** in 1995 and **density of flyspeck** on host-plants in borders in 1996.

In 1997-1999, a different group of blocks was evaluated for site factors and flyspeck infection. In this experiment, two of the key factors were planting density/tree size and IPM level. A main objective of the study was to evaluate the effectiveness of the range of IPM strategies that had been developed using fairly large semi-dwarf trees on plantings that included dwarf trees at high densities. Each of eight participating orchards provided two blocks of low density/large trees, two blocks of medium density/medium-sized trees, and two blocks of high density/small trees. The blocks that had the same planting density were divided into two groups: half were managed with first-level IPM strategies and half with "third-level" IPM strategies. The progression to third-level IPM was marked by the integration of advance pest-management strategies with horticultural strategies at the level of the whole orchard. The third-level blocks, which were seeded with beneficial mites and were managed with biologically-based third-level strategies for insects, received reduced rates or frequencies of fungicide applications, little or no EBDC fungicide, and only captan or benomyl after June 15. The first-level blocks were managed with the growers' choices of materials and frequencies of application. The blocks within a pair were not contiguous. They were often at either end of a long section of 'McIntosh' or 'Cortland' rows and were bordered by a wide variety of habitats. Some of the 48 blocks were surrounded by other rows of apple trees, some by grassy fields, others by dense woods or shrubby hedgerows.

During each growing season, the blocks and their surrounding borders were rated for static orchard factors which had proved significant in the earlier study.

These included: number of borders potentially influencing flyspeck development in an orchard block, distance between the trees and the borders, severity of flyspeck in alternate host plants in the borders, density of host plants themselves, foliar density of trees, height and diameter of tree canopies, slope and relative elevation of the block with respect to the orchard as a whole, and planting density of the block (no. trees/ acre). We examined all known host plants (from the ground to 6 ft. above ground), not just blackberry. Apples in the adjacent blocks were examined weekly or bi-weekly from mid-July to harvest.

At the end of each growing season we looked at the effect of each of the above-mentioned site factors (and all factors combined) on the amount of flyspeck on the apples, to begin deriving a predictive model for flyspeck incidence at harvest. Preliminary stepwise regression analyses done separately for each year suggested the importance of four variables: **density of flyspeck on alternate host plants in the borders, number of borders, distance from apples to border,**

and slope of the block. The other site factors did not explain substantial amounts of the variation in flyspeck incidence.

Combining data collected from unsprayed control trees from the years 1995, 1996, 1998, and 1999, we conducted a preliminary assessment usingg flyspeck incidence data from various dates. Data from 1997 were not used, because all blocks received summer fungicide sprays. Dates at or near harvest varied from year to year primarily due to cultivar and weather factors. Ultimately, we decided on a range of dates allowing maximum inclusion of orchards in the data set. Data from harvest or near-harvest ranged from 29 August to 23 September for the 4 years used in the analysis.

We concluded the static factor phase of model building by combining these four independent variables with the most inclusive range of harvest dates and a fifth derived variable, inoculum index. Inoculum index was expressed as the product of amount of flyspeck on alternate host plants and the density of those plants in
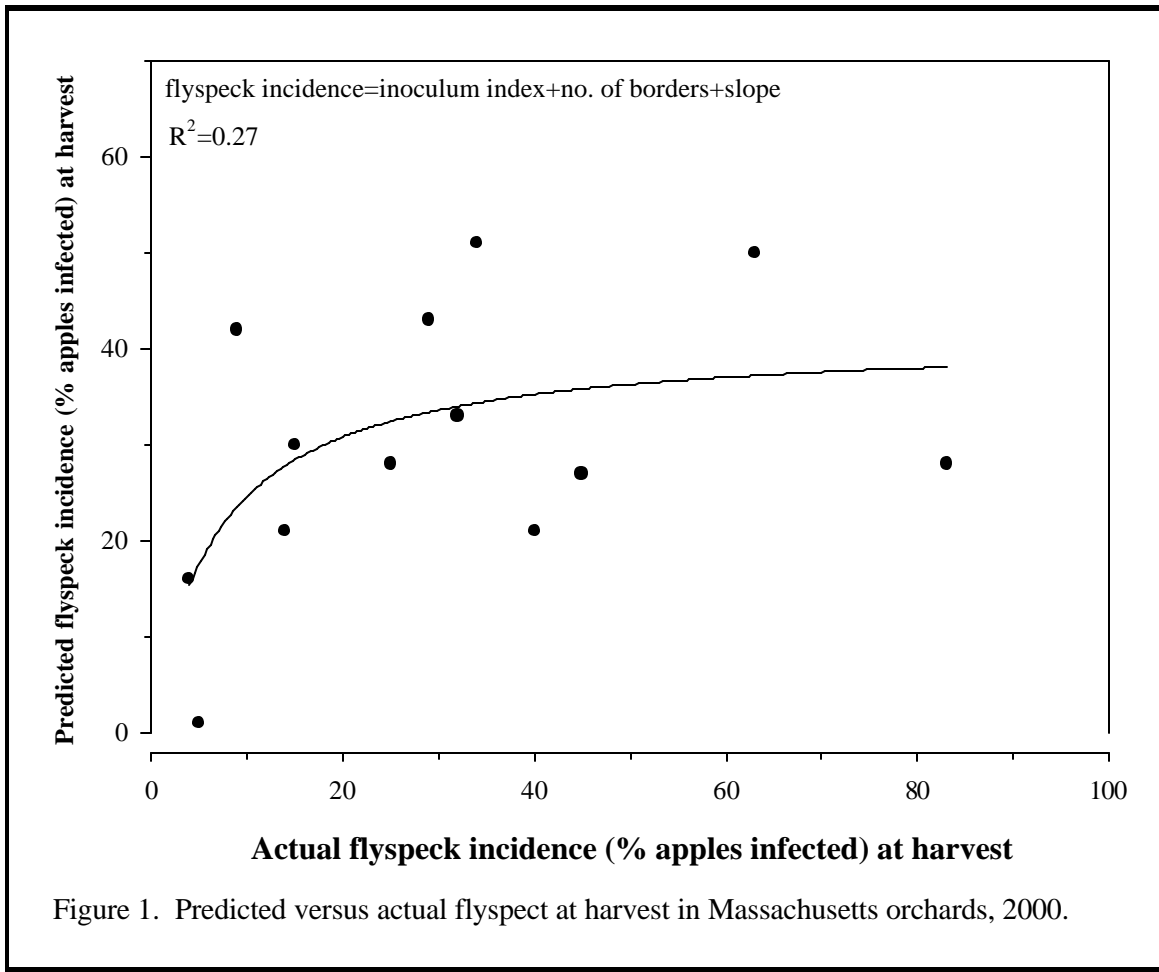

Figure 1. Predicted versus actual flyspect at harvest in Massachusetts orchards, 2000.

orchard borders. The best flyspeck prediction model included inoculum index, number of borders, and slope. We applied the model parameters derived here to flyspeck incidence at 13 orchards in 2000 and compared the resulting predicted values with observed flyspeck incidence. The best-fit regression for the data (R^2=0.27) is presented in Figure 1. Given the high "background noise" of variability in this kind of investigation (different years, orchards, blocks, sizes of trees, cultivars, pruning regimens, types of borders, etc.), we were gratified to see almost 30% of the variability in flyspeck incidence explained by these three site factors.

We applied the same model in 2001 to predict flyspeck in 11 of the same orchard blocks used in 2000. The relationship between model-predicted flyspeck and actual flyspeck in the apples was not close (only 2% of the variability was explained). However, 2001 was very dry during most of the growing season, and 2000 was a very wet year. Weather factors as well as differences in blocks at the different sites may have made a bigger difference in a drier year. We plan to develop a more comprehensive flyspeck model that combines static orchard factors with dynamic weather factors such as leaf wetness and rainfall. It would be useful to adjust for accumulations in moisture during a growing season. We may find that we need different models for wet years as opposed to dry years. The starting point, however, and key factor in rating a block for flyspeck risk will probably always be a measure of how much inoculum is in the orchard border areas at the beginning of the growing season.

This study identifies several factors which can combine to produce an environment which supports flyspeck: **density of flyspeck on alternate host plants in borders, number of borders, distance from apples to border, and slope of the block**. Modification of this environment in a number of ways, such as summer pruning, clearing-back borders or removing host plants or inoculum, or using high-density dwarf plantings could reduce flyspeck pressure considerably. The most stable management plans will involve several strategies, such as border management, orchard design, aggressive pruning, monitoring weather components, and careful fungicide selection and timing.

Acknowledgements

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