Increasing Fungicide Use in New England Apples

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Growers in the Northeast have found in recent years that they are approaching the limits on captan use in a given season, 40 lbs. of Captan 80 WDG or 64 lbs. of Captan 50W per acre. This translates to 32 lbs. of active ingredient per acre for either product. Both captan and the ethylene-bisdithiocarbamate fungicides (EBDCs) such as Dithane, Manzate, Penncozeb and Polyram have been used more frequently over the last 10 years. Primarily, this is because the sterol inhibitor (SI or DMI) fungicides such as Rally, Vintage, Procure, Inspire and Indar have lost effectiveness against apple scab in many orchards. As the scab fungus has become increasingly resistant to the SI fungicides, growers have turned to the old standard protectants, captan and the EBDCs.

Fungicide programs have moved away from the "10-day delay spray" based around the four-days plus post-infection activity of the SI fungicides, generally using programs that begin earlier and require more frequent protectant fungicide applications. This is because the major apple disease, scab, has developed widespread resistance to the SI fungicides. Beginning in the late 1990's, practical resistance of apple scab to SI's was detected in orchards in New York and throughout the U.S. Kerik Cox's lab at Cornell obtained samples of *Venturia inaequalis*, the fungus that causes scab, from 64 orchards in New England from 2004 – 2012, and found that 61% of the orchards had SI-resistant scab and another 16% of the orchards were moving towards resistance. Only 23% of the orchards had scab that was still sensitive to SI fungicides (Villani and Cox, unpublished data).

As a result, growers have increasingly used protectant, multi-site fungicides, because they the apple scab fungus has never developed resistance to them in spite of decades of heavy use in apples. The combination of captan plus an EBDC, the so-called "captozeb" program was widely recommended, requiring early and frequent fungicide applications. Rather than starting fungicide applications at tight cluster and then making three to five subsequent applications roughly 10 days apart as was done with the SI programs, growers start at or near green tip and re-apply fungicides approximately every 5 to 7 days with a protectant program.

While this general change in fungicide use patterns has been widely discussed in the apple industry, there has been virtually no real data on the specific changes in apple fungicide use over the last decade. Using a detailed set of pesticide use data from a set of five growers in New England, this analysis looks at apple fungicide use from 2004 to 2012. The number of acres in the program on individual farms varied in size from 35 acres to 193 acres. Over the eight years, an average of 430 total acres was in the program each year.

The amount of each fungicide active ingredient (AI) used by each grower in each year was calculated on a per acre basis. Due to limitations in the available data, this was done on a whole-orchard basis. For a given farm in a given year, the total amount of each fungicide used was divided by the total acres in the program for that farm. This gave the pounds of AI/acre used in that orchard during that year.

But the simple AI/acre alone is not enough to evaluate fungicide use. Since the recommended rates per acre of fungicides varies widely, it's useful to look at fungicide use patterns in terms of the recommended rates. For example, suppose a grower has a 50 acre orchard. During scab season, he sprays two times with a full rate of Captan on the entire orchard, and during the summer uses half the full label rate on half the orchard in three applications. Captan 80WDG has a maximum label rate of 5 lb./A. So, 50 acres x 5 lb./acre x 2 applications gives 500 lb., and 25 acres x 5 lb./acre x 3 applications gives 375 lb., for a total of 875 lb. of Captan 80WDG used for the season. He also sprays half the orchard with a full rate of Flint 50WG two times. The Flint 50WG maximum label rate is 2.5 oz./acre. So 25 acres x 2.5 oz./acre x 2 applications gives 125 oz. of Flint 50WG used for the season.

If we look strictly at the amount used, 875 lb. (14,000 oz.) vs. 125 oz., there is over 100 times as much Captan used as Flint. Yet each application was at the recommended rate or less, and appropriate for apple disease management. To get a more realistic picture of the grower's use of the fungicides, we need to adjust the amount used to reflect recommended use rates. To do this, we calculate a number called dosage equivalents, or DE. DEs are calculated by dividing the total pounds of fungicide used in a season in an orchard for each fungicide by the pounds recommended in the maximum label rate per acre for one application of that fungicide.

For Captan in the 50 acre orchard example, the orchard is 50 acres, so the amount of Captan 80WDG used per acre for the season is 875 lb./50 acre, or 17.5 lb./acre. The maximum label rate for Captan 80WDG is 5 lb./acre, so the number of dosage equivalents used in the orchard that year is 3.5. For Flint 50WG, 125 oz. were used over the season. This is an average of 2.5 oz./acre. The maximum label rate for Flint 50WG is 2.5 oz./acre, so the DE for Flint is 1.0.

Of course, this isn't the actual pattern the grower used for each material, but it does give a good estimate for the number of times each was used in the season. For example, the grower sprayed half the orchard with a full rate of Flint twice, not the whole orchard once. But we can see that overall, he used Flint much less than he used Captan, and this reflects the real use: five Captan applications vs. two Flint applications, with two full-orchard Captan sprays and no full orchard Flint sprays. Obviously growers do not always apply the maximum label rate of a fungicide, nor do they usually spray their entire orchard. Sprays are adjusted to fit the situations in each block, which vary by cultivar, location, size and disease history, to name a few important variables. In addition, the data used in this study did not always specify whether applications were tank mixes of fungicides. In the use rate calculations, each fungicide was considered individually, meaning that if a grower mixed two fungicides at full rates and then made a single application, this would count as 2 DEs, one for each fungicide. DEs aren't perfect, but are a good estimate.

Both the total pounds of fungicide active ingredient per acre and the number of maximum rate applications increased significantly from 2004 to 2012 (Figure 1). The 7 to 8 applications/yr. observed in 2004-05 are similar to numbers observed from 1991 to 1997 in New England when DMIs were commonly applied on an extended schedule (Cooley et al. 1994; Cooley & Autio 1997). While fungicide use in the five orchards varied across the years, in general the trend was up, from just under 8 to over 11 dosage equivalents.

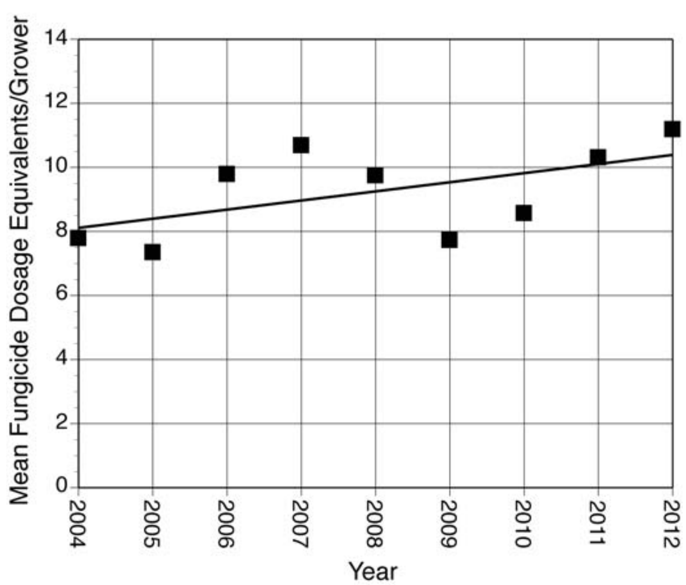

Figure 1. Fungicide use in terms of mean dosage equivalents per orchard for five New England orchards, 2004 to 2012. Dosage Equivalents = (total lb. fungicide used for the growing season) ÷ (number of acres of orchard).

Individual fungicides and classes of fungicides were then evaluated. The majority of the applications made over the nine-year period were for Captan and the EBDCs, the multi-site protectants. The trend lines for Captan and the EBDCs show increasing use (Figure 2); the actual mean number of Captan applications increased from 2.4 to 4.9, and actual EBDC applications from 1.2 to 2.9. By comparison, the SIs and the strobilurins had relatively lower and constant or decreasing use rates (Figure 2). The low number of max-apps for the SIs and strobilurins indicates that growers generally did not apply these over the entire production acreage, used less than the maximum label rate and/or made fewer applications than they did with Captan and the EBDCs.

The third most used fungicide over the period was thiophanate-methyl (Topsin-M, of the dosage equivalents per grower were for by captan and the EBDCs (Figures 4 & 5). These protectant fungicides accounted for 89% of the lb. AI used in 2004-06, and for 93% in 2010-12. Overall, the pounds A.I. of fungicide increased, and most of the increase came from captan and the EBDCs. This is not surprising since these fungicides are recommended at much higher rates, as noted earlier. Captan use increased from nearly 12 lb. A.I./acre to approximately 16.5 lb. A.I./acre, the equivalent of an increase from 15 lb. to over 20 lb of Captan 80 WDG per acre. Similarly, EBDC use increased from 9 lb. A.I./acre to 12.2 lb. A.I./acre, equivalent to an increase of 12 lb. to 16.3 lb. of Dithane 75DF. While proportion of captan and EBDCs used increased only slightly, the amounts increased by approximately 33% for these fungicides. Each of the other fungicides contributed 3% or less to the lb. A.I. used. Of these, the next highest amount used was for thiophanate-methyl, and its use remained constant at about 0.8 lb. A. I. per acre, equivalent to 1.2 lb. (19 oz.) of T-Methyl). The trend in use is slightly up, but not significantly, meaning that use has been the same over the nine years. Another older systemic fungicide, dodine (Syllit), shows decreased use. At the same time, anilinopyrimidine (Vangard, Scala) use has increased. It may be that these fungicides, which are effective in the very early part of the growing season and are a different type of systemic, have replaced the older dodine, which also tends to be used early but has a history of resistance development in many areas. Finally, copper use remained steady over the nine year period, at about 0.5 DE. Since copper is almost always used in just one very early spray, this indicated that it was either not used over all the acres on a farm or was generally used at less than the maximum label rate.

Three-year averages were calculated for both mean pounds of active ingredient used per acre by each grower, and for the mean dosage equivalents used per year by each grower. Most of the lb. AI/acre/grower and

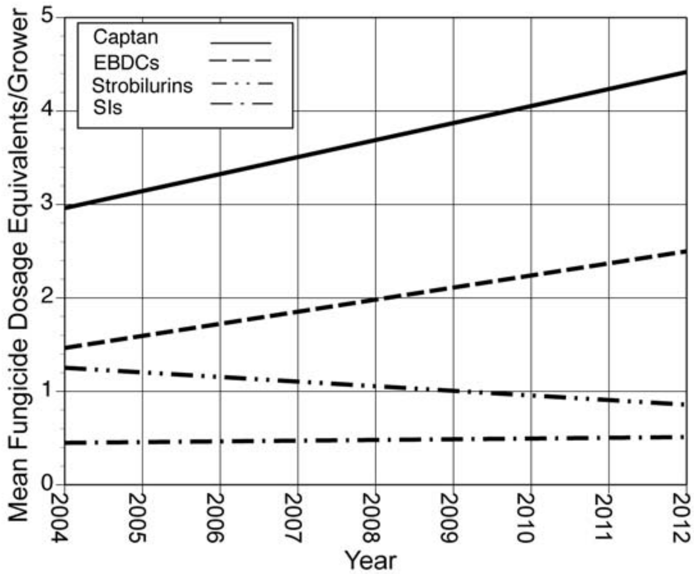

Figure 2. Fungicide use trend lines in terms of mean dosage equivalents per orchard by different fungicide classes including captan, ethylene bisdithiocarbamates, strobilurins (QoIs) and SIs (DMIs) for five New England orchards, 2004 to 2012.

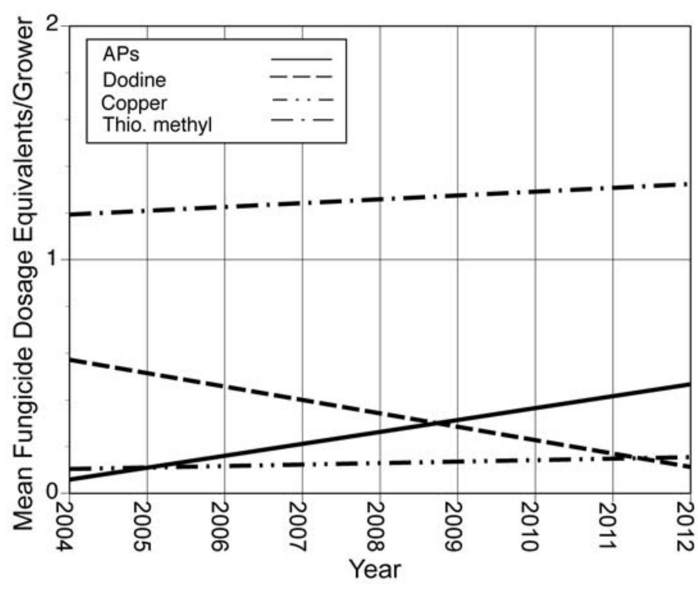

Figure 3. Fungicide use trend lines in terms of mean number of dosage equivalents per orchard (right) by different fungicide classes including thiophanate-methyl, dodine, anilinopyrimidines and copper compounds for five New England orchards, 2004 to 2012.

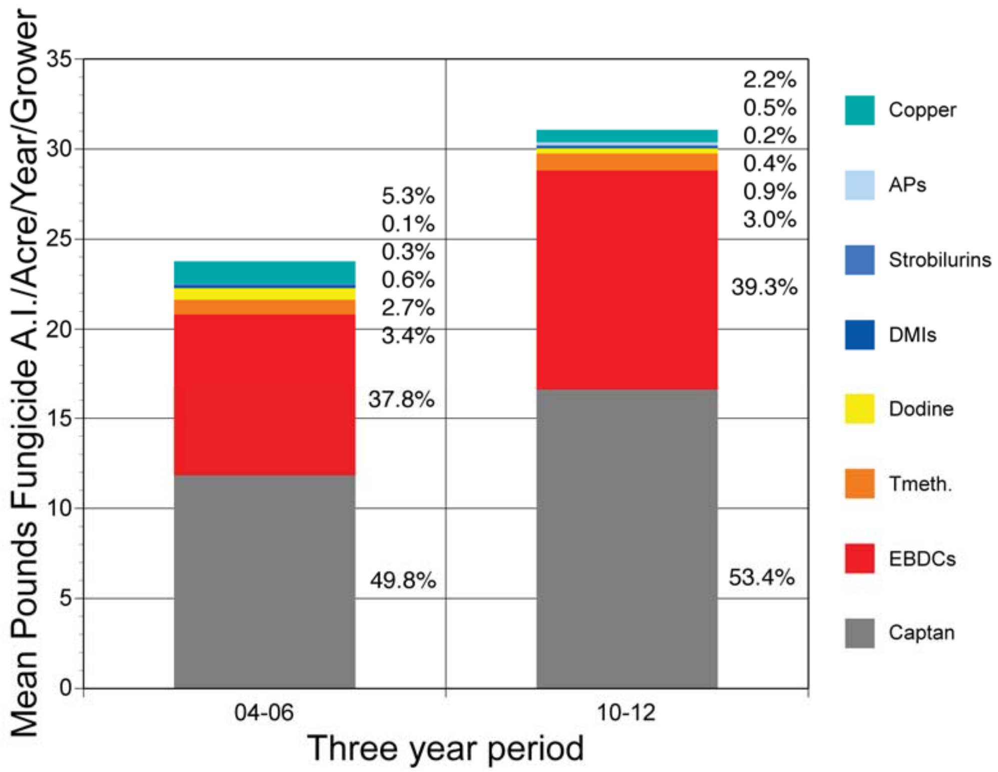

Figure 4. The mean pounds of fungicide AI per acre per year per grower applied in five New England Orchards calculated for two three-year periods, 2004-06 and 2010-2012.

Topsin M 70WDG.

In terms of dosage equivalents, captan and the EBDCs still dominated use, but to a lesser extent than they did for A.I./acre. They accounted for 55% of the dosage equivalents in the 2004-06 period, and 63% in 2010-12. Captan DEs increased from 2.9 to 4.0, while the EBDCs increased from 1.6 to 2.3. The only other fungicides that exceeded a DE of one were the strobilurines, which increased from 1.2 to 1.4, and thiophanate-methyl, which decreased from 1.2 to 0.9.

This analysis clearly shows that the protectant fungicides, captan and the EBDCs, dominate fungicide use in New England apple production, and their use is increasing. These fungicides were developed in the 1940's and 50's, and have been used on crops since then. Because they have multi-site activity, there are no known cases of fungal resistance to them, making them unique among the fungicides used for season-long apple disease control in New England. However, these fungicides have frequently come under regulatory review because studies indicate that they can be carcinogenic in laboratory animals. Canada is presently proposing a phase out of EBDC use in apples for health reasons.

Given this, the increasing use of EBDCs and captan in apples in New England is problematic. However,

Table 1. Fungicide pounds of active ingredient applied per acre per year per grower, and dosage equivalents applied per year per grower for two three year periods.

	Pounds A.I./Acre/Grower/Year		Dosage Equivalents/Grower/Year	
Fungicide(s)	2004-06	2010-12	2004-06	2010-12
Captan	11.8	16.6	2.9	4.0
EBDCs	9.0	12.2	1.6	2.3
Strobilurins	0.1	0.1	1.2	1.4
DMIs	0.2	0.1	0.6	0.3
Thiophanate-methyl	0.8	0.9	0.6	0.5
Dodine	0.6	0.3	1.2	0.9
APs	0.01	0.2	0.04	0.4
Coppers	1.3	0.7	0.1	0.2

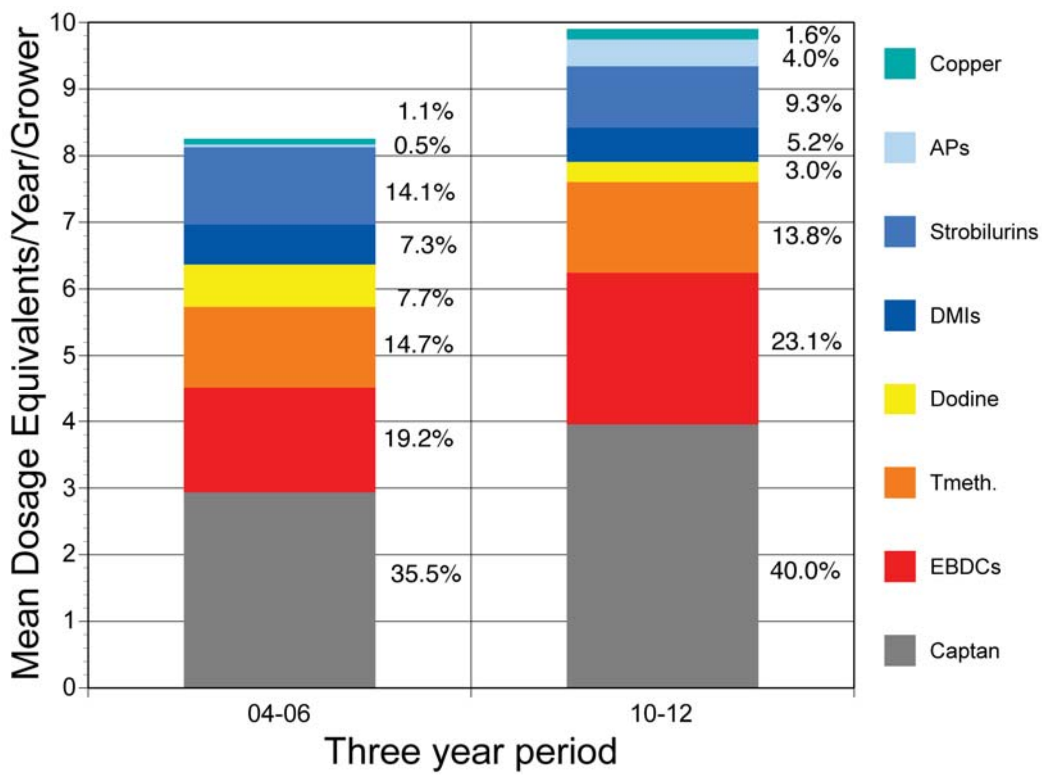

Figure 5. The mean dosage equivalents applied year per grower applied in five New England Orchards calculated for two three-year periods, 2004-06 and 2010-2012.

broadly effective, but is good against sooty blotch/flyspeck and fair against bitter rot. Neither fungicide controls powdery mildew.

Without captan and the EBDCs, the DMIs and QoIs could provide good to excellent control of powdery mildew. The DMIs are excellent against cedar apple rust, and the QoIs excellent against sooty blotch/flyspeck. However, the DMIs are not effective against summer rots, and the QoIs are only moderately effective against them.

In general there are alternatives to captan and EBDC that will control the major apple diseases. However, they are all fungicides that have a higher risk of producing resistance in fungal pathogens. In addition, they are all more expensive than the protectants.

After many years of reductions in apple fungicide use based around IPM and to a large extent post-infection systemic fungicides, fungicide use has steadily increased over the last 10 years. Growers are justifiably reluctant to implement IPM methods that could reduce fungicide applications. For over 70 years, commercial apple growers in New England have relied almost exclusively on chemicals to control diseases. Even the IPM reductions in In the 1980's and 90's were dependent on fungicides, the SIs. IPM developed because entomologists and plant pathologists warned that sooner or later chemicals disappear, either because they lose effectiveness or because the public demands they be banned. IPM strategy sought to reduce the need for

growers have very few alternatives to these multi-site protectants because virtually all other fungicides have a high risk of causing fungal resistance. The pesticide industry is increasingly marketing pre-mixed fungicide products containing two active ingredients, both with single-site systemic activity. This mixing both broadens the number of diseases that the products control, and theoretically decreases the risk of fungal resistance. Yet *V. inaequalis* populations with resistance to multiple active ingredients have been found in the Midwest and in New York. The protectants are the most effective way to deal with resistance in apple scab and other apple diseases.

Loss of the EBDCs and captan would also make disease management more difficult because the protectant fungicides are very effective against a number of apple diseases (Table 2). The EBDCs are rated as excellent to good against cedar apple rust, sooty blotch/flyspeck and the summer rots. However, while the EBDCs are very effective against summer blemishes and rots, they cannot be applied later than 77 days pre-harvest, so their utility against these diseases is limited. Captan is not as

Table 2. List of apple fungicides labeled in New England in 2013 and their efficacy against the most important apple diseases. Control ratings: 0 = none, 1 = slight, 2 = fair, 3 = good, 4 = excellent, — = Unknown or does not apply. Adapted from the New England Tree Fruit Management Guide.

Trade Name (active ingredient)	Fungicide Family	Resist. Risk	*Scab*	*PM**	*CAR**	*SBFS**	*Black/ White Rot*	*Bitter Rot*
Scala (pyrimethanil)	AP	High	3	—	0	0	0	0
Vangard (cyprodinil)	AP	High	3	1		0	0	0
Topsin M (thiophanate-methyl)	Benzimidazole	High	2	2	0	4	4	1
Dithane (mancozeb)	EBDC	Low	3	0	4	4	3	4
Manzate (mancozeb)	EBDC	Low	3	0	4	4	3	4
Penncozeb (mancozeb)	EBDC	Low	3	0	4	4	3	4
Polyram (metiram)	EBDC	Low	3	0	4	4	3	4
Indar (fenbuconazole)	DMI (SI)	High	4	3	4	2	0	0
Procure triflumizole	DMI (SI)	High	4	4	4	0	0	0
Rally (myclobutanil)	DMI (SI)	High	4	4	4	0	0	0
Rubigan (fenarimol)	DMI (SI)	High	4	4	4	0	0	0
Tebuzol (tebuconazole)	DMI (SI)	High	4	4	4	2	0	0
Topguard (flutriafol)	DMI (SI)	High	4	4	4	0	0	0
Inspire Super (difenoconazole + cyprodinil)	DMI (SI) + AP	Med.	4	3	4	4	0	0
Syllit (dodine)	Guanidine	Med.	2	0	1	1	1	0
COCS, Cuprofix, Kocide (coppers)	Inorganic	Low	3	0	0	_	_	_
Sulfur (sulfur)	Inorganic	Low	2	2	0	1	1	–
Captan, Captec (captan)	Phthalimide	Low	4	0		3	1	2
Cabrio (pyraclostrobin)	QoI	High	4	3	2	4	3	3
Flint (trifloxystrobin)	QoI	High	4	4	2	4	3	2
Sovran (kresoxim-methyl)	QoI	High	4	4	2	4	3	2
Fontelis (penthiopyrad)	SDHI	High	4	3	3	__	__	__
Luna Tranquility (fluopyram + pyrimethanil)	SDHI + AP	Med.	3	3	2	__	__	__
Luna Sensation (fluopyram + trifloxystrobin)	SDHI + QoI	Med.	4	4	3	4	3	2
Merivon (fluxapyroxad + pyraclostrobin)	SDHI + QoI	Med.	4	4	3	4	3	3
Pristine (boscalid + pyraclostrobin)	SDHI + QoI	Med.	4	3	2	4	3	3

* PM – Powdery Mildew; CAR – Cedar Apple Rust; SBFS – Sooty Blotch / Flyspeck

chemicals by developing other tools to manage disease: disease resistance, cultural controls, biological controls and monitoring crop health and important pathogens. But attempts to commercially grow disease-resistant apple cultivars have not succeeded. The idea that scab inoculum can be measured, and if low enough growers can eliminate one to three early fungicide sprays has never been widely accepted because growers feel it is too risky. If scab begins early in the year, it can explode, causing significant damage and increasing fungicide costs. Reliable biocontrols for apple scab and other apple diseases have simply never been developed. There are no obvious alternatives to chemical control, and the most IPM can accomplish in the present situation is guide growers in the most efficient and effective ways to use fungicides. Currently, the focus in apple disease management is to reduce risks: the risk that there will be economically significant disease outbreaks, and the risk that scab and other diseases will become resistant to fungicides.

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