Post Infection Control of Apple Scab
One Organic Grower's Experience fighting Apple Scab
By Harry Hoch

This article reflects some of the experience I have had using liquid lime sulfur and micronized sulfur to control apple scab on my orchard near LaCrescent Minnesota. You will see from our weather records that we have a rainy humid climate here in southeastern Minnesota. The following is an overview of my experience and may be of value to others trying to grow organic apples in the humid areas of the country. My trials are not properly replicated and there are not controls or comparisons with conventional fungicides. You can use my experience as a starting point to test a similar program on your own orchard. I am sharing my records with you but they should not be taken as recommendations.

Terminology
Some organic growers may not be familiar with terms commonly used in commercial fruit production so I will define them here. Apple scab is a fungal disease that overwinters on leaves that were infected the previous season. Spore cases develop in these decaying leaves and then expel spores for a limited period of time during the spring. **Primary scab** refers to the lesions created by spores that came from the overwintered leaves. **Secondary scab** refers to the lesions that spread from the primary scab actively growing on the leaves and apples. The fungus can be control one of two ways. A **protectant fungicide** coats the leaves and fruit and stops the spores from infecting the tissue. A **post-infection fungicide** will penetrate the fruit or leaf and kill the fungus initiating the infection. **Back action** refers to the number of hours a fungicide has activity after the infection begins. An **infection period** refers to the number of hours that is needed for a scab spore to grow and penetrate a leaf or apple skin. Scab spores require a film of water to start growing and penetrate the tissue, this time period is shorter with warm weather. As little as nine hours of wetness can be enough to cause an infection in hot weather, while 36 hours or more may be needed in very cold weather. The **wetting period** refers to the number of hours the leaf surface remains wet.

The Post Infection Concept
In 2006 we started to transition a few blocks of scab susceptible apple varieties to organic production. I did not want to rely on a protectant program because too many applications of sulfur or copper would be required in my climate. Before synthetic fungicides were available, apple growers would spray a wetable powder form of sulfur to protect the crop. This sulfur had to be on the tree prior to every rain. Some growers would also use liquid lime sulfur after every rain to insure no spores survived the protective layer of sulfur. This could easily add up to over thirty fungicide applications in a season. This may be an approved organic practice but it is far from a sustainable environmental practice. I looked into using liquid lime sulfur in a post infection program to control primary scab.

I attempted to use liquid lime sulfur but only after an infection period that was confirmed by weather data and a computer model. I am using one of the oldest known fungicides with some of the newest computer modeling technology. Not every rain event provides a wetting period long enough to cause an infection. So I am able to drastically reduce the number of applications needed by identifying which rain events actually cause an infection.

Spore Maturity and Emergence
Apple scab spores slowly ripen within their spore cases (within the decaying leaves on the ground) in the spring. We follow a process of collecting the spore cases, squashing them on a slide, and evaluating the presence and maturity of spores under a microscope. This is called the Squash mount Evaluation System. There is also a computer model that uses weather data to predict the period of time that the spores will be emerging. In Minnesota the scab spores usually begin to emerge around the first week of May and run out in the middle of June. I use both the

squash mount system and the computer model to verify the presence of mature spores. This knowledge can be valuable in combating apple scab.

The Hoch Orchard Trials
If infections are controlled during the primary scab season, fungicides will not have to be applied during the summer because the overwintered spores will have run out. My goal was to put all my energy into a post infection program to control primary scab. If I am successful controlling primary scab, I can get by with five or six properly timed sprays per season.

In the first season of our experiment, we treated all the apple varieties with the same rates of fungicide. Lime sulfur was applied in a post infection program using Spectrum Technologies data loggers and disease models to verify infection periods. We soon learned that varieties reacted differently to the post infection program.

In 2007 some varieties showed 100% control of scab while others had as much as 75% damage from scab. Much of the scab in the high damage areas was due to secondary scab that spread late in the summer months. In mid June (at the end of primary spore season) lesions were scattered and appeared to be infecting less than 5% of the fruit and leaves. The spread of secondary scab was not obvious in casual pest scouting in July and early August. A wet summer allowed the secondary scab to explode in late August and early September. It appears that secondary scab will spread much more vigorously in the highly susceptible varieties than in varieties with average susceptibility. In a Honeycrisp block a few scattered primary scab lesions left untreated produced a small amount of localized secondary scab. While a few scattered lesions in a Cortland block gone untreated resulted in crop failure.

In 2008 we tried different rates of lime sulfur. The varieties with low susceptibility to scab had good control with low rates of lime sulfur. On the most susceptible varieties higher rates of lime sulfur provided better control, but still allowed some lesions to develop during primary scab season. This resulted in secondary scab and high levels of damage again.

In 2009 we combined lime sulfur with micronized sulfur to give more protection in the blocks of highly susceptible varieties. While the calcium polysulfide in the lime sulfur works well penetrating the leaf and stopping the early infection, there is very little actual sulfur residue left on the tissue after the lime sulfur dries. A combination of liquid lime sulfur with micronized sulfur gave us kickback action followed by several days of protection. This combination greatly reduced the incidence of primary scab on the most susceptible varieties but did not give 100% control. In addition to using higher rates and a combination of lime sulfur with micronized sulfur we still had to apply fungicides through August to control secondary scab on the highly susceptible varieties.

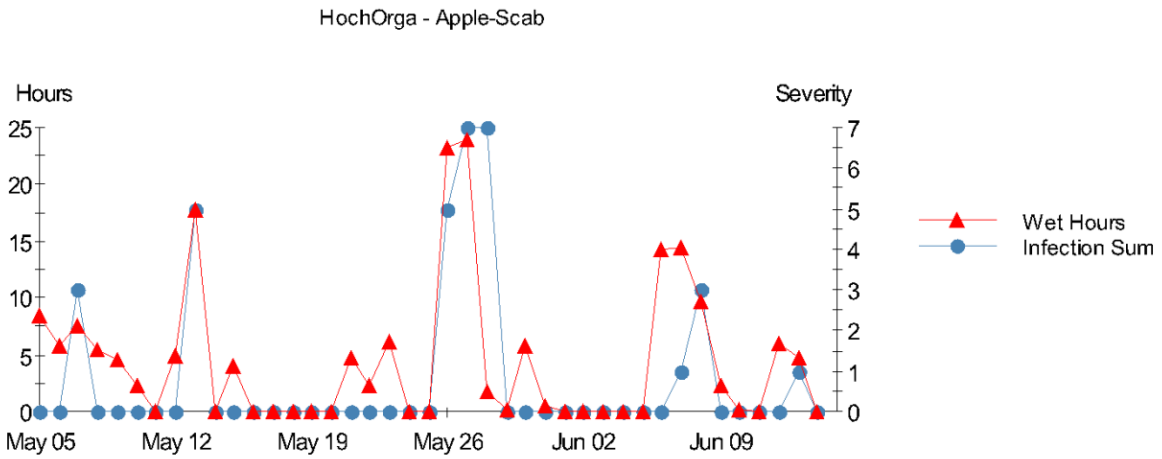
A Comparison of Honeycrisp and Cortland
We have found the varieties with low susceptibility to scab, in our case Honeycrisp, can produce a clean crop with a post infection application of lime sulfur during the primary scab season. After four years we have not yet had significant damage from scab on Honeycrisp using this program. We were able to stop applying fungicides after the primary inoculum ran out in mid June. On the other hand, we could not control scab on the highly susceptible varieties such as Cortland in a post infection program. Even a protectant micronized sulfur program in combination with a post infection lime sulfur program did not give us 100% control of primary scab.

In 2009 we had 21 days with rain events during the primary scab season. You can see the recorded wetting periods and infection periods on the table created by Spectrum Technologies software.

Date	Temperature High	Temperature Low	Wet Degree Hrs	Degree Days	%Spore Mature	Infection Mills	Infection Wash	Infection St Cornell
05/06	64.9	48.1	5.8	22	0	None	None	None
05/07	68.4	47.4	7.5	48	1	None	Light	Infected
05/08	69.7	44.5	5.5	72	2	None	None	None
05/09	51.0	38.5	4.5	84	2	None	None	None
05/10	49.6	36.2	2.3	94	3	None	None	None
05/11	62.8	33.8	0.0	111	3	None	None	None
05/12	64.9	43.0	5.0	133	4	None	None	None
05/13	58.0	41.5	17.8	151	5	Medium	Medium	Infected
05/14	60.1	39.3	0.0	167	6	None	None	None
05/15	60.8	45.2	4.0	186	8	None	None	None
05/16	50.3	33.8	0.0	196	8	None	None	None
05/17	64.9	32.2	0.0	212	10	None	None	None
05/18	66.3	41.5	0.0	234	12	None	None	None
05/19	83.0	49.6	0.0	269	19	None	None	None
05/20	81.6	58.7	0.0	307	25	None	None	None
05/21	63.5	52.4	4.8	333	29	None	None	None
05/22	67.7	48.1	2.3	358	33	None	None	None
05/23	67.7	51.7	6.3	382	38	None	None	None
05/24	71.1	43.7	0.0	407	43	None	None	None
05/25	66.3	45.9	0.0	432	47	None	None	None
05/26	53.8	45.2	23.3	449	50	Medium	Medium	Infected
05/27	51.0	44.5	24.0	463	53	Heavy	Heavy	Infected
05/28	67.7	43.7	1.8	485	57	Heavy	Heavy	Infected
05/29	68.4	51.0	0.3	512	62	None	None	None
05/30	69.0	46.7	5.8	536	66	None	None	None
05/31	70.4	39.3	0.5	561	71	None	None	None
06/01	69.0	55.2	0.0	591	76	None	None	None
06/02	70.4	45.9	0.0	616	80	None	None	None
06/03	64.9	41.5	0.0	637	83	None	None	None
06/04	73.2	42.3	0.0	665	87	None	None	None
06/05	73.9	47.4	0.0	693	90	None	None	None
06/06	52.4	42.3	14.3	706	92	None	None	None
06/07	47.4	42.3	14.5	719	93	None	None	Infected
06/08	55.9	45.2	9.8	736	94	Light	Light	Infected
06/09	60.8	45.9	2.3	756	96	None	None	None
06/10	66.3	46.7	0.3	779	98	None	None	None
06/11	65.6	49.6	0.0	805	99	None	None	None
06/12	69.7	45.2	6.0	830	99	None	None	None
06/13	73.2	48.8	4.8	858	99	None	None	Infected
06/14	77.4	52.4	0.0	892	99	None	None	None
06/15	73.2	53.8	0.0	925	99	None	None	None

We had eight days with confirmed infection periods, and treated the eight infections with five applications of fungicide in the susceptible Cortland block. Four of the applications were a tank mixes of lime sulfur and micronized sulfur (Kumulus brand), one application was Kumulus alone in anticipation of a predicted rain. The less susceptible Honeycrisp block required five applications to control primary scab. In the Honeycrisp block our scab sprays were applied on a post infection schedule and the fungicide rates were lower. We did add some Kumulus to the tank mix if rain was predicted within the next five days.

Primary Scab Season May 5 – June 14



2009 Hoch Orchard Fungicide application record for control of primary scab

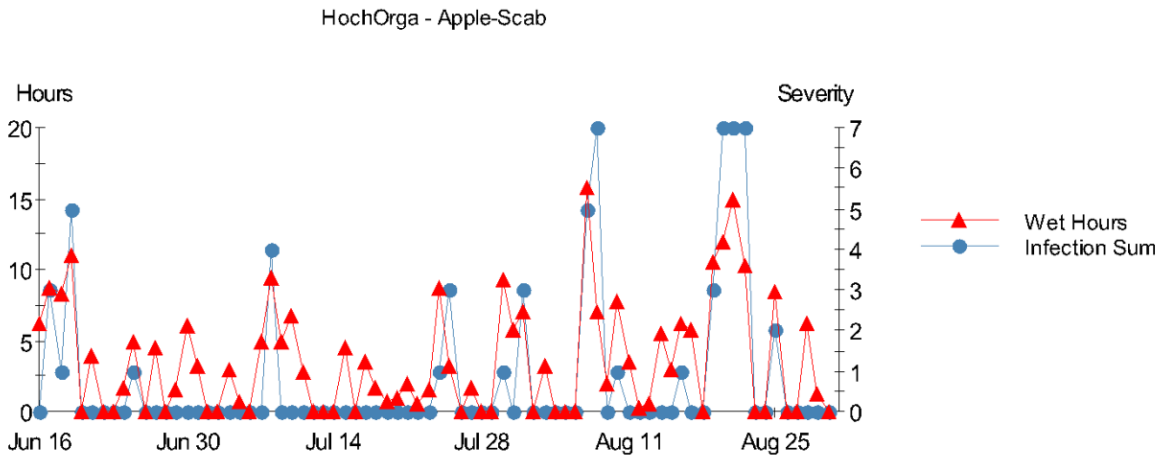
Date	Cortland Block	Date	Honeycrisp Block
4-27	Champion WP (copper for fire blight prevention, also is a good scab protectant)	4-28	Same
5-6	Infection		
5-7	Liquid Lime sulfur 2% Kumulus WP sulfur 7.5 #/acre	5-8	LLS 2%
5-13	Infection		
5-13	LLS 3% Kumulus 7.5 #/acre	5-14	LLS 2% Kumulus7.5 #/acre
5-25	Rain is forecast Kumulus 7.5 #/acre		
5-26,27,28	Major infection		
5-28	LLS 3% Kumulus 7.5 #/acre	5-28	LLS 2% Kumulus
6-7,8	Infection		
6-9	LLS 3% Kumulus 7.5 #/acre	6-9	LLS 2%
6-13	Light infection	6-13	No protectant LLS 1.3%

Controlling Secondary Scab

In four years of experimenting with lime sulfur we have not been able to control 100% of the scab in the highly susceptible varieties. In 2009 applied a tank mix of micronized sulfur with the liquid lime sulfur after every infection period. We also attempted to apply micronized sulfur to the highly susceptible blocks before each forecasted rain. Even with this intensive spray program we were not able to get 100% control of primary scab. Because of this we had to continue applying fungicide through out the summer.

You can see the amount of rain and the number of summer infection periods in the graph below. The following chart shows the number of additional fungicide applications that were needed to keep secondary scab in check on the highly susceptible varieties. We continued spraying the Cortland, McIntosh, and Honeygold throughout the summer. In my opinion the extra fungicide and lower packout makes these highly susceptible varieties uneconomical in an organic program. There are varieties that are less susceptible or immune to scab that can replace them.

Secondary scab season June 16 – August 30



2009 Hoch Orchard Fungicide application record for control of secondary scab

Date	
6-17	Infection
6-18	LLS 1.6%
7-4	Infection
7-4	LLS 1.6%, Kumulus 7.5 #/acre
7-11	Kumulus 10#/acre for protection
7-18, 19, 20, 21	Long wetting period and infection
7-22	LLS 1.6%, Kumulus 10 #/acre
8-19, 20,21,22nd	Long wetting period and infection
8-22	LLS 1.6%, Kumulus7 #/acre

Here are some important tips to follow when using a post infection organic fungicide program:

- Reduce the amount or eliminate the varieties that are highly susceptible to scab. We are phasing out Jersey Mac, Cortland, and McIntosh. These varieties require higher rates and more application per season to produce fruit that will grade out lower than the other varieties in an average season.
- Use well calibrated application equipment that gives thorough even coverage. I use 75 gallons of water per acre on dwarfs and well pruned standard trees. Overgrown standard trees or dwarfs in desperate need of pruning may need more volume per acre.
- Have backup equipment ready to go. The post infection program leaves no margin for error. You can only count on 24 to 36 hours of back action to get full control of scab. If a tractor or sprayer breaks down there is no time for repairs. I had a tractor quit right after filling up the sprayer with three loads to go after a severe infection period. I left the tracor and sprayer in the orchard, set up the other rig and was spraying within an hour.
- Do not use this system if it takes you more than 12 hours to spray your entire orchard. Either reduce the orchard size or increase the number of spray rigs and operators.
- Be equipped for spraying in wet muddy conditions. If you have to wait for your orchard to dry before you spray, this program will fail. It is critical to spray as soon as the wind and rain stops; in fact lime sulfur can be applied in a light rain or mist.
- Treat every infection period, even if it is a very light infection according to the computer disease modeling program. Some computer programs will show you the results of several different models. If one model shows a light infection and another model shows no infection you had better spray.
- Spray the most scab susceptible varieties first, then move to the more resistant ones.
- Implement good horticultural practices. This post infection Lime Sulfur program will not control scab in high inoculum conditions. Remove blocks that are shaded or in a slow

drying environment. Mow or remove leaf litter in the fall. Mow or flail again in the spring. Use a foliar spray of fish oil or neem oil to stimulate decay organism and break down leaves. Keep the orchard well pruned.

Growing scab susceptible varieties in a humid climate as we have here in the upper Midwest is a challenging feat. I cannot emphasize enough the value of the new scab immune varieties for our environment. A post infection program using lime sulfur appears to have the softest environmental impact of all the certifiable organic products. While lime sulfur may be the most dangerous and caustic material for the individual applying the fungicide, it seems to have the lowest impact on beneficial insects and soil organisms when compared to high rates of wetable sulfur or copper.

This post infection fungicide program could be a good option if you are transitioning a clean IPM orchard to organic production. However, I would advise against using this program on an abandoned orchard or a block of trees that had high levels of scab the previous year.

I will continue to tweak this system each season. In time I may develop different programs specific to apple varieties or based on harvest season. It appears some of the summer apples do not have as many problems with secondary scab as the later apples. Depending on the variety and the time of year leaves can be more resistant than the apples. Fruit thinning can remove much of the primary scab if leaf infections are minimal. There is a lot more learn about organic scab control. At this point I am fairly confident we can grow high quality apples with this fungicide program. Unfortunately this program will not work on every variety or on every orchard.