Copper free production of organic Elstar apples: three years experience in The Netherlands

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Abstract

The use of copper as fungicide in organic agriculture is often criticized as the only non-sustainable cultural practice in the system. In The Netherlands, Norway, Sweden and Denmark the use of copper in organic agricultural production has already been banned many years ago. Laboratory- and field trials have shown that potassium bicarbonate is not as effective as copper, but still might be an alternative for the use of copper to control apple scab.

In 2007, 2008 and 2009 a copper-free disease management schedule based on the use of potassium bicarbonate and sulphur was tested under practical conditions. Fully grown orchards of the variety Elstar where split up into a part treated according to the copper-free strategy, and a remaining part treated according the Standard organic practice. The applications where made by growers using their regular spraying equipment. Trials where run on five locations in 2007 and 2008 and on nine locations in 2009.

The limited rain fastness of both potassium bicarbonate and sulphur led to an average of 22, 31 and 41 applications between bud-break (middle of March) and harvest (middle of September) in the three successive years.

*The tight schedules resulted on all locations in about a 2*Log_{10} increase in the epidemic between May and September. This appears to be the maximum efficacy that can be achieved under practical conditions with a bicarbonate-sulphur schedule on the apple variety Elstar, under Dutch climatic conditions.*

Counting with this increase-rate, to achieve an acceptable level of apple scab of 100 infected leaves/100 shoots at harvest, the average disease level at the end of primary infection season should be lower than 1 leaf infected with scab per 100 shoots. At a higher initial disease level more powerful fungicides are necessary for the effective control of the disease.

Both the level of fruits scab, and the level of diseased leaves at harvest after a tight bicarbonate-sulphur schedule, depended on the success of the scab management during the primary infection period. Sanitation, and efficient management of primary apple scab infections are therefore the key to the feasibility of copper-free production of Elstar apples under Dutch conditions.

Keywords: *Venturia*, Apple, Organic, Disease management, Potassium bicarbonate

Introduction

The use of copper as fungicide in organic agriculture is often criticized as the only non-sustainable cultural practise in the system. Throughout the last two decades several projects where initiated to find a suitable replacement for copper to control scab on apple and pear. Today the general conclusion of these projects is that there is still no substance acceptable for organic production that is as effective as copper, but it may be possible to replace the use of copper by an alternative strategy combining new compounds, accurate timing of applications, and cultural practices.

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From 2002 onward several institutes in Europe tested potassium bicarbonate formulations in laboratory and field trials, and confirmed the effectiveness of bicarbonate on apple scab, pear scab, powdery mildew and sooty blotch. (2,5,6,7,8,9,10,11,12,15) Potassium bicarbonate proved to be one of the most promising alternatives to copper in the European REPCO project. (1,3,4) Until 2007 almost all trials where laboratory or small plot trials performed by advisers and researchers, during a limited period of the year. These trials do not show what a season-long replacement of copper by slightly less effective materials means for the development of the disease under practical conditions.The aim of our field trials in 2007, 2008 and 2009 was to compare the efficacy of a potassium bicarbonate and sulphur based scab management strategy with the standard spray program under practical conditions including copper , and evaluate the possible side effects on the cropping system. The 2007 results of these trials where reported before. (16,18) Preliminary results and general conclusions over the tree year period are reported here.

Material and Methods

Dutch organic fruit growers, forming a working group on ”alternative strategies to control apple scab”, applied a copper-free strategy on one or two 0.5 -1.0 ha. blocks of a fully grown orchard of the variety Elstar. The remaining part of the orchard was treated according to their standard program. Elstar is regarded as moderately susceptible to apple scab. With 40-50% of the organic apple production in the Netherlands Elstar is the most important variety.

The working group had regular discussions on the strategy to be followed based on our increasing understanding of the properties of potassium bicarbonate from research by others, and their own experiences. The strategy developed trough the years. Table 1 lists the 2009 copper-free and standard spray schedule. The following considerations, based on the present state of our understanding of the properties and mode of action of potassium bicarbonate, guided the growers in their decisions on scab management during the season:

- Potassium bicarbonate is to be applied protectively shortly before rain or preferably as ”stop spray” during infection development, but within 24 hours after infection.
- Potassium bicarbonate used as stop- or post infection treatment is to be applied on wet leafs, or with sufficient water to wet the tree completely.
- Applications are made with 5 kg Vitisan (= 99% food grade potassium bicarbonate) + 2-4 kg wettable sulphur (= 80% sulphur) per hectare and treatment. The combination with sulphur is made as Vitisan is an unformulated product, and the addition of Sulphur could serve as formulant in the tank mix. There is also growing evidence that the synergy by the mode of action of sulphur and potassium bicarbonate adds to the overall efficacy of the treatment.
- As potassium bicarbonate is highly soluable in water (> 300 gram/litre), we suppose bicarbonate is washed off from the trees rapidly, so residual activity does not last longer than 2-5 mm of rain, or at least when the trees start dripping.
- In situations with high infection risk, or practical impossibility of the application of bicarbonate in time, lime sulphur should be used post infection.
- Potassium bicarbonate should not be tank mixed with other materials than sulphur to prevent phytotoxicity.
- At dose of 5 kg of bicarbonate per hectare there is no evidence of risk of fruit skin- or leaf damage on Elstar.
- We suppose there is no negative effect on fruit set of applications during bloom.

Table 1: Strategy for the copper-free control of orchard diseases as advised by Bio Fruit Advies in the Netherlands in 2009.

	Copper-free	Standard Organic
Bud burst - Flowering	Protective: sulphur Stop-Spray: sulphur + bicarbonate Post infection: lime sulphur on main infections	Protective: copper Post infection: lime sulphur on main infections
Flowering-June	Protective: sulphur (+boron) Stop-Spray: sulphur + bicarbonate	Protective: sulphur (+boron) Stop-Spray: sulphur + bicarbonate
June-July	Stop-Spray: sulphur + bicarbonate Lime sulphur (in case of scab problems)	Stop-Spray: sulphur+ bicarbonate Copper + sulphur (in case of scab problems)
August-Harvest	Protective: sulphur Storage diseases: Myco-sin	Protective: copper + sulphur

Each grower had access to a weather station, and used infection calculations according to RIMpro in his decision making. Every three to four weeks the disease level was accessed by monitoring 200 shoots. At high disease levels the observations were limited to 100 or 50 shoots/treatment. The number of leafs with scab symptoms on each shoot, and the number of expanded leafs on 30 shoots was noted. Results of the observations where discussed with the growers during the season to decide on the next strategy to follow. In 2007 and 2008 within two weeks prior to harvest, 500 randomly chosen fruits where checked for scab symptoms in both the standard and the copper-free orchard block. In 2009 observations on fruit scab where made four times during the growing season. In June, July and August 300 fruits where examined for scab symptoms. Shortly before harvest 500 fruits per plot where checked. Leaf and fruit analysis on mineral contents where made in July and August respectively. In each plot 10 EPS 11 kg boxes containing in total about 800 randomly chosen fruits where picked for storage to evaluate skin quality and the development of storage diseases.

Results

Apple scab infections

The weather pattern in 2007 caused an exceptional primary infection season for the Netherlands. March and April where exceptionally dry. No primary apple scab infections developed during these months. Rain events between 6 and 12 May caused extreme numbers of ascospores released, both in the RIMpro-simulations, and as recorded in spore traps (P.Creemers, pers. comm.) and resulted in severe scab infections. Secondary infections later in the season developed from this single primary scab infection.

2008 had an average primary infection season for Dutch conditions with many long wetness periods causing three to five severe scab infection periods, and several less critical infection events. At the end of primary infection season in four of the five trial orchards very few scab lesions where found. In the fifth orchard both the copper-free and the standard program had already an increased disease level. The summer of 2008 was wet causing a strong increase in the disease level between bloom and harvest.

In 2009 vegetation started late, and there was a rapid development from bud-break around the 17th of March until full bloom around 25th of April. Three to four pronounced and well-foreseen primary infections occurred, and theoretically scab management should have been easy. Nevertheless an early infection on the 9th of April turned out the be very critical

causing severe scab symptoms on fruits (sepals) and leafs in organic as well as in well-managed integrated orchards. Although the summer was relatively warm and had exceptionally little rain events, disease levels steadily increased during summer.

Treatments

During the primary infection period all growers aimed their treatments at infection events as calculated by the RIMpro software. The use of Lime sulphur was limited to one or two applications per year. On several occasions applications with lime sulphur for fruit thinning during boom did coincide with important infection events giving the treatments a double meaning. Post bloom use of Lime sulfur was avoided to prevent any risk for negative effect on the fruit skin quality. In some extreme situations a few treatments with lime sulphur or low rates of copper where made in July or August in an attempt to reduce further increase of the epidemic. During the period of secondary spread of the disease, different strategies where followed. In 2007 and 2008 most growers still watched and reacted on the calculated infection events. In 2009 being a difficult year for scab control, some growers changed to protective routine sprays every second row with only a few days interval, resulting in a high number of applications. Post bloom all growers tried to avoid the user of copper as long as possible resulting in spray programs being identical for the copper-free and standard program until the increase of scab incidence made the return to a copper program unavoidable.

Table 2: Number of treatments between but break and harvest. (Average, minimum and maximum number of applications)

Year	Number of orchards	Copper-free	Standard
2007	5	22.0 (13-26)	20.8 (13-24)
2008	5	30.5 (25-40)	30.0 (27-38)
2009	9	40.8 (31-59)	42.7 (30-59)

The difference in number of treatments per year reflects the weather pattern and severity of the epidemic in each year. The knowledge that both bicarbonate and sulphur are rapidly washed off by rain led to frequently repeated applications during rainy periods, especially in situations with increased disease level. There is no difference in the number of applications between the copper-free and standard program as in most orchards the programs where the same for the major part of the summer.

Disease development on leafs

In each year and orchard the disease development expressed as number of diseased leaves per 100 shoots followed the typical logistic pattern of growth for an epidemic. (19) At the initial lower disease level the observed increase was logarithmic, but at higher disease level and later in summer the growth of the epidemic was limited by the availability and development of new susceptible leafs. (see also 16)

In Figure 1 disease progress in the copper-free plots in 2009 is plotted. In the case of the trial plot ”Stoker”, scab management appears to fail completely. Despite 47 fungicide applications from bud break till harvest, almost every newly developed leaf was infected by apple scab. Disease progress matches shoot growth in this orchard. In a few other orchards (e.g. ”Peters”, ”Konijn”) scab management appears to be very effective. The spray schedules of the participating growers where examined closely. However comparing the fungicide schedules applied by the more and the less successful growers during summer, no explanation for the differences in end results could be found.

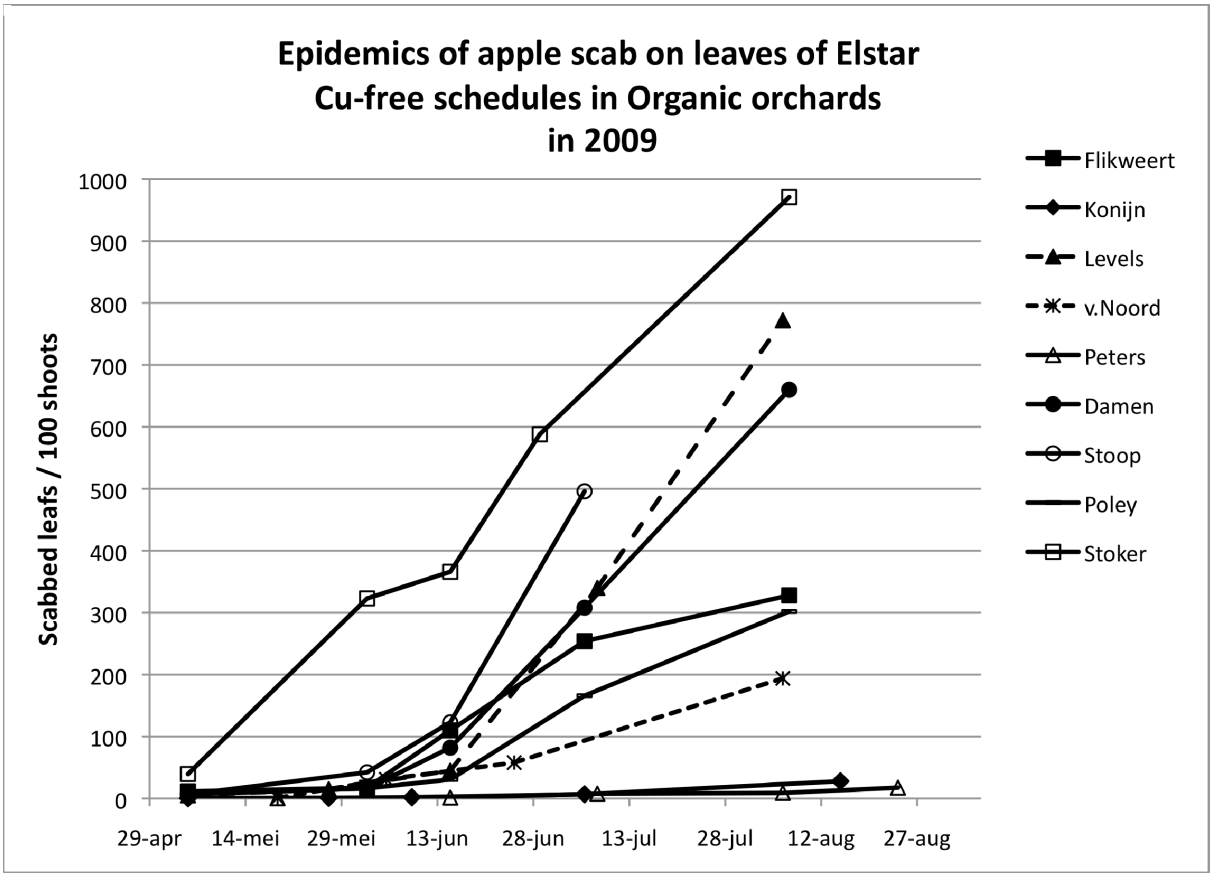

Figure 1: Development of the scab epidemic in the nine trial orchards in 2009.

While the fundamental effect of the application of fungicides is the reduction of the rate of increase of the disease (= slowing down the development of the epidemic), there is no relation between the fungicide schedule and the absolute disease level at harvest to be expected when looking at individual orchards. The more effective fungicide program would be recognized as the one that reduces the disease progress further than a less effective program.

To examine the results in this way the disease progress in each orchards was plotted against a logarithmic scale in figure 2. In the case of Stoker, disease progress after 1-june is limited by the availability of newly formed leafs.

The graph shows that the disease progress under the apparently more effective schedules (e.g. Peters, Konijn) is in fact comparable to the other orchards. From the graph can be concluded that in all orchards the rate of increase of the epidemic (slope) is comparable, and the increase of the epidemic between end of May and harvest is about $2*Log_{10}$.

The differences in final result are not due to difference in disease management during summer, but can be attributed entirely to the result of the disease management during the primary infection season.

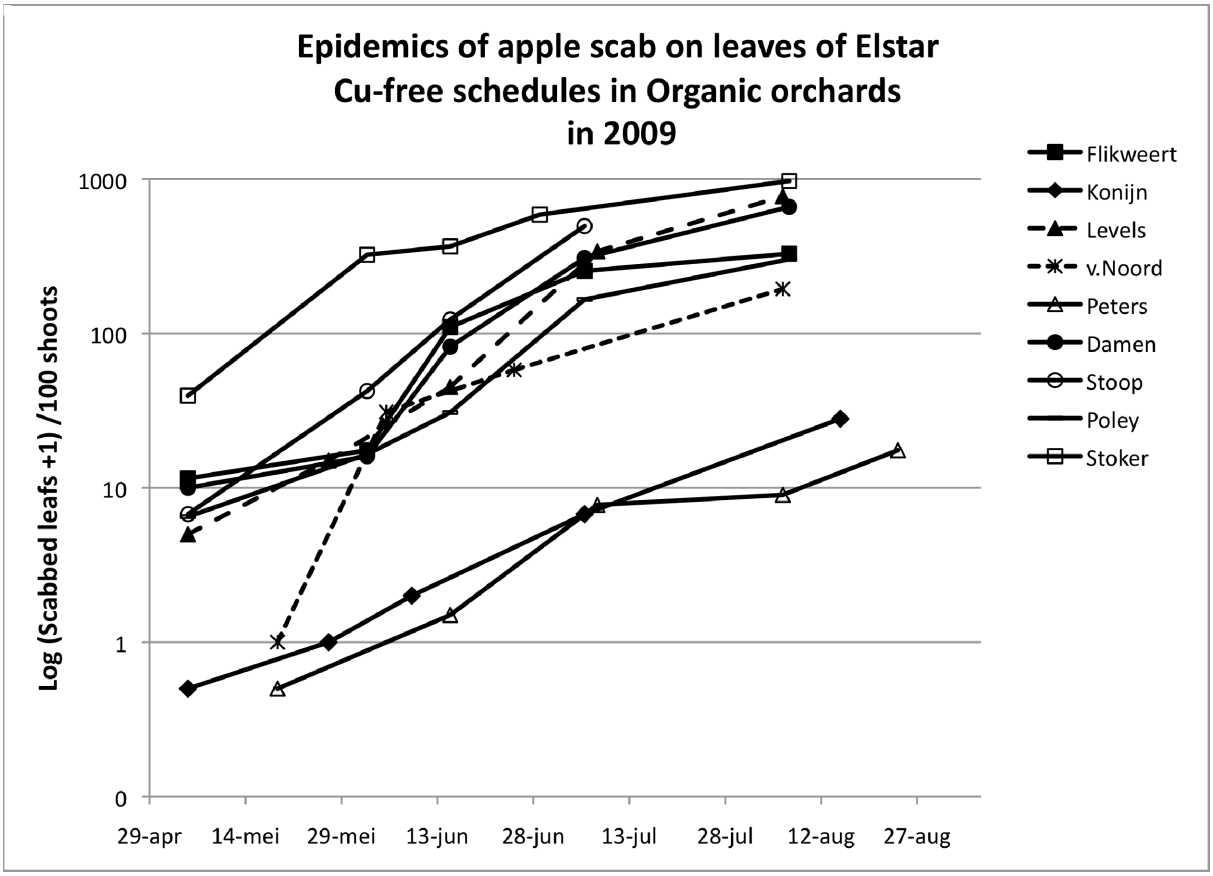

Figure 2: Development of the scab epidemic in the nine trial orchards in 2009.

Disease development on fruits

In 2009 an early infection caused scab on both fruits (on the sepals) and rosette leafs. The infection of fruitletts became visible from the 2nd of June onwards. During summer the severity of the symptoms on the infected fruits increased as scab spores spread from the sepals over the individual fruits. The incidence as percentage infected fruit did however hardly increase between June and harvest. (Figure 2)

Table 3 shows the percentage fruits with scab lesions at harvest in all plots and years. All infected fruits are shown here, including fruits with scab lesions < 0.5 cm^2 that are considered as economically insignificant.

On average in each year there where more scabbed fruits the copper-free than in the standard plots. As shown for 2009 above, also in 2007 and 2008 most fruit scab originated form early season infection events.

Looking at the results in the individual orchards in 2009, in four out of the eight orchards the copper-free and the standard program had a comparable level of fruit scab (Konijn, Peters, Van Noord, Levels). In two orchards the copper-free program was clearly less effective than the standard program (Poley, Damen). In the last two orchards both the copper-free and the standard program failed indicating an independent technical error. (Stoop, Stoker).

In the case of Flikweert 2009 waiting with the sulphur + bicarbonate treatment on 9th of April for two hours until the leaves had begun drying, made the difference between 25% and 1% fruits with scab lesions.

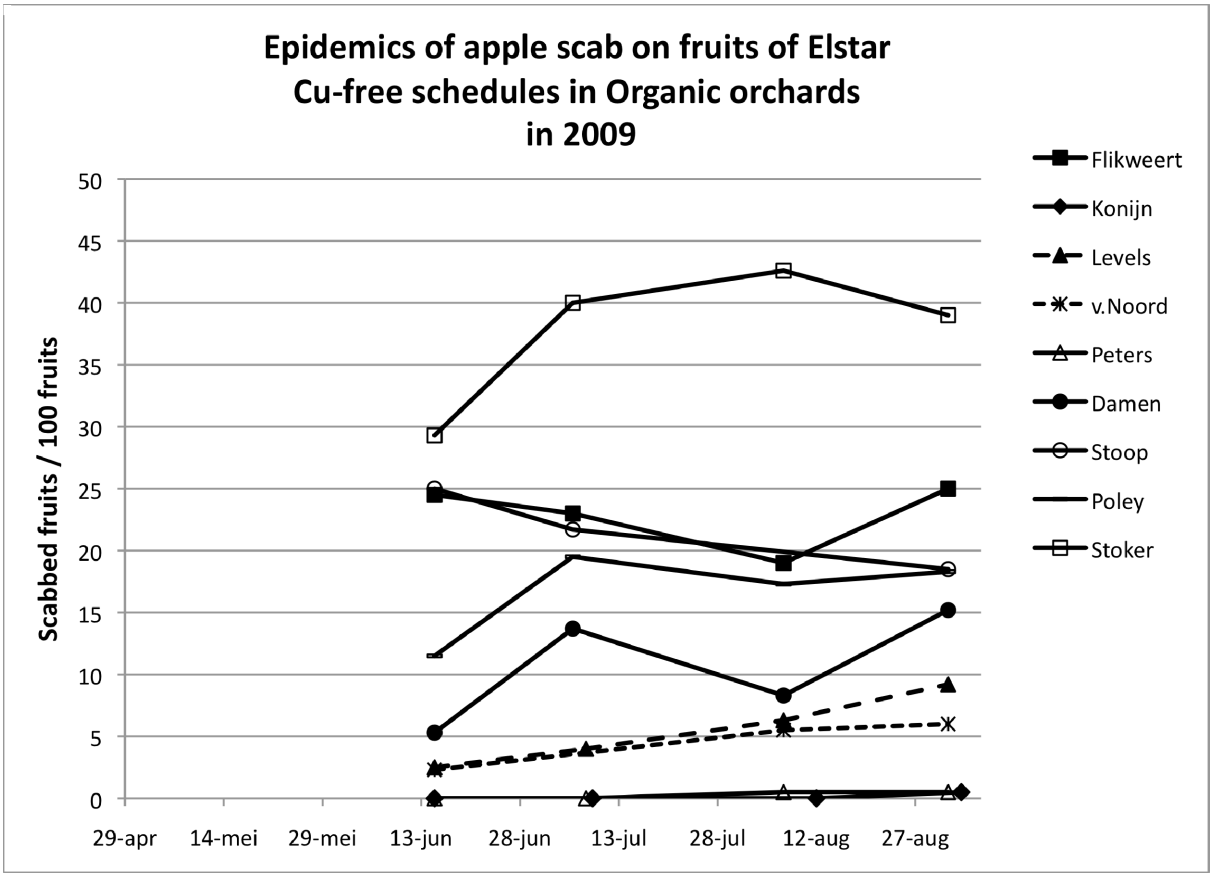

Figure 3: Development of the incidence of fruits with apple scab in the nine trial orchards in 2009.

Table 3: Percentage of fruits with apple scab lesions at harvest. (variety Elstar)

Orchard	2007		2008		2009	
	Cu-free	Standard	Cu-free	Standard	Cu-free	Standard
Korstanje	0,0	3,4	4,3	1,1		
Albers	2,2 *	3,0	6,4 *	3,0		
Flikweert	1,6	0,0	1,0	1,1	25,2 1,0	
Poley	3,6	0,8	11,2 *	1,9	18,3	4,3
Konijn	0,6	0,0	0,2	0,3	0,1	0,3
Peters					0,5	0,1
Van Noord					6,0	5,9
Levels					9,2	13,6
Damen					15,2 *	2,8
Stoop					18,5 *	11,3
Stoker					39,3 *	21,1
Average	**1,6**	**1,4**	**4,6**	**1,5**	**13,3**	**7,4**

*) In June and August a few applications with copper at low rate where made as in the standard block to control the epidemic.

Conclusions

The differences in scab development between orchards were more important than between the two strategies in the same orchard, meaning that orchard situations, management decisions, and application technique where more important for the final result than the availability of copper.

A tight schedule based on potassium bicarbonate and sulphur resulted in all orchards in about 2*Log_{10} increase in the epidemic between May and harvest. This seems to be the maximum efficacy that can be achieved with this copper-free schedule under practical conditions on the variety Elstar in The Netherlands.

To be able to achieve an acceptable level of apple scab of 100 infected leaves/100 shoots at harvest using a sulphur and potassium bicarbonate schedule, the disease level at the end of primary infection season should be lower than 1 scab infected leaf per 100 shoots. At a higher initial disease level more powerful fungicides are necessary for effective control of the disease.

A tight fungicide schedule based on potassium bicarbonate and sulphur, probably supported by the increasing ontogenetic resistance of the fruit during their development (13,14) prevented an increase of the incidence of scabbed fruits between June and harvest, even though the incidence of scabbed leaves strongly increased during this period.

More fruit scab developed during storage on plots already having an increased level of fruit scab at harvest (data not shown).

Both the level of fruit scab, and the level of diseased leaves at harvest after a tight bicarbonate-sulphur schedule, depended on the success of the scab management during the primary infection period. Sanitation and efficient management of primary apple scab infections are therefore the key to the feasibility of copper-free production of Elstar apples under Dutch conditions.

This contribution focuses on the control of apple scab without using copper. It should however be realized that the replacement of copper by other materials could lead to other system effects as the regular copper treatments in a standard organic disease management program also suppress other diseases. (17)

References

1. Bengtsson, M.V., B. Heijne, P.F. de Jong, H.J.L. Jørgensen, K. Paaske, H.L. Pedersen, M. Trapman, E. Wulff & J. Hockenhull (2006). Prospecting for new fungicides to control apple scab (Venturia inaequalis) in organic fruit growing. 8th Conference of the European Foundation for Plant Pathology & British Society of Plant Pathology Presidential Meeting KVL, 13- 17 August 2006, Copenhagen, Denmark.
2. Creemers,P, (2003) Unpublished results form field trials of the Royal Research Institute in Gorsem, Belgium.
3. Heijne, B., P.F. Jong, J. Köhl, A.G.C.L. Speksnijder, J. Hockenhull, M. Bengtsson, H. Lindhard Pedersen, K. Paaske, U. Eiben, L Tamm & M. Trapman (2006). Prevention and control of apple scab. European Joint Organic Congress, 30 & 31 May 2006, Odense, Denmark.
4. Heijne, B., P.F. de Jong, H. Lindhard Pedersen, K. Paaske, M. Bengtsson & J. Hockenhull (2007). Field efficacy of new compounds to replace copper for scab control in organic apple production. 3rd QLIF Congress, Hohenheim, Germany, March 20-23, 2007.
5. Heyne,P.Krusse,P.& Maxin,P.(2006) First experiences with bicarbonate against scab in Hamburg. Proceedings of the *12th International Conference on cultivation technique and phytopathological problems in organic fruit-growing*, ed. FÖKO e.V. (FÖKO e.V., Weinsberg), 98-100.

6. Jamar, L., Lefrancq, B., & Lateur, M. (2007) Control of apple scab (*Venturia inaequalis*) with bicarbonate salts under controlled environment. *Journal of Plant Disease and Protection* **114** :221-227.
7. Kelderer, M., Casera, C., & Lardschneider, E. (2006) First Results of the use of potassium bicarbonate against scab in South Tyrol. Proceedings of the *12th International Conference on cultivation technique and phytopathological problems in organic fruit-growing*, ed. FÖKO e.V. (FÖKO e.V., Weinsberg), 93-97.
8. Kelderer,M,Casera,C.,Lardschneider E. (2008) Formulated and unformulated carbonates to control appelscab *13th International Conference on cultivation technique and phytopathological problems in organic fruit-growing*, ed. FÖKO e.V. (FÖKO e.V., Weinsberg), 47-53.
9. Kunz,S.,Mögel,G., and Volk,F. (2008) Control of apple scab by curative applications of biocontrol agents. Proceedings of the *13th International Conference on cultivation technique and phytopathological problems in organic fruit-growing*, ed. FÖKO e.V. (FÖKO e.V., Weinsberg), 62-67.
10. Ilhan,K.,Arslan,U.&Karabulut,O.(2006) The effect of sodium bicarbonate alone or in combination with a reduced dose of tebuconazole on the control of apple scab. *Crop protection* Vol **25-9**:963-967.
11. Matedi, L., (2009) Results of trials to control apple scab with post infection treatements with potassium bicarbonate and sulphur in 2009. Presentation during the meeting of the European apple scab working group in Bigorio, January 2010.
12. Pfeiffer,B. (2008) Results from scab trials with Armicarb in the years 2006 and 2007. Proceedings of the *13th International Conference on cultivation technique and phytopathological problems in organic fruit-growing*, ed. FÖKO e.V. (FÖKO e.V., Weinsberg), 41-46.
13. Schwabe S.,(1982) Wetting and temperature requirements for infection of mature apples by *Venturia inaequalis* in South Africa. *Ann.appl. Biol.* **100**:415-423
14. Schwabe S.,Jones A., and Jonker J.,(1984) Changes in Susceptibility of Developing Apple Fruit to *Venturia inaequalis. Phytopathology **74**:118-121*
15. Tamm, L., Amsler, T., Schärer, H., & Refardt, M. (2006). Efficacy of Armicarb (potassium bicarbonate) against scab and sooty bloch on apples. Proceedings of the *12th International Conference on cultivation technique and phytopathological problems in organic fruit-growing*, ed. FÖKO e.V. (FÖKO e. V., Weinsberg), 87-92.
16. Trapman,M., (2008) Practical experience with the use of Baking Powder (potassium bicarbonate) for the control of apple scab. (*Venturia inaequalis*) Proceedings of the *13th International Conference on cultivation technique and phytopathological problems in organic fruit-growing*, ed. FÖKO e.V. (FÖKO e.V., Weinsberg), 68-75.
17. Trapman,M. and Jansonius,P., (2008) Disease management is more than applying the right product at the correct time. Proceedings of the *13th International Conference on cultivation technique and phytopathological problems in organic fruit-growing*, ed. FÖKO e.V. (FÖKO e.V., Weinsberg), 16-22.
18. Trapman,M., (2009) Copper-free production of organic apples: three years experience in The Netherlands. Proceedings of the *Journées Techniques Fruits et Légumes Biologiques – 8&8 décembre 2009*, ITAB, Paris.
19. Zadoks, J., and Schein, D. (1979) Epidemiology and plant disease management. Oxford university press, Inc. 427 pp.