Practical experience with the use of Baking Powder (potassium bicarbonate) for the control of Apple Scab *(Venturia ineaqualis)*

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Abstract
In small plot trials, performed by several institutes in the past years, potassium bicarbonate proved to be a promising alternative to the use of copper for the control of apple scab in organic orchards. Feasibility, effectiveness, consequences, and side effects of the replacement of copper by bicarbonate under practical conditions are largely unknown. In 2007 Five Dutch organic apple growers compared a bicarbonate based scab management strategy with their standard spray program. The use of 5 kg potassium bicarbonate + 2 kg. wettable sulphur shortly before rain or during infection development, was the core of the strategy. It was concluded that the control of apple scab with the potassium bicarbonate strategy was as effective as the standard spray plan, provided lime sulphur was available tot cover extreme situations. The applications did not lead to any phytotoxic damage on leafs or fruits. Potassium bicarbonate tank mixed with a Mn leaf fertilizer however resulted in severe leaf drop, and necrotic spots on the remaining leafs.
The use of potassium bicarbonate did not increase the potassium content of the fruits.

Keywords: *Venturia ineaqualis,* Apple scab, 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 many national and international projects where initiated to find a suitable replacement for copper to control scab on apple and pear. Today the general conclusion of these projects still is that there is still no acceptable substance 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. From 2002 onward several institutes in Europe tested bicarbonate formulations in lab- and field trials and confirmed effectiveness on apple scab, powdery mildew and sooty blotch. (2,5,6,7,8,9,10) Bicarbonate showed to be one of the most effective alternatives to copper in the European REPCO project. (1,3,4) The fact that potassium bicarbonate is effective on apple scab, the use within organic agriculture is approved by IFOAM, and that an American company is applying for a registration in Europe, makes this substance one of the most promising short term alternatives to the use of copper.
Until 2007 almost all trials where lab- or small plot trials performed by researchers, in a limited period of the year. These trials do not answer the question if it is practically feasible to replace copper completely by a bicarbonate based strategy to control apple scab at an economically acceptable level without adverse effects on the cropping system. The aim of the field trials in 2007 was to compare the efficacy of a bicarbonate scab management strategy with the standard spray program under practical conditions, and evaluate the possible side effects on the cropping system.

Material and methods

Five Dutch organic fruit growers, forming a working group on “alternative strategies to control apple scab”, applied a bicarbonate strategy on an 0.5 to 0.75 ha. large part of a full grown Elstar orchard block. The rest of the orchard was treated according to their standard program. After discussing the available trial results, the working group decided to base their decisions on scab control with bicarbonate on the following considerations:

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- Bicarbonate is best to be applied protectively shortly before rain or during infection development.
- All applications are to be made with 5 kg Vitisan (= 99% potassium bicarbonate) + 2 kg wettable sulphur (= 80% sulphur) per hectare and treatment. The combination with sulphur was made as Vitisan is a unformulated product, and there is some evidence that the addition of sulphur adds to the efficacy of the treatment.
- We suppose bicarbonate is degraded, and or washed away from the trees rapidly, so residual activity does not last longer than 5 – 10 mm of rain.
- In case of high risk situations, or practical impossibility of timely application of bicarbonate, Lime sulphur should be used post infection.
- Bicarbonate should not be tank mixed with other materials than sulphur
- At dose of 5 kg of bicarbonate per hectare there is no evidence of risk for fruit skin or leaf damage on apple.
- We suppose there is no negative effect on fruit set of applications during bloom.

Each grower had access to a weather station on or nearby his farm, 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. The number of leafs with scab symptoms on each shoot, and the number of expanded leafs on 30 shoots was noted. Results of the monitoring where discussed with the growers during the season to decide on the next to follow strategy. Within two weeks from harvest, 500 randomly chosen fruits where checked for scab symptoms in both the Standard and the Bicarbonate block. Leaf an fruit analysis on mineral contents where respectively made in July and August. In each plot 10 EPS boxes containing in total about 800 randomly chosen fruits where picked for storage te evaluate skin quality an storability.

Results

Apple scab infections in 2007

The weather pattern in 2007 caused a 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 brought out extreme numbers of ascospores, both in RIMpro-simulations, and recorded in spore traps (P.Creemers, pers. comm.) and resulted in severe scab infections. Secondary infections later in the season result from this single primary scab infection.

During the dry periods in March and April however, the growers tended to use their overhead irrigation frequently, sometimes causing infection- or near infection events, and moreover hard to interpret situations. In contrast to the warm and dry spring, the summer of 2007 was wet and cloudy, but the temperatures kept above normal. The amount of rain was above normal, and locally huge amounts of rain fell in a few hours or days.

Table 1: Number of treatments in 2007.

Orchard	*Standard Strategy*	*Potassium Bicarbonate Strategy*
Albers	22	26
Flikweert	24	25
Konijn	24	25
Korstanje	13	13
Poley	21	21
Average	21	22

The number of treatments

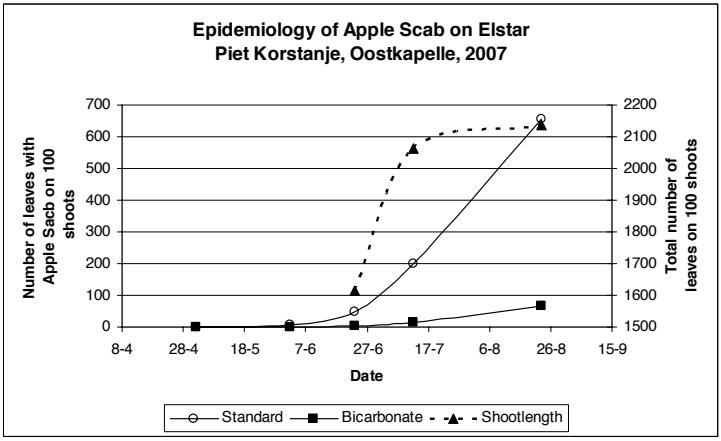
The growers handled their scab management very individually. They feared that the limited residual activity of bicarbonate would lead to more treatments in these plots, but the average number of treatments in the standard and Bicarbonate plots turned out to be comparable. (Table 1)

Disease development

As the pattern of apple scab infections was comparable for the trial orchards, and the variety was Elstar in each case, differences in disease development reflect the efficacy of the scab management strategy.

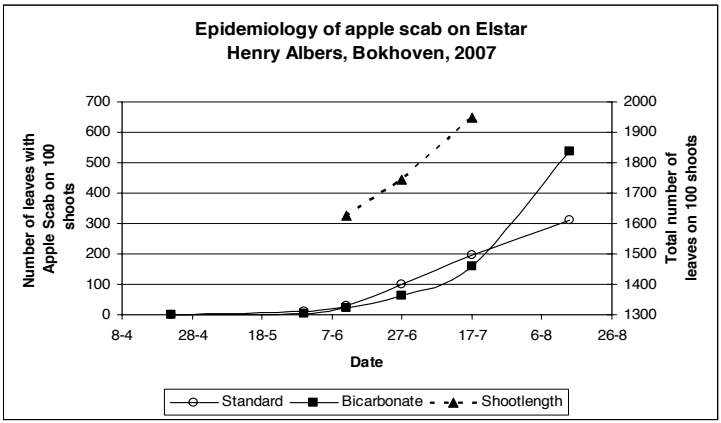
Orchard Piet Korstanje, Oostkapelle

Piet Korstanje used an extensive spray program with only 13 treatments in 2007. As his orchard is near to the sea where there are often high winds, he focused on preventive treatments at the moments spraying conditions where right, rather than aiming at a exact timing on infection development. The standard strategy consisted of regular treatments with 4 to 5 kg sulphur per hectare. The effectiveness of this standard strategy was poor. The disease progress curve matches the growth curve of the shoots meaning each new leaf that developed after beginning of June was infected by apple scab. The bicarbonate program with applications on the same dates as the sulphur treatments performed surprisingly well. Only after de schedule was discontinued from July 25th onward, some scab lesions developed on the last leafs that developed on the shoots.



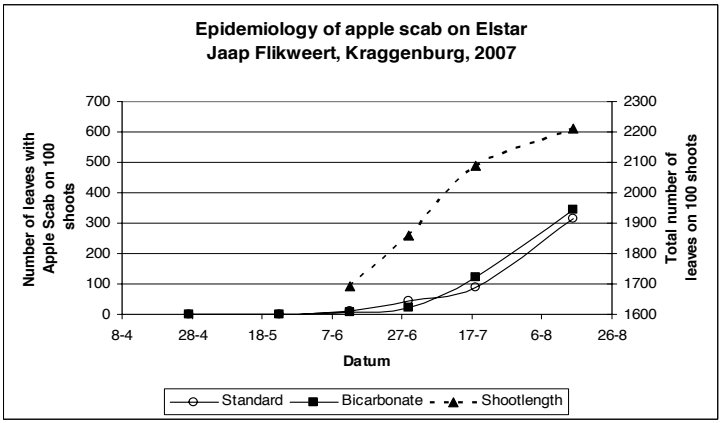
Orchard Henri Albers, Bokhoven

Henri Albers followed infection development closely, and tried to place the treatments as close as possible before or during infection events. He renewed applications as soon as he supposed the bicarbonate was washed off. Already during the second observation late May, some scab lesions where found. These could have resulted from the severe primary infection of 6-8 May, but probably also from “self-made infectious” caused by over head irrigation in April. During a continuous rain period that caused severe secondary infections in end of June Lime Sulphur (15 kg./ha.) was applied three times on both the trial bock and the rest of the orchard. Until July the bicarbonate/sulphur/lime sulphur strategy performed as well as the standard schedule.



Orchard Jaap Flikweert, Kraggenburg

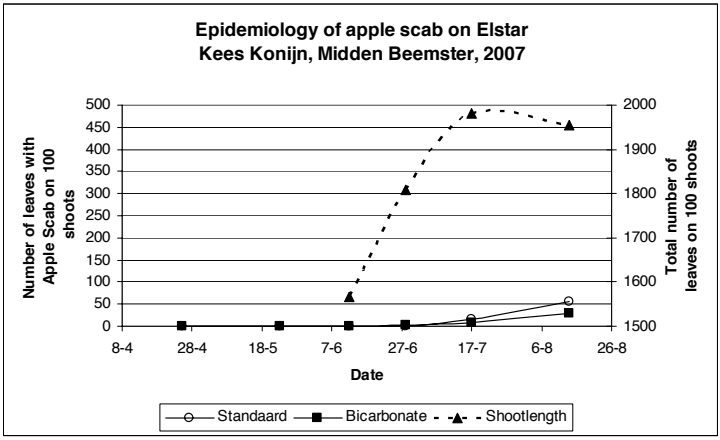
Jaap Flikweert also followed infection development quite closely, and aimed at treating shortly before or during infections. Occasionally he even treated twice on the same day in case of massive rainfall. Disease level was kept at an acceptable level until the end of June by both the standard and the experimental strategy. In the second halve of the summer the disease progress curve matches the leaf growth curve, meaning both strategies where not effective in preventing leaf scab infections. This is not surprising as his management was aimed at controlling fruit scab infections, and only four fungicide treatments where made during the last two months before harvest.



Orchard Kees Konijn, Midden Beemster

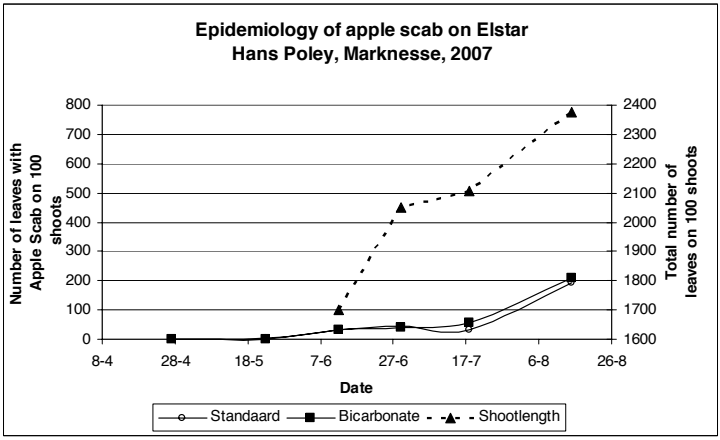
Kees Konijn consequently followed the bicarbonate strategy until harvest. During the period from June 21st until end of July both the experimental block and the standard block where treated with bicarbonate. Four of these bicarbonate treatments where made by overhead irrigation. After some smaller experiments, and encouraged by the results of Markus Kelderer on the Laimburg in 2006 (8), the grower used his overhead irrigation four times to apply bicarbonate during periods of excessive rainfall in July.

These treatments seem to have been effective. The disease progress curves in figure 8 show that both the experimental and the standard strategy performed very well.



Orchard Hans Poley

The scab management strategy of Hans Poley differs considerably from the other growers As the disease level at the beginning of June was already disturbing, he discontinued the use of potassium bicarbonate, and form the 14th of June onward the same Lime Sulphur schedule was followed on both the experimental and the standard block. Some disease developed at equal rate both in the experimental and in the standard strategy. The post infection lime sulphur treatments made from 14 June onwards proved to be very effective in preventing further disease progress. Only after these treatments where discontinued the disease grew rapidly.



Diseased fruits at harvest

As the first severe primary infection occurred not earlier than a week after full bloom, disease development in the orchards started late, and no early infections on fruits developed. The incidence and severity of scabbed fruits at harvest were low, and for organic production in the Netherlands, quite acceptable.

Table 2: Percentage of fruits with scab symptoms (assessment of 500 fruits in august)

Orchard	*Standard Strategy*	*Potassium Bicarbonate Strategy*
Albers	3.0%	2.2%
Flikweert	0.0%	1.6%
Konijn	0.0%	0.6%
Korstanje	3.4%	0.0%
Poley	0.8%	3.6%
Average	1.4%	1.6%

Effects on the mineral content of leafs and fruits

Early leaf analyzes taken in July show an 0.5 to 30% increase in K level in the leafs taken from the potassium bicarbonate treated blocks. It can not been concluded if this is an increase in the potassium levels in the leaves, or a result of potassium levels on the leaf surface. There was a minor increase in the K content of the fruits in three out of the five orchards. These differences seem to be a coincidence as there is no consistency in the results. I the case of Kees Konijn who applied potassium bicarbonate until harvest the K/Ca ratio improved, as in the case of Hans Poley who made the last bicarbonate treatment already June 14th the K/Ca ratio declined.

Table 3: Results of the leaf analyses in July. (mg./100 gram dry weight)

Orchard	*Standard Strategy*		*Potassium Bicarbonate Strategy*		*Increase*	
	K	K/Ca	K	K/Ca	K	K/Ca
Abers	1.48	1.0	1.91	1.4	29.1%	30.0%
Flikweert	1.77	1.2	1.99	1.5	12.4%	23.4%
Konijn	1.50	1.9	1.95	2.6	30.0%	31.7%
Korstanje	2.04	2.3	2.05	2.2	0.5%	-1.7%
Poley	2.03	1.3	2.14	1.4	5.4%	9.5%

Table 4: Results of the fruit analyses in august. (mg./100 gram fresh weight)

Orchard	*Standard Strategy*		*Potassium Bicarbonate Strategy*		*Increase*	
	K	K/Ca	K	K/Ca	K	K/Ca
Abers	120	18	115	15	-4.2%	-15.7%
Flikweert	118	22	128	25	8.5%	10.6%
Konijn	154	31	151	27	-1.9%	-10.9%
Korstanje	116	25	129	29	11.2%	16.3%
Poley	124	30	136	35	9.7%	15.3%

Phytotoxicity on leafs and fruits

The Vitisan-sulphur combination did not cause any phytotoxic effects on the leaves, although the leafs seemed to be more pale than the leafs on the standard treated trees. Damage as necrotic pots and growth stunting as reported for Armicarb in other trials where not observed. In one orchard severe leaf damage, and leaf drop occurred after the application of two sprays containing Vitisan, Sulphur and Mantrac (a Mn containing leaf fertilizer).

The damage did not occur in the standard block where at that time only sulphur and Mantrac where applied. During the growing season there were no obvious symptoms of fruit damage by bicarbonate, or differences in fruit skin quality between the standard and bicarbonate treated plots. Detailed assessments on fruit skin quality will be made after storage within a follow-up project.

Discussion and conclusions

Disease progress

Without adequate control measures the disease develops exponentially, and the progress curve matches the rate of development of new leafs on the shoots, starting form any level of primary attack. This confirms earlier observations in organic orchards in the Netherlands. This makes that sanitary measures and effective disease control during the period of primary infections are necessary for early season control, but a low disease level at any given time during the growing season does not allow for interruption of the spray plan when the management aim is to keep inoculum at a low level.

Scab management

In 2007 the growers were able to manage apple scab as well with potassium bicarbonate + sulphur as with their standard strategy, provided they could use lime sulphur in difficult situations. The results however do not reveal what is the best way to apply bicarbonate. The crude strategy Piet Korstanje used was as effective as the highly sophistic way Kees Konijn decided on his treatments.

Mineral content of leafs and fruits

In June and July the leafs on the potassium bicarbonate treated trees looked more pale then on the standard treated trees, but the leaf analysis made in July did not reveal a lower N, Mn or Mg content. The use of potassium bicarbonate did not lead to a higher potassium content of the fruits at harvest or an increase of the K/Ca ratio. It is not to be expected that the physical storability of the fruits from the potassium bicarbonate treated trees will differ from the standard treated trees.

Adverse side effects on the cropping system

No obvious phytotoxic effects were seen on leafs or fruits resulting from the use of 5 kg. Vitisan + 2 kg sulphur per hectare. The combination with a leaf fertilizer resulted however in severe leaf damage and leaf drop. This confirms the experience of other advisors who found that bicarbonate should generally not be tank-mixed with other materials to prevent physical problems in the spray solution and phototoxic effects.

Open questions

Although the results of these trials are highly encouraging, many questions are still open. Knowledge on the mode of action and physical properties of potassium bicarbonate as fungicide are necessary to develop sound scab control strategies. Also the effect of the change of materials used for scab control on the complex of other orchard diseases: as mildew, sooty blotch, *Nectria*, black-rot, and storage diseases, need to be studied under practical conditions to be able to conclude whether bicarbonate can replace copper as fungicide.

Acknowledgements

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