Evaluation of the users value of salts against apple scab and powdery mildew for fruit production

P. Creemers[1], S. Van Laer[1], A. Van Mechelen[1], B. Vorstermans[1] and K. Hauke[1]

Abstract

The research was aimed at finding anti resistance strategies for Integrated fruit growing. As the salts tested may be approvable for organic farming, the trial results are also of value for the development of scab an mildew control strategies for organic fruit growing. As new fungicides are mainly unisite action fungicides, the problem of fungicide resistance development is becoming more important every year. Combining chemical fungicides, which is the best anti-resistance strategy, is not always possible or recommended in the case when the number of available chemical fungicides are limited or a reduction in fungicide use is asked for. Therefore the use of salts as an anti-resistance strategy was looked upon. The salts evaluated were $K(HCO_3)$, KH_2PO_3, $KHPO_4$ and K_2SiO_3. When using these salts as an anti-resistance strategy the efficacy obtained when spraying the compounds alone was often to low to be used in rotation with chemical fungicides. Only with $K(HCO_3)_2$ a good efficacy can be observed in some years. The variation in efficacy with $K(HCO_3)_2$ observed is higher for powdery mildew. $K(HCO_3)_2$ can be considered as a ideal product for scab control in organic orchards at moments of low infection risk.

Keywords: Scab, Powdery mildew, salts

Introduction

The fungicidal activity of salts like bicarbonates and silicon against various fungal diseases has been known for more than 70 years and many research-ers have described the effects of different salts on a wide range of diseases including *Venturia inaequalis* and *Podosphaera leucotricha* on apple (Laffran-que and Shires, 2005; Schulze and Schönherr, 2003; Conway et al., 2004, 2005; Epstein, 1999; Kanto et al, 2004; Orober et al., 2002; Reuveni et al., 2000). Despite these efforts the use of salts as a fungicide in integrated farming is still limited. Uncertainties about the robustness of these treat-ments compared to chemical treatments makes salts unpopular. The study presented here covers results from different field trials carried out in the period between 2002 and 2006. In the field trials presented here not only the efficacy of salts alone but also combination treatments of salts with chemical fungicides were looked upon. Although it was not the primary objective, the results of this research are also of value for the organic fruit production.

Material and Methods

Trial design

The trial design is set up as a randomized block in 4 repetitions. The trial is carried out in a one row system. The number of trees in a trial is the same for each object and for each repetition. The minimum number of trees per repetition is 8. The untreated plots are positioned in a way that they cannot have an effect on the infection pressure in the treated plots. The time and the number of treatments depend on the trial, the climate conditions and the infection risks. Normally an application was per-formed every 8-10 days.

[1] Proefcentrum Fruitteelt v.z.w., De Brede Akker 13, 3800 Sint Truiden, Belgium

The products under evaluation are K(HCO3)2 (Armicarb©, Agritec inc., USA), KH2PO3 (Fructospor©; Hermoo, Belgium), KHPO4 (Nutrichem, Germany) and K2SiO3 (Hydro-agri, Netherlands / Silisorb, Celite Corp, USA). Also chitosan (Biochicol©, Gumitex, Poland) was included in two trials. The doses used are mentioned in the result tables.

Evaluation of the scab and powdery mildew infestation

The assessment of scab lesions on the leaf is made after the primary scab infection period. On fruits the evaluation was made before harvest. The evaluations were carried out according to the EPPO guideline nr 5. Efficacy evaluation of protectant applications against powdery mildew were carried out according to the EPPO guideline nr 69. The infection degree (TH3) and efficacy (Abbott value) were calculated according to the formula of Townsend-Heuberger and Abbott.

Results

Salt action against apple scab

During the time period between 2002 and 2006, 4 experiments were carried out to determine the efficacy of salts against apple scab. In the first trial performed in 2002 the action of $K(HCO_3)_2$ was looked upon (Table 1). $K(HCO_3)_2$ was applied alone or in combination with dithianon. The chemical reference schedules consisted out of a kresoxim-methyl based schedule and a dithianon schedule. The best results on the leaves were obtained with kresoxim-methyl, however the efficacy was not significantly better then the schedule where dithianon was combined with $K(HCO_3)_2$. No differences could be observed between $K(HCO_3)_2$ and dithianon applied alone. These schedules also did not differ from combined treatment schedule. On the fruits the best efficacy was obtained with the combined dithianon/ $K(HCO_3)_2$ schedule, however statistically this schedule was only better than the schedule where $K(HCO_3)_2$ was applied alone.

Table 1. Scab infestation % on the leaves and the fruits observed in the trial of 2002 and the efficacy of different treatment schedules against the scab infestation (Statistics: Anova, Duncan $p<0.05$)

Treatment	dose (%)	%A leaf (2/8/2002)		%A fruit (6/9/2002)	
untreated control		100		98.6	
		efficacy (ABBOTT)		efficacy (ABBOTT)	
dithianon	0.050	72.7	b	97.4	a
kresoxim-methyl	0.013	84.8	a	96.7	ab
$K(HCO_3)_2$	0.300	70.3	b	93.7	b
dithianon + $K(HCO_3)_2$	0.050 + 0.200	80.4	ab	98.1	a

In the trials performed in 2004 the combination treatments of dithianon with different types of salts were compared (Table 2 and 3). The infestation of the leaves could only be evaluated in dept in one trial due to the low infestation pressure on the leaves in the second trial. On the leaves the best efficacy was obtained with the combination of dithianon and KH_2PO_3. During the first evaluation of the leaf infestation this combination was only significantly different from dithianon applied alone or $K(HCO_3)_2$ applied alone. No significant surplus effect was observed with the other combination treatments schedules when comparing them with the dithianon schedule. The dithianon schedule itself did also not differ from $K(HCO_3)_2$ schedule.

During the second evaluation of the leaves all treatment schedules except the combined treatment schedule of dithianon with $K(HCO_3)_2$ differed significantly from the $K(HCO_3)_2$ based schedule.

Table 2. Scab infestation % on the leaves and the fruits observed in the trial of 2004 and the efficacy of different treatment schedules against the scab infestation (Statistics: Anova, Duncan p<0.05)

Treatment	dose (%)	%A leaf (29/7/2004)		%A leaf (13/9/2004)		%A fruit (8/9/2004)	
untreated control		66		68.3		24.3	
		efficacy (ABBOTT)		efficacy (ABBOTT)		efficacy (ABBOTT)	
dithianon	0.033	95.4	bc	83.5	a	97	ab
$K(HCO_3)_2$	0.300	89	c	59.5	b	79.2	c
dithianon + $K(HCO_3)_2$	0.050 + 0.300	98.1	ab	77.1	ab	95.5	ab
dithianon + K_2SiO_3 (Hydro-agri)	0.033 + 0.067	97.5	ab	79.4	a	89.3	bc
dithianon + K_2SiO_3 (Silisorb)	0.033 + 0.023	98.1	ab	81.3	a	99.1	a
dithianon + $KHPO_4$	0.033 + 0.050	98.1	ab	87.1	a	92.3	abc
dithianon + KH_2PO_3	0.033 + 0.200	99.3	a	87.8	a	98.2	ab

Table 3. Scab infestation % on the leaves and the fruits observed in the trial of 2004 and the efficacy of different treatment schedules against the scab infestation (Statistics: Anova, Duncan p<0.05)

Treatment	dose (%)	%A leaf (13/07/2004)		%A leaf (9/09/2004)		%A fruit (7/9/2004)	
untreated control		14.1		41.3		64.4	
						efficacy (ABBOTT)	
dithianon	0.033	67.8		92.2		86.6	abc
$K(HCO_3)_2$ (low dosis)	0.300	78.9		87.3		85	bc
$K(HCO_3)_2$ (high dosis)	0.500	82.6		92.6		82.3	bc
dithianon + $K(HCO_3)_2$	0.033 + 0.300	71.9		93.3		80.9	bc
dithianon + K_2SiO_3 (Hydro-agri)	0.033 + 0.067	72.7		81.6		83.6	bc
dithianon + K_2SiO_3 (Silisorb)	0.033 + 0.023	74.4		89		79	c
dithianon + $KHPO_4$	0.033 + 0.050	73.6		86.8		89.6	ab
dithianon + KH_2PO_3	0.033 + 0.200	89.7		91.7		93.8	a

When evaluating the infestation of the fruits, the same tendencies could be observed. Again the combination of dithianon with KH_2PO_4 resulted in a very good efficacy. Again the lowest efficacy was obtained with $K(HCO_3)_2$. All treatment schedules, except the combination treatment schedule with hydro-agri and $KHPO_4$, resulted in a better efficacy than the schedule with $K(HCO_3)_2$. In the second trial the results obtained with the combination of dithianon with Silisorb contradict the results of the first trial. Where in the first trial the highest efficacy was obtained with this combination, the schedule resulted in the lowest efficacy in the second trial. This efficacy was significantly lower than the combination schedules with $KHPO_4$ and KH_2PO_3. In this trial the application of KH_2PO_3 resulted in a significantly higher efficacy when compared with the other combination schedules or $K(HCO_3)_2$ applied alone. Only the combination with $KHPO_4$ resulted in an equal good efficacy.
In the last trial performed in 2006 the activity of two salts, namely $K(HCO_3)_2$ and K_2SiO_3, was compared with the activity of sulphur (Table 4). Only at the evaluation of the fruits significant differences could be observed. The best efficacy was obtained with sulphur, however this efficacy was only significantly higher than the efficacy obtained with K_2SiO_3. No statistical differences could be observed between the efficacy of K_2SiO_3 and $K(HCO_3)_2$.

Table 4. Scab infestation % on the leaves and the fruits observed in the trial of 2006 and the efficacy of different treatment schedules against the scab infestation (Statistics: Anova, Duncan $p<0.05$)

Treatment	dose (%)	%A leaf (5/9/2006)		%A fruit (22/9/2006)	
untreated control		39.1		30%	
		efficacy (ABBOTT)		efficacy (ABBOTT)	
$K(HCO_3)_2$ (low dosis)	0.333	68.8		68.4	ab
$K(HCO_3)_2$ (high dosis)	0.500	68.3		64.4	ab
K_2SiO_3 (Hydro-agri)	0.067	65.7		53.8	b
S (Hermovit)	0.500	80.8		86.6	a

Salt action against powdery mildew

The trial setup of the powdery mildew trial resembles that of the apple scab trial. The only difference concerns the reference chemical fungicide used. As dithianon has no effect on powdery mildew, other chemical references are included. The chemical references are triadimenol, kresoxim-methyl and penconazol. In the trial of 2002 the efficacy of $K(HCO_3)_2$ was evaluated (Table 5). The highest efficacy in this trial was obtained with kresoxim-methyl, which was significantly higher than the schedules that contained $K(HCO_3)_2$. In the trial of 2005 (Table 8) combining the two products results in a synergism, which was not the case for the first trial. The remark has to be made that in this case the dose of $K(HCO_3)_2$ used is higher than in the trial of 2002. Furthermore the overall efficacy of all the products is much lower in 2005. In 2005 also a second trial was conducted in which the effect of $K(HCO_3)_2$ was compared with both triadimenol and penconazol (Table 7).

As no statistical differences could be observed, it can be stated that all products had an equal effect on the infestation. Also the action of chitosan was looked upon in the trials of 2005. However chitosan has clearly no effect on powdery mildew on apple.

Table 5. Powdery mildew infestation % observed on the leaves in the trial of 2002 and the efficacy of different treatment schedules against the powdery mildew infestation (Statistics: Anova, Duncan $p<0.05$)

Treatment	dose (%)	%A (16/7/2002)	
untreated control		78.4	
		efficacy (ABBOTT)	
triadimenol	0.050	98.4	ab
kresoxim-methyl	0.013	98.7	a
$K(HCO_3)_2$	0.300	94.2	bc
triadimenol + $K(HCO_3)_2$	0.050 + 0.200	94.4	c

Table 6. Powdery mildew infestation % observed on the leaves in the trial of 2004 and the efficacy of different treatment schedules against the powdery mildew infestation (Statistics: Anova, Duncan $p<0.05$)

Treatment	dose (%)	%A (30/7/2004)	
untreated control		78.6	
		efficacy (ABBOTT)	
triadimenol	0.050	73.7	a
$K(HCO_3)_2$	0.300	39.3	b
K_2SiO_3 (Hydro-agri)	0.067	22.7	bc
K_2SiO_3 (Silisorb)	0.023	25.4	bc
$KHPO_4$	0.050	12	c
KH_2PO_3	0.200	12.1	c

Table 7. Powdery mildew infestation % observed on the leaves in the trial of 2005 and the efficacy of different treatment schedules against the powdery mildew infestation (Statistics: Anova, Duncan $p<0.05$)

Treatment	dose (%)	%A (6/7/2005)	
untreated control		60.1	
		efficacy (ABBOTT)	
triadimenol	0.050	62.7	a
penconazol	0.017	71.3	a
$K(HCO_3)_2$	0.333	40.2	ab
chitosan	0.500	0	b

In the trial of 2004 the activity of the different salts were compared (Table 6). The best efficacy was obtained with the chemical references, which scored significantly better then all other treatment schedules. When looking at the salts, the best efficacy was obtained with $K(HCO_3)_2$. The activity of $K(HCO_3)_2$ was better than that obtained with $KHPO_4$ and KH_2PO_3. The K_2SiO_3 treatment schedules resulted in an intermediate efficacy which could statistically not be differentiated from the efficacies obtained with other salt treatment schedules.

Table 8. Powdery mildew infestation % observed on the leaves in the trial of 2005 and the efficacy of different treatment schedules against the powdery mildew infestation (Statistics: Anova, Duncan $p<0.05$)

Treatment	dose (%)	%A (15/6/2005)	
untreated control		80	
		efficacy (ABBOTT)	
triadimenol	0.050	42.4	b
$K(HCO_3)_2$	0.333	45.1	b
triademol+$K(HCO_3)_2$	0.050 + 0.333	73.2	a
chitosan	0.500	19.3	c

Discussion

For all the salts evaluated, only with $K(HCO_3)_2$ a good efficacy was observed in some years. The efficacy obtained with $K(HCO_3)_2$ depends on the growth season and probably also the infection pressure present in the orchard. This variation in efficacy is higher for powdery mildew. Based on the results presented above, $K(HCO_3)_2$ can be considered as a ideal product for low infection risk moments. In biological fruit growing, $K(HCO_3)_2$ can be applied on low infection risk moments in rotation with sulphur and copper. The results obtained with sulphur and copper are less dependent on the infection risk and infection pressure. For this reason $K(HCO_3)_2$ is considered to be less reliable during high infection risk. In the case of integrated farming, the positioning of the sprays recommended is different for Scab and Powdery mildew. In the case of scab, $K(HCO_3)_2$ can be applied on low infection risk moments in rotation with other fungicides, whereas in the case of Powdery mildew it is recommended to use $K(HCO_3)_2$ in combination with the chemical fungicide as the efficacy of $K(HCO_3)_2$ fluctuates.

Acknowledgments

Research subsidized by IWT (Institute for the Promotion of Innovation by Science and Technology in Flanders) .

References

CONWAY W., JANISIEWICZ W., LEVERENTZ B., SAFTNER R. AND CAMP M. 2007 Control of blue mold on apple by combining controlled atmosphere, antagonist mixtures, and sodium bicarbonate. Postharvest Biol. and Tech. 45, 326-332.

CONWAY W., LEVERENTZ B., JANISIEWICZ W., BLODGETT A., SAFTNER R. AND CAMP M. 2004 Integrating heat treatment, biocontrol and sodium bicarbonate to reduce postharvest decay on apple caused by *Colletotrichum acutatum* and *Penicillium expansum*. Postharvest Biol. and Tech. 34, 11-20.

EPSTEIN E. 1999 Silicon. Ann. Rev. Plant Physiol. and Plant Mol. Biol. 50, 641-664.

KANTO T., MIYOSHI A., OGAWA T., MAEKAWA K. AND AINO M. 2004 Suppressive effect of potassium silicate on powdery mildew of strawberry in hydroponics. J. Gen. Plant Pathol. 70, 207-211.

LAFFRANQUE J. AND SHIRES S. 2005 A new bio-rational fungicide formulation of potassium bicarbonate for horticultural crops, vines and ornamentals. Procedings of the BCPC Seminars - Crop Science & Technology 2005, BCPC Publications, Hampshire, U.K., *publication accepted*.