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New Products against Apple Scab and Powdery Mildew Attack in Organic Apple Production

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Abstract

A study was undertaken on the effectiveness of some fungicides such as wettable sulphur, copper hydroxide, potassium bicarbonate and potassium bicarbonate mixed with potassium silicate against apple scab and apple powdery mildew attack, in the environmental conditions of Cluj-Napoca, Romania. The following cultivars were analyzed 'Jonathan', 'Gala', 'Jonagold', 'Jonica', 'Golden Delicious', 'Idared', 'Granny Smith' and 'Starkrimson', in an experiment conducted over two growing seasons (2009-2010), in five treatment variants. Potassium bicarbonate and a mixture between potassium bicarbonate and potassium silicate proved to be more effective in reducing the attack of apple scab and powdery mildew on leaves and fruit. Results were obtained for two years with favourable conditions of apple scab and powdery mildew development, when untreated variants exhibited an attack degree at a mean value of 49.77% for scab and 52.13% for powdery mildew. Potassium bicarbonate and potassium bicarbonate mixed with potassium silicate assured the best results in the case of the 'Idared', 'Jonathan', 'Jonica' cultivars regarding apple scab, and 'Golden Delicious', 'Starkrimson' and 'Granny Smith', regarding powdery mildew, where the mean value attack degree was reduced by about three times. The treatments with the products used in the experiments did not register symptoms of phytotoxicity on leaves or flowers. Given that this product is not toxic to human health, it becomes a perspective fungicide, especially for organic fruit tree growing in order to control apple scab and powdery mildew attack.

Keywords: apple cultivars, organic fruit growing, attack degree, effectiveness

Introduction

Apple scab, caused by the fungus *Venturia inaequalis*, and powdery mildew, caused by the fungus *Podosphaera leucotricha*, are the two most damaging diseases of apple orchards. These apple diseases are widely spread in Transylvania, Romania, due to the favourable climatic conditions, and well-known apple cultivars are susceptible to attack, while new apple scab resistant cultivars do not always meet the quality requirements and consumer demands (Sestras *et al.*, 2005, 2006; Mitre *et al.*, 2009).

Prevention and control of these diseases is often very difficult, especially due to increasing resistance of pathogens to chemicals used in treatments. There is a considerable number of chemicals used and recommended in preventing and controlling these diseases, some effective, others less effective. In organic fruit growing, in order to control apple scab and apple powdery mildew attack, copper or sulphur products are widely used (Kelderer *et al.*, 1997; Mitre *et al.*, 2009, 2010; Jamar *et al.*, 2010). These substances have several disadvantages, such as copper accumulation in soil, reduced efficiency at low temperatures, low fruit quality in terms of commercial depreciation appearance etc. which requires the replacement copper and sulphur products(Kelderer *et al.*, 2002, 2008a,b).

In recent years, a broad range of products based on potassium bicarbonate and silicon was used as an alternative to products based on copper and sulphur (Jamar and Lateur, 2007; Jamar *et al.*, 2007, 2008, 2010; Kelderer *et al.*, 2008; Peter, 2006; Tamm *et al.*, 2006; Trapman, 2006). Potassium bicarbonate is considered harmless from an ecotoxicological and toxicological point of view (Environmental Protection Agency – EPA, 1999) and this product has already been introduced in Annex II of European Regulation EEC 2091/92, list of active substances which may be used as plant protection products in organic farming (Kelderer *et al.*, 2005, 2006).

Materials and methods

Experiences were placed at SC Agroindustriala SA, Cluj-Napoca, in the centre of Transylvania, Romania, in 2009-2010, in commercial apple orchard with a density of 3200 trees/ha (trees were planted at a distances of 3.5 x 0.9 m) established in 2004. The biological material was represented by the cultivars 'Jonathan', 'Gala', 'Jonagold', 'Jonica', 'Golden Delicious', 'Idared', 'Granny Smith', 'Starkrimson'. The technology was specific to apple super-intensive orchards. In Tab. 1 and 2, information about timing of treatments and the products used is presented.

Potassium and silicon- based products were prepared in collaboration with the Faculty of Chemistry, Cluj-Napoca, Romania, as follows:

Tab. 1. The treatments and fungicides used in the experimental field

	Variants/Fungicide	Date of treatment (day, month, 2009)								
		02.05	18.05	4.06	18.06	30.06	10.07	24.07	10.08	24.08
1	Control	Untreated								
2	Wettable sulphur	4 kg/ha								
3	Copper hidroxid	5 kg/ha								
4	Potassium bicarbonate	5 kg/ha								
7	Potassium bicarbonate+Potassium Silicate	2.5 kg/ha								

Tab. 2. The treatments and fungicides used in the experimental field

	Variants/Fungicide	Date of treatment (2010 - day, month)								
		06.05	22.05	8.06	20.06	30.06	10.07	22.07	08.08	20.08
1	Control	Untreated								
2	Wettable sulphur	4 kg/ha								
3	Copper hydroxide	5 kg/ha								
4	Potassium bicarbonate	5 kg/ha								
7	Potassium bicarbonate +Potassium Silicate	2.5 kg/ha								

Potassium bicarbonate solution with a concentration of 20% was obtained by absorption of CO_2 in a solution of K_2CO_3.

Dispersion: For this purpose it was used with liquefied CO_2 pressure of 60 atm. and 99.8% purity. Contacting the solution with CO_2 absorbent was carried out through a glass Hun. Liquefied CO_2 flow solution was 2.5 kg/hour at a temperature of 24°C. The final solution Ph obtained was 8.5. The potassium silicate had a concentration of 30%.

The experiment was bi factorial, the first factor being the treatment with five graduations: control (untreated); wettable sulphur, copper hydroxide, potassium bicarbonate, mixture between potassium bicarbonate and potassium silicate. The second factor was the cultivar with eight graduations, thus resulting 40 experimental variants, located in three blocks (repetitions), 3 trees / repetition. Observations were made on the intensity and frequency of apple scab and apple powdery mildew attacks on leaves, the intensity and frequency of attacks of these two diseases on fruits and phytotoxicity on leaves and fruit. The interpretation of results was done by means of the analysis of variance (ANOVA test), while the interpretation of results was performed through Duncan test.

Results and discussion

Climatic conditions of the two years studied were favourable to the development of infections with apple scab and powdery mildew in the experimental field, fact demonstrated by the attack degree (AD %) values registered in the control variants (Tab. 3, 4, 5, 6).

Even in these conditions, the treatments with substances used in this study reduced the attack degree of the two diseases, compared to the control.

Tab. 3. Influence of fungicide and cultivar on apple scab attack degree (AD%) on the leaves

Cultivar/Treatment	Control	Wettable Sulphur	Copper hydroxide	Potassium bicarbonate	Potassium bicarbonate + Potassium silicate	Mean cvs.
'Jonagold'	34.60^{n}	20.53^{e}	12.33^{i}	8.23^{k}	7.20^{l}	16.58^{C}
'Golden Delicious'	49.77^{a}	18.47^{f}	14.00^{g}	10.10^{j}	8.60^{k}	20.19^{A}
'Idared'	31.10^{d}	14.43^{h}	11.97^{i}	4.07^{m}	11.57^{i}	14.63^{E}
'Jonathan'	21.53^{e}	14.00^{h}	13.07^{g}	14.00^{h}	10.33^{j}	14.59^{E}
'Jonica'	30.50^{d}	14.93^{h}	12.47^{i}	11.67^{i}	8.07^{k}	15.53^{D}
'Gala'	48.20^{b}	20.77^{e}	16.10^{g}	9.10k^{j}	6.97^{l}	20.23^{A}
'Granny Smith'	40.60^{c}	18.03^{f}	12.10^{i}	10.13^{j}	6.97^{l}	17.57^{B}
'Starkrimson'	37.07^{d}	15.03^{gh}	14.13^{h}	11.20^{ij}	10.13^{j}	17.51^{B}
Mean treatment	36.67^{M}	17.03^{N}	13.27^{O}	9.81^{P}	8.73^{Q}	
LSD 5% cv	0.19-0.22					
LSD 5% treatm.	0.12-0.13					
LSD 5% int. cv x tr	0.97-1.22					

Note: Different letters between cultivars, treatments and cultivars x treatments, denote significant differences (Duncan test, $p < 0.05$)

Tab. 4. Influence of fungicide and cultivar on apple scab attack degree (AD%) on the fruits

Cultivar/Treatment	Control	Wettable sulphur	Copper hydroxide	Potassium bicarbonate	Potassium bicarbonate + Potassium silicate	Mean cvs.
'Jonagold'	28.27^{c}	16.03^{g}	9.10^{k}	7.57^{lk}	6.87^{l}	13.57^{R}
'Golden Delicious'	30.43^{b}	17.60^{f}	10.27^{j}	8.77^{k}	7.93^{k}	15.00^{O}
'Idared'	29.77^{b}	13.10^{h}	11.30^{i}	9.60^{k}	9.57^{k}	14.67^{P}
'Jonathan'	18.87^{e}	12.67^{h}	11.73^{i}	9.23^{k}	8.33^{k}	12.17^{S}
'Jonica'	24.50^{d}	14.60^{h}	11.80^{i}	11.67^{i}	8.40^{k}	14.19^{Q}
'Gala'	30.30^{b}	17.20^{f}	14.43^{h}	9.10^{k}	6.97^{l}	15.60^{N}
'Granny'	28.60^{c}	14.03^{h}	11.43^{i}	10.13^{j}	6.97^{l}	14.23^{Q}
'Starkrimson'	32.40^{a}	12.27^{hi}	13.13^{h}	11.20^{i}	10.13^{j}	15.83^{M}
Mean treatment	27.89^{A}	14.69^{B}	11.65^{C}	9.66^{D}	8.15^{E}	
LSD 5% cultivar	0.14-0.16					
LSD 5% treatment	0.9					
LSD 5% int. cv x tr.	0.68-0.83					

Note: Different letters between cultivars, treatments and cultivars x treatments, denote significant differences (Duncan test, $p < 0.05$)

Tab. 3 introduces data referring to the influence of eight apple cultivars and five substances used and recommended as fungicides especially in organic fruit tree growing in reducing apple scab infection on the leaves. Tab. data show that regardless of the influence of cultivars, all products used in the experiment reduced the attack degree on the leaves, 2-3 times, in comparison with untreated control, with statistical differences provided.

The highest values of the attack degree were obtained in variants where wettable sulphur was used, followed by the variants in which trees were treated with copper hydroxide. The best behaviour in reducing the attack degree on the leaves had the trees sprayed with potassium bicarbonate + potassium silicate (8.73%), followed by variants in which trees were sprayed with potassium bicarbonate (9.83%). These last two products gave better results compared to classical ones like wettable sulphur or copper hydroxide. Regardless of the treatment, cultivars gave different results with respect to attack degree on leaves. The best response to scab attack on the leaves was exhibited by 'Idared' and 'Jonathan' cultivars and the most susceptible cultivars were 'Gala' and 'Golden Delicious'. The control of apple scab in treated variants with common fungicides was better in the case of using of copper hydroxide (AD% = 13.27) versus wettable sulphur (AD% = 17.03).

The apple scab attack degree on fruit in experimental variants was lower than that on the leaves. Results concerning the response of the eight apple cultivars in the treatments carried infection on fruits, are presented in Tab. 4.

Regardless of cultivar, the scab attack on fruits in treated variants was reduced in terms of statistical differences compared to the control. The lower values of the attack

Tab. 5. Influence of fungicide and cultivar on apple powdery mildew attack degree (AD%) on the leaves

Cultivar/Treatment	Control	Wettable sulphur	Copper hydroxide	Potassium bicarbonate	Potassium bicarbonate + Potassium silicate	Mean cvs.
'Jonagold'	35.93^{c}	19.87^{i}	26.33^{f}	9.30^{lm}	7.33^{m}	19.75^{N}
'Golden Delicious'	16.03^{j}	10.13^{l}	12.00^{k}	7.33^{m}	6.23^{n}	10.35^{T}
'Idared '	38.27^{b}	12.10^{k}	14.30^{j}	9.43^{l}	8.27^{m}	16.47^{P}
'Jonathan '	52.13^{a}	16.67^{j}	24.07^{g}	10.10^{l}	7.23^{m}	22.04^{M}
'Jonica'	29.00^{e}	21.10^{h}	20.13^{i}	8.40^{m}	7.97^{m}	17.32^{O}
'Gala'	31.07^{d}	16.10^{j}	20.43^{i}	9.27^{l}	6.90^{m}	16.75^{Q}
'Granny '	21.93^{h}	11.70^{k}	15.33^{j}	7.33^{m}	6.90^{m}	12.64^{R}
'Starkrimson '	19.97^{i}	15.03^{j}	12.27^{k}	6.27^{n}	4.20^{o}	11.55^{S}
Mean treatment	30.54^{A}	15.34^{C}	18.11^{B}	8.43^{D}	6.88^{E}	
LSD 5% cultivar	0.20-0.23					
LSD 5% treatment	0.13-0.14					
LSD 5% int. cv x tr.	1.10-1.28					

Note: Different letters between cultivars, treatments and cultivars x treatments, denote significant differences (Duncan test, $p < 0.05$)

Tab. 6. Influence of fungicide and cultivar on powdery mildew attack degree (AD%) on the fruits

Cultivar/Treatment	Control	Wettable sulphur	Copper hydroxide	Potassium bicarbonate	Potassium bicarbonate + Potassium silicate	Mean cvs.
'Jonagold'	25.87^{b}	12.17^{j}	16.33^{h}	7.17^{o}	6.00^{p}	13.51^{C}
'Golden Delicious'	13.83^{i}	9.47^{l}	11.33^{k}	5.27^{q}	4.43^{rq}	8.87^{F}
'Idared'	22.30^{e}	11.77^{k}	14.03^{i}	6.27^{p}	7.23^{o}	12.32^{D}
'Jonathan'	34.30^{a}	11.10^{k}	20.30^{f}	9.30^{m}	6.13^{p}	16.23^{A}
'Jonica'	23.33^{d}	14.13^{i}	18.23^{g}	8.13^{n}	5.10^{q}	13.79^{B}
'Gala '	24.67^{c}	10.10^{l}	14.10^{i}	7.03^{o}	4.27^{r}	12.03^{E}
'Granny'	14.40^{i}	8.33^{n}	10.03^{l}	6.40^{p}	4.27^{r}	8.69^{G}
'Starkrimson'	12.23^{j}	7.17^{o}	9.27^{m}	5.60^{q}	4.13^{r}	7.68^{H}
Mean treatment	21.37^{M}	10.53^{O}	14.20^{N}	6.90^{P}	5.20^{Q}	
LSD 5% cultivar				0.12-0.13		
LSD 5% treatment				0.7-0.8		
LSD 5% int. cv x tr.				0.58-0.73		

Note: Different letters between cultivars, treatments and cultivars x treatments, denote significant differences (Duncan test, $p < 0.05$)

degree were obtained in a mixture between potassium bicarbonate and potassium silicate variants (8.15% AD), followed by potassium bicarbonate variants (9.66% AD), compared with treatments with copper hydroxide (11.65 % AD) or wettable sulphur (14.69 % AD). Cultivars' response to scab infection on fruit in the experimental variants was different. The lowest degree of infection with apple scab was observed in 'Jonathan' and 'Jonagold', followed by 'Jonica' and 'Idared'. The highest degree of the attack was registered at Starkrimson.

One can say that the analysis results obtained with the treatment solution employing these products gave better results than classical treatments based on substances with copper and sulphur with all the advantages therein (substances do not accumulate in the soil, they are not toxic to human health and provide an additional foliar K for the tree area, etc.).

Regardless of cultivar, in the treated variants, the attack of powdery mildew on leaves showed lower values than the control, with statistical differences assured. The lowest values of the attack degree were obtained in variants in which trees were treated with a mixture between potassium bicarbonate and potassium silicate (6.88%), followed by variants with potassium bicarbonate (8.43%)(Tab. 5).

Potassium bicarbonate and potassium bicarbonate + potassium silicate mixture gave better results in fighting apple powdery mildew on leaves, not only compared to control but also to the conventional products used in organic plantations. While, copper hydroxide reduced the level of attack with statistical differences assured when compared to the control , it nevertheless provided the worst results in the fight against apple powdery mildew on leaves. Regardless of treatment, there were statistically assured differences between cultivars of experimental variants. The lowest values of attack degree occurred in the cultivars although 'Golden Delicious' (10.35%) and 'Starkrimson' (11.55%). 'Jonathan' and 'Jonagold' cultivars provided the worst results in the fight against apple powdery mildew on leaves. Two other cultivars behaved similarly, with no statistical differences that are statistically assured, namely 'Jonica' and 'Gala'.

Analyzing the data of the table from the view point of the treatment x cultivar interaction, one can say that the lower values of powdery mildew attack degree on the leaves occurs in 'Starkrimson' (4.2%) treated with potassium bicarbonate mixed with potassium silicate, followed by 'Granny Smith' and 'Gala', in the same treatment variant. In variants treated, the highest values of the attack degree were obtained from 'Jonathan' sprayed with copper hydroxide (24.07%).

Regarding the influence of the products used in fighting apple powdery mildew on the fruits, regardless of cultivar, all products have diminished the attack degree of powdery mildew, with statistically assured differences compared to the control (Tab. 6).

Furthermore, there were statistical differences between the four products used in fighting apple powdery mildew. The highest values of the attack degree occurred upon treatment with copper hydroxide (14.20%) and the lowest in the treatment with the mixture of potassium bicarbonate + potassium silicate (5.2%), followed by potassium bicarbonate (6.9%). Regardless of the experimental treatment, the experimental cultivars showed a different behaviour in reducing mildew attack on the fruits, these differences being statistically assured. The highest values of the attack degree have been registered in Jonathan (16.23), followed in descending order by 'Jonica', 'Idared', 'Jonagold', 'Gala', 'Golden Delicious', 'Granny Smith' and 'Starkrimson'.

The results proved that the mixture of potassium bicarbonate and potassium silicate showed the lowest values of the degree of attack, proving its effectiveness in fighting powdery mildew attack on apple.

Conclusions

At the end of the primary infection, all variants of the untreated cultivars exhibited apple scab and powdery mildew infection. Apple scab and apple powdery mildew control require a large number of treatments and substances, causing a large quantity of chemical residues on fruit, so it is necessary to use a new generation of non-toxic substances for human health in apple phytoprotection, such as potassium bicarbonate and potassium bicarbonate mixed with potassium silicate.

Treatments with a solution of potassium bicarbonate, potassium bicarbonate mixed with potassium silicate yielded better results than those copper or sulphur-based products in the prevention, as well as the control of apple scab and powdery mildew.

Treatments against apple scab and powdery mildew attack with products based on potassium bicarbonate, potassium bicarbonate mixed with potassium silicate could replace classical fungicides based on copper and sulphur.

All apple cultivars in the experiment have responded favourably to treatments with potassium bicarbonate and potassium bicarbonate mixed with potassium silicate, the best results were achieved in 'Idared', 'Jonathan', 'Jonica' in reducing apple scab attack degree , as well as 'Golden Delicious', 'Starkrimson' and 'Granny Smith' in reducing the powdery mildew attack degree.

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