

Comparison of efficacy of contact and systemic acting copper formulations for control of apple scab (*Venturia inaequalis* Cooke)

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A three-year trial was carried out in an apple plantation to compare the efficacy of several contact or systemic acting copper formulations for apple scab control (*Venturia inaequalis Cooke*). The tested formulations were based on copper-calcium oxychloride, copper sulphate and complexes or chelates of them with amino acids, peptides, EDTA, urea, octanoic and gluconic acid. Formulations based on Cu-oxychloride and Cu-sulphate were considered as contact acting trial standard fungicides. Other tested formulations had a partially systemic activity. Formulations were applied as foliar sprays (250 l/ha) preventively 12 to 18 times a season to apple trees of seven cultivars (Golden Delicious, Gala, Fuji, Idared, Braeburn, Jonagold and Elstar) at the rate of 200 g of pure copper ions per hectare per individual application. The efficacy for scab control was assessed by standard methods (visual scoring of the diseased leaf and fruit surface area and efficacy calculation according to the Abbot formula). The goal was to determine whether the selected recently developed systemic acting copper formulations can provide a higher level of biological efficacy to control apple scab than the traditional contact acting copper fungicides. Since the results of a three-year trial were not consistent, one can not claim for sure that systemic acting copper formulations can provide a statistically significantly higher rate of apple scab control on fruits (a three-year average 90.1%) than the contact acting ones (a three-year average 88.2%). The tested copper formulations provided just a little lower level of scab control as conventional fungicides and the preparations used for apple scab control in organic production systems, therefore they may be recommended for apple scab control.

Key words: copper fungicides, copper fertilizers, apple scab, disease control

INTRODUCTION

Copper products have been widely used for the control of bacterial and fungal diseases in agriculture for decades. As a result of a long-term use of copper products, a big depot of copper was formed in soils of orchards, which led to negative ecological impacts with detrimental effects on the soil biota and fertility (Georgopoulos et al. 2001, Van Zwieten et al. 2004). The existing rate of the application of copper preparations must, therefore, be lowered significantly. Some EU countries have already decided to ban all copper products, while others decided to significantly reduce their use. A significant reduction in the use of copper compounds can be achieved by partially replacing copper products with other active substances, by reducing the number of applications per year or by reducing the hectare rates of copper products on individual plant treatment (Golba 2001, Goebel et al. 2004, Jamar and Lateur 2007).

Reduction of hectare rates can be achieved by changing the formulation of preparations and by increasing their biological efficiency. The goal of the development of new copper formulations is to increase the biological efficiency of the control of pathogens with significantly lower hectare rates of pure copper ions.

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There are many new copper formulations which were recently developed to be marketed on the EU market. Some new formulations are classified as copper fungicides and some as copper containing foliar fertilisers and plant strengtheners (Lešnik et al. 2005). This brings some confusion among farmers. To produce crops in a more environmentally friendly way they are advised to control diseases by using special foliar fertilisers and plant strengtheners instead of applying conventional fungicides. The trend is to develop formulations in which copper ions are complexed with peptides, amino acids, organic acids or similar molecules. Most of the modern recently developed formulations are of that kind. There is only a limited amount of information available about the biological efficiency of these new formulations for the control of apple scab, therefore we decided to carry out a trial and to compare the biological efficacy of modern systemic acting formulations with the traditional ones based on copper oxychloride or copper sulphate. Three new systemic acting experimental formulations were also developed by laboratories of the company Cinkarna Celje. They were included into our study to compare them with the recently developed products of other European manufacturers. Results from this research also served for the development of new copper foliar fertiliser formulations of the company Cinkarna. The research hypothesis was that the biological efficacy of systemic acting copper formulations for apple scab control would be higher than the efficacy of the traditional contact acting ones, when the same hectare rate of pure

copper ions is applied.

MATERIALS AND METHODS

Trial design

During the seasons 2008 to 2010, trials were carried out in an apple plantation of the experimental station of Faculty of Agriculture and Life Sciences in Hoče near Maribor. Trees of 7 different cultivars were planted in a randomized block design so that the statistical experiment design was a two-factorial trial in four replications of randomized blocks. The first trial factor was the copper formulation and the second one was apple cultivar. Each experimental plot consisted of 14 trees in a row. Trees were grafted on M9 rootstock and were planted at 0.7 m distance in a row and at 2 m distance between rows. Trees were trained in a modified super spindle system. The canopy wall was 2.2 m high and 40 cm wide. In 2008 the plantation was 6 years old. To compare treatment means, the ANOVA analysis was performed, followed by the use of multiple comparison tools based on Tukey's HSD test at (α=0.05). Statistical analysis was undertaken using Statgraphics Plus for Window 4.0 (StatSoft Inc., USA). The formulations tested in the trial are presented in Table 1. Copper formulations were applied with a manual electric plot sprayer Technoma which delivered 250 l of spray per hectare.

Spray programs in individual seasons

Spray programs of three individual seasons were different. Each season the number of copper applications was increased. At every application 200 g of Cu^{2+} ions were applied per hectare. The hectare rates of the individual products were adopted in such a way that we always applied exactly 200 g of Cu^{2+} ions per hectare. Dates of applications per individual season are presented in Table 2. In season 2008 12 applications were done in total, in 2009 formulations were applied 14 times and 18 times in season 2010. When applying copper formulations, the control plots were always spayed with pure water.

Total hectare rate of copper per year was 2400 g of Cu^{2+} ions in season 2008. In season 2009 the rate was increased to 2800 g of Cu^{2+} ions per hectare (14 applications) and in season 2010 to 3600 g of Cu^{2+} ions per hectare (18 applications). In seasons 2009 and 2010, the plots which were treated with conventional fungicides (integrated spray program) and with the preparations registered for organic production systems (organic spray program) were included in the trial. The aim of including plots of those two spray programs was to compare the efficacy rate of copper preparations with conventional and organic fungicides. Spray programs are presented in Tables 3, 4 and 5.

In the tables with the data on the sprays carried out, commercial names of products are presented. The active substances of the products are presented here: Chorus 50 WG (50% ciprodynil), Clarinet (5% flukvinconazol, 15% pyrimethanil), Cosan (80% Sulphur), Delan 700 WG (70% ditianon), Indar 5 EW (5% fenbuconazol), Merpan (50% Captan), Mycosin (diatomaceous earth, silic acid, horsetail extracts), Salukarb (38% Potassium hydrogen carbonate), Score 250 EC (25% difenoconazol), Serenade (*Bacillus subtilis* strain of QST 713), Stroby WG (50% Krezoxim – methyl), Syllit 400 SC (40% dodine), Tercel (12% dithianon, 4% piraclostrobin), Thiram 80 WG (80% thiram), Ulmasud (10-12% Al-oxide, 80% Si-oxide, 2% Ti-oxside), Vitisan (60% Potassium hydrogen carbonate) and Zato 50 WG (50% trifloxystrobin).

Methods of evaluation of disease severity and of biological efficacy of products

Visual evaluation of the disease severity on fruits and leaves (visual determination of the percentage of the infected surface) was carried out twice during the season. Evaluations were done according to the protocols developed by the chemical industry (Bleiholder 1989) and EPPO (PP 1/5(3)). In this paper only the results of the second evaluation of the disease severity on fruits at picking period are presented. 200 fruits were selected randomly out of all parts of the tree canopy per each plot and were evaluated. The efficiency of the products applied to control scab was calculated according to the Abbot's formula (European Plant Protection Organisation; PP 1/5(3)).

RESULTS AND DISCUSSION

Results and discussion for season 2008

The scab pressure in season 2008 was moderate. In the control plots more than 50% of the fruits were heavily scabbed. Significant differences in the level of scab control were determined among the tested copper formulations when comparing average values for all cultivars together and also in the case of individual cultivars. Results showed that systemically acting products are more efficient than standard formulations (see Table 6). The highest efficacy for the apple scab control on fruits was achieved by applying the Peptiram formulation (systemic Cu-sulphate peptide complex). The efficacy of the Copper Protein formulation was higher than the efficacy of contact acting preparations as well. Efficacy achieved by the application of the Cinkarna EDTA1 experimental formulation (Cu-EDTA complex) was comparable with the efficacy of Copper Protein (Cu-protein complex) and with all others, except with Peptiram (Cu-peptide complex). Perhaps this formulation would provide a better result if a higher portion of total copper content was chelated with EDTA, not only a small part (aprox. 20 %). Efficacy rates achieved at different apple cultivars were significantly different. That means that the performance of different formulations for scab control in different cultivars is not uniform. This can not be explained by any known phenomena. One reason for the differences could be between-plot variability in the disease pressure; the other might be the differences in the structure of the fruit cuticle of different cultivars. Differences in cuticle structure can influence the persistence of the spray deposits on the fruit surface and also the level of penetration of systemic acting compounds inside the structures of the fruit cuticle. This then interacts with the depot of copper ions which are continually realized from the spray deposit and which are available on the fruit surface to intoxicate the germinating spores of scab.

Table 1: Formulations of copper products tested in the trials 2008-2010

Formulation	Producer	Country	Chemical form of copper	g Cu^{2+} - ions/kg
Atempo Cueva	Nidorf	DE	Cu-octanoate complex	18.0
Cinkarna amino	Cinkarna, Inc.	SLO	Cu-Ca oxychloride amino complex	27.5
Cinkarna EDTA2	Cinkarna, Inc.	SLO	CuCa oxychloride – EDTA chelate	39.3
Cinkarna EDTA1	Cinkarna, Inc.	SLO	CuCa-oxychloride – EDTA complex	32.0
Cuprablau Z Ultra (ZU)	Cinkarna, Inc.	SLO	CuCa oxychloride with ultra fine particles	350.0
Cuprablau Z	Cinkarna, Inc.	SLO	CuCa oxychloride	350.0
Cinkarna TiO2	Cinkarna, Inc.	SLO	CuCa oxychloride – micronized TiO2 amino complex	27.0
Cinkarna UF TiO2.	Cinkarna, Inc.	SLO	CuCa oxychloride – nano TiO2 amino complex	32.0
Copper Protein	Nova Prot GmbH	DE	Cu-hydroxide- protein complex	18.0
Coptrel 500	Yara Vita TM	GB	Cu-oxide + urea complex	330.0
Kupro 190 SC	Agro Ruše	SLO	Cu-oxysulphate	190.0
Labicuper	Macasa S.L.	ES	Cu-gluconat complex	65.0
Peptiram 5	Sicit 2000 S.p.a.	I	Cu-sulphate-peptide complex	50.0
Protex-Cu	Ares Europe BV	NL	water soluble Cu sulphate	60.0

Table 2: Dates of application of copper formulations in seasons 2008-2010

Dates (day/month)			Formulations tested (year)
2008	**2009**	**2010**	
16/4	6/ 4	2/4	Atempo Cueva 2010
22/4	10/4	9/4	Cinkarna amino 2009
29/4	19/4	16/4	Cinkarna EDTA2 2009
8/5	21/4	23/4	Cinkarna EDTA1 2008
14/5	24/4	29/4	Cuprablau Z Ultra 2008, 2009, 2010
19/5	28/4	4/5	Cuprablau Z 2010
2/6	8/ 5	10/5	Cinkarna TiO_2 2009
20/6	14/5	17/5	Cinkarna UF TiO_2 2010
4/7	18/5	24/5	Copper Protein 2008, 2009
14/7	26/5	29/5	Coptrel 500 2008, 2009, 2010
27/7	18/6	3/6	Kupro 190 SC 2010
	26/6	11/6	Labicuper 2009
	6/7	18/6	Peptiram 5 2008
	22/7	28/6	Protex-Cu 2008
		9/7	
		19/7	
		27/7	
		4/8	

With each of the presented dates all formulations tested in a specific year were applied at the same rate (200 g Cu^{2+}/ha).

Table 3: Integrated and Organic spray program in season 2009

Date	Integrated program DOSE	Organic program DOSE
6/4	Cuprablau Z Ultra 1.5 kg/ha	Cuprablau Z Ultra 1.5 kg/ha
10/4	Tiram 80 3 kg/ha	Cuprablau Z Ultra 1 kg/ha + Salukarb 8 kg/ha + Cosan 3 kg/ha
19/4	Chorus 75 WG 0.4 kg/ha	Serenade 4 kg/ha + Cosan 3 kg/ha
		+ Cuprablau Z ultra 1 kg/ha
24/4	Score 0.3 L/ha + Syllit 1.3 L/ha	Salukarb 8 kg/ha + Cosan 3 kg/ha
28/4		Cosan 3 kg/ha + Cutisan 5 kg/ha + Cuprablau Z ultra 1 kg/ha
30/4	Zato 0.15 kg/ha + Tiram 3 kg/ha	
14/5	Score 0.3 L/ha + Syllit 1.3 L/ha	Ulmasud 8 kg/ha + Cosan 3 kg/ha
18/5	Clarinet 1 L/ha + Stroby 0.2 kg/ha	Salukarb 8 kg/ha + Cosan 3 kg/ha
26/5	Delan 700 WG 0.75 kg/ha	Cosan 3 kg/ha + Cutisan 5 kg/ha
4/ 6	Score 0.3 l/ha + Syllit 1.3 L/ha	+ Salukarb 8 kg/ha + Cosan 3 kg/ha
10/6	Zato 0.15 kg/ha + Delan 0.75 kg/ha	Salukarb 4 kg/ha + Kaolin 5 kg/ha
18/6	Stroby 0.2 kg/ha + Delan 0.75 kg/ha	Cosan 3 kg/ha + Kaolin 5 kg/ha
26/6	Score 0.3 L/ha + Merpan 2.5 kg/ha	Serenade 3 kg/ha + Kaolin 2 kg/ha
6/ 7	Zato 0.15 kg/ha + Delan 0.75 kg/ha	Salukarb 4 kg/ha + Kaolin 5 kg/ha
	Merpan 2.5 kg/ha + Sulfur 3 kg/ha	Cosan 3 kg/ha + Kaolin 5 kg/ha
22/7	Merpan 2.5 kg/ha + Sulfur 3 kg/ha	Serenade 3 kg/ha + Kaolin 2 kg/ha

Table 4: Integrated spray program in season 2010. Total of 1050 g of Cu^{2+} ions per hectare/year applied in the integrated program

Date:	Integrated program	Dose
2/ 4	Cuprablau Z Ultra	1.5 kg/ha = 525 g Cu^{2+} - ions /ha
9/ 4	Sylit + Cosan	1.5 L/ha + 2 kg/ha
16/4	Delan + Cosan + Cuprablau Z Ultra	0.75 kg/ha + 2 kg/ha + 1.5 kg/ha
23/ 4	Syilit + Chorus 75 WG	1.3 kg/ha + 0.40 kg/ha
29/ 4	Chorus + Stroby	0.40 kg/ha + 0.2 kg/ha
4/ 5	Score + Sylit	0.3 L/ha + 1 L/ha
10/ 5	Tercel + Cosan	2.5 kg/ha + 1 kg/ha
17/ 5	Stroby + Delan	0.2 kg/ha + 0.75 kg/ha
24/ 5	Zato + Cosan	0.15 kg/ha + 2 kg/ha
1/ 6	Score + Merpan	0.3 L/ha + 2.5 kg/ha
11/ 6	Chorus + Stroby	0.40 kg/ha + 0.2 kg/ha
18/ 6	Indar + Merpan	0.9 L/ha + 2.5 kg/ha
28/ 6	Clarinet + Merpan	1 L/ha + 2.5 kg/ha
7/ 7	Delan	0.75 kg/ha
15/ 7	Syilit + Chorus 75 WG	1.3 L/ha + 0.40 kg/ha
28/ 7	Delan	0.75 kg/ha
6/ 8	Merpan	2.5 kg/ha
13/ 8	Thiram 80	3 kg/ha
23/ 8	Chorus 75 WG	0.40 kg/ha
31/ 8	Thiram 80	3 kg/ha

Table 5: Organic spray program in 2010

	Date	BIO Program without Cu application 1925 g Cu^{2+} - ions/ha/year	BIO with Cu application
1	2/ 4	Sulfuric lime suspension 80 l/ha	Cuprablau Z Ultra 1,5 kg/ha + Sulfuric lime suspension 30 l/ha
2	9/ 4	Sulfuric lime suspension 60 l/ha	Cuprablau Z Ultra 1,0 kg/ha + Sulfuric lime suspension 30 l/ha
3	16/4	Ulmasud 10 kg/ha + Cosan 3 kg/ha	Ulmasud 10 kg/ha + Cosan 3 kg/ha
4	23/4	Salukarb 8 kg/ha + Cutisan 5 kg/ha	Salukarb 8 kg/ha + Cutisan 5 kg/ha + Cuprablau Z Ultra 1,0 kg/ha
5	29/4	Mycosin 5 kg/ha + Cosan 3 kg/ha	Mycosin 5 kg/ha + Cosan 3 kg/ha
6	4/ 5	Vitisan 10 kg/ha + Cosan 2 kg/ha + Cutisan 2 kg/ha	Vitisan 10 kg/ha + Cuprablau Z 1 kg/ha + Cutisan 3 kg/ ha
7	10/5	Vitisan 10 kg/ha + Cosan 2 kg/ha	Vitisan 10 kg/ha + Cuprablau Z Ultra + Cutisan 2 kg/ha 1 g/ha + Cutisan 3 kg/ha
8	17/5	Serenade 3 kg/ha + Cosan 2 kg/ha	Serenade 3 kg/ha + Cosan 2 kg/ha
9	24/5	Mycosin 5 kg/ha + Cosan 3 kg/ha	Mycosin 5 kg/ha + Cosan 3 kg/ha
10	1/ 6	Ulmasud 10 kg/ha + Cosan 3 kg/ha	Ulmasud 10 kg/ha + Cosan 3 kg/ha + Cuprablau Z Ultra 1 kg/ha
11	11/6	Vitisan 10 kg/ha + Cosan 2 kg/ha Cutisan 4 kg/ha	Vitisan 10 kg/ha + Cosan 2 kg/ha + Cutisan 4 kg/ha
12	18/6	Ulmasud 10 kg/ha + Cosan 3 kg/ha	Ulmasud 10 kg/ha + Cosan 3 kg/ha
13	28/6	Cosan 3 kg/ha + Cutisan 5 kg/ha	Cosan 3 kg + Cutisan 5 kg + Cuprablau Z Ultra 1 kg/ha
14	7/ 7	Mycosin 5 kg/ha + Cosan 3 kg/ha	Mycosin 5 kg/ha + Cosan 3 kg/ha
15	15/7	Serenade 3 kg/ha + Cosan 2 kg/ha	Serenade 3 kg/ha + Cosan 2 kg/ha
16	28/7	Vitisan 10 kg/ha + Cosan 2 kg/ha Cutisan 2 kg/ha	Vitisan 10 kg/ha + Cosan 2 kg/ha + Cutisan 2 kg/ha
17	6/ 8	Vitisan 10 kg/ha + Cosan 2 kg/ha Cutisan 2 kg/ha	Vitisan 10 kg/ha + Cosan 2 kg/ha + Cutisan 2 kg/ha
18	13/8	Cosan 4 kg/ha	Cosan 4 kg/ha
19	23/8	Cosan 4 kg/ha	Cosan 4 kg/ha
20	31/8	Cosan 4 kg/ha	Cosan 4 kg/ha

Table 6: Efficacy of copper formulations (Abbot, %) applied for control of scab on fruits in season 2008 assessed on September 14th as a result of the application of 2400 g of Cu^{2+} ions per hectare per year. Ida - Idared, Jon - Jonagold, G. Del - Golden delicious, Gal - Gala, Bra - Braeburn, Fuj - Fuji

Formulations:	Ida	Jon	G.Del	Els	Gal	Bra	Fuj	Average:
Cuprablau ZU	78.3a	87.2ab	90.4a	94.1b	87.4a	82.6a	87.1a	86.7 a
Cinkarna EDTA1	84.7ab	80.6a	87.1a	80.4b	92.b5	81.6a	94.1bc	85.9 a
Peptiram 5	94.7b	96.9b	98.1b	89.2b	91.6b	91.6a	95.6cd	94.0 b
Coptrel 500	92.9ab	92.9ab	96.9b	90.8b	73.6b	73.6a	89.9ab	87.0 a
Protex CU	80.1ab	86.1ab	84.4a	75.3b	73.4b	73.4a	92.4bc	80.7 a
Copper Protein	95.1b	95.5b	88.1a	89.2b	87.9b	87.9a	98.8d	91.8 ab
Average:	87.6AB	89.9B	90.8B	86.5A	84.4A	81.8A	93.0C	

Average values marked with the same letter do not, according to the Tukey's HSD test (α=0.05), differ significantly. Small letters serve for comparisons of copper formulations and big letters for comparisons among apple cultivars.

Results and discussion for season 2009

The scab pressure in season 2009 was high. This was the reason to increase the number of copper applications. More than 85 % of fruits in the control plots were severely damaged by scab. The differences in the performance of different formulations in different apple cultivars were noticed. Gala was again the most susceptible cultivar. For example, in Braeburn apples all formulations gave comparable efficacy results but in the case of Golden delicious apples, the systemic acting formulations provided higher efficacy than the contact acting ones. It was interesting to learn that there were no significant differences determined among the formulations when comparing average values (see the last column of Table 7). In season 2009 we tried to improve the Cinkarna EDTA1 formulation from season 2008 and developed three new formulations. The EDTA2 formulation was improved by increasing the level of chelated Cu-Ca-oxychloride, which increased the systemic activity of that formulation. It was decided to develop two new types of complexes, the amino complex and the titanium oxide (TiO2) complex. The new amino formulation (Cinkarna amino) almost reached the efficacy of the systemic acting Copper Protein (the highest trial efficacy rate) and Labicuper (highly systemic Cu-gluconate). Statistically, the result obtained by the application of the amino formulation was not so good because of the bad performance in the case of Gala apples. The reason for a very big decrease of the efficacy at that cultivar is unknown. Perhaps some trial mistakes were made during the application of the product. Performance of this formulation was better later on, in year 2010. The performance of the titanium complex was comparable with the performance of the amino complex. Despite the fact that both of the tested products produced by the company Cinkarna are only partially systemic, they still provided comparable levels of efficacy, similar to those of other tested systemic acting products.

Organic spray program provided results which were slightly better than the results obtained by the spray program based only on the applications of copper products, but was not statistically better. It was surprising to see that it also provided the efficacy level that was statistically no different from the efficacy level of the integrated program. Efficacy of the spray program based only on the application of copper containing products was around 10% lower than the results from the integrated spray program. This is a relatively small difference, but a big one if one takes into account the percentage of the fruit infected with apple scab (data not presented). In the integrated spray program 5 to 10 % of fruits had a few scab lesions, whereas in the copper spray programs the share was much higher (10-25% in systemic acting and 12-30% in contact acting). Fruits from the plots treated with copper products had only one or two very small scab lesions; however, the fruit delivered to the general market nowadays has to be perfect, without any visible scab lesions. In terms of the percentage of scab infected fruits, all spray programs showed disappointing results, while in a realistic production system such results would lead to a significant reduction of the producer's net income and net profit.

Results and discussion for season 2010

In season 2010 copper products were applied 18 times (total of 3600 g copper ions per hectare) because the season was very rainy and many preventive sprays were necessary to have fruits always covered with copper deposit. Due to very suitable conditions for scab, the obtained efficacy was not higher than in the previous years, despite the significantly increased rate of the applied copper. In the control plots more than 50% of fruits were totally destroyed by fungus already in the beginning of July. We were not successful at controlling scab. This was also true for the integrated spray program and especially for the organic program which provided lower efficacy than copper products (see Table 8). In case of Jonagold apples copper formulations provided an even better result than the integrated program. It can be said that none of the spray programs provided the results that are usually expected to be reached in practice in commercial orchards and can enable the economic feasibility of the production.

In season 2010 a new copper formulation Cueva (Cu-octanoate) was tested which is becoming to be some kind of a new standard in the European organic production systems. Further on, we tried to improve our amino and titanium formulation by changing the size of copper and titanium oxide particles. We increased the share of nano particles (particles smaller than 0.1 micron) and developed the Cinkarna Cu-Ca-amino-titanium UF complex (Cinkarna UF TiO2).

When comparing average values (last column of Table 8) one can see that there were some differences among the formulations. The highest efficacy was reached by the application of Cueva product (systemic Cu-octanoate) and the second highest by the application of Cuprablau Z (contact Cu-Ca-oxychlorid). This result and quite a high efficacy rate of the Kupro (Cu-oxysulphate) formulation drives to a conclusion that a systemic acting formulation possibly can not provide significantly higher efficacy for scab control than the contact acting formulations. Better results were achieved with the contact acting Cuprablau Z product than with a partially systemic acting Cinkarna UF TiO2 formulation. The differences between the three Cinkarna formulations were not statistically significant.

An interesting fact was that the Cueva product managed to deliver similar or almost identical results as the integrated spray program. When analyzing the scab rate on leaves (data not presented) it was found out that the systemic acting products performed significantly better on laves than the contact acting ones, therefore there may be an interactive effect between the disease rate on leaves and fruits. Scab passes over from the infected leaves to fruits. Perhaps in comparison to the contact acting products, in the case of systemic acting formulations there was less transition of scab spores from the leaves to the fruits in the second part of the season. The outcome was the increased efficacy of the systemic acting formulations on fruits. At the end of the season, the Cueva formulation turned out to be useless for Slovenian conditions due to its very high rate of phytotoxicity (the highest in our trial, data not shown) and also because of its very high purchase price.

Table 7: Efficacy of copper formulations (Abbot, %) applied for control of scab on fruits in season 2009 assessed on September 10th as a result of the application of 2800 g of Cu^{2+} ions per hectare / year. Ida - Idared, Jon - Jonagold, G. Del - Golden delicious, Gal - Gala, Bra - Braeburn, Fuj - Fuji

Formulations:	Ida	Jon	G.Del	Els	Gal	Bra	Fuj	Average
Cuprablau ZU	95.6b	93.9a	84.3b	86.0a	72.1b	85.8a	91.8b	87.1a
Cinkarna TiO2	88.8a	94.7a	94.3c	86.3a	74.4b	90.1a	83.9a	87.5a
Cinkarna EDTA2	95.6b	98.2b	81.9a	89.6a	82.5c	89.6a	93.4b	90.1a
Cinkarna amino	98.6c	97.5b	94.5c	88.3a	53.6a	90.4a	92.5b	87.9a
Copper Protein	94.8b	99.1b	92.4c	94.5ab	74.1b	86.1a	90.1b	90.2a
Labicuper	92.6ab	93.8a	88.6bc	92.1ab	77.2b	87.4a	93.4b	89.3a
Coptrel 500	88.4a	96.7b	85.4b	91.6ab	79.1b	84.6a	95.4bc	88.7a
Organic progr.	96.1bc	95.2ab	91.6c	99.0b	80.4bc	87.7a	91.7b	91.7ab
Integrated progr.	96.1bc	98.4b	94.6d	99.1b	91.9d	98.6b	96.5c	96.5b
Average:	**94.1BC**	**96.4C**	**89.7B**	**91.8BC**	**76.1A**	**88.9B**	**92.1BC**	

Average values marked with the same letter do not, according to the Tukey's HSD test (α=0.05), differ significantly. Small letters serve for comparisons of copper formulations and big letters for comparisons among apple cultivars

Table 8: Efficacy of copper formulations (Abbot, %) applied for control of scab on fruits in season 2010 assessed on September 2nd as a result of the application of 3600 g of Cu^{2+} ions per hectare / year. Ida - Idared, Jon - Jonagold, G. Del - Golden delicious, Gal - Gala, Bra - Braeburn, Fuj - Fuji

Formulations:	Ida	Jon	G.Del	Els	Gal	Bra	Fuj	Average:
Cuprablau Z Ultra	92.1a	92.7a	88.9a	95.7b	83.0a	92.1b	87.9ab	90.3abc
Cuprablau Z	95.8b	96.0b	93.9bc	96.4b	90.1b	87.1b	87.1ab	92.3bc
Cinkarna UF Titan	96.1b	93.2ab	88.6a	96.5b	88.0b	83.7ab	83.8a	90.0ab
Kupro 190	95.6b	95.8b	94.8bc	93.9b	84.6ab	88.9b	89.6b	91.9bc
Coptrel 500	95.6b	91.8a	93.4bc	96.6b	84.8ab	80.0a	85.9ab	89.7ab
Cueva	95.1b	95.7b	95.8c	95.8b	89.8b	89.5b	89.8b	93.1c
Organic with Cu	92.6a	92.3a	93.3bc	94.4b	91.4bc	79.5a	86.6ab	90.0ab
Org. without Cu	91.8a	92.4a	90.8ab	88.3a	80.7a	79.7a	88.3b	87.4a
Integrated program	95.2b	92.4a	92.4b	95.4b	94.4c	90.2b	92.4c	93.2c
Average:	**94.4B**	**93.6B**	**92.4B**	**94.8B**	**87.4A**	**85.6A**	**87.9A**	

Average values marked with the same letter do not, according to the Tukey's HSD test (α=0.05), differ significantly. Small letters serve for comparisons of copper formulations and big letters for comparisons among apple cultivars.

Organic program came out with the worst results in 2010. It is evident from the data in Table 8 that a small addition of copper in the organic program has slightly improved the overall efficacy of the program. Comparable effects of adding of copper products to organic spray program were confirmed also by other researchers (Holb and Heijne 2001). Final results of the 2010 trial were unexpectedly bad. In most plots only 30% of all fruits were totally clear of any scab lesion, while the other 70% had a few very small scab lesions. This creates big troubles when marketing the apples since the demands on fruit quality are very high even for fruits from the organic production systems.

CONCLUSION

All tested copper products, as long as they are applied preventively, can provide a high level of control of apple scab on fruits (90%-97%), even in the case of the application of low hectare rates, as those in our trial (only 200 g of Cu^{2+} - ions/ha per treatment).

When used regularly throughout the season the efficacy of the newly developed and tested systemic acting formulations (Cu- gluconate, Cu-octanoate, Cu-amino acid complex, Cu-EDTA complex) for apple scab control is statistically not significantly higher or lower than the one of the conventional fungicides, commonly used in the integrated production of apples and of fungicides that are used in the organic production systems.

In terms of scab control on fruits, copper formulations with a certain level of systemic action (Cu- gluconate, Cu-urea complex, Cu-amino acid complex, Cu-Ca-amino acid complex, Cu-EDTA complex) have a little higher efficacy than the standard contact acting ones. While the results of all there years of trial were not consistent it can not be claimed for sure that the tested systemic acting formulations have a statistically higher efficacy than the already established standard contact acting formulations (Cu-oxide, Cu-Ca-oxychloride, Cu-sulphate).

A three-year long experiment showed that it would be reasonable to continue to develop systemic acting copper fungicides which combine different complexed forms of copper in one product and to keep developing formulations that are categorized as systemically acting foliar fertilizers.

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