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EFFECT OF WATER QUALITY ON THE EFFECTIVENESS OF FUNGICIDES AGAINST POWDERY MILDEW (*Sphaerotheca pannosa* var. *rosae*)

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ABSTRACT

Saprol 190 EC (trifryna) and Rubigan 12 EC (fenarimol) were diluted in 6 types of water without any addition of adjuvants, and they were applied against powdery mildew on roses in field cultivation. Only the emulsions of fungicides diluted in the water from Poznań were prepared with any addition of a surfactant (Citoewtt AL). Generally, no significant effect of the water type on the efficacy of fungicides against powdery mildew on roses was found. Slightly better results of rose protection were obtained when for the dilution of Saprol 190 EC very soft waters (distilled water and water after reverse osmosis) and well water from Szczepankowo were used. On the other hand, in case of Rubigan 12 EC, better results were obtained with very hard waters (hardened and well water from Kościan i Śmigiel) and well water from Szczepankowo. An essential influence on the increase of fungicides effectiveness was exerted by the addition of a surfactant (Citowett AL).

Key words: water quality, triforine, fenarimol, rose, *Sphaerotheca pannosa*

INTRODUCTION

Significant amount of mineral salts contained in the water used for the preparation of spray mixtures had a negative effect on the biological effectiveness of herbicides applied in the form of water solutions, among others it refers to glifosat and 2,4-D [7, 8]. The effect of chemical compounds of water on the quality of emulsion is very high and depend on the type of ion occurring in the water and on the surfactant applied in the formulation [3]. In case of the most frequently used anion surfactant, the action force depends primarily on the cation type and it increases with the increase of its value. After the exceeding of the limiting ion value in water, there occurs an intensive flocculation. In natural waters, there occur mostly two-valid cations (Ca^{+2}, Mg^{+2}), which decide in the highest degree about the water hardness and its usefulness for the dilution of plant protection products [3].

However, in the literature, there is no information referring to the effect of water quality on the biological effectiveness of fungicides.

The objective of this work was the evaluation of the effect of water quality on the effectiveness of fungicides used in the form of emulsion against powdery mildew.

MATERIALS AND METHODS

Experiments were carried out in the years 1997-1999 in the rose plantation in Krzesiny (Wielkopolska province). The experiments were established in a completely random design in 4 replications. On each plot of 3×1.5 m dimensions, 30 rose shrubs were grown in each plot. The effect of 2 factors: I – water type, II – fungicide type, were investigated in the studies. The control consisted of a combination without any fungicides.

Saprol 190 EC (triforyna) – 1.6 $dm^3 \cdot ha^{-1}$and Rubigan 12 EC (fenarimol) – 0.48 – $dm^3 \cdot ha^{-1}$ were applied in the experiment.

The waters used in the studies included: well waters originating from several sources, and conditioned waters whose chemical (except distilled water) is shown in table 1. The well waters originated from Szczepankowo and from Kościan (in 1998 and 1999), or from Śmigiel (only in 1997). The conditioned waters included: 1) municipal water from Poznań, 2) water from reverse osmosis, 3) distilled water, 4) water artificially hardened to 215.04 mval by an addition of calcium chloride analytically pure (1.216 $g \cdot dm^{-3}$) and magnesium chloride analytically pure (0.692 $g \cdot dm^{-3}$) added to distilled water.

Table 1. Chemical composition of waters used in field experiments – mean value from the years 1997-1999

Component ($mg \cdot dm^{-3}$) or parameter	Type of water or place of its origin				
	Hardened	Kościan and Śmigiel	Szczepankowo	Poznań	reverse osmosis
$N\text{-}NH_4$	-	0.175	trace	0.004	trace
$N\text{-}NO_3$	-	54.55	1.28	0.31	0.68
P	-	1.448	0.860	0.043	0.117
K	-	31.18	2.97	4.2	0.18
Ca	439.15	153.75	30.1	113.6	6.29
Mg	109.6	44.63	29.20	11.76	0.81
Na	-	66.62	82.20	21.07	0.33
Cl	-	69.47	24.37	40.5	0.4
$S\text{-}SO_4$	-	69.83	3.3	97.93	0.3
HCO_3^- ($mval \cdot dm^{-3}$)	-	4.658	7.9	3.99	0.8
pH	-	6.90	7.00	7.42	6.67
EC	-	2.205	0.718	No date	0.063
Fe	-	0.054	0.328	0.097	0.009
Mn	-	0.019	0.051	0.02	0.004
Zn	-	0.298	0.764	0.087	0.060
Cu	-	trace	trace	0.002	trace
B	-	0.078	0.02	No date	0.002
Hardness Ca+Mg ($mval \cdot dm^{-3}$)	215.04	89.01	30.63	52.02	3

From the and of July until mid-September, rose were sprayed with the spray mixture and its volume was: 1600, 800, 400 or 200 $dm^3 \cdot ha^{-1}$. Each year, 5 fungicide treatment were carried out in 7-14 week intervals. The spray mixture was applied to the plants using a shoulder pressure-sprayer Kwazar Orion 6 equipped with a slit-atomizer Tee Jet XR 110-02 and a pressure regulator (Lurmark Co.) maintaining a constant liquid pressure of 0.2 Bar. Control of diseases (except for the period of experiments) weeds, pests and other agrotechnical treatments was carried out according to the respective recommendations in a homogenous way on the whole plantation.

The evaluation of rose infestation by powdery mildew was performed only once, 8-10 days after the termination of a series of treatments, on 50 leaves of each plot using a conventional 7-degree classification scale: 0 – no damage; 1 – up to 1/8 of leaflet surface covered by fungus mycelium (up to 1.8% of the total leaf surface); 2 – 1/8-¼ of leaflet (1.8-3.6%); 3 – ¼-½ (3.6-7.2%); 4 – ½-1 (7.2-14.4%); 5 – 1-3 leaflets in a leaf (14.4-43.2%); 6 – more than 43.2%.

Statistical analysis of the experiments was carried out using Fisher-Scnedecor F-test and Tukay's multiple test at significance level of 0.05. A synthesis of experiments of any years was carried out as well using a mixed model in which the effect of years is a random one.

RESULTS

Powdery mildew of roses occurred with different intensity during years of studies. The highest infestation of rose leaves by Sphaerotheca pannosa was found on control plots in 1999, while the least intensive damages were recorded in 1997. Chemical protection was the most effective in 1999, and the least effective one was in 1997. Saprol 190 EC and Rubigan 12 EC did not differ significantly regarding their efficacy against rose powdery mildew (tab. 2).

Table 2. Effect of water type on the efficacy of Saprol 190 EC and Rubigan 12 EC against powdery mildew on roses

Water type	Leaf side	1997	1998	1999	Mean value	1997	1998	1999	Mean value
		disease rating							
	mean value for each side				mean value for both sides				
Saprol 190 EC									
Hardened	Front	0.58	2.08	2.66	1.77	0.51	2.15	2.47ab*	1.71
	Back	0.43	2.22	2.28	1.64				
Kościan and Śmigiel	Front	0.84	2.60	2.25	1.89	0.73	2.70	2.14abc	1.86
	Back	0.63	2.80	2.03	1.82				
Distilled	Front	0.60	2.11	1.64	1.45	0.52	2.17	1.64cde	1.44
	Back	0.45	2.24	1.63	1.44				
Reverse osmosis	Front	0.72	2.16	1.88	1.59	0.72	2.12	1.90abcd	1.58
	Back	0.73	2.08	1.91	1.57				
Szczepankowo	Front	0.56	2.25	1.57	1.46	0.46	2.39	1.65cde	1.50
	Back	0.37	2.53	1.74	1.55				
Municipal from Poznań	Front	0.48	2.69	2.46	1.88	0.40	2.76	2.52a	1.89
	Back	0.32	2.83	2.58	1.91				
Municipal from Poznań + Citowett AL	Front	0.49	1.47	0.89	0.95	0.52	1.66	0.87e	1.01
	Back	0.55	1.84	0.85	1.08				
Mean value	Front	0.61	2.19	1.91	1.57	0.55	2.28	1.88	1.57
	Back	0.50	2.36	1.86	1.57				
Rubigan 12 EC									
Hardened	Front	1.03	2.20	1.18	1.47	1.01	2.22	1.20de	1.48
	Back	0.99	2.25	1.22	1.49				
Kościan and Śmigiel	Front	0.72	2.36	1.69	1.59	0.59	2.42	1.57cde	1.52
	Back	0.46	2.47	1.44	1.46				
Distilled	Front	0.98	2.31	2.16	1.82	0.98	2.35	2.03abc	1.79
	Back	0.99	2.39	1.90	1.76				
Reverse osmosis	Front	0.98	2.19	1.68	1.61	0.89	2.18	1.72abcd	1.60
	Back	0.80	2.18	1.75	1.58				
Szczepankowo	Front	0.42	2.26	1.69	1.46	0.34	2.34	1.73abcd	1.47
	Back	0.26	2.43	1.76	1.48				
Municipal from Poznań	Front	0.90	2.71	2.21	1.94	0.76	2.72	2.13abc	1.87
	Back	0.63	2.73	2.04	1.80				
Municipal from Poznań + Citowett AL	Front	0.64	1.19	1.70	1.17	0.59	1.29	1.85abcd	1.24
	Back	0.54	1.40	1.99	1.31				
Mean value	Front	0.81	2.17	1.76	1.58	0.74	2.22	1.74	1.57
	Back	0.67	2.26	1.73	1.55				
No treatment	Górna	1.16	3.73	4.41	3.1	1.05	3.64	4.17	2.95
	Dolna	0.93	3.55	3.94	2.81				

* Letter marks of mean values have been shown only in case when any statistical significances were found. Mean values marked with the same letter do not differ significantly at alpha = 0.05.

Generally, the water type had no significant effect on the efficacy of fungicides against powdery mildew on rose (tab. 2). Only in 1999, significant differences were obtained in the results without the consideration of the leaf side. It was shown that Saprol 190 EC was more effective after dilution in distilled water or in the water from Szczepankowo than in the hardened and water from Poznań. In contrast, Rubigan 12 EC gave better results after dilution in hardened water than in distilled and water from Poznań. However the least intensive infestation by powdery mildew was found in 1999 after the application of Saprol 190 EC with an addition of Citowett AL surfactant. A comparison of the mean results from the total experimental period obtained with the application of extremely hard waters showed that Saprol 190 EC in contrast to Rubigan 12 EC had a better biological activity after dilution in very soft waters (distilled water and water after reversed osmosis) than in very hard waters (hardened water and water from Kościan and Śmigiel). Similarly, a better efficacy of Saprol 190 EC diluted in very soft water, and Rubigan 12 EC diluted in very hard waters was found in roses after control of rose rust [6].

This thesis is supported by the results of laboratory studies on the stability of emulsion (Ratajkiewicz 2002). The emulsion of Saprol 190 EC demonstrated the best stability in the range of 3.36-13.44 mval of hardness, while Rubigan 12 EC – in the range of 13.44-53.76 of hardness. Directly after the preparation of Saprol 190 EC emulsion with the use of both very hard waters, under field conditions, there occurred the intensive flocculation and sediment what caused considerable and frequent troubles with sprayer filter blocking. The above mentioned phenomens are regarded as negative ones as far as the efficacy of plant protection agents is concerned [1, 3]. Flocculation was not observed in any evaluated Rubigan 12 EC emulsions.

Although the waters from Szczepankowo and Poznań did not differ so much regarding their hardness as did the very soft and the very hard waters, a better effectiveness of both fungicides was obtained when they were diluted in the first than in the second water (tab. 2). Significant differences in the results, however, were found in 1999, in case of Saprol 190 EC. On the basis of the ion composition analysis of water, no factors were found which might have been responsible for a poor effectiveness of the fungicides diluted in the water from Poznań, which, in contrast to the water from Szczepankowo was conditioned and was transported in pipelines for many kilometers to the place of consumption.

A better effectiveness of both fungicides diluted in the water from Szczepankowo resulted rather from the whole composition of the chemical content of water than from any single component or property. On the basis of the performed analysis, one can indicate a proportionally greater content of single-valued ions in relation to multivalent ions in water from Szczepankowo than in other waters. It must be also noted that thanks to the water from Szczepankowo, a good biological effectiveness was achieved and in spite of the fact that it contained a great amount of iron than in the remaining waters. However, it was too small to deteriorate significantly the stability of emulsion [3] or to decrease the efficacy of the preparation, as it was the case in the experiment with glifosat [4, 7].

The experiments confirm the usefulness of adding surfactants to the spray mixture used in rose protection against powdery mildew [5]. A significant increase of the fungicides efficacy was found independent of their type (tab. 3). The role of surfactant is to produce a better wetting and spreading of the liquid on leaves [2] contributing to the contact of the preparation with the mycelium of Sphaerotheca pannosa growing on the surface of plant tissues.

Table 3. Effectiveness of rose protection against powdery mildew depending on the type of water used for fungicide emulsion preparation

Water type	Disease rating			
	1997	1998	1999	mean value
Hardened	0.76	2.18a*	1.83ab	1.59ab
Kościan and Śmigiel	0.66	2.56a	1.85ab	1.69ab
Distilled	0.75	2.26a	1.83ab	1.61ab
Reverse osmosis	0.81	2.15ab	1.80b	1.59ab
Szczepankowo	0.40	2.37a	1.69b	1.49ab
Municipal from Poznań	0.58	2.74a	2.32a	1.88a
Municipal from Poznań + Citowett AL	0.55	1.47b	1.36b	1.13b
No treatment	1.05	3.64	4.17	2.95

*Letter marks of mean values have been shown only in case when any statistical significances were found. Mean values marked with the same letter do not differ significantly at alpha = 0.05.

Results obtained for waters without the addition of Citowett AL did not differ significantly between each other except in the year 1999 when a significantly worse action of fungicides was obtained under the influence of Poznań municipal water when compared with the water from Szczepankowo and the water after reverse osmosis. In the whole period of studies, the best results were obtained with the water from Szczepankowo and the worst results were shown by Poznań municipal water. However it was not confirmed on the basis of statistical analysis.

CONCLUSIONS

1. In some years, water quality can exert a significant effect on the efficacy of Saprol 190 EC and Rubigan 12 EC against powdery mildew on roses.
2. Addition of Citowett AL to fungicide emulsion contributes to the efficacy against powdery mildew on roses and has a higher importance than the selection of the adequate water type for fungicide dilution.

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