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POWDERY MILDEW CONTROL BY UNPOLLUTANT METHODS IN APPLE ORCHARDS WITH SULPHUR BASED ON PRODUCTS

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Abstract: Powdery mildew is one of the most damaging and common diseases of the apple, being caused by the fungus *Podosphaera leucotricha*. In the years with favorable conditions for the disease infection, especially for the sensitive varieties, it may produce important damages in the orchards, because it can manifest throughout the growing season. This disease can affect from the beginning of the vegetation the young leaves and shoots, flowers and even fruits in a situation of severe infection. Sulphur-based products are contact fungicides that provide good protection against powdery mildew without polluting the environment. The mechanism of action is a multi - site, with low risk of occurrence of the pathogen resistance phenomenon. This paper highlights the effectiveness of the two sulphur - based on products in controlling powdery mildew in three apple orchards where no other fungicides have been applied. The products tested in the trials were: Polisulf, Sulfomat 80 PU and Kumulus DF (standard product). Data obtained demonstrated that the efficacy of Polisulf at the proposed rate of 30 l/ha and Sulfomat 80 PU at the proposed rate of 4.5 kg/ha was equivalent or close to the efficacy of the reference product Kumulus DF at 4.5 kg/ha against *P. leuchotricha* in apple.

Keywords: *Powdery mildew, apple orchard, sulphur - based on products, effectiveness*

INTRODUCTION

Apple growing has occurred since oldest times and apple has become one of the most important fruits that are fit for human consumption. Anatolia, Caucasia, Turkistan, and Europe were centres of origin for the domestic apple (*Malus domestica* Borkh.), now grown in continental climates in the Northern and Southern Hemispheres (Pirlak et al., 2003). Apples are among the world`s fruits crops, figuring in both the Bible and the tales of Homer (Jackson, 2003). It has multiple uses and this fact makes it popular in the entire world, also in areas where it is more difficult to grow. In most cases, apples are consumed fresh or after storage for up to 6 months or even longer (Belete & Boyraz, 2017).

Apple is an important fresh fruit crop also in Romania where it could find very favourable pedo - climatic conditions to obtain good quality yields (Ghena & Branişte, 2003). On the other hand, apple may suffer significant yield and quality losses because of infections by the parasitic fungus *Podosphaera leuchotricha*, c. f. *Oidium farinosum*, the causal agent of powdery mildew. Many apple cultivars over the world (e.g. Ionathan, Ionared, James Grives) are susceptible to this fungus (Jackson, 2003). Current control of powdery mildew of apple in Romania requires the routine application of fungicides at 7 - 14 days intervals sometime, to achieve the blemish-free fruit required by the consumers. Such practices are generally effective, but with nowadays increased public concern about pesticides and rising costs to the fruit-grower, they are now less and less acceptable.

Powdery mildew caused by *P. leuchotricha* has been recognised as an important and widespread disease of apple in the growing areas of this crop in Romania. It affects the leaves, shoots, flowers, rarely the fruits. It can occur very early on, even after the bud break. A fine mycelium fabric is noted on the shoots grown from infected buds (Gheorghieş & Geamăn,

2001), which shortly can reach the entire shoot, but also the leaves and flowers. Symptoms of powdery mildew appear as irregular chlorosis of gray-white with white powder on the leaf surface and also may include whitish lesions on curled or longitudinally folded leaves, stunted whitish gray twig growth and fruit russeting. Due to attack, the leaves do not fully open, remain small and thicken and twist to the top, taking on the appearance of a *„little boat"* (Paraschivu, 2010). Most economic damages occur in the form of aborted blossoms, reduced fruit finish quality, reduced vigor and yield of the bearing trees and stunting and poor form of young, nonbearing trees. Weather conditions, particularly during the pre-flowering period was shown markedly to affect the crop from year to year. Conditions favourable to infections and pathogen fungi evolution are 80% humidity and 18 - 22°C temperatures. Powdery mildew can also spread under lower humidity, because apple trees transpiration, on the surface of the green shoots and leaves, can form enough humidity for infections (Gheorghieş & Geamăn, 2001).

Elemental sulphur is known, undeniably, the oldest pesticide ever to control powdery mildew. Ancient Greeks were aware of its pesticide properties as early as 1000 B.C. In the scientific published literature, Forsyth (1802) cited by Tweedy (1969) was the first to suggest the application of sulphur for disease control. Unfortunately, the fungicidal properties of sulphur were apparently forgotten during the middle ages and were not rediscovered until the beginning of the nineteenth century (Fry, 1982). Ever after, sulphur has been used in various forms for disease and pest control, especially against powdery mildew and mites on plant.

Continuation of the use of sulphur in spray programs is important to prevent the development of powdery mildew resistance to newer single-site fungicides and ensure optimum disease control in orchards. (Department of Primary Industries Victoria, Primary Industries and Resources South Australia and Centre for Environmental Stress and Adaptation Research, La Trobe University, 2003). However, fungicide resistance is not a problem with them and they fit well into IPM (Integrated Pest and Disease Management) programs (Grove et al. 2000).

The aim of this study was to account the evolution of the pathogen *P. leucotricha* infection and to determine the effectiveness of the applied sulphur -based products in three orchards located in distinct places under different pedoclimatic conditions.

MATERIALS AND METHODS

Six field trials on Southern Romania apple orchards were established on a set of complete randomized blocks in 4 replications per treatment. The locations were: Didactic Farm Moara Domnească (Ilfov county), Fruit Growing Research Station Voineşti - (Dâmbovița county) and Research Station for Fruit Tree Growing Băneasa, Bucharest. Each plot in Moara Domnească had five trees with a 150 cm space between them, and row length of 4 m. In Băneasa and Voineşti, each plot had five trees with a 300 cm space between them, and row length of 4.5 m. The orchards were planted in 2005 (Moara Domnească), 2000 (Voineşti and Băneasa) and were maintained using conventional practices for apple production. In the experimental year of 2019 no other fungicides were applied.

Conventional tillage was carried out consisting in autumn plowing on intervals between rows during plant dormancy. Early spring pruning was then carried out so as to thin out of the fruit and grow.

Chemical application was by dilute spraying (ca. 1500 l/ha) using hydraulic nozzles. Fungicide sprays were applied at high volume in 1500 l/ha using a portable Grùnman 3 WF-3 knapsack mist blower. Sprays were applied between April and July, at 10-15 day intervals during the primary infection season and also during the second one. Three treatments with

Polisulf and Kumulus DF and five treatments with Sulfomat 80 PU and Kumulus DF were preceded. The tested products are shown in the table 1.

Table 1. Fungicides used to control powdery mildew in the trials

Sample	Active ingredient	Rate (kg, l/ha)	Volume of water (l)
Untreated check	-	-	-
Polisulf	sulphur thiosulphuric 3%+ sulphur polisulfhydric 12%	30	1500
Sulfomat 80 PU	sulphur 800g/kg	4.5	1500
Kumulus DF	sulphur 80%	4.5	1500

Treatments were scheduled at the following stages:
Polisulf and Kumulus DF:
– 1st treatment: mouse ear (BBCH 10);
– 2nd treatment: shoots about 40% of final length (BBCH 34);
– 3rd treatment: at the end of flowering (BBCH 69).
Sulfomat 80 PU and Kumulus DF:
– 1st treatment: mouse ear (BBCH 10);
– 2nd treatment: shoots about 40% of final length (BBCH 34);
– 3rd treatment: red bud stage (BBCH 57);
– 4th treatment: end of flowering (BBCH 69);
– 5th treatment: second fruit fall (BBCH 73).

Foliar powdery mildew incidence (Pesinc %) and severity (Pesssev %) were evaluated before each spray and after ten days until the latest treatment by visually rating 100 leaves on ten shoots per tree for percent area covered by powdery mildew. Consequently, the degree of attack was evaluated following the formula: DA(%) = Pesinc % x Pesssev %/100. Phytotoxicity on the foliage was evaluated at the same time by recording any visible damage to foliage that was not due to powdery mildew.

The assessment of efficacy in the treated plots was made in relation to the untreated plot on an overall plot basis (scale 0-100%). The efficacy of fungicide was calculated according to Abbott`s formula: (degree of attack in untreated control - degree of attack in treated plot)/ degree of attack in untreated control x 100. All data were subjected to statistical analysis provided by ARM-9 (P=.05, Student-Newman-Keuls) software (Grădilă & Jalobă, 2017).

Polisulf is a fungicide that acts directly by the decomposition of elemental sulphur as a protective fungicide. Thus, sulphur interrupts the transfer of electrons, causing sulphur reduction in hydrogen sulphide (H_2S). Sulphur also forms a protective layer, which inhibits germination of spores.

Sulfomat 80PU is a dust free, flowable micronised sulphur granules, containing 80% sulphur as active ingredient and balance adjuvants, easy of measuring and handling. It has a lot of advantages as follow:

· it has instant dispersion and high suspensability in water, therefore it don’t cause scorching;
· it has triple action as fungicide, micronutrient (Sulphur) and miticide;
· it has sustained action for longer effect;
· there are no stains on fruits and leaves after spraying, nor do leaves get burnt.

RESULTS AND DISCUSSIONS

In the trials fields of the three locations, the weather conditions were quite atypical, sometimes different from the normal ones. March was dry, with low amounts of rainfall,

being had registered 33.30 and 25 liters on square meter for Băneasa, Moara Domnească and Voineşti respectively. April was a normal month as regards both rainfall and temperatures, but May was rainy in all three places. The values of 156 (Băneasa), 151 (Moara Domnească) and 123 liters (Voineşti) created conditions which encouraged the increasing infestations of the pathogen *P. leucotricha* in the untreated plots. More of that, in July it rained 335 liter on square meter in Voineşti orchard, a well above average value for this area. In these conditions, assessments made on the Pest Incidence (Pesinc %) and Pest Severity (Pessev %) of pathogen attack were recorded in the database table 2 and table.

Table 2. Development of the pathogen *P. leucotricha* at untreated check – Polisulf trial

Days after treatment	Assessment	Băneasa	Voineşti	Moara Domnească
0 DA-A	Pesinc.	23.0	34.2	7.2
(0 day after first treatment)	Pessev.	8.0	25.7	3.5
10 DA-A	Pesinc.	26.9	41.0	17.5
(10 days after treatment A)	Pessev.	11.2	29.2	14.1
10 DA-B	Pesinc.	46.0	65.5	35.0
(10 days after treatment B)	Pessev.	17.2	44.4	20.0
10 DA-C	Pesinc.	76.5	76.0	75.8
(10 days after treatment C)	Pessev.	31.2	51.5	29.9
LSD at 10 DA-C	Pesinc.	1.362	3.912	2.004
(least significant difference)	Pessev.	3.861	3.106	0.745

Table 3. Development of the pathogen *P. leucotricha* at untreated check – Sulfomat trial

Days after treatment	Assessment	Băneasa	Voineşti	Moara Domnească
0 DA-A	Pesinc.	23.0	33.5	6.8
(0 day after first treatment)	Pessev.	8.0	25.2	4.0
10 DA-A	Pesinc.	26.9	41.5	17.5
(10 days after treatment A)	Pessev.	11.2	29.2	14.2
10 DA-B	Pesinc.	46.0	64.5	36.2
(10 days after treatment B)	Pessev.	16.9	45.0	20.2
10 DA-C	Pesinc.	76.5	76.5	52.5
(10 days after treatment C)	Pessev.	30.4	51.0	24.5
10 DA-D	Pesinc.	79.9	85.0	73.8
(10 days after treatment D)	Pessev.	49.9	65.0	42.5
10 DA-E	Pesinc.	81.1	87.2	76.0
(10 days after treatment E)	Pessev.	51.6	71.2	45.0
LSD at 10 DA-E	Pesinc.	2.476	6.999	5.183
(least significant difference)	Pessev.	2.599	8.258	6.582

As a result of Pest Incidence and Pest Severity evaluations, DA% was calculated. Its evolution for each trial is shown in figure 1 and figure 2. As one can see, the degree of attack had an upward evolution and increased at every assessment at untreated checks, due to weather conditions and lack of treatments. So, at Polisulf trial, the degree of attack reached from 0.3 to 22.7% (Moara Domnească), from 1.8 to 23.9% (Băneasa) and from 8.8 to 39.1% (Voineşti). At Sulfomat 80PU trial, which was carried out on a longer - term, the infestation was stronger, so that the degree o attack increased from 0.3 to 34.2% (Moara Domnească), from 1.8 to 41.9% (Băneasa) and from 8.5 to 62.2% (Voineşti). The highest value, the most intensive infestation with powdery mildew was recorded at Voineşti, where apple is been growing for centuries on large surfaces and there is a large amount of pathogenic inoculum.

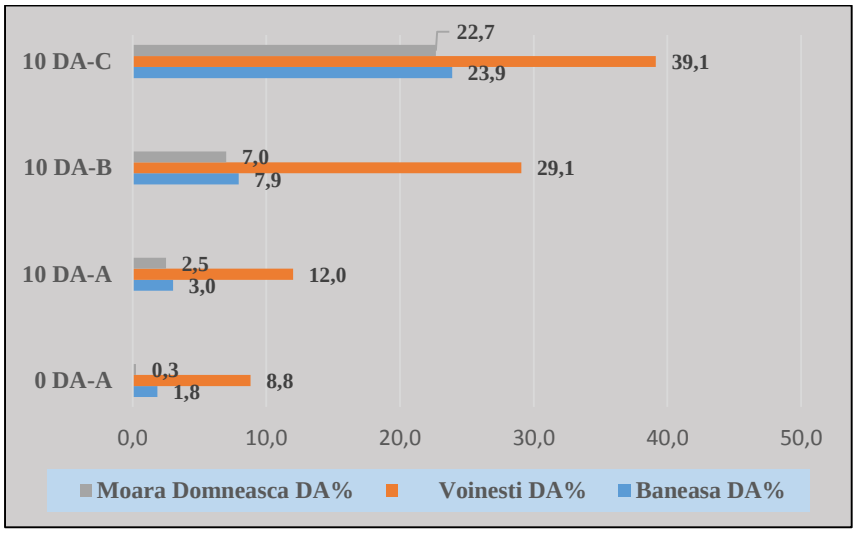

Figure 1. Degree of attack evolution at untreated check at Polisulf trial

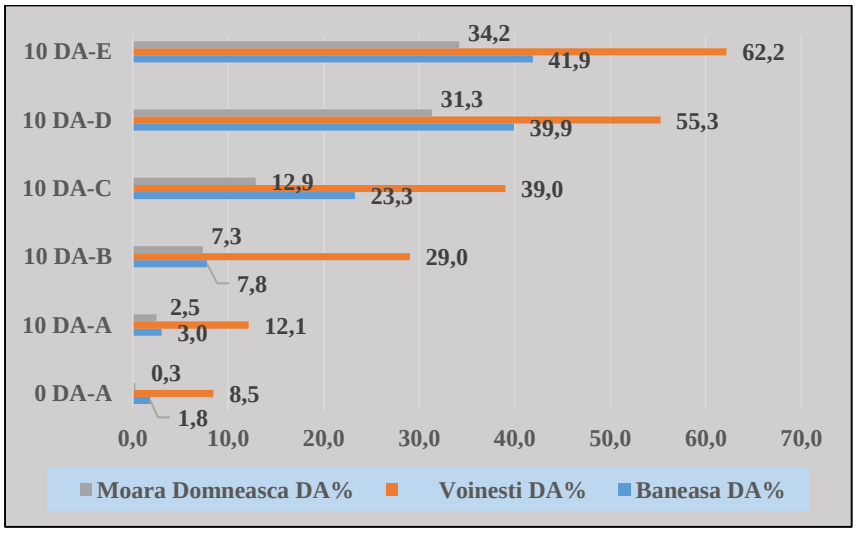

Figure 2. Degree of attack evolution at untreated check at Sulfomat 80 PU trial

The effectiveness of the product Polisulf is shown in the table 4. As we can see, the efficacy grew progressively from 10 days after treatment A to 10 days after treatment C and was close or even better than those of the standard product Kumulus DF. Thus, at Băneasa orchard where the degree of attack at untreated check was 23.9%, Polisulf proved a satisfactory efficacy (81.4%), close to standard product (84.7%).

At Voinesti, under the circumstances of 39.1% degree of attack, the result of Polisulf was good, too, almost similar to standard reference (80.6% and 82.8% respectively). It must be mentioned that at this location the degree of attack was at highest level.

Best result provided by Polisulf was at Moara Domneasca`s orchard (84.8%), where efficacy of Kumulus DF (82.9%) was exceeded. There, the degree of attack at untreated check was 22.7%.

Due to a longer time of testing, the degree of attack at Sulfomat 80 PU trial was higher as the disease could develop and spread the amount of mycelium in untreated plots. The highest level of the degree of attack (DA%= 62.2%) was recorded at Voinești, where there was a sudden increase of *P. leuchotricha* incidence and severity in the second part of the

experiment due to abundant rainfall and favourable temperature. However, in this case too, tested product proved good efficacy, close to standard reference effectiveness. Best result provided by Sulfomat 80 PU was at Voineşti`s orchard (87.7%), comparable to those of Kumulus DF (90.5%).

Table 4. Efficacy % of Polisulf in control of *P. leucotricha*

	Băneasa		Voineşti		Moara Domnească	
Days after treatment	Polisulf	Kumulus DF	Polisulf	Kumulus DF	Polisulf	Kumulus DF
10 DA-A	46.4	49.1	35.4	36.3	68.8	65.3
P value*	**0.9980**					
10 DA-B	69.2	71.8	62.4	66.8	75.8	74.2
P value*	**0.7059**					
10 DA-C	81.4	84.7	80.6	82.8	84.8	82.9
P value*	**0.4479**					
LSD** at 10 DA-C	1.721 3.058		2.235 3.247		2.313 2.234	

Legenda: *P-value is the probability of obtaining the observed results of a test, assuming that the null hypothesis is correct; **LSD – Least Significant Differences 10 days after treatment C

Table 5. Efficacy % of Sulfomat 80 PU in control of *P. leucotricha*

	Baneasa		Voinesti		Moara Domneasca	
Days after treatment	Sulfomat 80 PU	Kumulus DF	Sulfomat 80 PU	Kumulus DF	Sulfomat 80 PU	Kumulus DF
10 DA-A	47.0	49.0	34.6	35.9	52.2	55.8
P value*	**0.7850**					
10 DA-B	70.0	71.8	57.9	60.4	53.8	51.0
P value*	**0.9515**					
10 DA-C	82.3	83.8	73.9	77.5	64.7	66.3
P value*	**0.7722**					
10 DA-D	86.5	88.9	87.1	92.1	76.9	83.7
P value*	**0.3138**					
10 DA-E	86.7	89.4	87.7	90.5	81.2	88.3
P value*	**0.1184**					
SD**at 10 DA-E	2.182 3.622		6.086 5.454		5.071 6.409	

**LSD – Least Significant Differences 10 days after treatment E

According to Anova Test, if the P-value is greater than 0.05, that indicates that there is weak evidence against the conjecture, so the investor would fail to reject the null hypothesis.

In our situation, at Polisulf trials, when α (probability) = 0.05, as one can see, the P-value is always >0.05, this means there is no differences between samples, we accept the nule hypothesis, Polisulf and Kumulus DF has almost the same efficacy to control powdery mildew on apple.

As far as it concerns the Sulfomat 80 PU trials, when α = 0.05, as one can see, the P-value is always >0.05, this means there is no differences between samples, the effectiveness of the two products (Sulfomat 80 PU and Kumulus DF) is almost similar, the tested product performed very well, just like the standard reference. In order to illustrate more clearly the importance of application of the sulphur based-on products during growing season on apple commercial orchards, we have to check out figure 3 and figure 4, where is shown the level of effectiveness of Polisulf and Sulfomat 80 PU at 10 day after the last treatments.

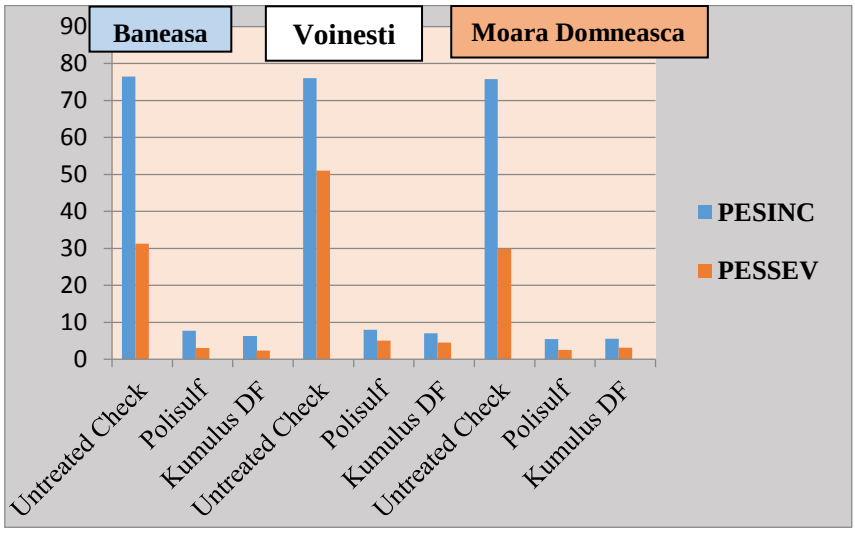

Figure 3. Pest Incidence and Pest Severity at 10 DA- C in Polisulf trial

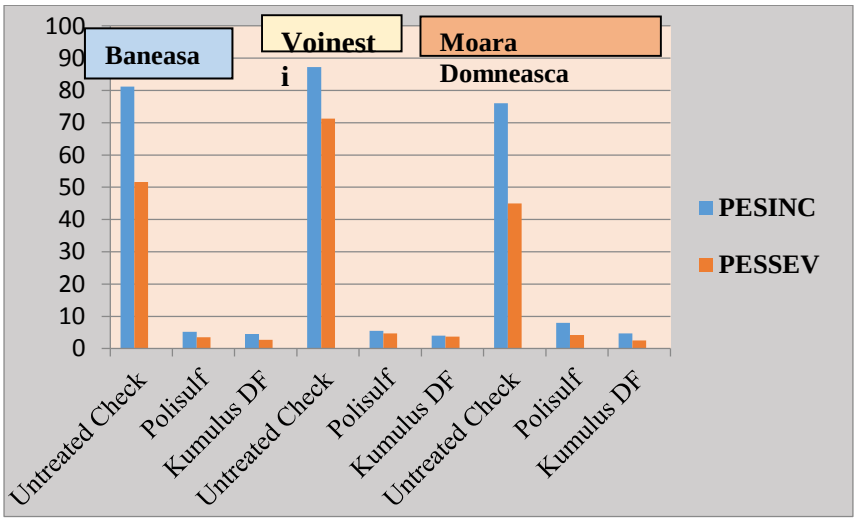

Figure 4. Pest Incidence and Pest Severity at 10 DA- E in Sulfomat 80 PU trial

Voineşti

Moara Domnească

Băneasa

Figure 5. Infected leaves by *P. leucotricha* in the trials

Treatment application

Efficacy of Sulfomat 80 PU (87.7%)

Figure 6. Aspects from Voineşti orchard

CONCLUSIONS

Powdery mildew was a problem to be taken into account by apple growers during 2019, too. It was present in our every trial place and farmers had to strive to control this disease. Very good effective control of powdery mildew was obtained by applying Polisulf and Sulfomat at both at the end of flowering (BBCH 69) and second fruit fall (BBCH 73) stages. The results were close to standard product Kumulus DF and even better (at Moara Domneasca with Polisulf).

There is no evidence that apple resistance to powdery mildew is correlated with Sulphur based - on products. This is an important attribute for early season disease management in areas where powdery mildew is a problem, and particularly so if someone is attempting to grow fruit as certified organic where effective controls are lacking.

However, this practice has to be integrated with other agro technical measures in order to protect both the apple orchards and the environment.

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