CONTROL OF THE PEACOCK'S EYE IN FRIULI VENEZIA GIULIA WITH LOW QUANTITIES OF COPPER

Gianluca GORI[1], Marco STOCCO[2], Linda STEL[3], Lara MANZONI[4]

[1]ERSA FVG Phytosanitary and Chemical Service, Research, Experimentation and Technical Assistance

ABSTRACT

Starting from 2021, anexperimental trial has been carried out in Northern Italy (Friuli Venezia Giulia) with the aim to compare various copper-based formulations with low inputs per hectare associated with some adhesive products. In an area with high disease pressure, on the cv Bianchera, very sensitive, 7 different formulations were compared to verify the effectiveness of the products and the best plant protection strategy to control the peacock spot disease. From the first results, it is highlighted that the use of more persistent copper products expecially if combined with sticking agents increases the protection period by the products. This strategy has proven particularly useful to contain the disease, especially during periods with heavy rainfall.

Key words: defence, olive trees, *Venturia oleaginea*

1 INTRODUCTION

Olive leaf spot (OLS), also known as peacock's eye, is the main fungal disease of olive trees in Friuli Venezia Giulia caused by *Venturia oleaginea*. In some periods of the year the symptoms of the infection are not easily distinguishable (latent infections). Especially during winters, the disease, even if present, may not be visible; on the contrary, in summer the characteristic symptoms are clearly evident on the upper surface of the leaves (Graniti 1993; Shabi et al. 1994).

The damage is characterized by a progressive and gradual fall of the infected leaves. The symptoms concern the presence of dark, circular spots, with a sooty appearance and a yellowish halo. They cause a reduction in the vegetative and photosynthetic function of the plant, as well as the differentiation of flower buds with a negative effect on olive production.

The upper Friulan plain is characterized by heavy rainfall, especially in autumn and spring; these are the ideal conditions for the development of the peacock's eye, which requires prolonged leaf wetness to initiate infections.

The spread of the fungus is closely linked to meteorological conditions and is favored by rain and high relative humidity, leading to prolonged leaf wetness (at least 18 hours are needed for the initiation of infection) in conjunction with mild temperatures.

[1] gianluca.gori@ersa.fvg.it

Temperatures around 15-16°C significantly reduce the latency period, while high temperatures inhibit the fungus's development, extending the latency period.
In northern Italy, the environmental parameters required for the fungus's development are found in spring or autumn. Particularly mild winters, like those of recent years, have extended the fungus's activity even into late winter. *V. oleaginea*'s incubation period varies considerably depending on the infection period; if it starts in late spring, it may take 2 or 3 months before typical symptoms appear. The incubation period is shorter for autumn infections, taking only 15 days (Graniti 1993; Shabi et al. 1994).
Reduced productivity mainly results from the defoliation of infected trees, poor growth of vegetation, the dieback of defoliated branches, and a decrease in fruit yield (Graniti 1993; Viruega et al. 1997). Furthermore, it was observed that severe defoliation causes a delay in fruit ripening and a reduction in oil yield in Italy (Graniti 1993) and in New Zealand (MacDonald et al. 2000).
The management of the disease is of significant importance for all varieties, but specifically for the Bianchera cultivar, which is particularly sensitive. This study arises from the need to control *Venturia oleaginea* through reduced copper inputs per hectare and a low number of treatments, aimed at ensuring adequate coverage of the vegetation.

2 MATERIALS AND METHODS

The trial was conducted in Ragogna (UD) starting from September 2021 in an olive grove of about 1 hectare, planted in 2006, with a spacing of 5.0 x 6.0 meters, and without irrigation. The Bianchera cultivar represents 40% of the plantation, shaped as a polyconic vase.

Table 1: Products and related doses used in the trial.

Formulations	Composition	Dose (ha)	Cu (kg/ha) / treatment	Cu 2022 (kg/ha)
Coprantol	Copper hydroxide	3,25	0,65	1,95
Poltiglia Disperss	Bordeaux mixture	3,75	0,75	2,25
Nisus 3B	Tribasic copper sulphate	4,93	0,75	2,25
Airone	Copper hydroxide and oxychloride	3,75	0,75	2,25
Thiopron	Sulphur	6	-	0
Cobre nordox	Copper oxide	1	0,75	2,25
Poltiglia Disperss + Thiopron	Bordeaux mixture + Sulphur	3,75	0,75	2,25

Due to particularly rainy weather and the absence of specific treatments, at the beginning of the trial, the olive grove showed significant infections of OLS, to the extent that the Bianchera variety plants were noticeably defoliated. Given the poor conditions of the plants, a basic NPK (12.12.17) fertilisation was applied at a rate of 1 kg per plant,

along with 350 g per plant of urea in February 2022; in April 2022, an additional 400 g per plant of the same nitrogen fertiliser was applied.
From September 2021, 5 treatments were applied in the period of major development of peacock spot: the first on September 2, 2021, the following ones on November 16, 2021, April 14, 2022, September 7, 2022, and November 15, 2022.
The study aimed at evaluating the effectiveness of reduced annual copper metal inputs (2.3 kg/ha) by performing only 3 treatments, compared to the maximum limit set at 28 kg/ha over 7 years by European Regulation 2018/198.
The trial was conducted using a randomized experimental design, with 3 replicates and plots of 3 plants (90 m^2), comparing 8 treatments, for a total of 72 plants.
A water volume of 350 L/ha (sufficient to ensure adequate wetting) was sprayed on the canopy with a backpack sprayer (Stihl® SR 450 model). The main copper-based products available on the market, also suitable for organic farming, were tested at a copper dose of 0.75 kg/ha per intervention (Table 1). In the case of hydroxide, the maximum label dose allowed, equal to 0.65 kg/ha was used. Thiopron, a sulphur-based product (with sticking properties) was also tested both alone and in combination with Bordeaux mixture (as indicated on the label); in both cases, the minimum label dose was used (6 L/ha).
Disease evaluations were conducted from the appearance of new circular spots starting in August 2022; 5 following assessments were made, chosen based on symptom development: 26 August 2022, 28 September 2022, 12 December 2022, 20 January 2023, and 8 May 2023.
During these field inspections, the number of affected leaves was evaluated. On 20 January and 8 May 2023, the degree of foliar infection was also assessed, considering 6 classes of intensity (0%, 1-5%, 6-10%, 11-25%, 26-50%, and 51-100%). The assessments were carried out on 100 leaves per replicate, collected equally from the 3 plants of each replicate (300 leaves per treatment). In the laboratory, the collected leaves were treated with a 5% solution of sodium hydroxide (NaOH) to highlight latent infections, enabling a more objective and comprehensive assessment compared to visual evaluation in the field.
On 8 May 2023, a specific measurement was also carried out to evaluate the extent of defoliation. The number of total leaves present on 10 branches, each 30 cm in length, was determined for each replicate (30 branches per treatment).
The obtained data underwent analysis of variance (ANOVA) and Duncan's test at a confidence level of $P \leq 0.05$.

3 RESULTS AND DISCUSSION

During the winter of 2021-2022, from early December until mid-March, the average temperatures remained sufficiently low to ensure a period of relative quiescence of the fungus. The first significant temperature drops were recorded only in mid-December, followed by a January characterised by temperatures above average. It is noteworthy, however, that both the winter of 2021-2022 and 2022-2023 were particularly mild, with minimum temperatures rarely below 0°C (Fig. 1).

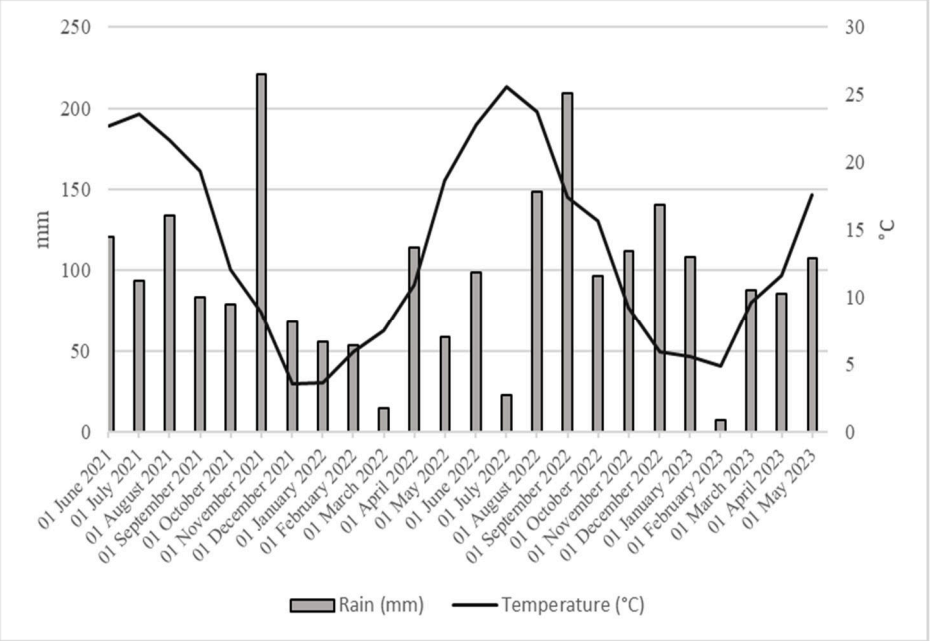

Fig. 1: Meteorological trend between June 2021 and May 2023 in Pignano di Ragogna, monthly temperature averages and rainfalls are visible.

Table 2: Statistical values of spread in the various surveys.

Treatments	26/08/22	28/09/22	12/12/22	20/01/23	08/05/23
Control	65,3 a*	60 a	57 a	62,2 a	57,1 a
Copper hydroxide	20,3 b	46,3 ab	26 b	27,4 c	25,9 b
Bordeaux mixture	33 b	34 b	22,1 bc	10,9 d	22,1 bc
Tribasic copper sulphate	27 b	37,7 b	17,8 bc	15,1 d	17,8 bc
Copper hydroxide and Oxychloride	36,7 b	43,3 ab	16,7 bc	14,7 d	16,7 bc
Thiopron	62,7 a	59,7 a	48,3 a	51,3 b	48,3 a
Copper oxide	33,3 b	38,7 b	12,7 c	11,1 d	12,7 c
Bordeaux mixture + Thiopron	41,7 b	35,7 b	16,6 bc	10,4 d	16,6 bc

*Values in the same column accompanied by the same letter do not differ significantly in the Duncantest.

Regarding the rainfall pattern, important episodes occurred in November 2021, followed by a period of scarce rainfall in winter, spring, and partially in summer. However, when compared to the regional average, Ragogna experienced a higher number of significant rainy events (above 5 mm). The rains from September to

November 2022, accompanied by mild temperatures, initiated several autumn infections, also favoured by a shorter incubation period of the fungus.
For the evaluation of the spread trends of the disease, it should be taken into account that the control group, the plants treated only with Thiopron and those sprayed with it in combination with bordeaux mixture were the first to be affected by a progressive defoliation (between 26 August and 28 September). Only later did the other treated plants become affected. The incidence was high for all the plants (Table 2), possibly as a consequence of the intensity of the inoculum from previous years, of the varietal sensitivity and of the generally wetter climate compared to the regional average.
In the first sampling (26 August 2022), all copper-based products significantly deviated from both the control group and the plants treated only with Thiopron. It is noteworthy that the lower average incidence was observed in the trees treated with hydroxide.
The following inspection (28 September 2022) revealed that the spread of symptoms on leaves in the plants sprayed with Bordeaux mixture, Bordeaux mixture combined with Thiopron, tribasic copper sulphate, and oxide were statistically different and lower compared to the control group and the only-Thiopron-treated trees.
On 12 December 2022, the lowest spread was observed with oxide, while the least effective of the copper-based products was hydroxide, still significantly better than the plants treated only with Thiopron and the control group.
Between the December and January inspections, it is noted that for the control group, Thiopron, and hydroxide, there is an increase in the spread of symptoms on leaves, while for the other products, there is a decrease, likely facilitated by lower washout and greater persistence of action of the products used.
In the last sampling of 8 May 2023, the lowest spread was observed for oxide, while the plants treated with Thiopron did not show statistical differences from the control group.

Table 3: Frequency of some class of intensity on 20 January 2023.

Treatments	Class 0%	Class 26-50%	Class 51-100%
Control	1,3% c	20% ab	63,3% a
Thiopron	3,3% c	21,7% ab	49,3% a
Copper hydroxide	17,3% bc	26% a	15,3% b
Copper hydroxide and oxychloride	33% ab	11,3% ab	5,7% b
Tribasic copper	35% ab	16,3% ab	4,3% b
Bordeaux mixture	45,7% ab	10,3% b	2,7% b
Copper oxide	47,7% a	9,7% b	4% b
Thiopron + Bordeaux mixture	55,3% a	9,3% b	2,7% b

*Values in the same column accompanied by the same letter do not differ significantly in the Duncantest.

Regarding disease severity, in the field inspection of 20 January (Table 3), it is observed that for the intensity class equal to 0%, the trees sprayed with Bordeaux mixture combined with Thiopron were the best, along with the oxide-treated plants. Significant

differences are also noted for the intensity classes between 26 and 50% and those above 51%.
The intermediate classes from 1-5%, 6-10%, and 11-25% did not show a relevant statistical difference, and for this reason, they have not been reported.
For the intensity class that ranges between 26 and 50%, hydroxide, Thiopron, and the control group have a higher incidence in terms of severity, while the plants sprayed with Bordeaux mixture, oxide, and Bordeaux mixture combined with Thiopron appear to be the most effective. In the intensity class above 51%, the control group and Thiopron alone show lower efficacy, while Bordeaux mixture and Bordeaux mixture combined with Thiopron are the most performant.
The field inspection of 8 May 2023 (Table 4) revealed that for the intensity class of 0%, Bordeaux mixture combined with Thiopron appeared to be the most effective, followed by the ones with oxide, hydroxide with oxychloride, and tribasic copper sulphate. The treatments of hydroxide, Thiopron, and the control group have very low values. Significant differences are observed for the intensity class above 51%, where the control group and Thiopron alone appear to be the least effective.

Table 4: Frequency of different intensity classes on 8 May 2023.

Treatment	Class 0%	Class 26-50%	Class 51-100%
Control	7% d	21% ab	57% a
Thiopron	9,3% d	30,7% a	40% b
Hydroxide	23,6% c	26,7% ab	13% c
Hydroxide + Oxychloride	40,3% ab	19,3% ab	7% c
Tribasic	39,7% ab	23% ab	5,3% c
Bordeaux mixture	32,3% bc	18,3% ab	10,7% c
Oxide	45% ab	13,7% b	4,3% c
Bordeaux mixture + Thiopron	45,7% a	22% ab	6% c

*Values in the same column accompanied by the same letter do not differ significantly in the Duncantest.

Regarding the sampling on remaining leaves per branch (Fig. 2), which is inversely correlated with the degree of defoliation, the trees sprayed with Thiopron show the highest degree of defoliation, followed by the control group. The most effective formulations, on the other hand, were the one in which Bordeaux mixture was combined with Thiopron and the one with oxide.

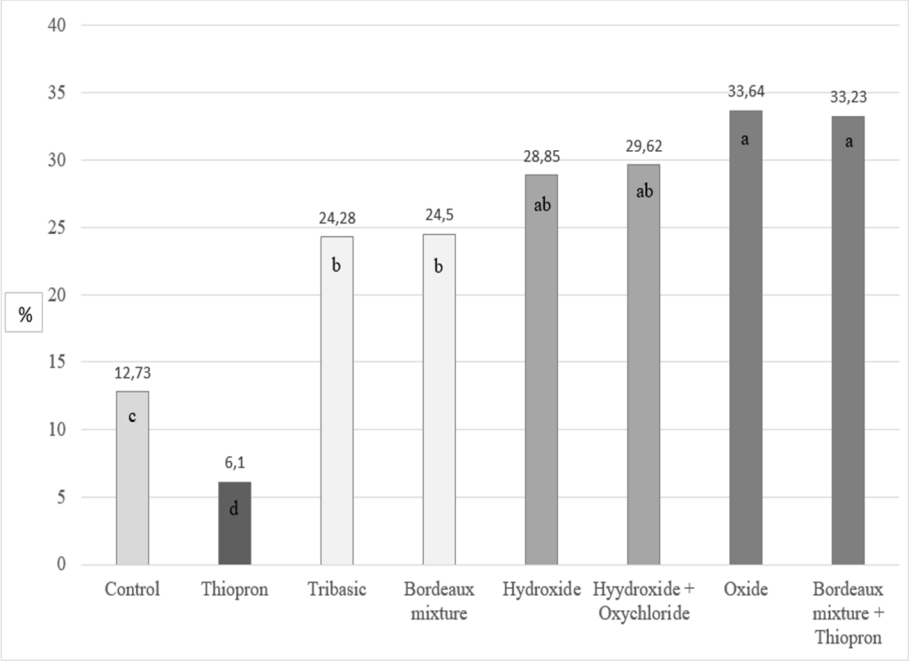

Fig. 2: Average number of leaves per 30 cm branch (8 May 2023).

From the 5 surveys on the spread of the disease, it is evident that as the trial progresses, statistical differences between the products become more apparent, likely due to a cumulative effect of treatments over time. In all field inspections, the control group and the plants treated with Thiopron significantly deviate from the other products, highlighting a poor efficacy of Thiopron alone in containing *Venturia oleaginea*.

This limited effect of Thiopron is also supported by the fact that on the 8 May 2023 evaluation, trees treated with this fungicide alone showed a lower number of leaves per branch, even compared to the control group. The results related to disease progression were comparable to the untreated control group (except for the 20 January 2023 sampling, where a slight statistical difference is present, likely due to the product's effect on inducing leaf drop and the subsequent reduction in symptom spread per leaf). Similarly, for severity, the results indicate a pattern very similar to the untreated control group.

Thiopron used in combination with Bordeaux mixture had a significant synergistic effect, which is evident when compared to the plants treated only with Bordeaux mixture. Particularly in the average result of leaves per branch, it can be seen that the trees sprayed with Bordeaux mixture combined with Thiopron are significantly better (33.2 a) than the ones treated with only Bordeaux mixture (24.5 b).

The initial good performance of hydroxide can be explained by the meteorological conditions preceding the inspection of 26 August 2022, characterised by limited rainfall throughout the winter, spring, and partly even the summer. This allowed the product to express its antifungal activity to the fullest, characterised by a high availability of readily available copper ions. On the other hand, hydroxide is less resistant to washout. It is particularly significant in this regard that, between the December and January evaluations, the control group, the trees treated only with Thiopron, and those treated with hydroxide showed an increase in the spread of symptoms on leaves (indicating early washout of hydroxide); whereas for all others, a decrease was observed (Table 2). From 28 September 2022, hydroxide consistently resulted statistically less performing compared to the other tested copper-based products, both in terms of spread and severity of symptoms; a result likely influenced by the high rainfall during that period. With regards to the average number of leaves per branch, which is inversely correlated to the extent of defoliation, plants sprayed with hydroxide combined with oxychloride obtained an intermediate result but still preferable to the trees treated with tribasic copper sulphate and Bordeaux mixture.
The efficacy of hydroxide in containing the fungus until the sampling of 26 August 2022, allowed limiting the defoliation of the plant (the defoliation process is usually long, and the initial positive results of hydroxide likely had a lasting impact).
An opposite behaviour was observed when Bordeaux mixture was combined with Thiopron and with copper oxide, which showed a relatively high initial level of spread (in the 26 August 2022 inspection). However, starting from 12 December, lower levels of spread and severity of the infection were observed, resulting in less defoliation. In this regard, both products were still visibly present on the leaves after several washout-inducing rain events. It remains to be verified whether this effect is solely due to the adhesive component of the product (possible activity in modulating the release of copper ions), the sulphur present, or their combined action.
The effectiveness of Pinolene as a replacement for Thiopron is currently under evaluation.

4 CONCLUSIONS

From these initial results, it can be stated that during periods of low rainfall and low relative humidity (characteristics observed from January to August 2022), the immediate effect of hydroxide was evident. In periods characterized by prolonged and washout-inducing rainfall events (especially during the autumn season of 2022), the importance of using products characterized by lower washout and greater persistence of action, such as Bordeaux mixture combined with Thiopron and copper oxide, was evident.
It is highlighted that Thiopron has little effect on *Venturia oleaginea* when used alone, except in inducing marked defoliation on infected leaves. Conversely, its combination with Bordeaux mixture proved particularly useful in limiting leaf drop, probably due to the lower washout of the product and the greater persistence of copper.

Throughout the experimentation, it has been demonstrated that in case of severe infestations, the use of hydroxide in initial treatments appears to be more effective, while in the long term, it could be replaced by mixtures containing Thiopron or copper oxide.

5 ACKNOWLEDGMENTS

Our thanks for the collaboration go to f.lli Molinaro, Diego Corsi, Michele Pestrin and Valentina Caron.

6 REFERENCES

Graniti, A. 1993. Ticchiolatura dell'olivo: una rassegna. Bollettino OEPP/EPPO, 23, 377-384.

MacDonald, A.J., Walter, M., Trought, M., Frampton, C.M., Burnip, G., 2000. Survey of olive leaf spot in New Zealand. New Zealand Plant Protection, 53, 126-132.

Shabi, E., Birger, R., Lavee, S., Klein, I. 1994. La macchia fogliare (*Spilocaea oleaginea*) sull'olivo in Israele e il suo controllo. Acta Horticulturae, 356, 390-394.

Viruega, J.R., Lique, F., Trapero, A. 1997. Caída de aceituhas debida a infectciones del pedunculo por *Spilocaea oleagina*, agente del Repilo del olivo. Fruticultura Profesional, 88, 48-54.