Organic World Congress 2020 | FRANCE

SEPTEMBER 21st TO 27th, 2020 IN RENNES
AT THE COUVENT DES JACOBINS • RENNES MÉTROPOLE CONFERENCE CENTRE
www.owc.ifoam.bio/2020

OWC 2020 Paper Submission - Science Forum

Topic 1 - Ecological approaches to systems' health

OWC2020-SCI-624

SCREENING OF ALTERNATIVES TO DECREASE COPPER DEPENDENCY FOR PLASMOPARA VITICOLACONTROL IN ORGANIC GRAPE PRODUCTION

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Abstract: Downy mildew caused by *Plasmopara viticola* is a major pest in viticulture worldwide. Organic viticulture is highly dependent of copper-based product to control this disease. Because copper has negative environmental impact, strategies to decrease dependency to copper-based products are needed. In that context, during 2005-2017 period, we have assessed the efficacy of 35 compounds to control downy mildew on-farm. This study presents a selection of our results. The screening showed that several formulated products and compounds have an efficacy to control the downy mildew when they are compared with the untreated control, but none at an efficiency similar to copper. When alternatives compounds are associated with a low copper dose, significant additional effect are rarely observed over the whole season.

Introduction: The downy mildew caused by *Plasmopara viticola* is an important disease of grapevine distributed worldwide. Most commercially important cultivars in France are highly susceptible to downy mildew, especially in warm and wet climates. In European organic grape production, copper-based preventive treatments are applied to avoid significant yield losses. However, soil accumulation and negative effect on soil biota are major disadvantages of copper uses (Lamichhane et al, 2018). Among the diseases controlled by copper-based products, downy mildew is one of the most challenging disease to find reliable alternatives to copper (Schmitt et al 2017). In order to decrease the dependency of organic grape systems to copper, we have assessed the efficacy of compounds to control mildew on-farm in the South-East of France during 13 years.

Material and methods: The experimental plots were located in the South-East of France in Drôme valley region. The vineyards were planted with local cultivar "Muscat petit grain" at 2.3 x 0.9m plantation distances. This cultivar is known to be susceptible to downy mildew. The trial was set-up on one experimental plot per year, at Barnave from 2004 to 2009 and at Espenel from 2010 to 2017.

During 2005-2017 period, the experimental design of the trial was composed of 8 treatments randomly distributed on 4 blocks following the slope of the plot. Each treatment was composed of 12 vine stock x 4 repetitions, covering approximately a surface of 100m^2. Between each block, 3 vine stocks were kept untreated to favour a homogeneous mildew development within the plot.

Each year, three modalities were set-up: untreated, the reference copper dose (400g Cu/ha/application) and the low copper dose (100 Cu/ha/application). Thirty alternatives compounds were assessed in association with a low copper dose and 14 alternatives compounds were assessed as stand-alone, i.e. without copper. Sprays was carried out manually with a pneumatic air sprayer (Solo 450) with a 150 L / ha volume. Experimental applications were realized according to mildew pressure, climatic risks and phenological stage, which corresponds to application every 5 to 15 days. Applications were repeated in case of rain leaching (>20mm). Powdery mildew was controlled by sulfur-based treatments (5-8 kg sulfur / application) from May to August according to climatic conditions.

The surface of downy mildew symptoms was observed on leaves (3200 leaves / modality) and on bunches (1800 bunchs / modality) from 2 to 5 time per year, according to the dynamic of symptom's development.

The Area Under Disease Progression Curve (AUDPC) of the intensity and frequency of mildew symptoms observed on leaves and bunches was calculated each year using MESS package on R software. In order to compare the efficacy of the alternatives products with a reference (untreated, copper reference or low copper dose), a meta-analysis approach was used thanks to *rma* function from *METAFOR* packages on R software (methodology described in Makowski et al, 2018).

Results: Among all the alternatives compounds assessed from 2004 to 2017, we have selected those that have been evaluated under sufficient downy mildew pressure and that have at least one year of observation on leaf or on bunch (Table 1).

The copper reference (400g Cu/ha/application) has a high positive significant effect when compared to the untreated control (n=13 years), and the low copper dose (100g Cu/ha/application) has a positive medium significant effect (n=4). When compared to the low copper dose, the copper reference has a medium positive significant effect and the untreated control show a significant negative effect, which is consistent with our expectations.

When we compare the efficacy of the 12 alternatives compounds assessed without copper in comparison with the untreated control, 10 of them have a significant efficacy on leaf or on bunch. Armicarb and Trichodex have an effect to control downy mildew on leaf but not on bunch, which can be explained by the conditions of the disease development that year, for example. Chitoplant showed a medium and high efficacy on leaf and bunch damages respectively. However, at that dosage (12,5 g/L), phytotoxicity was observed on bunch, which decreased yield. Since Chelal Cu is a copper chelate which contain 10% of copper, it is not alternative to copper but a potential way to decrease the use of copper as a fungicide. Chelal Cu showed a low positive effect on leaf and bunch damages over one year. Timorex has a positive effect on leaf and bunch damages over 3 and 2 years, respectively. No significant effect was observed for Saponin (yucca extract) and PrevB2 on our experimental conditions.

In a second step, we have quantified the additional effect of 11 alternatives compounds when they are added to a low copper dose (100g Cu/ha/ application). In that case, following the same methodology, we observe that only one compound has a significant additional effect on downy mildew control, i.e. the copper chelate Chelal Cu. However, if we focus on the data for each date of observation, significant differences were observed for *Thymus zygis* essential oil the 25 July 2017 and 17 August 2017, for example (data not shown).

Table 1: Magnitude of the efficacy of the alternatives compounds in comparison with the UnTreated Control (UTC) or a low copper dose at 100gCu/application. The comparison is based meta-analysis: the logarithm ratio between the AUDPC of the intensity of downy mildew symptoms for a given treatment and the AUDPC of the reference treatment. n is the number of year of observation. Green and red cells indicate a significant positive or negative effect of the treatment in comparison with the reference used for the comparison, respectively. The number of '+' and '-' indicate the magnitude of the effect. 0 indicates no significant efficiency. EO: essential oil; Hyd: hydrolate; BS: black soap.

		LEAF		BUNCH	
Treatment and dose per application	reference in meta-analysis	Efficacy	n	Efficacy	n
Armicarb (1kg/ha)	UTC	++	1	0	1
Chelal Cu (0.5-1.0L/ha)	UTC	+	1	+	1
Chitoplant (12.5g/L)	UTC	++	2	++++	1
Saponin (3kg/ha)	UTC	0	3	0	2
Thymus zygis EO (0.2%)+ BS (0.2%)	UTC	+	1	0	1
PrevB2 (0.6%)	UTC	0	2	0	2
Timorex (0.5-1.0%)	UTC	+	3	++	2
Timorex (0.5-1.0%)+ Trapper	UTC	+	1	0	1
Trichodex (4kg/ha)	UTC	++	1	0	1
Cu100	*UTC*	++	*4*	+	*4*
Cu400	*UTC*	++++	*13*	++++	*9*
Cu100+Chelal Cu (0.5-1.0L/ha)	Cu100	0	1	+	1
Cu100+Chelal MnZn (1.0-1.5L/ha)	Cu100	-	1		0
Cu100+Corymbia citriodora EO (0.2%)+Heliosol (0.2%)	Cu100	0	1	0	1

Cu100+Syzygium aromaticum EO (0.2%)+Heliosol (0.2%)	Cu100	0	1	0	1
Cu100+Origanum vulgare EO (0.2%)+BS (0.2%)	Cu100	0	2	0	1
Cu100+Thymus zygis EO (0.2%)+emulsifier (0.2%)	Cu100	0	3	0	2
Cu100+Thymus zygis EO (0.2%)+BS (0.2%)	Cu100	0	3	0	2
Cu100+Thymus zygis Hyd. (0.2%)+BS (0.2%)	Cu100	0	1	0	1
Cu100+Propolis (300g/ha)+emulsifier	Cu100	0	1	0	1
Cu100+BS (0.2%)	Cu100	0	1	0	1
Cu400	*Cu100*	++	*13*	++	*9*
UTC	*Cu100*	--	*13*	-	*9*

Discussion: This study show that several formulated products and compounds have an efficacy to control the downy mildew when they are compared with the untreated control: Armicarb, Chitoplant, Timorex, Trichodex, Chelal Cu and *Thymus zygis*essential oil. However, only one compounds have a significant additional effect when added at a low copper dose, and it is composed itself of 10% of copper (Chelal Cu).

Some results of this study show significant efficacies of the compounds as it was observed in others studies (e.g. Armicarb in Lukas et al, 2016) or not (e.g. *Origanum vulgare* in Rienth et al, 2020). This highlight the crucial role of the condition of compounds assessment (cultivar, climatic conditions, etc.).

The use of raw compounds raise practical questions such as the choice of emulsifiers for non-aqueous compounds. For example, we have observed that mixing essential oils with black soap 24 hours before mixing it with water increase the quality of the sprayed emulsion.

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Disclosure of Interest: None Declared

Keywords: Plasmopara viticola, downy mildew, viticulture, Copper, Alternatives