A guide to the sustainable use of copper and alternative products in SUDOE vineyards

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1.- Introduction

One of the most economically important diseases in European viticulture is caused by the fungus *Plasmopara vitícola*, commonly known as downy mildew. To control this fungal disease, the application of copper on the leaves has been used since the 1880s', when *Caldo Bordelés* (Bordeaux mixture), characterized by the presence of copper, sulphate and lime, was discovered.

Due to the excessive use of copper in European agriculture in the last decades, not only in vineyards but also in the most important horticultural crops, copper levels in the soil have increased significantly during the last years in Europe (Ballabio et al., 2018). The accumulation of this heavy metal in the soil generates a negative impact on the biodiversity of the organisms present in the soil, due to the toxicity. In addition, the accumulation of copper in the soil can pose a risk of leaching of the heavy metal into groundwater and contaminate other water sources.

Therefore, this concern for environmental protection on the part of the European authorities has led to the limitation in the use of copper in agriculture. In 2002 the use of copper was limited for organic production (Commission Regulation EC 473/2002), since in organic agriculture the use of copper is more common, as the use of other alternative products to copper is very limited. In 2018 this limitation has been extended also to conventional production, limiting to a maximum of 28 kg Cu/ha in 7 years (Commission Implementing Regulation EU 2018/1981).

Due to this environmental concern of European viticulture, research projects have emerged, such as COPPEREPLACE, which seeks integrated, innovative and viable solutions to reduce the use of copper and its environmental impact in vineyards in the SUDOE region.

2.- Objective of the guide

The objective of this guide is to disseminate good practices for the application of fungicide products in SUDOE vineyards, maximizing application efficiency and minimizing environmental risk.

To this end, this guide explains how to calculate the optimal application rate, as well as the choice of the most suitable nozzles and pressure, and parameters to be taken into account to reduce the risk of drift of Plant Protection Products (PPPs).

3.- Good practices for copper-based products application in vineyards in the SUDOE region.

Although this guide is based only on good practices for copper application in vineyards, it should not be forgotten to take into account good practices of transport and storage

of plant protection products, as well as good practices after application, for example with cleaning of the sprayer or waste management.

3.1.- Quantification of the optimum application volume during spray application.

Adapted Crop Spraying consists of keeping the quantity of product to be applied constant (mg/cm^2), for which the volume of vegetation to be treated per hectare must be calculated. Tree Row Volume (TRV) is a well-known methodology that allows to quantify the amount of vegetation per ground surface, which requires to know canopy height (h), canopy width (a) and row spacing (c). TRV (m^3/ha) is calculated according to the following equation:

$$TRV = \frac{h\ (m)\ x\ a\ (m)\ x\ 10.000}{c\ (m)}$$

Once this value has been established, the optimum application volume (L/ha) can be calculated according to the following equation:

Application volume (L/ha) = TRV (m^3/ha) x i (L/m^3) x 10^3

For this calculation, the volume index (i) must be known, which indicates the liters of spray to be applied per m^3 of vegetation, and whose recommended value according to the optimum coating method is 0.095 liters per m^3 of vegetation (Gil et al., 2007).

3.2.- Reading the pesticide label and determining the amount of copper.

A pesticide label is a legal document that indicate how the product should be used, so it is against the law to use the product in any other manner or to use it in an unsafe mode. According to the FAO (2015), the pesticide label is the principal, and sometime the only, contact between the manufacturer and the user of the PPs, and they must provide essential information about the product (Table 1), about safety information and about the method of using the product (Table 2).

Table 1. Product information on the label of plant protection products.

Information about the product	
Product name	
Formulation type	The way the active ingredients are combined to make a stable product.
Summary of uses	Most common uses of the product.
Common name	An agreed, short name for the active ingredient.
Active ingredient statement	The technical name of the chemical(s) that kills or controls the pest.
Name and address of manufacturer, distributor, agent or registrant	The company responsible for this product in the country stated.
Registration number	The unique number which identifies the product to regulators, manufacturers and poison control centers.
Date of Manufacture/ Formulation/ Batch Number	Identifies when and where the product was made.
Shelf life	The length of time the product may be kept before use.

Net contents (g)	The amount of product in the container e.g. L, ml, kg, g.

Table 2. Information about how to use the plant protection products noticed on the label.

Information about how to use the product	
Directions for use: how when and where to apply the product	When and where the product can be used legally. How to use the product to get the best effect; and safely to protect the crop, the user and the environment.
How to mix the product	To get a stable spray mix of an even concentration. How the product should or could be mixed with other products.
How to apply the product	To get the spray deposit on target surfaces for best effect and least risk.
Compatibility with other products	Other products with which this product can and cannot be used.
Withholding period / re-entry period / pre-harvest interval	The minimum number of days between the date of spraying and harvesting or entering the treated area.
General instructions for use	
Limitations of use (susceptible crops/varieties)	Lists what the product will not control or particular cases where the product should not be used.
Warning phrases and statements for Good Agricultural Practice	Advice on how to protect the user, the consumer, the environment and by-standers.
How to avoid harming beneficial insects or wildlife	
Limitations of use (weather conditions)	Weather that may affect the product's performance.
Timing and frequency of use	To get the best effect from the product and to lower the risk of pest resistance to the product.
Crops, targets, area	Lists where regulators permit the product to be used.
Dose rate	Quantity of product to be applied

In relation to the dose rate, a deepest explanation is needed, as is one of the most important points in relation to the application of phytosanitary products. As mentioned, there are generally three common manners of expressing how much product should be mixed with how much water:

1) Recommended concentration, which can be expressed in two ways:

- An amount of pesticide in water (g/L or cc/L), as for example 200 mL of product in 9.8 L of water to make 10 L of spray solution.

- Concentration (%), which means quantity of product per 100 liters of water. For example, a 0.2% solution means 200 g of product in 100L of water.

  **Some product labels give the percentage in terms of "volume of water", which in this case means 2 L of product in 100 L of water, whereas other product labels give the percentage in terms of "spray mix", which means 2 L of product in 98 L of water. It is therefore important to note whether the label says a certain percentage "by volume of water" or "by spray mix".*

2) Dose per recommended ground surface (kg or L/ha).

3) Product dose and water volume rate, as for example 4 L of pesticide product applied at water volume rate of 200 L /ha.

3.3.- Proper sprayer's calibration

After the volume application rate (l/ha) is decided, the calibration of the sprayer is a key point for an efficient application of crop protection products in order to minimize the environmental risk of contamination.

Spray volume should fit the shape of the canopy to be sprayer, so the number of nozzles and its position and orientation should be decided according to the canopy height.

For this purpose, it is important to determine some parameters. Forward speed of the tractor (Km/h) will be selected according to the canopy volume, the amount of air flow that the sprayer generates and the soil conditions. Moreover, the number of sprayer rows is a key point, as this will determine the working width. For an optimal spray distribution, it is suggested to spray every row. However, when a multirow sprayer is used, the working with is defined by the number of rows sprayed.

From the optimum application volume (V, L/ha), the working width (a, in meters) and the forward speed (v, km/h), the flow rate (Q, L/min) to be applied can be calculated.

$$Total\ flow\ rate\ (Q) = \frac{V\ x\ a\ x\ v}{600}$$

From the flow rate, the most suitable number and type of nozzles for the application can be determined. The number of nozzles per side is determined according to the height of the vegetation, so that the application of the crop protection product is correctly adjusted to the vegetation. When the total flow rate is divided by the total number of nozzles, the unit flow rate of each nozzle (L/min) is obtained.

Based on the flow rate information provided by the nozzle manufacturers, nozzles are selected that are best suited to the theoretical flow rate required, and whose working pressure is between 6 and 14 bar, approximately. To facilitate these adjustments, the use of calibration discs such as the one in Figure 1 is very useful.

It is also important to choose the nozzle based on the droplet size from the manufacturer's information. Bearing in mind that a larger droplet size ensures better penetration into the vegetation and less risk of drift, although the coating is smaller.

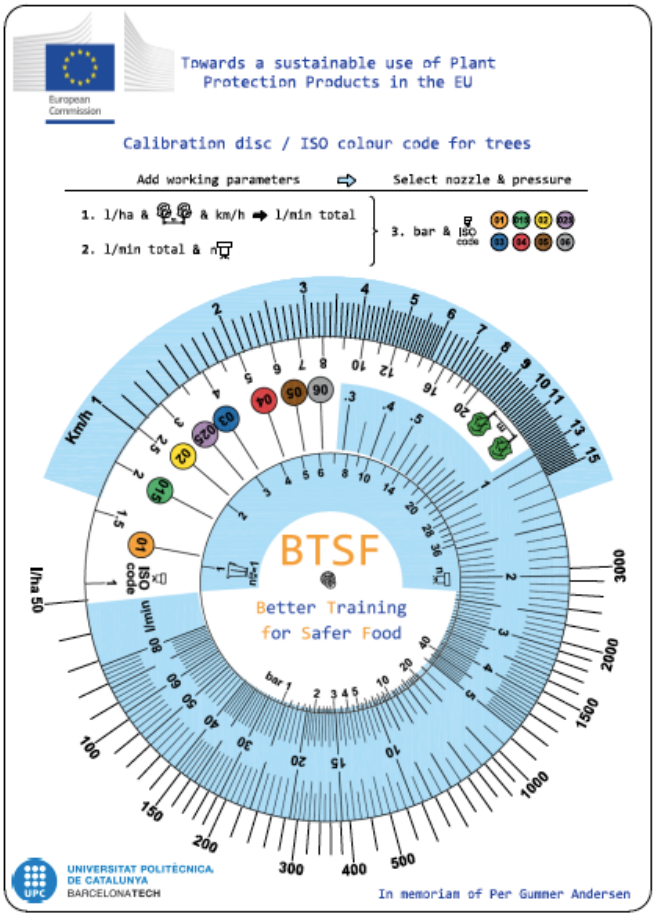

Figure 1.- Calibration disc to determine nozzle type and working pressure from the total flow rate to be applied.

3.4.- Tool to facilitate the efficient application of crop protection products.

To facilitate the calculation of the optimum application rate in vineyards, there are various applications, among which DOSAVIÑA© stands out (Gil et al., 2011; Gil et al., 2019). DOSAVIÑA® is a tool for determining the optimum application volume for spray application in vineyards based on the structural characteristics of the vegetation and the sprayer used.

For the calculation of the optimum application rate, the application allows a choice of three driving systems: trellised vineyard, vineyard in goblet and vineyard in pergola. A representative height (m) and width (m) of the entire plantation is needed in order to calculate the application rate (Figure 2). It is important to take several measurements in different places of the plot and calculate the average value. In addition, the canopy density appearance should be introduced.

In relation to the calculation of the application rate, DOSAVIÑA© allows you to choose between entering it as a percentage of concentration or as a dose per surface area. Once the type of sprayer to be used and the amount of water in the tank have been chosen, the application provides the information about the recommended application rate (L/ha), the pesticide dose (L/ha) and the amount of pesticide to add to the tank (L or kg) (Figure 3).

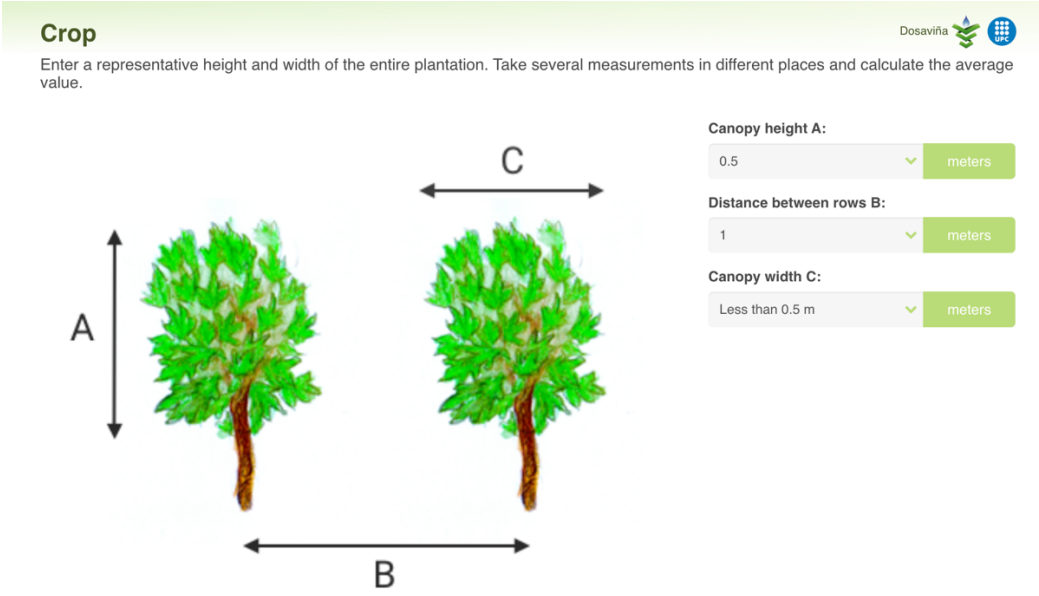

Figure 2.- DOSAVIÑA ® application screen where the user enter the height of the canopy (A, in metres), the distance between rows (B) and the canopy width (C, in meters).

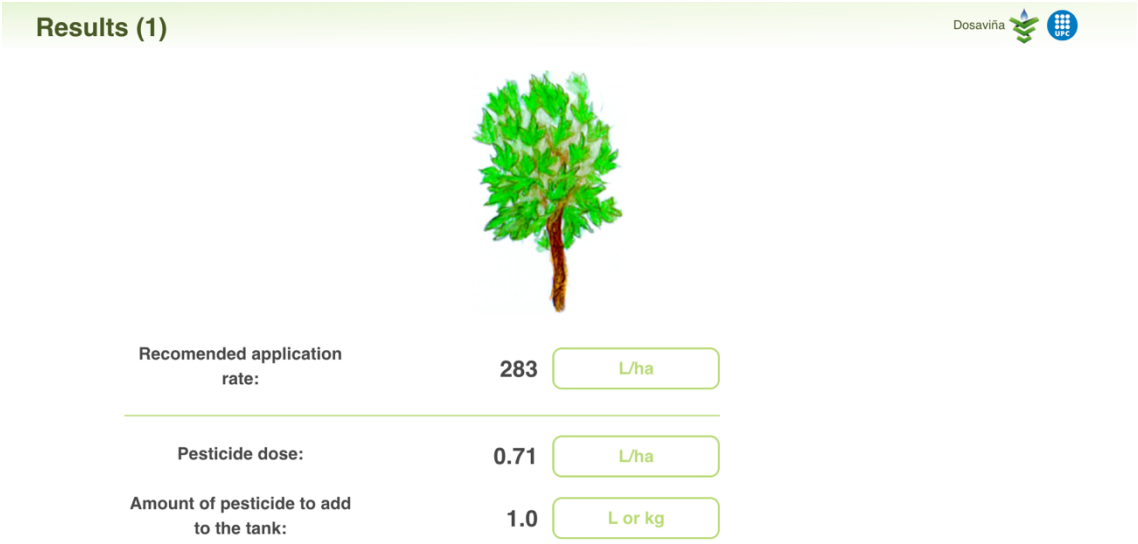

Figure 3.- DOSAVIÑA ® application screen where the recommended application rate (L/ha), the pesticide dose (L/ha) and the amount of pesticide to add to the tank (L or kg) are showed.

Moreover, DOSAVIÑA© allows the farmer to select the suitable parameters for a correct application. The sprayer calibration starts with the input of the tractor speed (km/h), which is recommended between 4 and 6 km/h for spray application in vineyards. The working width should be introduced, and is calculated from the number of rows applied at a time and the distance between the rows. The number of nozzles per side must be selected, depending on the height of the vegetation. Based on the recommended dosage and application speed, DOSAVIÑA© recommends different nozzle combinations, and information is included regarding nozzle type, working pressure (bar), flow rate (L/min) and droplet size for each nozzle (Figure 4).

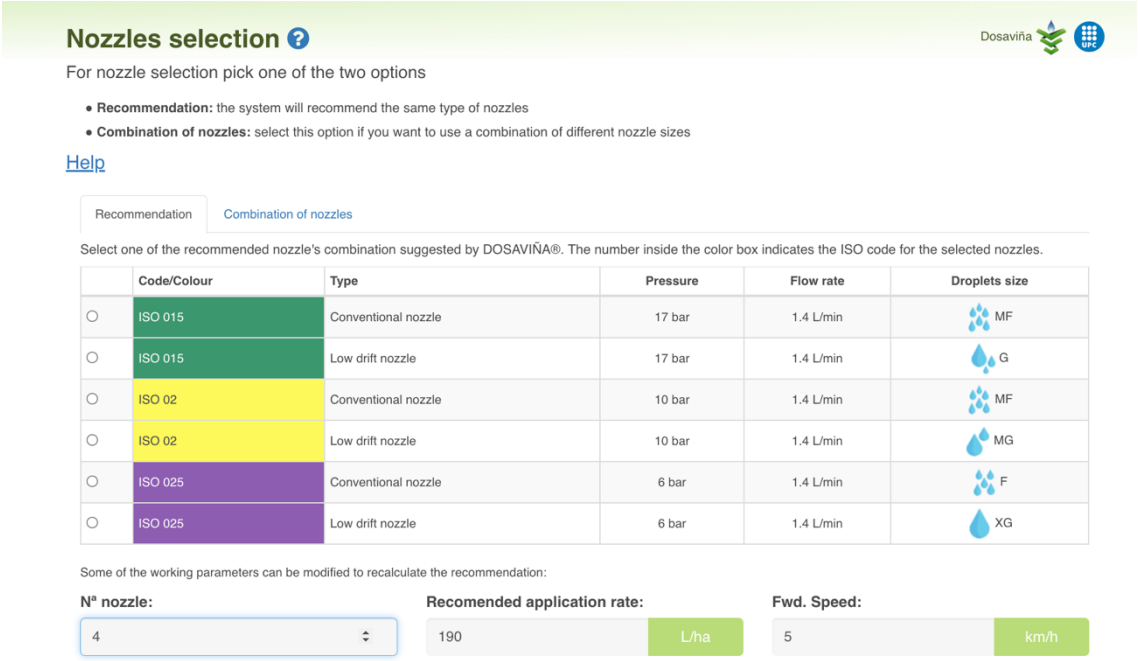

Figure 4.- DOSAVIÑA ® application screen where the type of nozzle, working pressure (bar), flow rate (L/min) and droplet size are showed, from the number of nozzles used, the recommended application rate (L/ha) and the forward speed (km/h) used by the farmer.

Within this guide for the sustainable use of copper and alternative products in SUDOE vineyards, the use of this tool or other calculation tools for the correct application of phytosanitary products is recommended.

3.5.- Reducing the risk of environmental pollution

Firstly, a well-inspected equipment improves the quality of applications and avoids unnecessary product losses. Therefore, it is important that all machinery used in the application of phytosanitary products achieve the corresponding Technical Inspection of Application Equipment for Phytosanitary Products. This will result in improved operator safety, reduced drift, less waste and more efficient distribution of the product in the crop.

Secondly, a properly calibration of the sprayer is a key measure to reduce the environmental risk of contamination. This includes checking the flow rate of the nozzles according to the manufacturer's specifications, and selecting the working parameters according to the expected application volume.

Moreover, it is decisive to adapt the quantity of plant protection product and water to the crop vegetation in each application, to the machinery used and to the specifications of the product used. Existing tools, such as DOSAVIÑA, can be used for this purpose.

And finally, take into consideration some aspects that help to reduce drift (Figure 5):

- Use sprayers with airflow speed adjustment system. The air flow speed must be carefully adjusted according to the size of the vineyard by orienting the fan

blades, adjusting the rotational speed (RPM) of the fan and properly selecting the power take-off (PTO) speed.

- Orient nozzles and deflectors to vegetation.

- Select the right droplet size. Fine droplets (< 100μm) represent a high drift risk, as the distance they can travel due to the wind can reach hundreds of meters. Therefore, in order to reduce the quantity of fine droplets, it is recommended to use anti-drift nozzles.

- Avoid spray applications when optimal conditions for application are not met, i.e: with high wind speed (> 2.5 m/s), high temperatures (> 25ºC) and low humidity (< 50%).

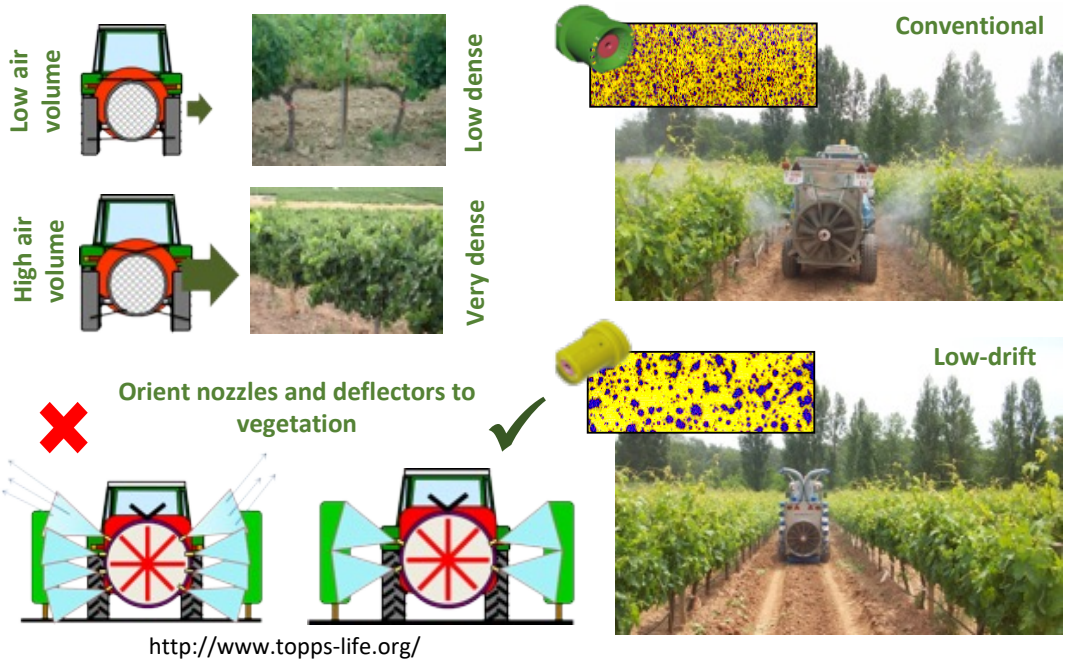

Figure 5.- Main aspects on the application of crop protection products to reduce drift. Source: LIFE-FITOVID project[1] and TOPPS project[2].

[1] Project LIFE-FITOVID: Implementation of Demostrative & Innovative Strategies to reduce the use of plant protection products in viticulture (LIFE13 ENV/ES/000710)

[2] Project TOPPS: Train Operators to Promote best management Practices & Sustainability. http://www.topps-life.org/

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