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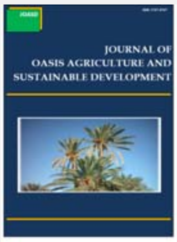


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# Efficacy of fungicides for control of powdery mildew on grapevines in Chott Sidi Abdel Salam oasis, southeastern Tunisia

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## Abstract

Grapevine is an important fruit crop grown in the Chott Sidi Abdel Salam oasis in south eastern Tunisia. It provides great economic potential for the oasis population due to its higher yield and monetary returns. It, also, has a good nutritional value and is consumed fresh or in dried form. Powdery mildew represents one of the most destructive diseases affecting viticulture, especially in temperate-humid climate. It is an economically important fungal disease in the grapevine farms. This pathogen is able to differentially attack leaves and grapes, and is currently controlled with repeated applications of fungicides. This research aimed to use chemical control in order to assess the ability of contact, systemic and the combination of both routes of fungicides' administration, at three different sampling moments to manage powdery mildew infestation of grapevines (Cv. Bazzoul Kalba), under field conditions. The experiments were conducted in the oasis of Chott Sidi Abdel Salam in southeastern Tunisia. Both Pristine WG and Vectra 10 SC allowed controlling the disease intensity of powdery mildew compared to Talendo® showing a highly significant augmentation of the inhibitory growth potential (84.26% and 88.94%, respectively at 21 days after the first fungicide application) and the protective potential (73.11% and 76.92%, respectively at 21 day). This information can be used to help grapevines growers to improve powdery mildew control and enhance marketable yields

## 1. INTRODUCTION

The grapevine (*Vitis vinifera* L.) is a worldwide cultivated crops that originated in the Caucasian zone. Its distribution area includes Iraq, Turkey, Georgia, Spain, France, Italy, and many other countries (Mullins et al., 1992). Approximately, there are 7.4 million hectares of grapevine implants, around the world, with a global production of 77.8 million tons in 2018 (OIV, 2019).

In Tunisia, grapevine was cultivated since the medieval history, and was grown in many regions with different climatic and edaphic conditions (Snoussi et al., 2004). According to the General Directorate of Agricultural Studies and Development (DGEDA, 2017) districts of Ben Arous, Nabeul and Sidi Bouzid contain about 44% of the total national grape vineyard. In southern regions with arid climates, grapevine is grown in oases (Gabes, Gafsa, Kebili and Tozeur oases) under the palm-trees shadow (Habib et al., 2020). Grapevines' national production reached 133500 tons in 2016; and constitutes a non-negligible part of the socioeconomic for the population (GIFruit, 2016).
Among pests and phyto-pathologies that destroys the viticulture and reduces its

production, powdery mildew (Order of Erysiphales) fungal infection is of a great concern in many regions of the world (Staudt, 1997; Gadoury et al., 2012, Nakova et al., 2017). It mostly causes leaves curling and senescence, stems weakening, bud sprouting inhibition, and affects both flowers and fruits (Gadoury et al., 2012; Ben Maachia et al., 2015; Ahmed, 2018), resulting in a significant decrease in the plant growth, and its yield quality and quantity (Pool et al., 1984; Calonnec et al., 2004). Erysiphe necator (Schwein) and Oidium tuckeri (Berk.) have been described as "pests" of grapevine that need harsh chemical management (Braun and Takamatsu, 2000). Huge plethora of studies suggested that powdery mildew becomes more and more resistant to chemical fungicides (Staudt, 1997; Alimad et al., 2017; Singh et al., 2017), and strategies involving seasonal-repetitive treatments and usage of various chemical compounds are required to ameliorate the fungus' management. This is due, in part, to differences of their modes of application (translaminar, systemic or contact applications (Rhouma et al., 2016; Innerebner et al., 2020; Matrood and Rhouma, 2021a,b).

In the present work, the efficacy of different fungicides with different application's modes (contact (Talendo®), systemic (Pristine WG) and a combination of both contact and systemic (Vectra 10 SC)) was evaluated against powdery mildew infesting grapevine grown under oasis' conditions.

## 2. MATERIAL AND METHODS

### 2.1 Study area

The present investigation was conducted in the oasis of Chott Sidi Abdel Salam located in the Gulf of Gabes (South-East of Tunisia: 33°89' to 33°91'N and 10°10' to 10°11'E), during the agricultural campaign of 2017. It is the unique coastal oasis in the Mediterranean basin with a long-lasting history of traditional agricultural activity. It is a typically three-stages cultivated oasis with fruit trees implanted under Palm trees' shadow. The climate of the region is of semi-arid features under Mediterranean Sea influences. The second fruit-trees stage comprises pomegranate, figs, olive, grapevines, etc. (Rhouma, 2017; Rhouma et al., 2020; Rhouma et al., 2021).

### 2.2 Fungicides used

The three fungicides (Talendo®, Pristine WG and Vectra 10 SC) with different route of application were chosen to be evaluated in an experimental in-situ design, because of their large usage in counteracting powdery mildew of grapevine. Table 1 summarizes their characteristics and dosages.

### 2.3 Field assessment and fungicides efficacy

The experimental field consisted of three randomized blocks comprising 15 grapevines (Cv. Bazzoul Kalba) each. Each fungicide was applied on five trees randomly distributed in each field. A single application of fungicides was performed using spray technique (pressure of 5-6 bars). The treatment was done within one day of the appearance of the first symptoms of powdery mildew. A fourth size-location matched grapevine's group was treated with vehicle (water) only and served as a negative control one.

Leaves of grapevines were collected from each experimented tree at 7, 14 and 21 days after the first fungicide application (DAFA), in order to assess fungus growth. The incidence (I (%) = (Number of infected leaves/Total of leaves) x

**Table 1.** Characteristic and dosages of the evaluated fungicides to control powdery mildew of grapevine in the Chott Sidi Abdel Salam oasis, Southeastern Tunisia.

| Trade name | Active ingredient | Chemical families | Action | Formulation | Product rate (recommended dose) |
|---|---|---|---|---|---|
| **Talendo®** | Proquinazid 200 g/L | Quinazolinones | C | EC | 25 cc/hl (250 cc/ha) |
| **Pristine WG** | Boscalid 25.2% + Pyraclostrobin 12.8% | Carboxamide + Strobilurin | S | WG | 650 g/ha |
| **Vectra 10 SC** | Bromuconazole 100 g/L | Triazole | C + S | SC | 30 cc/hl (300 cc/ha) |

S: Systemic; C: Contact; EC: Emulsifiable Concentrate; WG: Water Dispersible Granule; SC: Suspension Concentrate.

100) and relative leaf area covered by powdery mildew (PLA (%) = (Leaf area covered by powdery mildew/Total leaf area) x 100) were calculated in order to evaluate the protective potential (PP = 100 x (mean Icontrol- Itreated leaf)/ mean Icontrol) and inhibitory growth potential (IGP = 100 x (mean PLAcontrol- PLAtreated leaf) / mean PLAcontrol) which are considered as indicators for fungal infestation and growth.

### 2.4 Statistical analysis

Statistical analyses were carried out using (SPSS 20.0) Duncan's Multiple Rank Test, to compare results from the three fungicides treatments, at various periods. The evolving of the studied parameters was checked using dependent-variable comparison. The significance was retained for p≤ 0.05. All results were expressed as mean ± standard deviation.

## 3. RESULTS AND DISCUSSION

The result of this study showed significant differences between fungicides effectiveness in controlling powdery mildew on grapevine under field condition. The percentage of leaf area covered with powdery mildew (PLA), disease incidence (I), inhibitory growth potential (IGP) and protective potential (PP) significantly differed (P <0.05), between the three treatments. There was, also, a statistically significant time-dependency of the effectiveness of the studied fungicides (P <0.05), in particular which of Talendo®. The lowest PLA were observed at 7 days after the first fungicide application (DAFA) with values ranged between 2.2±0.33% for Talendo® and 3.8±0.64% for Pristine WG. The lowest records of the infection's incidence (I) ranged from 5.16±0.74% (Pristine WG) to 7.78±0.59% (Vectra 10 SC), at the first week of application. In contrast, the highest percentages were recorded at 21 DAFA (Tables 2 and 3).

**Table 2.** Effect of fungicide treatments on the percentage of leaf area covered with powdery mildew (PLA) in grapevine grown in open field conditions at different sampling periods (7, 14 and 21 days after the first fungicide application (DAFA)).

| **Fungicide treatments** | **PLA/Sampling periods** | | | **P-value[b]** |
|---|---|---|---|---|
| | **7 DAFA** | **14 DAFA** | **21 DAFA** | |
| **Talendo®** | 2.20±0.33bC[a] | 16.60±1.54bB | 38.80±2.90bA | <0.01 |
| **Pristine WG** | 3.80±0.64bC | 8.40±1.04cB | 14.80±2.64cA | <0.01 |
| **Vectra 10 SC** | 3.60±0.44bB | 8.80±1.49cAB | 10.40±1.65dA | <0.05 |
| **Control** | 20.75±1.23aC | 35.65±1.85aB | 78.85±2.95aA | <0.05 |
| **P-value[b]** | <0.05 | <0.05 | <0.01 | Nd |

[a]Duncan's Multiple Rank Test, values followed by different superscripts are significantly different at P ≤ 0.01. [b]Probabilities associated with individual F tests. Capital letters are for means comparison in the same row. Small letters are for comparison of means in the same column. Data are the average of 30 grapevine leaves per treatment and per block (3 replicates). Nd: not determined.

**Table 3.** Effect of fungicide treatments on the disease incidence (I) in grapevine grown in open field conditions at different sampling periods (7, 14 and 21 days after the first fungicide application (DAFA)).

| **Fungicide treatments** | **I/Sampling periods** | | | ***P-value*[b]** |
|---|---|---|---|---|
| | **7 DAFA** | **14 DAFA** | **21 DAFA** | |
| **Talendo®** | 6.71±0.33aC[a] | 18.91±1.54bB | 76.41±2.65bA | **<0.01** |
| **Pristine WG** | 5.16±0.74aC | 8.91±0.95dB | 26.89±1.46cA | **<0.01** |
| **Vectra 10 SC** | 7.78±0.59aC | 10.57±1.12cB | 23.08±1.68cA | **<0.01** |
| **Control** | 27.44±0.97bC | 45.44±2.58aB | 98.09±2.97aA | **<0.01** |
| ***P-value*[b]** | **<0.01** | **<0.01** | **<0.01** | **Nd** |

[a]Duncan's Multiple Range Test, values followed by different superscripts are significantly different at P ≤ 0.01. [b]Probabilities associated with individual F tests. Capital letters are for means comparison in the same row. Small letters are for comparison of means in the same column. Data are the average of 30 grapevine leaves per treatment and per block (3 replicates). Nd: not determined.

These findings suggest that the effectiveness of a single application of fungicides in reducing powdery mildew's infection and growth diminishes within time. Pristine WG and Vectra 10 SC treatments are the most effective and lead to the lowest PLA, at 21 DAFA (14.80±2.64% and 10.40±1.65%, respectively) than Talendo® (78.85±2.95%) (Table 2). Similar results were observed for the infection incidence (Table 3).

Talendo® presents a decreasing growth inhibitory effect that reaches 50.79±1.95%, at the 21 DAFA. However, Pristine WG and Vectra 10 SC that exert potent and long-lasting effect on powdery mildew growth reaching up to 80% at 21 DAFA (81.23±2.59% and 86.81±2.13%, respectively) (Figure 1). Similarly, the protective potential was the highest in grapevines treated with Pristine WG (PP= 72.59±2.34%) and Vectra 10 SC (PP= 76.47±1.94%) in comparison to Talendo® (PP= 22.10±1.85%) at 21 DAFA (Figure 2). Noticeably, Talendo® significantly loses its effect on the fungus development on grapevine leaves within the first two weeks of its application.

Boscalid in association to pyraclostrobin (Pristine WG) and bromuconazole (Vectra 10 SC) are active as a foliar spray against a wide range of fungal plants' pathogens, notably *Phomopsis viticola* and *Uncinula necator* under both greenhouse and field conditions (Margot et al., 1998; Stark-Urnau and Kast, 1999; Gadoury et al., 2003). Their mode of action against *P. viticola* and *U. necator* is well studied. They inhibit zoospore motility and emptying, and germ tube formation of the fungus (Gadoury et al., 2003; Rhouma et al., 2016; Reddy et al., 2017; Matrood and Rhouma, 2021b). At low concentrations, boscalid, pyraclostrobin and bromuconazole have a strong inhibiting effect on spore germination of *U. necator* with the potential to decrease initial infection and pathogen spread. It has been documented that they inhibit the mitochondrial respiration by blocking the movement of electrons in cytochromes b and c (Ypema and Gold, 1999). Boscalid, pyraclostrobin and bromuconazole have been, also, indicated for their ability to inhibit the germination of conidia on the reverse side of the leaf (Margot et al., 1998; Ypema and

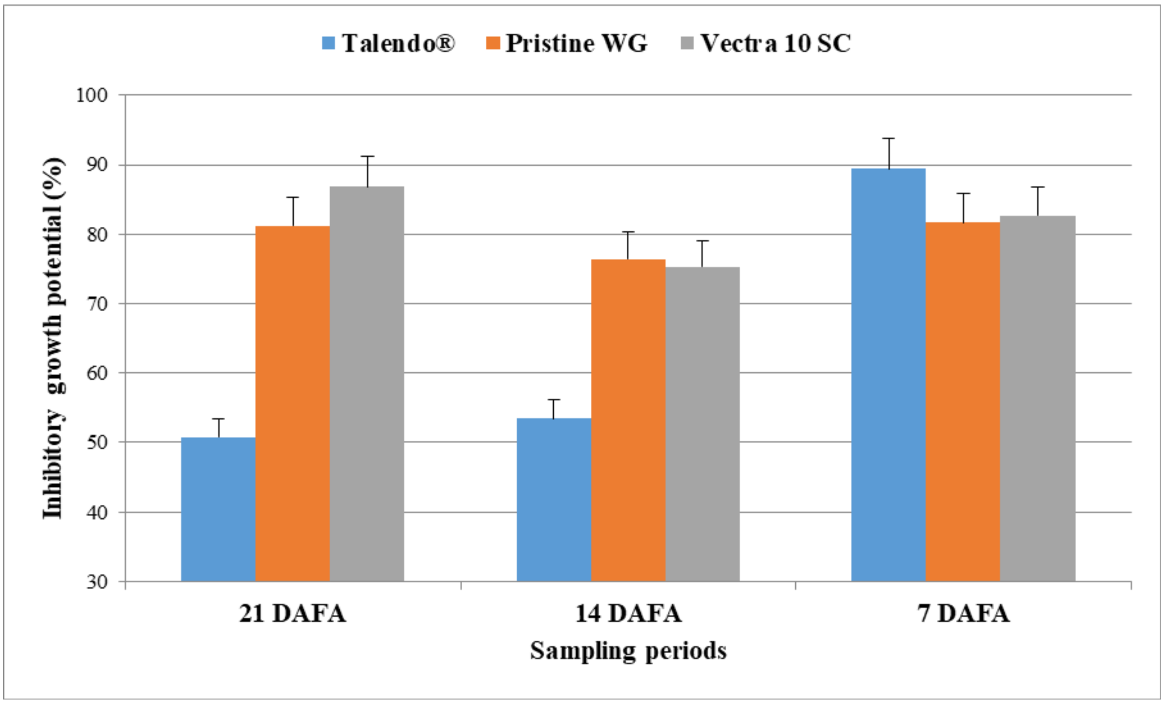


**Figure 1.** Effect of fungicide treatments on the inhibitory growth potential in grapevine grown in open field conditions at different sampling periods (7, 14 and 21 days after the first fungicide application (DAFA)). Small letters are used to compare different treatments at the same sampling moment. Capital letters are used to compare the same treatment at different sampling moments. Different letters above bars indicate statistically significant differences within the experiments (P≤ 0.5) according to the Duncan's multiple range tests. Bars without letter are not significantly different (each bar has capital and small letters). Data are the average of 30grapevine leaves per treatment and per replicate (with 3 replicates).

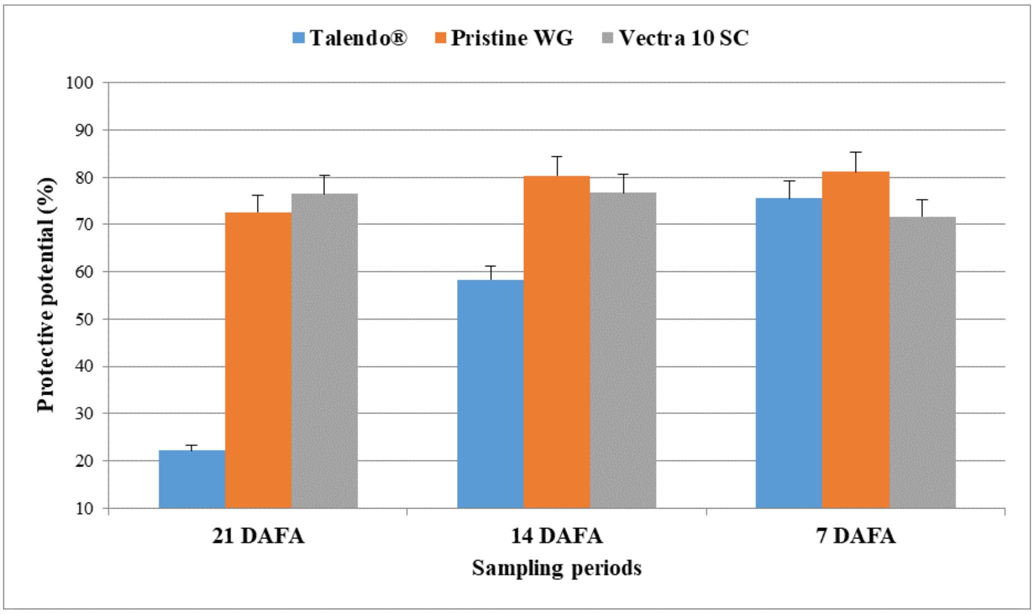


**Figure 2.** Effect of fungicide treatments on the protective potential in grapevine grown in open field conditions at different sampling periods (7, 14 and 21 days after the first fungicide application (DAFA)). Small letters are used to compare different treatments at the same sampling moment. Capital letters are used to compare the same treatment at different sampling moments. Different letters above bars indicate statistically significant differences within the experiments (P≤ 0.5) according to the Duncan's multiple range tests. Bars without letter are not significantly different (each bar has capital and small letters). Data are the average of 30grapevine leaves per treatment and per replicate (with 3 replicates).

Gold, 1999). Their powerful inhibitory effect at different stages of the infection's process and preventing spore germination and penetration (Reuveni and Reuveni, 1995; Reuveni, 2000; Narayana et al., 2005), might explain their effectiveness in preventing the fungal infection and development on grapevine leaves that is observed herein. Talendo®, the proquinazid derived fungicide, is practically ineffective in managing the infected grapevine, however it might be applied as preventive before powdery mildew appearance on leaves. Seemingly, the contact route of powdery mildew's management is less effective under this oasian condition.

Our finding spots for the choice of Boscalid and Pyraclostrobin or Bromuconazole chemicals to better manage the grapevine fungal pest.

## 4. Conclusions

Boscalid and Pyraclostrobin or Bromuconazole chemicals might be the fungicides of choice to control powdery mildew infection on grapevine under Gabes oasis condition. Mainly, they should prevent and inhibit the fungus germination and growth. It is suggested that environmental conditions in the oasis might affect the effectiveness of many chemicals in managing pests. Such variability should be considered in programs of pests controls.

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