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Short communication

Effect of the irrigation dose on Verticillium wilt of olive

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ABSTRACT

From autumn 2012 to autumn 2013 a survey comprising 70 olive orchards was carried out in an Irrigation Community of the central Guadalquivir Valley, (Andalucía, Southern Spain) with the objective of studying the influence of the irrigation dose on Verticillium wilt (*Verticillium dahliae* Kleb.) of olive (VWO). The 93.1% of the visited orchards were planted with susceptible cultivars to *V. dahliae* ('Picual' and 'Hojiblanca'). Mean disease incidence (DI) of the orchards accounted for 14.9%. In almost all investigated plantations disease onset occurred after farmers had introduced irrigation. In the case that it was present, the introduction of the irrigation always encouraged VWO development, and DI was positively associated with the number of years of irrigation, showing a linear trend ($P = 0.006$). VWO was significantly more severe in olive plantations irrigated with high irrigation doses. The 47.1% of olive plantations were irrigated with mean values of 2059.9 (in 2012) and 1793.4 (in 2013) m^3/ha, and showed the highest DI (21.42%). Plantations watered with lesser doses (the 28.6%) with average values of 712.5 (in 2012) and 741.5 (in 2013) m^3/ha showed a DI significantly lower, which accounted for 13.3%. Finally, dry-land olive orchards (24.3%) showed the lowest DI (4.0%).

1. Introduction

Verticillium wilt (*Verticillium dahliae* Kleb.) of olive (VWO) is nowadays the most threatening disease in many of the olive producing countries (López-Escudero and Mercado Blanco, 2011; Tsror, 2011).From the last decade, several epidemiological aspects have been identified regarding the influence of irrigation on the development of the disease in olive orchards. López-Escudero and Blanco-López (2005) demonstrated that pathogen population in soil was higher in wet zones close to drippers used for irrigation than in dryer zones. Indeed, surveys conducted by López-Escudero et al. (2010) showed higher values of VWO incidence in infected irrigated orchards compared to dry-land ones. García-Cabello et al. (2012) verified that microsclerotia, associated to soil particles and/or infected plant debris were distributed by irrigation systems. These effects may even be accentuated when using saline water (Levin et al., 2003). The most recent studies (Pérez-Rodríguez et al., 2015) evidence that daily irrigation frequencies favour VWO in susceptible cultivars when compared to more widely spaced in time irrigations. These studies have had the objective of identifying how this practice could influence on the development of VWO. However, information of the effect of different watering dosages on the disease remains still unknown. Therefore, objective of this research was to obtain and assess data from orchards in a representative zone of olive cultivation in Andalucía, for determining a best practice guide of irrigation under risk conditions, that allow ameliorate VWO control.

2. Materials and methods

2.1. Disease surveys

During autumn 2012 and 2013 a survey comprising 70 olive orchards (53 irrigated, mainly by drip-irrigation, and 17 dry-land plantations) was carried out in an olive cultivated zone affected by VWO that belongs to the Genil-Cabra Irrigation Community of Córdoba province (southern Spain). In each orchard, companied by the farmer or a technician, a survey consisting of two parts was completed. First one comprised general information related to irrigation in the orchards (watering regime, number of years on irrigation, the estimated-by-farmer watering doses in the orchard, watering periods etc.). In a second part, information about the disease (first

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Table 1
Irrigation regime, disease incidence and mortality caused by *Verticillium dahliae*, in olive orchards surveyed at Guadalquivir Valley (Spain).[a]

Factor	Sub-factor	Field (n°)	Disease incidence (%)		Estimated mortality (%)[d]
			In the surveyed plot[b]	Estimated for the whole olive orchard[c]	
Irrigation regime	Irrigated	53	18.5 a	10 a	2.9 a
	Dry-farming	17	4.0 b	1.9 b	1.0 a

[a] The values in columns followed by the same letter were not significantly different according to *T*-student test.
[b] Incidence was recorded in a rectangular plot chosen at random containing 100 trees.
[c] Incidence according to farmers.
[d] Mortality according to farmers.

disease symptom onset, estimated mean disease incidence (DI) and tree mortality in the plantation) was recorded. Finally, the DI in a rectangular plot chosen at random in each olive orchard containing 100 trees was assessed. From some of affected trees, plant material samples were taken for confirming *V. dahliae* infections according to López-Escudero et al. (2010). Indeed, the Irrigation Community provided us the real value of water consumption for irrigation during the years 2012 and 2013 for the orchard zone where the plot was chosen for recording the DI. After assessing data, visited plots were classified in three groups depending on water consumption, regarding normal mean values of consumption in this crop: High (2400–1800 m^3/ha), reduced (1400–500 m^3/ha), and dry-land (just rainfall). Water consumption was correlated with the recorded phytopathological parameters.

2.2. Data analysis

Analyses of variance and Pearson's correlation coefficient of the studied disease parameters (incidence and mortality as dependent variables) regarding irrigation recorded values (watering consumption of 2012 and 2013 years; number of years of irrigation, etc.) were analyzed according to a completely randomized design using the Statistix 10.0 software program (Analytical Software, Tallahassee, FL, USA). Mean values were compared using the *T*-student test or the Fisher's protected LSD test at $P = 0.05$ for two or more than two treatments, respectively. In addition, trend was studied using polynomial contrast. A principal component analysis (PCA) was carried out using Xlstat v.7.5.2 excel add-in software (http://www.xlstat.com, Addinsoft) in order to represent the relationship between DI and irrigation parameters and age of visited orchard.

3. Results and discussion

Present study provides novel information about the relationship between VWO incidence and water consumption in olive plantations. The disease was widespread in the 70 visited orchards, with a mean DI of 14.9%, values lightly lesser than those reported by López-Escudero et al. (2010), which accounted for 20.4% as a mean in affected trees in the Guadalquivir Valley. In the 94.3% of cases *V. dahliae* could be recovered from affected sampled tissues. The DI recorded inside the assessed plots was significantly higher in irrigated (18.5%) than in dry-farming (4.0%) olive orchards (Table 1). Also the values of DI estimated by farmer for the whole farm followed this pattern, accounting for 10.0 and 1.9%, respectively (Table 1). The estimated mortality values of the plantation did not showed significant differences between irrigation regimes, reaching an average of 2.0%.

Previous reports (López-Escudero et al., 2010) also showed significant differences of DI between irrigated (20.7%) and dry-land (18.3%) orchards in the Guadalquivir Valley. Nevertheless, the DI in dry-land visited plots in present research was much lower (4.0%). Probably differences are due to that, in the former cited surveys, owner would have stopped of watering before the visit date as a consequence of the alarming disease progress in the plots.

In this work we have also novelty demonstrated that water consumption has a strong influence on VWO (Table 2). Thus, plots classified as highly irrigated, according to water consumption in years 2012 and 2013, showed significantly higher values of DI (21.4%) than those irrigated with reduced doses (13.3%). Indeed, dry-land visited plots showed significantly lesser values of DI compared with irrigated ones (Table 2). Interestingly, the 93.1% of visited olive orchards were planted with olive cultivars 'Picual' and/or 'Hojiblanca', in which WVO develops very fast (López-Escudero and Mercado-Blanco, 2011), particularly when irrigated frequently (Pérez-Rodríguez et al., 2015). Estimated values of DI and mortality that were provided by farmers did not show significant differences (Table 2).

Other interesting results of this work is that in 70% of olive farms, disease symptoms onset coincided with the conversion of the orchard from dry-land into irrigation, and the DI progress was influenced by the number of years of irrigation. Thereby, non-irrigated orchards and those irrigated for less than one year showed significant lower DI (4.0%) than olive plantations irrigated for longer, that moved from 15.6% (from 2 to 4 year under irrigation) to 23.2% (more than 10 years of irrigation), following a linear trend ($P = 0.006$) (Table 3).

According to the Pearson test, DI recorded in plots was positively correlated with the water consumption for years 2012 ($r = 0.35$, $P = 0.002$), 2013 ($r = 0.25$, $P = 0.03$) and accumulated during both years ($r = 0.33$, $P = 0.004$). Nevertheless, the value of "*r*"

Table 2
Water consumption, disease incidence and mortality caused by *Verticillium dahliae*, in olive orchards surveyed at Guadalquivir Valley (Spain).[a]

Groups of consumption[b]	Number of the fields	Water consumption (m^3/ha)			Disease incidence (%)		Estimated mortality (%)[f]
		2012	2013	Accumulated[c]	In the surveyed plot[d]	Estimated for the whole olive orchard[e]	
High	33	2059.9	1793.4	3853.3	21.4 a	12.7 a	3.8 a
Reduced	20	712.5	741.5	1454.3	13.3 b	7.0 a	1.6 a
Dry-land	17	3.3	0	3.3	4.0 c	1.9 a	1.0 a

[a] The values in columns followed by the same letter were not significantly different at $P = 0.05$ according to Fisher's protected LSD test.
[b] The plots were classified in three groups depending on water consumption: High (2400–1800 m^3/ha), reduced (1400–500 m^3/ha), and dry-land (just rainfall).
[c] Accumulated consumption (m^3/ha) of years 2012 and 2013.
[d] Incidence was recorded in a rectangular plot chosen at random containing 100 trees.
[e] Incidence according to farmers.
[f] Mortality according to farmers.

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