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Frost tolerance of 24 olive cultivars and subsequent vegetative re-sprouting as indication of recovery ability

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ABSTRACT

The objective of the present study was to assess the frost tolerance of 24 olive cultivars after a freezing event that occurred in February 2012 in Marche Region (Central Italy), and their recovery ability during the following growing seasons (2012 and 2013). The studied cultivars were locally, nationally and internationally spread. Trees were three-year-old and in the rest phase at the time of the freezing event. Frost tolerance was determined by two damage visual scoring: defoliation and bark split, both defined three months after the event. During the following growing seasons, the recovery ability of the cultivars was also assessed throughout a third visual index describing the vegetative re-sprouting. Results indicated differences in frost tolerance and recovery ability among the studied cultivars. In particular, 'Arbequina' recorded the highest canopy defoliation together with 'FS17', 'Raggia' and 'Sargano di San Benedetto', whereas 'FS17', showed the highest level of bark split on primary branches and trunk. This cultivar also registered a strong vegetative re-sprouting, mainly from the basal portion of the trunk. On the contrary, 'Ascolana dura' and 'Orbetana' resulted the most frost tolerant cultivars and showed the best recovery ability in 2012 and 2013, with a re-sprouting activity from the 1- and 2-year-old shoots. The results suggest low frost tolerance for the tested varieties and supply helpful information for the selection of the most suitable ones for the set of new olive orchards in cold climates.

1. Introduction

Olive is an evergreen species that lacks a true dormancy and its cultivation is greatly impeded by the inability to survive temperatures below −12 °C, with severe leaf damage already occurring at −7 °C (Larcher, 2000). Fontanazza (1986) individuated a −10 °C temperature threshold for frost damage induction in olive, while Barranco et al. (2005) indicated − 8,6 °C as a lethal freezing temperature for sensitive cultivars tested in January. Ruiz et al. (2006) reported greater anatomical evidence of frost damages on 1-year-old shoots compared to bark of trunk or major branches, in olive trees exposed to cold, with freezing temperatures ranging from −6 to 0 °C.

Frost symptoms on the tree can range from shoot tip burns and defoliation up to bark split on branches or trunk in the case of intense injury (Gucci and Cantini, 2001). Such symptoms are frequently-used indices to evaluate the level of frost damage as indicated by Jacoboni (1985), Pezzarossa (1985), Tombesi (1986), Bini et al. (1987), Denney et al. (1993), Rotondi and Magli (1998).

Sanzani et al. (2012) reported a destructive frost on olive every 10–40 years in Italy and Gucci et al. (2003) reported that in 1907, 1929, 1956 and 1985 very low winter temperatures induced intense frost injuries to olive trees during the XX Century in Central Italy. The period of the year when freezing temperatures occur might influence plant tolerance: cold resistance in evergreen species is closely correlated with the hardening process which depends on cold acclimation in terms of exposure to a period of low but non-freezing temperatures that increases the ability to withstand the subsequent freezing temperatures (Palliotti and Bongi 1996; Travert et al., 1997; Mancuso, 2000).

Cansev et al. (2009) demonstrated that the pattern of exposure to frost could affect olive tree susceptibility since a programmed acclimation to cold produced an increase in frost tolerance in several cultivars. Nevertheless, de-acclimation process occurs in response to substantial increases in temperature, usually pro-

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gresses more rapidly that acclimation, and is associated with wide-ranging structural and functional changes associated with resumption of vegetative growth. Although typically occurring in the spring, de-acclimation may occur prematurely during winter in response to transient warm spells (Kalberer et al., 2006). In woody plants of mild climates including olive, cold hardiness can be rapidly lost after a short exposure to warmer temperatures (Kozlowski and Pallardy, 1997), also depending from the increase of photosynthetic activity and total soluble sugar (TSS) accumulation (Gulen et al., 2009), thus making plants particularly vulnerable in late winter when freezing event might take place after periods of relatively warm temperatures.

Several methods have been proposed for selecting frost tolerant genotypes in olive species, such as stomatal density (Roselli et al., 1989), photosynthetic activity (Antognozzi et al., 1990), stomatal size (Roselli and Venora, 1990), release of phenolic compounds (Roselli et al., 1992), differential thermal analysis (Fiorino and Mancuso, 2000), ionic leakage (La Porta et al., 1994) and electrochemical techniques combined with leaf fractal analysis (Azzarello et al., 2009).

The conclusions of the numerous analytic methods where generally confirmed by visual observations (Bartolozzi and Fontanazza, 1999). Furthermore, small portions of the plants do not always reflect the frost tolerance of the whole plant and the response of isolated tissues and cells to low temperature may differ in some respects with that known for the whole plant system, thus supporting the power of a whole plant approach to the analysis.

Fiorino and Mancuso (2000) studied the freezing temperatures of different organs in four Italian cultivars ('Ascolana tenera', 'Frantoio', 'Leccino' and 'Coratina') acclimated to cold and reported 'Ascolana tenera' and 'Coratina' to be the most and the least frost tolerant, respectively.

Alfei et al. (1999) studied the frost tolerance of 3-year-old trees of Italian local and nationally spread olive cultivars after a natural freezing event, and reported that 'Piantone di Mogliano' and 'Leccino' showed a high frost tolerance (low level of damage), while 'Canino' and 'Rosciola' resulted highly susceptible. Lodolini et al. (2014) did not confirm the high frost tolerance of 'Piantone di Mogliano' showing strong damages and no significant differences when compared to 'Oliva Grossa', 'Sargano di San Benedetto', 'Sarganella', 'Piantone di Falerone', 'Ascolana tenera' and 'Carboncella'.

Several studies successfully discriminated between frost-tolerant and frost-susceptible olive cultivars, though they have focused on a limited number of genotypes. In particular, local varieties of Center-North Italy, potentially greatly adapted to cold condition, had rarely been tested.

The use of the more tolerant olive cultivars together with the understanding of the mechanism of frost hardiness could represent the most effective methods to avoid frost damages. The objective of the present study was to evaluate 24 olive cultivars (20 of them locally spread) for the level of frost damage and recovery ability in terms of vegetative re-sprouting after a freezing event occurred in February 2012 in Marche Region (Central Italy).

2. Materials and methods

2.1. Study site

The study was carried out in a three-year-old experimental olive orchard (1.5 ha) located in Maiolati Spontini (latitude, 43°28′37″N; longitude, 13°07′09″E; altitude 405 m a.s.l.) in Central Italy with a planting density of 416 trees ha^{-1} (i.e. 6.0 m × 4.0 m arrays). Trees were trained as the central leader free canopy system and were regularly fertilized during spring and rain-fed from planting. The trees were coetaneous and homogeneous at October 2011 in terms

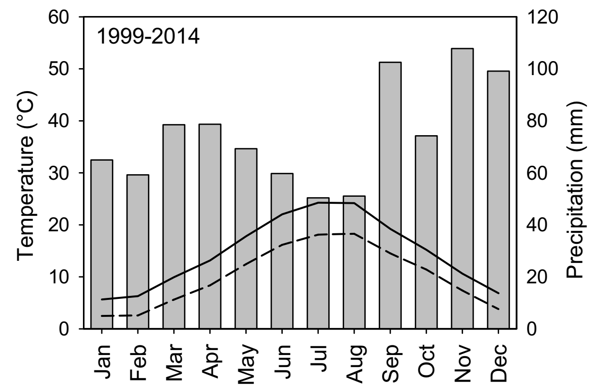

Fig. 1. Monthly average (solid line) and minimum (dotted line) air temperature and rainfall (columns) over a period of fifteen years (1999–2014) climatic records for the studied area (source: Centro Agrometeo ASSAM).

of trunk cross sectional area at 0.25 m height from the ground (2.5 ± 0.05 cm^2) and total tree height (1.8 ± 0.01 m). The orchard was arranged with one cultivar per row and each row was about 100 m long. Twenty-four cultivars ('Ascolana dura', 'Ascolana tenera', 'Capolga', 'Carboncella', 'Cornetta', 'Coroncina', 'Lea', 'Mignola', 'Mignolone', 'Nebbia del Menocchia', 'Oliva Grossa', 'Orbetana', 'Piantone di Falerone', 'Piantone di Mogliano', 'Raggia', 'Raggiola', 'Rosciola Colli Esini', 'Sarganella', 'Sargano di Fermo' and 'Sargano di San Benedetto' locally spread in Marche Region; 'FS17', 'Don Carlo' and 'Giulia', nationally distributed; and 'Arbequina' internationally spread) were assessed for their frost tolerance and recovery ability after the freezing event occurred in February 2012. At the time of the event, all the trees were in the rest phase, without any noticeable apical growth. Chilling units during the winter reached the 950 h, which in olive is barely enough to induce acclimation against cold (Bartolozzi and Fontanazza, 1999). The monthly precipitations and the average air temperatures of the studied area are reported in Fig. 1 according to climatic records referring to a period of fifteen years (1999–2014) (source: Centro Agrometeo ASSAM). The winter 2011–2012 showed ten days (from January 7th to 17th) with mild minimum temperatures (mean value of the decade of 6.5 °C), thus significantly higher than the historical monthly average minimum temperature of 2.6 °C in January. The relatively mild period was followed by a 12-days freezing event with a mean minimum temperature of −4.7 °C in the period included between February the 3rd and the 15th and an absolute minimum temperature of −6.4 °C on the 15th. Abundant snow events (cumulated precipitation of 200 mm) and strong and cold wind (wind gust speed up to 43 km/h) from northeast affected the considered area for the whole mentioned period.

2.2. Visual indicators

Three months after the freezing event, 20 trees per cultivar were selected in the central portion of each row and assessed throughout damage visual scoring.

Two visual indexes (Fig. 2) were used to evaluate the level of frost damage in terms of canopy defoliation ranging from 0 to 3 (0: no leaf drop, 1: <50%, 2: >50% and 3: totally defoliated) and bark split ranging from 0 to 4 (0: none, 1: only on 1-year-old shoots, 2: extended to 2- and 3-years-old branches, 3: extended to primary branches and 4: extended to the trunk) adapting the methodology reported by Ruiz Baena et al. (2007) and Alfei et al. (1999). After five months from the freezing event, the recovery ability of the studied cultivars in terms of vegetative re-sprouting was described on the same trees using a visual index ranging from 0 to 3 (0: only in the apical portion of the canopy, 1: in the 1- and 2-year-old shoots in