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Short communication. Harvest time in hedgerow 'Arbequina' olive orchards in areas with early frosts

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Abstract

The shortening of harvest time attained in hedgerow olive (*Olea europaea* L.) orchards represents an advantage for the adoption of this cropping system in areas that are prone to suffer frost during the harvest period. To establish an optimal harvesting window, we carried out a study of the fruit ripening process on a hedgerow orchard of 'Arbequina' olive trees, located in Zaragoza (Spain). From 2007 to 2009, oil accumulation on the fruit (% of dry weight) and oil yield (grams of oil per 100 fruits) were monitored, from early September to late November. Over the three years both variables peaked around November 15th, indicating that Arbequina reached full ripening earlier than has been reported previously for this variety. In two of the three seasons the orchard suffered several frosts during November. Long term climatic data from this area indicated that the risk of early frosts (<–2°C) increases as November progresses with a high risk after November 20th. In conclusion, the optimal harvesting period for Arbequina in this area should not extend beyond November 20th. A rapid harvesting before this date is advisable to avoid the risk of damage caused by early frost in Zaragoza. Hedgerow planting provides an additional advantage in frost-prone areas, because mechanization of operations permits a short harvest period, easier to fit into the optimal harvesting window.

Additional key words: harvest time; hedgerow orchard; Olea europaea L.; physiological maturity.

Resumen

Comunicación corta. Fecha de cosecha en plantaciones en seto de olivos de "Arbequina" en zonas con heladas precoces

El acortamiento del periodo de recolección que permiten las plantaciones de olivar (*Olea europaea* L.) en seto representa una ventaja para adoptar este sistema de plantación en áreas con heladas precoces durante el periodo de cosecha. Para establecer una ventana óptima de cosecha, llevamos a cabo un estudio de la maduración del fruto en una plantación en seto de 'Arbequina', localizada en Zaragoza (Aragón). De 2007 a 2009 se analizó la evolución del contenido en aceite en el fruto y la producción total de aceite, de primeros de septiembre a finales de noviembre. En los tres años ambos parámetros mostraron los valores máximos hacia el 15 de noviembre, indicando que Arbequina alcanza la madurez fisiológica antes de lo reportado hasta el momento. En dos de las tres campañas la plantación se vio afectada por fuertes heladas en noviembre. Datos climatológicos de la zona indican que el riesgo de heladas (<–2°C) aumenta según avanza noviembre, con un riesgo alto a partir del 20 de noviembre. En conclusión, el periodo apropiado de cosecha de Arbequina en esta zona no debería extenderse más allá del 20 de noviembre; una rápida recolección anterior a esa fecha limitará el riego de daños por heladas. El sistema de plantación en seto es el que mejor permite acortar la recolección. Y representará una ventaja añadida en zonas con heladas tempranas, al permitir ajustar más fácilmente el periodo de recolección a la ventana óptima de cosecha.

Palabras clave adicionales: madurez fisiológica; *Olea europaea* L.; olivar en seto; periodo de cosecha.

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In the early 1990s a new approach to growing olives (*Olea europaea* L.), that was based on very high density hedgerows (> 1,000 trees ha^{-1}) and intensive management techniques was developed in Catalonia (Spain). This new type of olive orchard is suited to fully mechanized harvesting, which represents one of its main advantages (Tous *et al*., 2008). Vineyard straddle-harvesting machines are used to collect the fruit. This harvesting system reduces drastically the labor need. And also, and more important, it affects directly the quality of oil produced, because harvest is significantly shortened. In fact, the high efficiency of this type of machinery allows harvesting more than 5 ha day^{-1} (de la Rosa *et al*., 2007). In few years, hedgerow olive orchards have been rapidly adopted in other Spanish regions, with special emphasis in Aragon, and other olive countries (León *et al*., 2007; Navarro & Parra, 2008).

Several studies have addressed issues associated with the hedgerow orchards in recent years. In particular, planting design (Connor, 2006; Gómez del Campo *et al*., 2009), planting density (León *et al*., 2007), water use efficiency (Orgaz *et al*., 2006; Iniesta *et al*., 2009) and cultivar choice (de la Rosa *et al*., 2007; Tous *et al*., 2008). However, many features of high-density olive orchards remain understood poorly. In relation to the ripening process of the olive fruit, intensively cultivated orchards appear to reach maturity earlier than is generally accepted for standard olive orchards (Beltrán *et al*., 2008). Oil accumulation on the fruit (% of dry weight) is influenced by environmental and agronomic conditions (Lavee & Wonder, 1991); and the final oil content is dependent on the interaction between genetic potential of the variety and the growing conditions (Lavee & Wodner, 2004). Therefore, it would be necessary to characterize the dynamics of the ripening process to establish the optimal harvesting period for this type of orchards.

The timing of harvest is a key factor that determines the yield and quality of olive oil (Mailer *et al*., 2007; Issaoui *et al*., 2008). Deciding on an optimal harvest date requires consideration of fruit ripening, in terms of maximum oil content, and other factors that may affect negatively oil yield and quality, such as the risk of early frost affecting the fruit.

Currently, Arbequina is the most widely planted variety in the new high-density orchards. In Aragón, most of the 11,200 ha of irrigated olive orchards (70% in the province of Zaragoza) are planted with Arbequina in high-density stands (Anuario Estadístico Agrario de Aragón, 2009). It is an early producing variety, with commercial yields 3 years after planting and has yearly good production (de la Rosa *et al*., 2007). In addition, oil produced from Arbequina olives has excellent quality characteristics (Vossen, 2007; Gracia *et al*., 2009).

We present the results of a study on the process of olive ripening in an experimental hedgerow orchard in Zaragoza. The aim was to determine the optimal harvest period, taking into account the effect of ripening on oil yield, and the risk of occurrence of early frost.

The study was carried out from 2007 to 2009 in a high-density orchard (4.0 m × 2.0 m, 1,250 trees ha^{-1}) of 'Arbequina I-18' olive trees, located at the Aula Dei Experimental Station, CSIC, Zaragoza, Spain (41°43' N, 0°48' W, 219 m altitude). The orchard was planted in 2002 in a north-south hedgerow orientation, with a buried drip irrigation system. Seasonal irrigation schedule was designed in accordance with the FAO method (Doorenbos & Pruitt, 1974). In the location of the orchard and in the years of the study, average yearly rainfall was 350 mm, and average mean, maximum and minimum temperatures were 14.2, 27.7 and 2.0°C, respectively. In 2007 and 2008 the orchard suffered several frosts during November.

The ripening of the olive fruit was monitored by sampling fruits twice a week from October to November in 2007, and from September to November in 2008 and 2009. The study design included two replicates, each with 180 trees in three rows. Samples consisted of 200 olives that were hand-picked from 12 trees per replicate (four trees per row). Samples were weighed to determine the fresh weight and were immediately processed with a hammer mill equipped with a 5-mm sieve. The paste obtained was used to determine the moisture and oil content with a type 78,800 OliveScan (FOSS, Denmark), using the rapid indirect near infrared (NIR) method (Gracia & Marco, 2010). Two NIR measurements were made per sample and the average was used. Regression analyses were performed to determine the influence of harvest date on the relative oil content (on dry weight basis) and estimated yield (grams of oil per 100 fruits).

The relative oil content on dry weight followed a similar pattern of accumulation over the three seasons (Fig. 1). More than 80% of the final oil content accumulated rapidly before mid-October, then tapering off until maturity. This accumulation model has been described previously (Mailer *et al*., 2007; Beltrán *et al*., 2008). In all three years maximum oil content was reached around November 15th, despite rainfall during the last part of the ripening period (October-November) was very different in 2007 (19.4 mm), 2008 (109.0 mm) and 2009

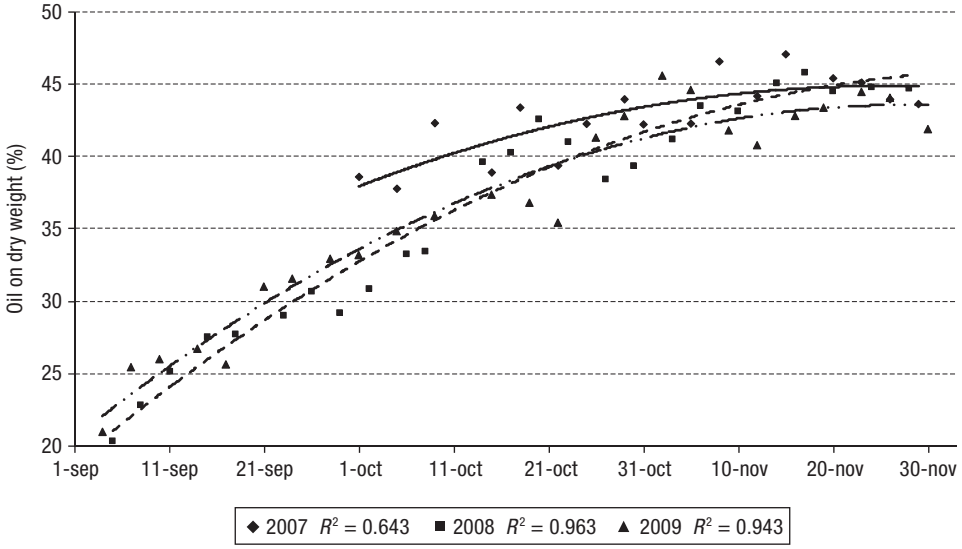

Figure 1. Relative oil content of Arbequina olives on the basis of dry weight during the ripening period in 2007, 2008 and 2009.

(44.2 mm). Peak fruit oil concentration has been proposed as an estimator of physiological maturity in olive (Ayton *et al*., 2001; Mickelbart & James, 2003). In this sense, Arbequina in this study reached full ripening earlier than has been reported previously for this variety in other regions (Gómez-Campo *et al*., 2009), or growing systems (Beltrán *et al.,* 2008). Differences in agronomic and climatic conditions might explain this discrepancy.

Oil yield per 100 fruits also showed a similar pattern across years (Fig. 2), peaking around November 15th. The differences in absolute values among years are derived from the smaller fruit size in high fruit yielding campaigns. So maximum oil yield per 100 fruits was attained in 2007 with a fruit yield of 4,200 kg ha^{-1}, it was intermediate in 2008 (6,800 kg ha^{-1}) and it was minimum in 2009 (10,100 kg ha^{-1}).

In November 2007 the orchard suffered several frosts in the range of –3°C and –9°C, starting November 11th (Fig. 2), which affected oil yield negatively. In November 2008 there were three frost days (from

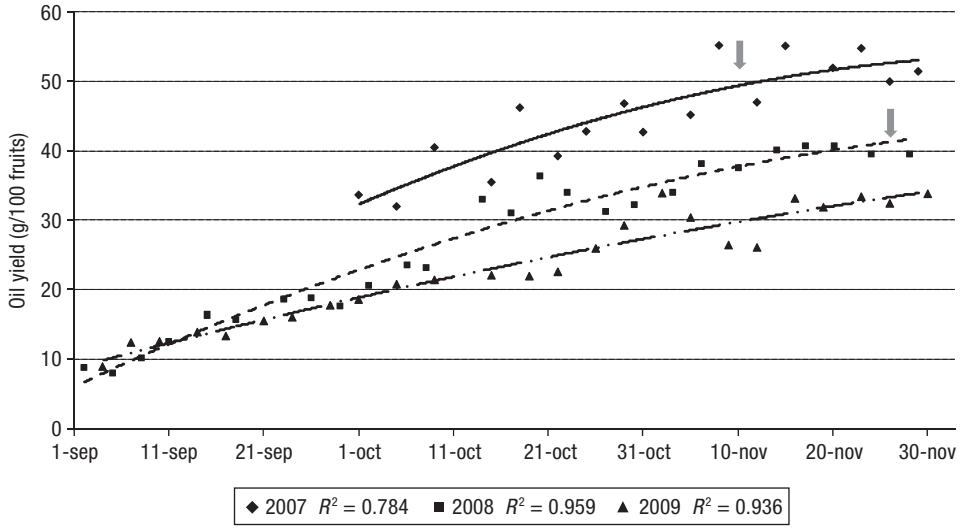

Figure 2. Yield of Arbequina olive oil (g/100 fruits) during the ripening period in 2007, 2008 and 2009. Arrows show the date of the first significant frost (< –2°C) in 2007 (November 11th) and 2008 (November 26th).

Table 1. Risk of frost below –2°C from November 1st to December 1st in the study area (period 1961-2008)

Date	Number of days with T_{min} < –2° C before date	Probability of frost < –2° C before date
November 15	2	4.2%
November 20	5	10.4%
November 25	11	22.9%
December 1	14	29.2%

26th to 28th) with minimum temperatures ranging from –2°C to –6°C. On the basis of climatic data from the study area, which were obtained over a period of 48 years (Table 1), it was found that the risk of early frosts (< –2°C) increases as November progresses with a high risk after November 20th.

In conclusion, November 20th appears to be an appropriate end for the harvesting period for hedgerow Arbequina olive orchards in the area. Harvest beginning will derivate from machinery availability and the surface to be managed. Hedgerow planting provides an additional advantage in frost-prone areas, because mechanization of operations permits a short harvest period, easier to fit into the optimal harvesting window.

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