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Sprouts seasonal elongation of two olive cultivars in a high-density orchard

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ABSTRACT

The new high-density cropping systems (>1200 trees ha^{-1}) represent a very interesting proposal for olive orchard profitability. It is crucial to know the morphology and the dynamics of sprout elongation of a cultivar in order to fully assess its suitability for a high-density olive orchard. For this reason we planned a research on two cultivars, Coratina and Arbequina, in a high-density orchard. The apical sprouts elongation of Arbequina early stopped at fruit set without a further step, while Coratina showed a little growth flux after pit hardening. Similar trends showed the lateral proleptic sprouts. Only the sylleptic sprouts of both cultivars had a second period of activity. In all cases, the sprouts elongation finished at the end of summer, when oil accumulation started. Coratina showed higher apical shoot growth and internodes mean length than Arbequina. On the contrary, Coratina showed lower lateral proleptic shoot growth and nodes number than Arbequina, but the same internodes mean length. No significant differences were observed between cultivars for growth, nodes number and internodes mean length of sylleptic shoots. The differences observed between the two cultivars could be explained considering their different vigour. The introduction of this innovative cropping system is allowed to register a considerable reduction of production costs. The result is a considerable increase in the economic performance of the olive grove and a consequent reduction in the unit cost for kg of oil. These data are very useful for varietal choice and field management in high-density orchards and then for new olive breeding programs.

Keywords: Arbequina; Coratina; Proleptic Axis; Sylleptic Axis; Growth Flux

1. INTRODUCTION

Today the millennial olive tree cultivation all over the world can be defined in a change of epoch: it tends quickly to move from traditional low-density (<200 trees per hectare) to modern medium-density cropping systems (300 - 400 trees per hectare) and overall to new high-density cropping systems (>1200 trees per hectare), which represent a very interesting proposal for olive orchard profitability [1]. The high-density cropping systems are characterized by strong reduction of production costs thanks to total mechanization, from planting to harvesting [2]. Cost reduction allows you to make new competitive companies with production facilities archaic. The improvement of productivity is fundamental in contexts that are now confronted with major international challenges, and the cost containment is essential for the survival of the farm. This cost reduction must then necessarily be accompanied by sustainable production policies as now required from Europe and from the market [3].

The high-density cropping systems are based on early bearing (3rd year from planting), yield stabilization starting from 5th - 6th years from planting (8 - 10 t per hectare per year) with very negligible alternate bearing and continuous harvesting [1,4].

Several physiological and agronomic aspects are already started to be studied for high-density olive orchards: light interception [5], soil management [6], irrigation [7, 8], harvesting time [9]. Moreover, in the literature some vegetative and productive parameters are considered in order to assess the varietal response since considerable differences are observed among different cultivars, mainly depending on both growth habit and vigour [1,2,4, 10]. In fact the benefit of these new systems mainly depends on the availability of cultivars with compact habit and slow canopy growth, owned by Arbequina and Arbosana, two Spanish cultivars on which these systems were calibrated up to now [2]. It is crucial to know the morphology and the dynamics of sprout elongation of an olive cultivated genotype in order to fully assess its suitability for a high-density olive orchard. The first one to define and introduce the study of plant morphology was Goethe, the famous German writer [11]. It has long been accepted that the plants are modular organisms that develop through repetition of elementary botanical entity, continually subject to change during ontogeny [12]. The study of the plant architecture has been developed as a new scientific discipline about 40 years ago, coming from the earlier works on plant morphology [13]. At first, plant architecture investigations have focused on canopy analysis of the tropical species [14]; then these concepts were applied on temperate forestry tree species [15,16] and only more recently on fruit tree species, such as apple [17], apricot [18], and peach [19]. Although the architecture of some plants consists in single vegetative axis, most of the tree species show a more complex architectture, composed of several axes (sprouts, shoots, branches) one derived from the other by means of a repetitive process known as branching [20]. In particular, according to the time of woody bud breaking on the shoot, two types of axis can be distinguished: proleptic if they come from resting buds and sylleptic if they derive from steady buds [21]. Analysis of shoots vegetative growth and modelling growth dynamics of olive tree (*Olea europaea* L. var. *sativa* Hoffm. and Lk.) is very recent, but made in arid areas under low and very-low densities and rainfed cropping systems [22,23]. Considering that sprouts are the fundamental units for both yield load and vegetative growth of an olive tree [24], the aim of our research was to study the seasonal elongation of all types of sprouts (apical, lateral proleptic and sylleptic) on a olive shoot in order to highlight different varietal behaviours under high-density irrigated conditions.

2. MATERIALS AND METHODS

The study was carried out in the olive grove located at the experimental farm of the Department of Agricultural and Environmental Sciences at Valenzano (Bari, Southern Italy—41˚01'N; 16˚45'E; 110 m a.s.l.), on a sandy clay soil (sand, 630 g·kg^{-1}; silt, 160 g·kg^{-1}; clay, 210 g·kg^{-1}) classified as a Typic Haploxeralf (USDA) or Chromi-Cutanic Luvisol (FAO). The site is characterised by a typical Mediterranean climate, with a long-term average annual rainfall of 560 mm, two third concentrated from autumn to winter, and a long-term average annual temperature of 15.6˚C. The olive grove has been planted in 2006 with self-rooted plants; the trees were trained according to the central leader system and spaced 4.0 m × 1.5 m (1667 trees ha^{-1}) with a North-South rows orientation, according to the Spanish high-density cropping system. Props, drip irrigation and routine cultural practices (nutrition, pruning, disease control) were set up as already described [1,4]. The study was conducted on two cultivars: Arbequina, on which the high-density system was calibrated, and Coratina, the most important traditional Apulian olive cultivated variety [25]. The measurements were carried out in 2009, 2010 and 2011, respectively at 5th, 6th and 7th years after plantation. A randomized block experimental design was adopted: for each cultivar the measurements have been replicated on 3 blocks of 3 plants and the observations were carried out on all plants of each block. Before woody bud breaking, two healthy well light-exposed shoots per tree (E-W) were labelled (18 shoots per cultivar) in the middle part of the crown. The shoots were homogeneous, with 25 - 30 cm in length and 15 - 20 nodes as mean. After woody buds breaking, the length of the sprouts issued by the apical bud and by lateral buds, both proleptic and sylleptic, and the nodes number were measured fortnightly on each labelled shoot. At the end of the vegetative season, the total length and the total nodes number of the new shoots on each labelled shoot were determined. In this work we did not separate sylleptic sprouts coming from the apical or the lateral sprouts.

For each cultivar seasonal data were statistically treated by one-way analysis of variance (ANOVA) followed by post hoc testing (Tukey post hoc test) using the R 2.15.0 software (R Foundation for Statistical Computing); standard error (SE) was also calculated. For detect statistical differences between the two cultivars at each measurement time t test was adopted.

3. RESULTS AND DISCUSSION

3.1. Apical Sprouts Elongation

In all years, apical woody buds expanding began in the early spring (80 - 90 DOY), while lateral proleptic and sylleptic buds breaking started few weeks after (110 - 120 DOY), just before full blooming (130 - 140 DOY), without any difference between the cultivars (**Figures 1**-**3**). A general model of olive tree sprouts elongation provides for two periods of activity: the major one occurs during spring before blooming and the second one, less important, occurs during early autumn separated by a summer rest [26]. Our data differ from this general model and statistical differences among sprouts type and between cultivars were observed. Indeed the apical sprouts elongation of Arbequina early stopped at fruit set (150 - 160 DOY) without a further step, while Coratina showed a little growth flux after pit hardening (190 - 230 DOY) better following the general model (**Figure 1**).

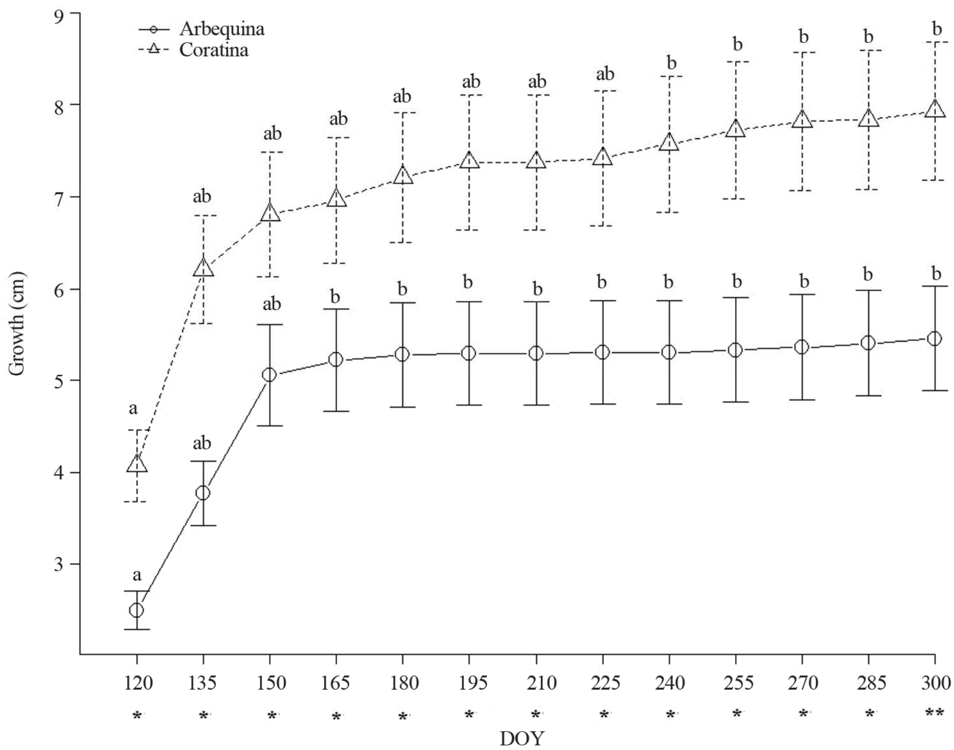

Figure 1. Seasonal growth trend of apical sprouts of the Arbequina and Coratina cultivars (2009-2011 mean values, ± SE $p \le 0.01$ $n = 54$). The letters denote statistical differences among different times within each cultivar (Tukey test, $p \le 0.05$). The symbols on the x-axis denote statistical differences between the cultivars at each time (t test, $^{**}p \le 0.01$, $^{*}p \le 0.05$).

3.2. Lateral Sprouts Elongation

Similar trends showed the lateral proleptic sprouts (**Figure 2**). Only the sylleptic sprouts of Arbequina and Coratina had a second period of activity (**Figure 3**). In all cases, the sprouts elongation finished at the end of summer (255 DOY) when oil accumulation started. Indeed during this last period, when daily temperatures decrease, there is a strong competition between the nutritional resources allocated to the vegetative organs and those ones allocated to fruits [27,28]. In the high-density orchard no sprouts elongation was ever observed in autumn: it disagree with what commonly reported in more arid Mediterranean climate especially for medium- low densities cropping systems [22,23].

3.3. Shoots Growth

In **Table 1** growth, nodes number and internodes mean length of apical, lateral proleptic and sylleptic shoots of the Arbequina and Coratina cultivars at the end of vegetative season (300 DOY) are reported. Coratina showed higher apical shoot growth and internodes mean length than Arbequina (8.0 cm vs 5.5 cm and 13.3 mm vs 10.0 mm, respectively), but the same nodes number (5.5 - 6.0). On the contrary, Coratina showed lower lateral proleptic shoot growth and nodes number than Arbequina (3.4 cm vs 4.4 cm and 3.1 vs 4.1, respectively), but the same internodes mean length (11 mm). No significant differ-

Table 1. Growth, nodes number and internodes mean length of apical, lateral proleptic and sylleptic shoots of the Arbequina and Coratina cultivars at the end of vegetative season (2009-2011 mean values, ± standard error; t test, $^{**}p \le 0.01$, $^{*}p \le 0.05$, n.s. = not significant).

	cv. Arbequina	cv. Coratina	t test
Apical			
Growth (cm)	5.5 ± 0.6	8.0 ± 0.8	**
Nodes (n)	5.5 ± 0.5	6.0 ± 0.4	n.s.
Internodes mean length (mm)	10.0 ± 0.1	13.3 ± 0.7	**
Lateral proleptic			
Growth (cm)	4.4 ± 0.4	3.4 ± 0.4	*
Nodes (n)	4.1 ± 0.3	3.1 ± 0.2	**
Internodes mean length (mm)	10.7 ± 2	11.0 ± 2	n.s.
Lateral sylleptic			
Growth (cm)	4.0 ± 0.5	4.0 ± 0.7	n.s.
Nodes (n)	3.6 ± 0.4	3.1 ± 0.4	n.s.
Internodes mean length (mm)	11.0 ± 3	12.9 ± 5	n.s.

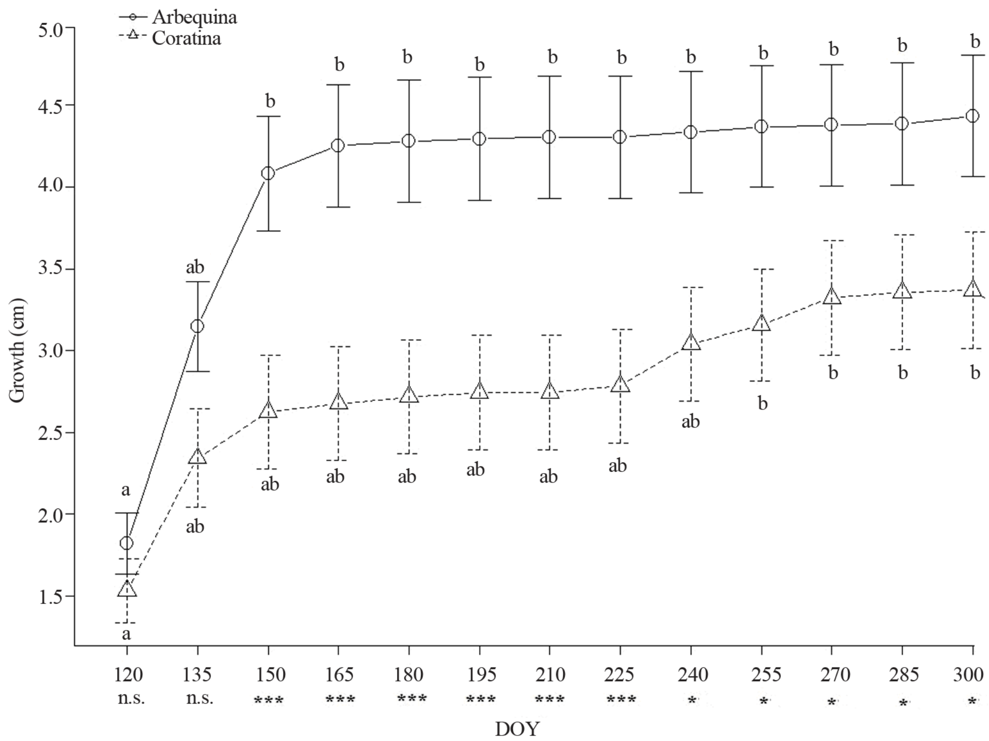

Figure 2. Seasonal growth trend of lateral proleptic sprouts of the Arbequina and Coratina cultivars (2009-2011 mean values, ± SE $p \leq 0.01$ $n = 54$). The letters denote statistical differences among different times within each cultivar (Tukey test, $p \leq 0.05$). The symbols on the x-axis denote statistical differences between the cultivars at each time (t test, $^{***}p \leq 0.001$, $^{*}p \leq 0.05$, n.s. = not significant).

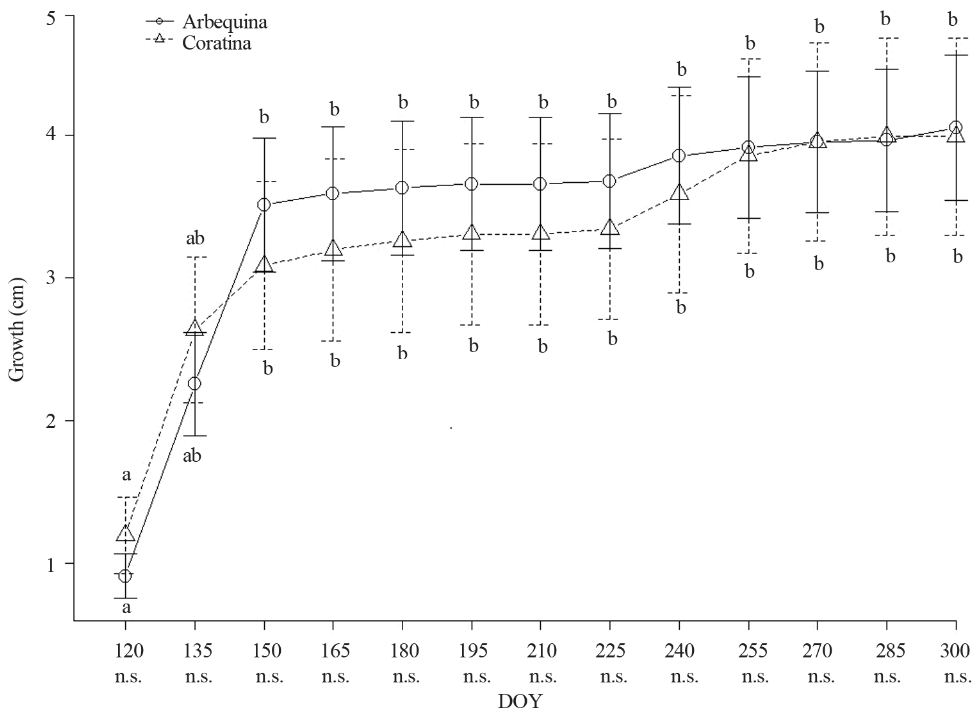

Figure 3. Seasonal growth trend of sylleptic sprouts of the Arbequina and Coratina cultivars (2009-2011 mean values, ± SE $p \leq 0.01$ $n = 54$). The letters denote statistical differences among different times within each cultivar (Tukey test, $p \leq 0.05$). The symbols on the x-axis denote statistical differences between the cultivars at each time (t test, n.s. = not significant).

ences were observed between Coratina and Arbequina for growth, nodes number and internodes mean length of sylleptic shoots (4.0 cm, 3.1 - 3.6, 12.9 - 11.5 mm, respectively).

As shoot development was the result of the two complementary phases, known as organogenesis and distension [29], consequently in the climatic and cultural conditions under study these phases should be in general concentrated and sped up in spring, particularly for the cv. Arbequina.

At all measurement times, Coratina showed ever significant higher apical sprouts growth values with respect to those ones of Arbequina (**Figure 1**). On the contrary, Arbequina showed significant higher lateral proleptic sprouts elongations with respect to those ones of Coratina, except for the first two times (**Figure 2**). Finally, no different sylleptic sprouts growth values were observed between the cultivars at all measurement times (**Figure 3**).

The differences observed between the two cultivars could be explained considering their different vigour, already stated in the literature: Coratina is a cultivated variety with a medium vigour, while Arbequina is a low-vigour genotype [1,2,4].

4. CONCLUSION

These are the first data on seasonal elongation of all types of sprouts (apical, lateral proleptic and sylleptic) on an olive shoot under high-density irrigated conditions. The introduction of this innovative cropping system allows a considerable reduction of production costs. In traditional olive groves most of the production costs are definitely linked to the farming operations carried out manually. These operations are fully removed in this context as performed by continuous machines responseble for the management of the olive. The result is a considerable increase in the economic performance of the olive grove and a consequent reduction in the unit cost for kg of oil [30]. These data are very useful first of all for varietal choice and field management, such as fertilization and pruning not only in high-density orchards, and then for new olive breeding programs.

5. AKNOWLEDGEMENTS

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