Training Initiation Date Affects Height of Nursery Olive Trees

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ADDITIONAL INDEX WORDS. **propagation, pruning, single-shoot, forced growth.**

SUMMARY. An experiment was carried out to determine when to initiate training potted rooted cuttings of olive (*Olea europaea* L.), so that tall and well developed nursery trees could be produced in an 8-month growing season. Initiating training to single shoot when average height of tallest shoots was 38 cm (15.0 inches) produced 1-m (3.28-ft) tall nursery trees in 7.5 months, with training restricted to the last 2.5 months. Taller plants [1.17 m (3.84 ft)] and some lateral shoots growing above 1 m were produced following another 0.5 month of growth. Five training months were needed to produce 1.43-m (4.69-ft) trees if training was initiated when main shoots were only 16 cm (6.3 inches). Initiating training at the beginning of the growing season did not produce significantly taller trees. Untrained plants only reached a height of 69 cm (27.2 inches) at the end of the test period.

Weak apical dominance of the olive (*Olea europaea*) allows lateral buds to develop at the shoot base. Basal lateral shoots then become strong sinks for assimilates and grow rapidly, eventually becoming thicker and taller than the shoots from which they originated. Nursery olive trees develop as bushes, unless these basal lateral shoots are removed (Caballero and del Río, 1997).

This natural growth pattern is a serious constraint for nurseries pro-

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To Ignacio Lorite, for his assistance in propagating and training plants. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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ducing 1-m (3.28-ft) tall single-shoot trees with no lateral shoots below that height. A tall, single-shoot nursery tree is preferred to a shorter one because it has a good root system and needs less training to establish its canopy at 90 to 100 cm (35.4 to 39.4 inches) above soil level (Caballero and del Río, 1997; García-Ortiz et al., 1997; Sibbett and Osgood, 1994). Training this tree in the orchard consists of letting its canopy grow unrestricted for 3 to 4 years, then confirming the main scaffold branches and removing those falling to ground from either the trunk or the main branches. Some shoot thinning also may be needed inside the canopy at that time and for some more years. In this way the tree is trained to support heavy crops and to be suitable for mechanical harvest by a trunk shaker. This limited training during the first few years in the orchard results in rapid growth and early production, at lower pruning costs than when planting shorter nursery trees (García-Ortiz et al., 1997).

A recent paper reviewed factors affecting the rooting of olive softwood cuttings under mist (Caballero and del Río, 1997). However, less attention has been paid to determine how to grow rooted cuttings in the nursery (Preziosi and Tini, 1990; Tattini et al., 1990a, 1990b). So, most olive nurseries plant those rooted cuttings in plastic bags of ≈ 3 L (0.79 gal) capacity filled with silty-sand soils, complemented with soil and/or foliar fertilizers. In this way a single-shoot tree, 60 to 80 cm (23.6 to 31.5 inches) tall is produced in 1 year (Fontanazza, 1984; Preziosi and Tini, 1990; Sutter, 1994). For taller trees a second growing season is needed (Preziosi and Tini, 1990; Sibbett and Osgood, 1994). The training procedure for these plants usually consists of eliminating all but one of the shoots that grow from the rooted cutting. At all times, lateral shoots are removed from this single-shoot tree, except those developing at its upper one third (Caballero and del Río, 1997). However, no experimental data are available about when to initiate training.

Our objective was to determine the height of main shoot at which to initiate the training of potted plants in the nursery, so that a saleable, tall olive nursery tree could be obtained in a single growing season without excessive pruning costs.

Materials and methods

'Picual' olive was used for the experiment because it is the most important cultivar in Spain, where it is grown on $\approx 650,000$ ha (1.6 million acres). It is also among the most used in some of the countries where olive-growing acreage has increased in recent years. It is easy-to-root, productive, has good fruit size and oil yield, and is easy-to-harvest (Barranco and Rallo, 1984; del Río et al., 1986; Nahlawi et al., 1975). 'Picual' softwood cuttings 14 cm (5.5 inches) tall were rooted under mist and potted into 9×11 -cm (3.5×4.3 -inch) peat pots containing a 1:1 (v/v) mixture of alkaline peatmoss (Floragard GmbH, D-26135 Oldenburg, Germany) and silty sand. Those rooted cuttings then grew in the same greenhouse for ≈ 10 d, until at least one lateral shoot per plant had grown 2 to 3 cm (1 inch) (Caballero and del Río, 1997).

After this hardening period those rooted cuttings were planted into 3-L plastic bags of black polyethylene filled with the medium described above and grown in a greenhouse from November 1996 until the beginning of March 1997, when they were transferred to a lathhouse to continue growing until July of that year. To simulate spring growing conditions, the greenhouse was provided with a 14-h photoperiod by means of high pressure halogen lamps of $2000 \text{ mmol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ (1000 w), whose height above the plants was changed with time so that upper leaves would receive light intensity of 400 to $500 \text{ mmol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$. A temperature range of 14 to 28°C (57 to 82°F) was used in the same greenhouse. In the lathhouse temperature ranged from 15 to 18°C (59 to 64°F) to 25 to 28°C (77 to 82°F) from March through May, and to 28 to 32°C (82 to 90°F) during June and July. Thus, plants were grown for 8 months under conditions similar to those occurring during the normal local growing season of March through October. Once a week each plant was irrigated with 400 mL (13.5 fl oz) of water. Every 2 weeks a commercial fertilizer, Hakaphos 15N-11P-15K (BASF Española SA, Barcelona, Spain), and Fe as Fe-EDDHA (Esantrene

HP, Massó SA, E-08029 Barcelona, Spain), were added to the water, at rates of $1 \text{ g} \cdot \text{L}^{-1}$ (0.13 oz/gal) and $0.94 \text{ mg} \cdot \text{L}^{-1}$ (1.25×10^{-4} oz/gal), respectively.

The experiment was designed as a randomized block with four training treatments, replicated 18 times. One rooted cutting was used per replicate and treatment. Training plants to single shoot by eliminating all but the main shoot was initiated at four different dates (treatments): 0, 3, 5, and 8 months after the initiation of the experimental growing season. This last treatment (8 months) was the control which was left unpruned until the conclusion of the experiment.

Height of selected shoot, and number, length and dry mass of lateral shoots removed were recorded when treatments were initiated. Following treatment initiation, training was the same for all treatments: the selected shoot was kept bare by removing all growing lateral shoots every 15 d, until the selected shoot reached 1 m (3.28 ft). Each shoot was kept vertical by staking. Shoot height was recorded every month. Average pruning time was recorded for each treatment every time training was performed. Laterals

Fig. 1. Influence of training initiation date (after 0, 3, 5, and 8 months of growth) on height of olive nursery trees. Within each date different letters indicate significant differences ($P = 0.05$) among treatments according to Tukey's test ($2.54 \text{ cm} = 1.0 \text{ inch}$).

Table 1. Number, length and dry mass of lateral shoots of nursery olive trees at the time of initiation training to single shoot (25.4 mm = 1.0 inch; 28.35 g = 1.0 oz).

Training date ^y	Lateral shoots ^z		
	Number	Length (cm)	Dry mass (g)
0	4.0 a ^x	2.9 c	0.4 d
3	5.8 a	5.6 c	2.3 c
5	4.7 a	26.8 b	7.2 b
8	4.2 a	46.0 a	21.7 a

^zMean of 18 plants.^yMonths since beginning of test period.^xWithin each column different letters indicate significant differences ($P = 0.05$) among treatments, according to Tukey's test.

developing above 1 m on the selected shoot were allowed to grow.

Shoot diameter at 25 cm (9.8 inches) height was measured in every plant at the end of the experiment. Dry mass distribution was then determined by separately drying roots and shoots of each plant during 48 h in a forced-air oven at 80 °C (176 °F).

Results and discussion

Ultimate height of olive nursery trees was affected by the date of training initiation (Fig. 1). In the 8-month growing period used, trees did not differ significantly in final height if the elimination of all but the main shoot was done at the beginning of growing season or following 3 months of growth, when average height of these tallest shoots was 4 cm (1.6 inch) or 16 cm (6.3 inches), respectively. If training was initiated following 5 months of growth, when main shoots were 38 cm (15.0 inches) tall, final plant height was significantly shorter. Trained plants attained the desired 1 m height following either 6, 6.5, or 7.5 months of growth, and needed 6, 3.5, or 2.5 months of training, respectively. Lateral shoots had developed above 1 m in all trained trees. Untrained trees grew as bushes consisting of several

shoots, the tallest reaching only 69 cm (27.2 inches) at the end of the test.

Length and dry mass of eliminated lateral shoots increased as the date of initiating training was delayed (Table 1). On the other hand, by test period end, dry mass accumulation in the selected shoot decreased with that delay; and root dry mass was larger for unpruned trees than for those whose training initiation date was after 3 and 5 months of growth, while those trained since beginning of growing season occupied an intermediate position (Table 2). These results confirm that all growing shoots act as metabolic sinks for available assimilates and show that pruned trees have a total and shoot dry mass larger than unpruned ones. Moreover, trained trees did not differ significantly in root dry mass and shoot diameter (Table 2). Therefore, to advance training initiation date would not diminish quality of resulting nursery tree.

Average number of eliminated shoots per plant was similar for all training initiation dates (Table 1). This result explains that the first training operation always took 5 min per plant; the length of the eliminated shoots did not affect pruning time. Until trees reached 1 m high, 3 more min per

plant were used every 15 d to eliminate new laterals. So, total training required 41, 26, and 20 min per plant for the 0, 3, and 5 month training treatments, respectively. Thus, delaying the initiation of training resulted in savings in training time and, therefore, in plant production cost.

Taking into account the recorded growth and the training times used, the best date to initiate training of nursery olive trees is when the average height of the tallest shoots is 38 cm (15.0 inches), following ≈5 months of growth. This practice produced 1-m tall trees in just 7.5 months, with training restricted to the last 2.5 months. This height is considered the minimum for planting an olive tree, mainly because it avoids most training in the orchard (Caballero and del Río, 1997; García-Ortiz et al., 1997). Additional height [up to 1.17 m (3.84 ft)] was attained by letting plants grow in the nursery for another 0.5 month. This also allowed for lateral branching above 1 m, thus constituting even better quality trees as the future main scaffold branches are already growing when the tree is planted.

If plant growth is anticipated to be reduced due to a shorter growing season, the time required to produce 1-m tall plants can be reduced 1 month by initiating training when their main shoots are 16 cm (6.3 inches) height, following ≈3 months of unrestricted growth. To initiate training at the beginning of the growing season does not provide any significant advantage in tree height, but increases production costs because of the need to remove lateral shoots during 3 more months.

This work shows that training initiation date is a key factor in producing nursery olive trees in a normal 8-month growing season. The possibility of attaining good, marketable tree size by midfall, following one growing season, is very convenient for most olive nurseries, which root softwood cuttings during the previous fall and early winter.

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Table 2. Shoot diameter and dry mass distribution of nursery olive trees following 8 months of growth (25.4 mm = 1.0 inch; 28.35 g = 1.0 oz).

Training date ^y	Shoot diam (mm) ^x	Dry mass (g) ^z	
		Shoot	Roots
0	5.4 a ^w	33.6 a	4.3 ab
3	4.6 a	25.5 b	3.5 b
5	4.5 a	18.3 bc	3.4 b
8	4.3 a	9.7 c	7.5 a

^zMean of 9 plants.^yMonths since beginning of test period.^xMean of 18 plants.^wWithin each column different letters indicate significant differences ($P = 0.05$) among treatments, according to Tukey's test.

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