



Effect of Rejuvenation Pruning on the Vegetative Growth and Productivity in Olive under Hot and Arid Environment of Mexico

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Authors' contributions

This work was carried out in collaboration among all authors. Authors RLGC, RMD and ALC designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors RLGC and FNR managed the analyses of the study and the literature searches. Authors FRC and RLGC wrote and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Currently in Mexico there are few studies on agronomic management in olive production. The objective of this experiment was to evaluate three rejuvenation pruning intensities (25, 33, 50% and Control "traditional pruning") in olive tree cv Manzanilla under hot and arid environment of Mexico. The experiment was carried out during four consecutive years from 2016 to 2019 at National Research Institute for Forestry, Agriculture and Livestock (INIFAP) in the Experimental Station Coast of Hermosillo, Sonora, Mexico. The experiment was carried out on 25-year-old olive orchard cultivar Manzanilla, planted at distance of 8 x 8 m (156 trees ha⁻¹) and under surface

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irrigation. The variables evaluated were: vegetative parameters (wood weight, canopy diameter and plant height), olive yield and fruit characteristics (fruit weight and pulp-pit ratio). The experiment was organized as a randomized complete block design with five replications. Our results showed statistical differences ($P < 0.01$) in all parameters evaluated with exception of fruit characteristics. During the rejuvenation process of the olive tree the treatment that obtained the higher yield was pruning with 25% intensity removing one trunk per year, which obtained an average yield in four years of $39.2 \text{ kg tree}^{-1}$, while in the control treatment the yield was of $34.1 \text{ kg tree}^{-1}$. Thus, it is possible to rejuvenate an olive orchard in four years without to affect olive yield.

Keywords: Canopy control; *Olea europaea* L; olive yield; rejuvenation pruning.

1. INTRODUCTION

The olive (*Olea europaea* L.) was native to Asia Minor and spread from Iran, Syria and Palestine to rest of the Mediterranean basin 6000 years old. It is among the oldest cultivated trees in the world [1]. Currently, olive cultivation is associated with several countries of the Mediterranean Sea basin and plays an important role in the diets, economies and cultures of the region. However, olive production has extended beyond this region to South and North America, South of Africa and Australia. The olive is considered as dry climate crop, capable of sustaining long periods of water deficit and with a moderate tolerance to saline soils, because of which it has been successfully cultivated in saline soils where other fruit trees cannot grow [2,3].

Commercial production of olive tree in the world is between 30° and 45° North and South latitude. The production of olive in the world reaches an annual average of about 12 million tons of olive of which 90% is dedicated to obtain oil and only 10% is consumed processed for table olive. The major olive oil producing country is Spain with 30% and together with Italy, Greece and Turkey produce about 90% of world production [4]. The trend of consumption of olive oil in the world has increased to 97% in the last 20 years [5].

In Mexico the acreage planted with olive trees in the year 2018 was 7406 hectares of which about 72% are in production. National production of olive in this year was low only 10698 tons due climatic problems, such as lack of winter cold and high temperatures during the flowering ($> 34^\circ\text{C}$). The production value was of 7.8 millions of dollars [6]. On the other hand, it is estimated that around 40% of olive production is destined for table olive and the majority was exported to the United States as fresh fruit being Manzanilla and Mission the main cultivars [7].

In Northwestern Mexico, the 30% of olive orchard are very old (>20 years) and are planted in fertile soil and under irrigation. The last practice causes a vigorous vegetative growth, and very tall trees that gradually produce a large amount of wood, and a reduced low leaves/wood ratio, leading to yield reduction, fruit quality degradation, higher harvest cost and an intensive alternate bearing. A viable alternative to solve this problem is the rejuvenation pruning [8,9,10].

There are several types of rejuvenation pruning depending on the problem to be solved. The standard practice is to spread the process out over three years, removing one third of the three at a times [9]. An advantage of this method is that it does not stop producing, the initial cost of pruning is minor and very important is that there is a notable reduction in the emission of shoots along limb and cut after pruning [10,11,12].

Currently, in Mexico there are few studies on agronomic management in olive production and the acreage has not been increased despite the proximity with United States which is the main importer of olive in the world [13]. A limiting factor in the low productivity of the olive tree is the presence of old orchards with shading problems that cause low fruit set, olive fruit with minor quality, low yield and high labor cost at harvest. The present study had the objective to evaluate the different pruning intensities in olive tree cv Manzanilla under hot and arid environment of Mexico.

2. MATERIALS AND METHODS

2.1 Description of Experimental Site

The experiment was carried out during four consecutive years from 2016 to 2019 at National Research Institute for Forestry, Agriculture and Livestock (INIFAP) in the Experimental Station Coast of Hermosillo, Sonora, Mexico ($30^\circ 42' 55''$ N, $112^\circ 21' 28''$ W and 200 meters above sea

level (masl). The annual evaporation ranges from 2400 to 2700 mm. Annual mean temperature is 22°C, being January, the coldest month and July is the month with the higher temperature with 40.2°C. Chilling hours recorded during last 10 years of 276 hours according to Damotta method [14]. The soil was sandy with pH 7.96 and electrical conductivity of 1.22 dS m⁻¹.

2.2 Treatment Applied and Orchard Management

This experiment was organized as a randomized complete block design with five replications, where one tree corresponded to an experimental unit. Different rejuvenation pruning intensity strategies on olive trees were tested having a total of four treatments or pruning (25, 33, 50% and “traditional pruning” as control). Control treatment was the elimination of damaged and crossed dry branches. In the first year central

trunk was removed in all treatments. The trunks were pruned to a height of 1.2 m using a chainsaw and covering the cut with tree seal product. The rejuvenation pruning was carried out during the months of October to December in each year (Fig. 1).

The experiment was carried out on olive orchard cultivar Manzanilla of 25 years old, planted at a spacing of 8 x 8 m (having 156 trees ha⁻¹) and under surface irrigation. The annual volume of water applied was 1.4 m on average for each year. In each year, orchard olive was fertilized with Triple15 at rate of 2 kg per tree (312 kg ha⁻¹) during February and with ammonium nitrate (150 kg ha⁻¹) during the postharvest period. The olive harvest was done manually during first week October. Other agronomic practices were done in accordance to commercial recommendations [15]. The harvest was done in mid-August manually.

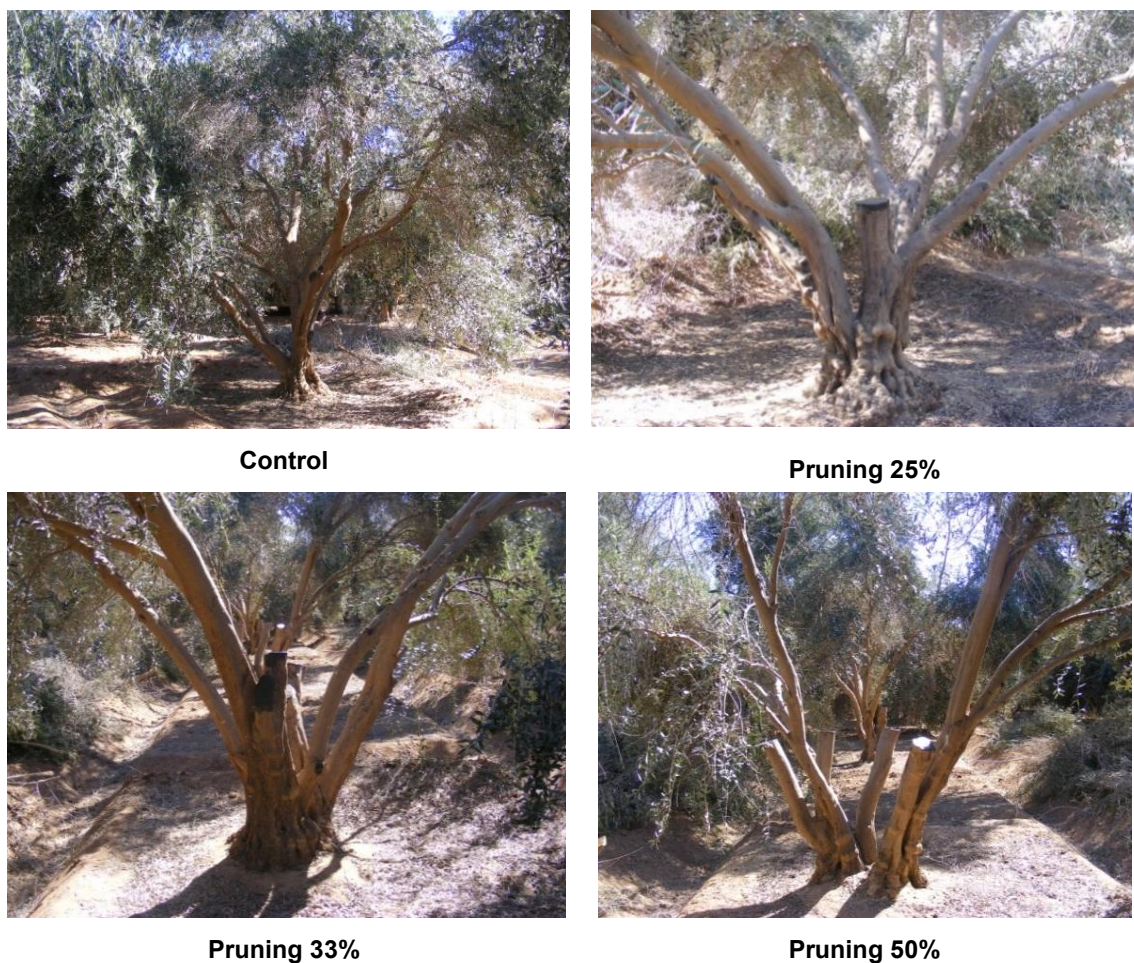


Fig. 1. Different rejuvenation pruning tested in olive cultivar Manzanilla

2.3 Measurement Variables

The following measurements were taken: i) pruned wood weight (kg tree^{-1}) was recorded each year; ii) number of new shoots growth, counted from the pruning cut to ground level. This variable was recorded only on July 26, 2016; iii) canopy diameter (m); iv) plant height (m). Canopy and tree height was measured using wood ruler and was recorded on November 15, 2019; v) yield (kg tree^{-1}) and fruit characteristics (fruit weight and pulp-pit relation) were evaluated taking a random sample of 100 fruit for each tree.

2.4 Statistical Analysis

Means were compared by least significant difference test (LSD) at 5% level of significance. The analysis of variance and means tests were analyzed using the UANL computer package program [16].

3. RESULTS AND DISCUSSION

3.1 Vegetative Parameters

There were significant ($P<0.01$) statistical difference among treatments on the quantity of pruned wood in each year (Table 1). During 2016 and 2017 the higher value was obtained in T4 with 426.0 and 412.8 kg tree^{-1} , respectively. The trees in this treatment were completely rejuvenated for 2018. T2 and T4 were statistically equal during 2016 to 2018 years. The trees in these treatments were completely rejuvenated in 2019 and 2020 for T3 and T2 respectively. Control treatment only dried branches due to shading problems and branches damaged each year were removed. The quantity of pruned wood in this treatment was statistically lower and the values varied between 9.4 to 67.2 kg tree^{-1} in each year being 2016 where the higher value was obtained. The average weight of wood pruning during the four years in the rejuvenation pruning treatments ranged from 180.9 to 215.5 kg tree^{-1} without statistical difference among them, while in the control treatment it was only 27.2 kg tree^{-1} . Rodriguez et al. [17] reported that hard pruning in olive tree with removal of 50-70% of the foliage and performed every four years removed 2700 $\text{kg dry matter ha}^{-1}$, from which 600 kg ha^{-1} corresponded to leaves. The wood obtained from the pruning of rejuvenation can be used as firewood to heat the home during the cold months [18], for charcoal, utensils and toys elaboration and to build fences [19].

There were statistical differences on all vegetative characteristics among treatments (Table 2). The number of new shoots growth by the pruning cut showed difference at ($P<0.01$) the higher value was obtained in T4 with 349.5 shoots, followed by T3 and T2 with 158.5 and 162.5 shoots, respectively and no statistical difference between them. The lower value was recorded in T1 with only 12.5 shoots. By other side, the canopy diameter was affected statistically ($P<0.01$) among treatments, being T1 with higher value with 7.1 m, while the rest of treatments were statistically equal and the values ranged from 3.4 to 4.2 among them. Finally plant height showed difference at ($P<0.01$) and the treatment with higher value was recorded for T1 with 8.7 m. The lower plant height was obtained in the rejuvenation pruning treatments with values from 4.2 to 5.1 m.

The olive tree has many dormant vegetative buds throughout the trunk which can grow when a pruning is done, this capability is very key to the success of rejuvenation pruning [20]. The number of shoots to develop depends mainly of the age of the plant, trunk diameter, fertilizer application, height of the cut and others [11]. The number of new shoots growth obtained in this experiment was much higher than those found by [21]. These authors reported value between 4.68 to 54.45 although with other pruning techniques and under rainfall conditions.

In general terms, in the fourth year the treatments with different pruning intensities significantly reduced the canopy diameter between 48 and 59% and the plant height was reduced in 48 to 58% compared to the Control treatment. The advantages of a rejuvenated olive orchard are: minimizes alternate bearing, improve production and fruit quality and very important lower harvest cost due to a 60% saving in manual labor [10,22].

3.2 Olive Yield

The results in Table 3 indicate that there was statistical ($P<0.01$) difference in olive yield in all years with exception in 2019. During 2016 the higher olive yield was obtained in T2 and T3 with 50.7 and 44.5 kg tree^{-1} and lower in T4 and T1 with 25.5 and 34.6 kg tree^{-1} , respectively. In 2017 the higher olive yield was recorded for T2 with 56.3 kg tree^{-1} although with statistical differences to T1 and T3 with 46.8 and 33.3 kg tree^{-1} , respectively, while T4 was the lower with only 5.9 kg tree^{-1} . In 2018 the higher yield was for T2 and

T1 with 28.6 and 23.5 kg tree⁻¹ without statistical difference between them. While lower yield was recorded for T3 and T4 with only 7.7 and 12.5 kg tree⁻¹ being statistically equal. Finally, in 2019 no statistical differences were found among treatments. The values ranged from 21.3 to 36.1 kg tree⁻¹.

The average yield in four years (2016 to 2019) in the rejuvenation pruning treatments varied from 39.2 kg tree⁻¹ (T2) to 20.0 kg tree⁻¹ (T4), while in the control treatment (T1) was 34.1 kg tree⁻¹ although without statistical difference among them. According to the results obtained in this experiment, with the use of T2 it is possible to rejuvenate an olive orchard in four years and increase the yield by 15.2% with respect to the control during the rejuvenation process, while T3 and T4 reduced olive yield 18.7 and 41.3%, respectively. Similar results were reported by [23] who recommend an olive rejuvenation by removing a main branch every year.

The results of the effect of the rejuvenation pruning treatments are still preliminary, the main effect will be after the rejuvenation pruning where there will be higher yield, fruit quality and savings in production costs. In this regard, Ahmad and Ayoub [23] reported that three years after

rejuvenation pruning in olive trees, significantly higher yield was obtained, the control treatment had a yield of 5.78 kg tree⁻¹ and the treatment of removing a trunk for each year was 24.71 kg tree⁻¹. By other side, Cimato et al. [20] found that after nine years the cumulative olive yield of the rejuvenated trees equaled that of the control trees and advantages were seen in the reduction of labor, both for pruning and harvesting, and above all, in the recovery of yield in rejuvenated trees.

3.3 Fruit Characteristics

There were not statistical differences among treatments in fruit weight and pulp-pit ratio in both parameters (Table 4). Fruit weight varied from 4.65 to 4.72 grams per fruit, while pulp-pit relation the value varied from 5.26 to 5.31 although without statistical difference the highest value was in T4 in both parameters. The values found in the Manzanilla cultivar are similar to those reported by previous research in conditions and very similar agronomic management [7]. However, other study indicated that all fruit characteristics were significantly higher when the rejuvenation pruning was done to those of the control [23]. Olive fruit size and pulp-pit ratio are important characteristics for table olive production.

Table 1. Quantity of pruned wood (kg tree⁻¹) in the evaluation of pruning intensities on olive tree cultivar Manzanilla in different production years

Pruning intensity	Production Year (kg tree ⁻¹)				Combined Mean
	2016	2017	2018	2019	
Control (T1)	67.2 ^c	16.1 ^c	9.4 ^b	15.8 ^b	27.2 ^b
25% (T2)	179.2 ^b	168.2 ^b	182.8 ^a	193.4 ^a	180.9 ^a
33% (T3)	235.4 ^b	255.3 ^b	268.6 ^a	15.2 ^b	193.6 ^a
50% (T4)	426.0 ^a	412.8 ^a	10.2 ^b	12.0 ^b	215.2 ^a
Significance	**	**	**	**	**
CV (%)	40.8	38.5	31.0	15.4	22.6

Means followed by the same letter in a column do not differ significantly (LSD 0.05) ** Significant at ($P \leq 0.01$)

Table 2. Vegetative parameters in the evaluation of pruning intensities on olive tree cultivar Manzanilla

Pruning Intensity	Number of New Shoots Growth ^y	Canopy Diameter ^z (m)	Plant Height ^z (m)
Control (T1)	12.5 ^c	7.1 ^a	8.7 ^a
25% (T2)	162.5 ^b	3.4 ^c	4.2 ^b
33% (T3)	158.5 ^b	3.7 ^c	4.5 ^b
50% (T4)	349.5 ^a	4.2 ^c	5.1 ^b
Significance	**	**	**
CV (%)	56.6	18.2	15.3

^z Recorded only one year (November 15, 2019 and ^y Recorded only one year (July 26, 2016).

Means followed by the same letter in a column do not differ significantly (LSD 0.05) ** Significant at ($P \leq 0.01$)

Table 3. Olive yield (kg tree⁻¹) in the evaluation of pruning intensities on olive tree cultivar Manzanilla in different production years

Pruning intensity	Production Year				Combined mean yield
	2016	2017	2018	2019	
Control (T1)	34.6 ^b	46.8 ^a	23.5 ^a	31.4	34.1
25% (T2)	50.7 ^a	56.3 ^a	28.6 ^a	21.3	39.2
33% (T3)	44.5 ^a	33.3 ^a	7.7 ^b	25.3	27.7
50% (T4)	25.5 ^b	5.9 ^b	12.5 ^b	36.1	20.0
Significance	**	**	**	N.S.	N.S.
CV (%)	15.6	20.5	20.2	9.8	13.8

Means followed by the same letter in a column do not differ significantly (LSD 0.05) N.S Non Significant, and ** Significant at (P≤0.01)

Table 4. Fruit characteristics in the evaluation of pruning intensities on olive tree cultivar Manzanilla

Pruning Intensity	Fruit weight (g)	Pulp-pit relation
Control (T1)	4.66	5.28
25% (T2)	4.65	5.30
33% (T3)	4.70	5.26
50% (T4)	4.72	5.31
Significance	N.S.	N.S.
CV (%)	7.1	6.5

Means followed by the same letter in a column do not differ significantly (LSD 0.05) N.S. Non Significant at (P≤0.01)

4. CONCLUSION

The rejuvenation pruning in olive trees with an intensity of 25%, removing a trunk every year, reduced the plant vigor around 50% and during the pruning process increased the yield by 15.2% without affecting fruit quality.

The results are preliminary, it is required to know the productive behavior three or four years after finishing the rejuvenation pruning and determine the time necessary to carry out the next pruning.

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COMPETING INTEREST

Authors have declared that no competing interests exist.

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