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# A new device to improve the mechanical winter pruning in olive trees hedgerows

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*Key words*: branches, fruit bearing, leaves, *Olea europaea*, shoots, superintensive plantations.

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All relevant data are within the paper and its Supporting Information files.

**Competing Interests:**
The authors declare no competing interests.

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**Abstract: The economic success of superintensive olive plantations is mainly due to the full mechanization of the harvesting and pruning. While the advantage of straddling machines is undoubted, winter mechanical pruning determines falls in productions. This is due to the indiscriminate suppression of both fertile leafy shoots destined to fruiting and growth, and exhausted parts of the plant. To reduce this damage, an innovative device has been developed, applied to a pruning machine, able to selectively cut the "aged" parts of vegetation. The selection is achieved by an air's fluid dynamic action obtained throughout defined and directional air jets able to push the young and flexible shoots upwards and downwards; in this way they are saved by the cut, regenerating at least one year in advance the new fruiting hedge. Tests were carried out on the cultivar Arbequina, Tosca and Sikitita, in three superintensive olive groves located in the province of Grosseto, Rome and Latina, assessing the amount of leaves, shoots and branches, as well as fruits present at harvest, preserved from the pruning thanks to the action of the air flow, respectively for the East and West side of the rows. To get a profile of the biomass distribution along the cross section of the tree canopy, in the Grosseto farm a trial was also carried out to better assess leaves, shoots and branches distribution in the canopy. The statistical data analyses immediately evidenced two different populations due to the selective pruning. The work highlighted the remarkable effectiveness of the air jet in safeguarding the flexible and leafy vegetation and allowed to quadruple leaf surface and production.**

## 1. Introduction

The improved knowledge and agronomic techniques during the last decades have allowed the development of olive cultivation beyond the original distribution area (Mediterranean basin), in new zones where olive growing represents one of the most promising crops (Marone and

Fiorino, 2012).

Since the beginning of the 1990s, the introduction of a canopy management and training system defined as "superintensive" contributed to the spread of olive cultivation (Tous *et al.*, 1997; Tous *et al.*, 2010; Rallo *et al.*, 2013), as the high number of trees per hectare (over 1600), with particularly short distances between the plants on the row; the close canopies form, such as in the vine, a single hedge; the system allows the complete mechanization of the harvesting, carried out with straddling machines that detach, intercept and storage the fruits at once, working continuously; the system also allows the mechanical pruning (Vivaldi *et al.*, 2015), performed by circular saws fitted on adjustable bars, by eliminating the vegetation along horizontal (topping) or vertical (hedging) planes. The continuous harvesting yards, based on the use of straddle machines, allow strong scale economies and guarantee the greatest efficiency with respect to other systems like shakers and vibrating combs, which can work in traditional or intensive farming systems (Fiorino *et al.*, 2010).

The mechanical pruning using circular saws fitted on bars, borrowed from viticulture, can be applied to both intensive (individual canopies) and superintensive (hedge) plantations. The comparison between manual and mechanical pruning highlight a greater operative speed of the second (Giametta and Zimbalatti, 1997), partially compromised by the decreasing of productivity (Ferguson *et al.*, 2002; Peça *et al.*, 2002). In fact, the mechanical pruning simultaneously eliminates, together with the exhausted, also the young vegetation, influencing the canopy vegetative-productive ratios, as well as the distribution of the natural resources and of the light (Cherbiy-Hoffmann *et al.*, 2012). In intensive plantations, it needs several years to evaluate the influence of regular winter pruning on plant productivity (Dias *et al.*, 2012) and, according to Albarracín *et al.* (2017), depending on the intensity of the intervention, it can take up to two growth seasons to reconstitute a fruiting canopy and three to bring the plants back to full production.

While in traditional and intensive plantations the mechanical pruning can be considered an economical and convenient alternative to the manual one, it is the only technique available to manage the canopy of adult plants grown in superintensive plantations. In this case its role changes, from tool to preserve the vegetative-productive plants equilibrium, to tool for constraining the plant dimensions within defined limits of height and width, required to perform the harvesting by straddling machines (Vivaldi *et al.*, 2015); as a consequence it is largely applied in these plantations, despite the negative consequences on the productive vegetation, due to the particular growth model of the olive tree. In fact, in the olive tree, the fruiting takes place on the vegetation of the previous year, simultaneously with the elongation of the shoots apex that will take fruits the following year; over the time, these shoot elongations progressively move away from the central leader of the tree and, as the competition between the different sinks (apical shoot growth and fruits energy demand), progressively become weak and less productive. At the same time, from the branch that originated them, some latent buds can sprout, fated to reiterate the cycle, by substituting the fertile vegetation that has already produced fruits (Fiorino and Marone, 2010).

These vegetative structures coexist on the surface of the plants, or along a "wall" in the case of hedgerows, where the renewal vegetation is dragged downwards by the weight of the sprouts, being the wood of olive branches flexible, and due to the weight of olives, which also curve the young branches. The "aged" and exhausted parts are periodically eliminated by the winter pruning (Fiorino and Marone, 2010).

An innovative device has been designed and built, inserted on a bar equipped with counter-rotating circular saws, able to delivering defined and directional air jets that push the shoots upwards and downwards, bending them. In this way the young flexible shoots inserted on the two or three year-old branches escape the action of the pruning machine blades, recovering their natural position after the course of the tool, while the short shoots inserted on the rigid vegetation that produced fruits, depleted and to remove, are cut.

The present study would to test the efficiency of a new selective blower device, with the goals: a) to save leaves on the green wall, improving its efficiency in light interception, and b) to save a greater number of fertile buds since the first year after cutting and at least a part of the fruits resulting from the subsequent flowering.

Moreover, the study would determine the quantity of the biomass produced in olive hedgerows as by-product of the mechanical pruning, characterized by a remarkable presence of leaves, to verify the possibility of alternative uses, in addition to those already tested for manual pruning residues that, mixed with olive pomace, contribute to the production of pellets (Barbanera *et al.*, 2016) and, as already demonstrat-

ed for pomace, to identify a possible use as supplements/components of livestock feed (González *et al.*, 2012; Castellani *et al.*, 2017; Taticchi *et al.*, 2017) or as a natural source of antioxidant compounds (Talhaoui *et al.*, 2015).

## 2. Materials and Methods

*Plant material*

Three different pruning trials were carried out in three different localities in high density plantations, on rows of olive trees trained with a central leader, allowing their natural lateral branching.

1) Year 2014. The first trial was performed in the "Castello di Torrimpietra" farm, located in Torrimpietra (Rome) (41° 53 '43'' North Latitude, 12° 14' 8'' East Longitude, 44 m asl), on trees of the cv. Arbequina and Tosca, 8 years old, with planting density of 3.8 x 1.6 m (2630 m of rows per hectare). The plants were branched about 60 cm from the soil; the thickness of the canopy walls at the time of the pruning was about 120 cm, the height of 2.20-2.40 cm. The useful height of the fruiting wall was 180 cm. The soil is sandy (over 60% sand), pH = 7.6.

2) Year 2015. The second trial was performed in the "Casale San Giorgio" farm, located near Latina (41° 37' 7'' North Latitude, 12° 34' 50'' Est Longitude, 64 m asl), on trees of the cv. Arbequina and Sikitita, 5 years old, with planting density of 3.8 x 1.6 m (2630 m of rows per hectare). The plants were branched about 60 cm from the soil; the thickness of the canopy walls at the time of the pruning was 120 cm, the height of 2.00-2.20 cm. The useful height of the fruiting wall was 160 cm. The soil is clayey (36% clay), with a high percentage of sand (40%), pH = 6.7.

3) Year 2018. The third trial was performed in the "Tombolo" farm located in Grosseto (42° 44' 3'' North Latitude, 10° 59' 10'' Est Longitude, 8 m asl), on trees of the cv. Arbequina, 10 years old, with planting density of 4.0 x 1.6 m (2500 m of rows per hectare). The plants were branched about 60 cm from the soil; the thickness of the canopy walls at the time of the pruning was 140-160 cm, the height of 2.00-2.20 cm. The useful height of the fruiting wall was 160 cm. The soil is sandy-silty (over 60% sand), pH = 7.2.

The rows in the three farms are oriented North-South. All the plants were subjected to fertigation, soil management by grassing between rows and weed control on the rows, and fight against *Spilocaea oleagina* and *Bactrocera* (*Dacus*) *oleae*. In all trials the mechanical pruning was set to leave a maximum thickness of the canopy of the hedge of 80 cm (40 cm on the East side and 40 cm on the West side).

To verify the efficiency of the air-jet apparatus, samplings were carried out to quantify leaves, shoots (up to 1 year old) and branches (over 1 year old) saved when cut as pushed by the air of the blower device towards the inside of the canopy and then come back to its original position.

During the pruning, the machine proceeded along each row keeping constant the driving speed and the cutting depth of the blades, let the blower device operating for a defined number of spans (15-20 m each, depending on the plantation), alternating with spans where it remained off, and for each row on both sides (East and West orientation of the plants, respectively). The surveys were made at the center of the spans.

To perform the surveys on the vegetation, a square frame (1.0 x 1.0 m) was used, placed in correspondence to the central axis of a plant, at a height of 1.0 m from the soil, and positioned at the theoretical cutting blades surface (Fig. 1); all the plant material (leaves, shoots, branches) found outside this frame after the cutting was removed.

Table 1 shows the list of the number of plants chosen for each locality, from which the different samples of vegetal material were taken, used to carry out the experimental surveys, which concerned, for the East side and the West side, respectively: leaves number and surface, shoots length, branches length. In the third test, surveys were also made on the number of fruits present at harvest on pruned plants with and without the presence of the air flow, respectively, to evaluate the difference in the production ability of the plants determined by the two types of techniques, for the two sides of the rows (East and West).


Fig. 1 - Sampling units after the pruning in the Casale San Giorgio farm (2015): A) Air flow Off; B) Air flow On.

Table 1 - List of the sampling units related to different cultivar and locality

| Codex | Samples provenience | East air On | East air Off | West air On | West air Off | Total |
|---|---|---|---|---|---|---|
| 1 | cv. Arbequina, Torrimpietra, Roma (2014) | 6 | 6 | 6 | 6 | 24 |
| 2 | cv. Tosca, Torrimpietra, Roma (2014) | 9 | 9 | 9 | 9 | 36 |
| 3 | cv. Arbequina, Casale San Giorgio, Latina (2015) | 12 | 12 | 12 | 12 | 48 |
| 4 | cv. Sikitita, Casale San Giorgio, Latina (2015) | 4 | 4 | 4 | 4 | 16 |
| 5 | cv. Arbequina, Grosseto, (2018) | 12 | 12 | 12 | 12 | 48 |
| | Total | 43 | 43 | 43 | 43 | 172 |

In the Tombolo farm, the day before the winter pruning (March 2018), on 6 plants of the cv. Arbequina, the amount of leaves, shoots and branches on unpruned trees was determined, separately for the East and the West side, to obtain a profile of the canopy biomass distribution along the transversal section of the hedgerow. At this aim, the vegetal material present in the selected sampling units (1 $m^2$) was collected, keeping separated the outer 15 cm of the canopy (outer layer), corresponding to a "light" pruning, the next approximately 25 cm (intermediate layer), corresponding to a "severe" pruning, and the remaining 40 cm up to the permanent structures (inner layer) of the hedge.

For all the samples the leaves number and the leaf surface, the leaves dry weight, the shoots total length, the branches total length have been determined.

The leaf surface was measured by collecting 50-100 leaves per sampling unit; for the trials before the pruning of 2018 in the Tombolo farm the leaf area was instead determined through a sampling of at least 100 leaves completely developed per sampling unit (total 600 leaves), chosen in the different sections (outer, intermediate and inner) in which the canopy has been subdivided. The leaf area was determined by scanning and analyzing the image (UTHSCSA Image Tool IT Version 2.03), and the dry weight was determined for the same samples.

All trials and surveys were carried out in the second half of March, after the winter cold and shortly before the vegetative restart.

*The selective pruning device*

The pruning machine (BMV-FL480S), designed for use in intensive olive groves, is equipped with a removable device able to perform selective cutting, unlike commonly adopted solutions, that cut all the shoots and branches which are in a predetermined position. This is achieved by the air's fluid dynamic action.

Characteristics: the pruning machine used for the tests consists of a 240 cm cutting bar fitted on a frame that allows the adjustment in lateral height and inclination, composed of six blade disks with a diameter of 500 mm, a fluid dynamic flow generator and four air flow conveyors arranged in front of the cutting bar (Fig. 2). In all the trials a vehicle of more than 80 HP was used.

Fig. 2 - A) Cutting bar equipped with the selective pruning device; B) The pruning machine working along a row.

*Statistical analyses*

The experimental design was chosen to guarantee the uniformity of sampling units, deriving from the same starting population for each locality and cultivar. Average and standard deviations of raw data related to the four treatment (East air On, East air Off, West air On, and West air Off) for each locality and cultivar were compared; since in this experiment Authors were interested in the evaluation of the effectiveness in the performances of a pruning machine (i.e. kg of production or cm of elongation $tree^{-1}$, or $ha^{-1}$), only raw data were submitted to the parametric test, as logarithmic transformation is most suitable to express magnitude discrepancy; for each data set, tests were carried out to evaluate the normality of the distributions, and Levene's test were performed to evaluate homoscedasticity at 95% confidence level. Since in the most of cases the data distribution indicates some significant nonnormality (the standardized skewness and/or kurtosis is outside the range of -2 to +2), and since significant difference amongst the standard deviations at the 95.0% confidence level were evidenced, neither analyses of variance nor non-parametric tests to compare the medians instead of the means could be performed; as a consequence, average values and S.D. were only reported; Box and Whiskers plot were built up to

compare the medians, as the effect of the applied air flow to the pruning machine is so high to generate two populations different at all. This aspect is very important to consider, as the standard deviation can play a meaningful role also when it results to high to allow the application of the common descriptive statistical tests (Marone *et al.*, 2017). The same approach was applied to evaluate the differences in the fruit bearing parameters measured in olive trees of cv. Arbequina (Tombolo farm, 2018), and the same conclusions were drawn.

One-way analyses of variance (ANOVA) were performed to compare vegetative growth parameters in olive trees of cv Arbequina (Tombolo farm, 2018) measured in the sampling units (1 unit = 1 $m^2$) before carrying out the pruning trials, evaluating the side effect (Est/West); separation of means was performed by the Fisher's LSD test ($p = 0.05$). Levene's test to check the variance, and Mood's median $\chi$-square test to evaluate the medians samples differences, if necessary, were also applied.

All the computations were performed on the raw data by Statgraphics Centurion XV v. 15.0.04. A multivariate partial least squares-discriminant analysis (PLS-DA, supervised method), based on venetian blinds cross validation procedures, was applied on the data obtained from all the samples of the cv. Arbequina, after applying the two alternative pruning methods, coming from the sampling units collected in the three different zones, to highlight the possibility of differentiating the sampling submitted to the pruning with the air flow On, based on the chosen canopy vegetative parameters. For a description of the method, see Colzi *et al.* (2017). Data were preprocessed by a logarithmic transformation (log+1) to express magnitude discrepancy. The analysis was performed by PLS-Toolbox v. 8.0.2 (Eigenvector Research Inc., West Eaglerock Drive, Wenatchee, WA) for MATLAB® R2015b (Mathworks Inc., Natick, MA, USA).

A Factor Analysis (FA) was performed on (log+1) data obtained from the sampling units of cv. Arbequina (farm of Tombolo, 2018), considering as factors both vegetative and productive parameters (leaves number and areas, shoots and branches length, fruits number). Computations were performed by XLSTAT 2014.5.03.

## 3. Results

*Vegetative growth and fruiting parameters*

Table 2 shows the data related to the canopy parameters measured on the (residual) vegetation outside the cutting surface: leaves number (n.) and surface ($cm^2$), shoots total length (cm) and branches total length (cm). For each locality and cultivar, the average and standard deviation values of the sampling units (1 $m^2$), obtained with and without air flow, are separately indicated for the two sides of the row (East/West).

All the cultivars under study belong to the class of vigor suitable for their use in superintensive plantations. The data shows the great difference between the values of all the "On" tests parameters compared to those of the "Off" tests. In particular, the number of leaves (and axillary buds) results in many combinations more than quadrupled in the "On" tests (Table 2, Fig. 3), and the same proportion is found in the leaf surface present after the cut which, in the West On test of the cv. Tosca overcome the coefficient of 1.12 $m^2$ of leaf area per $m^2$ of cutting area. It can be also seen that, in general, the west side of the row is richer in leaves, compared to the east side, except the cv Arbequina in Casale San Giorgio (2015) and Tombolo farms (2018), which show a behavior that tends to be opposite.

Vegetation up to 1 year old shows the same

Table 2 - Differences in vegetative growth parameters in olive trees measured as residual vegetation in the survey units (1 m2) due to action of the selective device and the side (East/West) effect (average ± S.D.)

| Treatment | Leaves (number) | Leaves ($cm^2$) | Shoots (cm) | Branches (cm) |
|---|---|---|---|---|
| 1 East Off | 99.0±65.2 | 471.6±350.4 | 273.8±201.2 | 21.0±35.3 |
| East On | 406.5±75.3 | 2060.7±359.6 | 1040.5±361.4 | 125.0±75.7 |
| West Off | 179.4±100.8 | 795.4±434.2 | 368.3±226.5 | 27.8±20.9 |
| West On | 714.2±322.4 | 3322.3±1480.7 | 1134.0±428.5 | 118.2±56.8 |
| 2 East Off | 660.6±211.6 | 2542.5±926.3 | 782.2±220.1 | 66.3±40.2 |
| East On | 2358.1±564.7 | 8823.2±2098.2 | 2926.4±840.2 | 133.8±48.9 |
| West Off | 855.7±255.9 | 3287.1±1124.6 | 855.4±233.6 | 78.2±33.4 |
| West On | 2980.3±665.3 | 11160.5±2527.3 | 3479.2±917.9 | 142.5±47.7 |
| 3 East Off | 115.7±65.1 | 542.7±305.3 | 270.2±83.3 | 5.2±9.0 |
| East On | 928.9±379.8 | 4356.5±1781.5 | 1453.9±552.6 | 57.08±35.9 |
| West Off | 57.1±22.4 | 268.0±105.0 | 196.9±67.0 | 10.2±8.9 |
| West On | 596.0±232.4 | 2795.2±1090.2 | 1124.1±418.3 | 69.3±42.6 |
| 4 East Off | 15.0±10.0 | 46.8±31.0 | 200.0±92.5 | 9.2±14.8 |
| East On | 79.5±36.1 | 247.2±112.4 | 911.7±282.4 | 65.5±72.8 |
| West Off | 22.3±10.9 | 69.5±33.9 | 256.5± 12.1 | 8.7±17.5 |
| West On | 103.3±21.4 | 321.3±66.4 | 1342.0±434.9 | 80.7±34.6 |
| 5 East Off | 35.6±15.2 | 167.2±71.3 | 99.0±34.3 | 2.4±4.5 |
| East On | 285.7±68.6 | 1335.6±321.9 | 572.9±223.9 | 48.3±37.5 |
| West Off | 35.0±14.0 | 164.1±65.5 | 84.0±19.5 | 0.0±0.0 |
| West On | 572.7±223.9 | 2681.4±1050.1 | 943.9±295.2 | 29.2±12.8 |

Samples 1, 3 and 5 refer to the same cv. Arbequina. Sample 2 to the cv. Tosca, sample 4 to the cv. Sikitita.

trend. The amount of branches is generally negligible, except for the cv. Tosca, which gives length values from 66 (East Off) to 142 cm (West On).

Figure 4 shows the score plot and the summary statistics of the PLS-DA model, that compare the data related to all the samples of the cv. Arbequina, coming from the sampling units collected in the 3 localities under test, after applying the two alternative pruning methods, based on the chosen vegetative parameters of the trees canopy. The model statistic indicators and the score plot clearly confirm the presence after pruning performed with and without air flow of two completely different populations. As the model is representative of three distinct agronomic situations (Castello di Torrimpietra, Casale San Giorgio and Tombolo farms) and of the two sides (East/West) of the rows, this output confirms the validity of the air jet system in safeguarding a significant part of the most important vegetation useful for the fruit production and the subsequent growth of the fruiting shoots, subtracting it from the indiscriminate mechanical cutting inevitable using the current pruning machines without blower device.

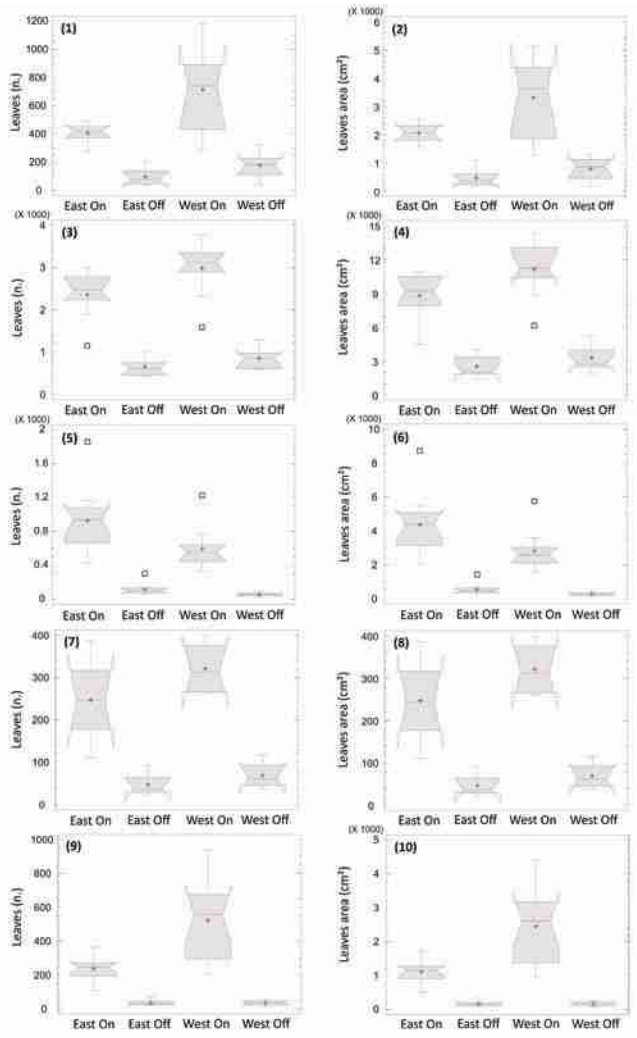
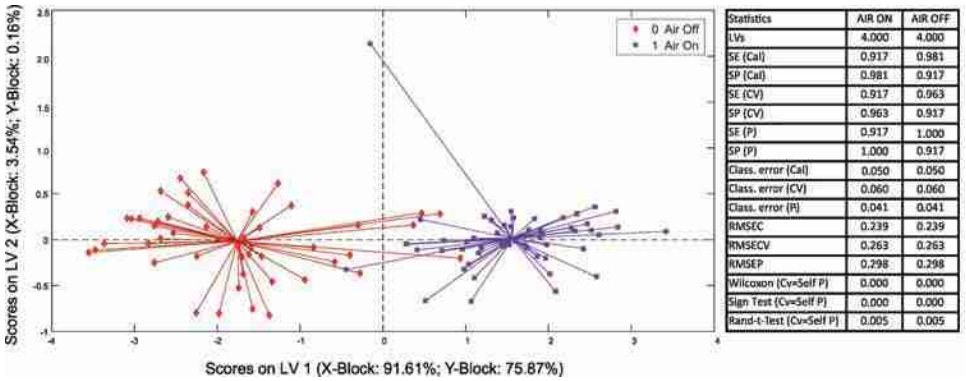



Fig. 3 - Box-and-Whisker plots related to the leaves number and area as influenced by the flow (On/Off) and side (Est/West). 1-2: 'Arbequina', 2014; 3-4: 'Tosca', 2014; 5-6: 'Arbequina', 2015; 7-8: 'Sikitita', 2015, 9-10: 'Arbequina', 2018. Median notches, and mean (+) ± S.D. Notches added to the plot show the estimation error associated with each median; if they do not overlap, highlight which medians are significantly different from which others at 95% confidence level. Mean markers (+) indicate the location of samples mean. Outliers are indicated ( ) if present.

In the Tombolo farm, the number of fruits per $m^2$ of fruiting area (sampling unit) present on the plants of the cv. Arbequina was also determined. The numerical differences between Air On and Air Off units related to the two orientations (East and West), respectively, highlight the enormous advantage obtained using the selective blower device, exceeding 100 fruits (with an increase of 107 fruits for the East and 116 for the West) (see table in Fig. 5). Calculating an average increase of only 100 fruits per $m^2$, multiplied by an useful area of about 8000 $m^2$ $ha^{-1}$, there would be a productive advantage already on the first yield after the pruning of 800000 fruits; multiplying this value by the average weight of 1 fruit of cv. Arbequina in the area (about 2.0 g), gives over 1600 kg of increased product in average per hectare, compared to the production of 284 kg that would have been obtained without the support of the device, with an average increase of 412% in olive production, and a recovery of over 1.7 t of product already in the pruning year.

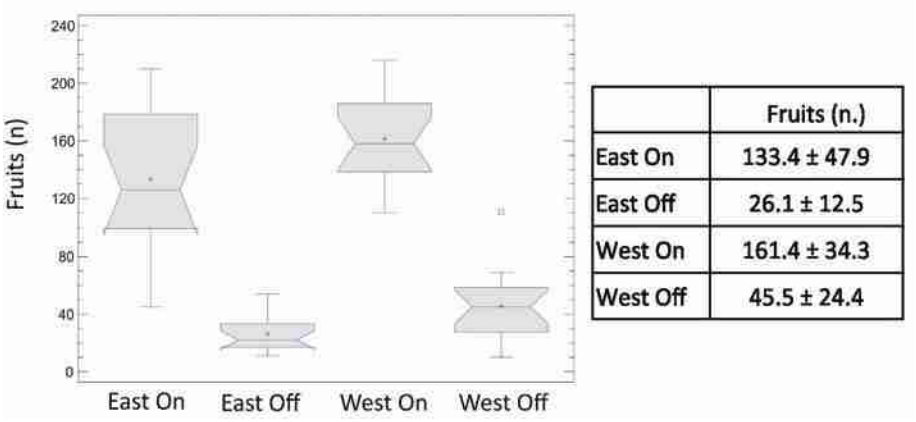
In the figure 6 a biplot from Factor Analysis is shown, simultaneously representing the relationships amongst the vegetative and productive parameters measured on the cv. Arbequina (Tombolo farm, 2018).

The first axis explains the 97.83% of the total variability in the data. The four populations deriving from the treatments and the orientation are well separated in the four plots of the diagram. The two clusters that represent the trials with the application of the blower device (on the right in the figure) are significantly related to the vegetative-productive parameters of the leaves. It is interesting to note how the parameters related to leaves, shoots and fruits are also influenced by orientation to the West, as shown by the direction and length of the arrows in the graph.




| Statistics | AIR ON | AIR OFF |
|---|---|---|
| LVs | 4.000 | 4.000 |
| SE (Cal) | 0.917 | 0.981 |
| SP (Cal) | 0.981 | 0.917 |
| SE (CV) | 0.917 | 0.963 |
| SP (CV) | 0.963 | 0.917 |
| SE (P) | 0.917 | 1.000 |
| SP (P) | 1.000 | 0.917 |
| Class. error (Cal) | 0.050 | 0.050 |
| Class. error (CV) | 0.060 | 0.060 |
| Class. error (P) | 0.041 | 0.041 |
| RMSEC | 0.239 | 0.239 |
| RMSECV | 0.263 | 0.263 |
| RMSEP | 0.298 | 0.298 |
| Wilcoxon (Cv=Self P) | 0.000 | 0.000 |
| Sign Test (Cv=Self P) | 0.000 | 0.000 |
| Rand-t-Test (Cv=Self P) | 0.005 | 0.005 |

Fig. 4 - Score plot of PLS-DA model and summary statistics for the cv. Arbequina samples in the three different zones after the pruning, based on the measured vegetative growth parameters: 0) Air Off (Red), 1) Air On (Blue).




| | Fruits (n.) |
|---|---|
| East On | 133.4 ± 47.9 |
| East Off | 26.1 ± 12.5 |
| West On | 161.4 ± 34.3 |
| West Off | 45.5 ± 24.4 |

Fig. 5 - Differences in fruit number in olive trees of cv. Arbequina (Tombolo farm, 2018). In the table: average ± S.D.; in the Box and Whisker plot: median notches, and average (+) ± S.D.

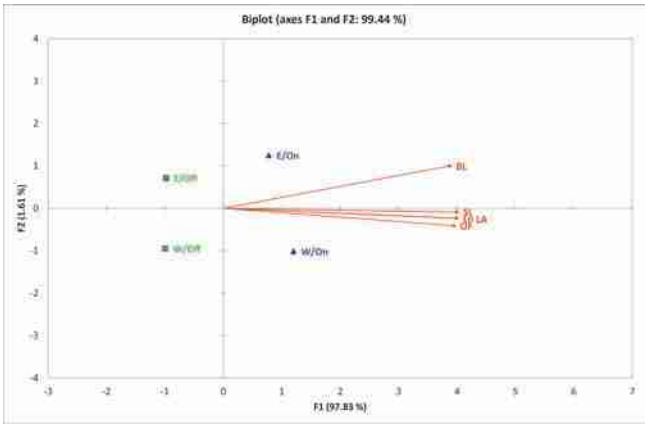



Fig. 6 - Biplot from Factor Analysis. Relationships among leaves number (LN), leaves area (LA), shoots length (SL), branches length (BL), fruits number (FN), and the four different treatment: East air On (E/On), East air Off (E/Off), West air On (W/On), West air Off (W/Off); cv. Arbequina, Tombolo farm, 2018.

*Canopy distribution of biomasses in hedgerows trained olive trees*

Table 3 compares the vegetative parameters (leaves number and area, shoots and branches length) per m$^2$ of the three sections in which the canopy has been transversely divided. An initial evaluation seems to indicate that, for the particular area of Tombolo farm, the East/West orientation plays an important role in determining the vegetative parameters taken into consideration; in fact, in the West section, regardless of the depth of the evaluation, the leaves number and surface (cm$^2$), and the shoots length (cm) is greater. Branches cannot be taken into consideration, since they are absent from the outer part, and almost absent from the intermediate section. This advantage determined by the orientation, whose causes are to better investigate, seems to be present also in the plot of Castello di Torrimpietra farm for both the cultivar (Arbequina and Tosca) and in the plot of Casale San Giorgio farm limited to the cv. Sikitita.

Table 3 - Partition of components (leaves number and surface, shoots and branches lenght) of the three canopy transversal sections in olive trees of cv Arbequina (Tombolo farm, 2018) measured in the sampling units (1 unit = 1 m$^2$), side (Est/West) (average ± S.D.). Average leaves dry weight for the three sections.

Taking into account the East/West averaged values, it results that a “light” pruning (taking away the

Table 3 - Partition of components (leaves number and surface, shoots and branches length) of the three canopy transversal sections in olive trees of cv. Arbequina (Tombolo farm, 2018) measured in the sampling units (1 unit = 1 m²), side (Est/West) (average ± s.d.)

| Section | Parameter | East | West | Average leaves dry weight (g) |
|---|---|---|---|---|
| Outer section (15 cm) | Leaves (no.) | 689.1 ± 66.2 a | 815.2 ± 86.9 b | 67.69 (33.4%) |
| | Leaves (cm²) | 3232.0 ± 310.4 a | 3823.3 ± 407.5 b | |
| | Shoots (cm) | 1234.7 ± 30.6 a | 1121.5 ± 111.3 b | |
| | Branches (cm) | 0.0 ± 0.0 | 0.0 ± 0.0 | |
| Intermediate section (about 25 cm) | Leaves (no.) | 680.4 ± 39.7 a | 1243.4 ± 88.2 b | 86.57 (42.7%) |
| | Leaves (cm²) | 3191.3 ± 186.2 a | 5831.5 ± 413.5 b | |
| | Shoots (cm) | 2132.7 ± 510.7 a | 2979.7 ± 232.3 b | |
| | Branches (cm) | 214.0 ± 64.1 a | 240.3 ± 82.0 a | |
| Inner section (40 cm from the main tree axis) | Leaves (n.) | 367.8 ± 145.1 a | 708.4 ± 206.6 b | 48.43 (23.9%) |
| | Leaves (cm²) | 1725.1 ± 680.6 a | 3322.6 ± 968.9 b | |
| | Shoots (cm) | 2016.2 ± 423.8 a | 1817.4 ± 904.2 a | |
| | Branches (cm) | 580.2 ± 234.3* | 709.2 ± 71.3* | |

Average leaves dry weight for the three sections

*There is more than a 3 to 1 difference between the smallest standard deviation and the largest. Since the Levene's test P-value is less than 0.05 (0.0004) there is a statistically significant difference amongst the standard deviations at the 95.0% confidence level. Since the Mood's median χ-square test is greater than or equal to 0.05 (0.102467), the medians of the samples are not significantly different at the 95.0% confidence level.

first 15 cm of the vegetation), removes about 1/3 of the leaves thus reducing 1/3 the leaf surface of the plant, and a "severe" pruning (at a depth of about 40 cm), would remove more than ¾ of the present leaves, leaving the final permanent structure with a highly reduced leaf apparatus. Even considering the shoots length (cm) it is possible to evaluate the meaningful effect of the intervention: a "light" pruning would remove about 1/5 of the present shoots, while a "severe" pruning would leave only 35% of the shoots, thus eliminating most of the vegetation potentially productive.

Figure 7 shows an example of partition between the different components of the canopy for each of the three considered sections.

It is also interesting to consider the amount of leaves biomass that, by the pruning, can be made available for other uses: a "light" pruning, limited to a 15 cm layer, could produce, in this typology of rows, 541 kg of leaves (dry weight), and further 692 kg (dry weight) would also be removed from the intermediate section, for a total of 1.2 t of dry weight leaves to be considered an additional resource and not longer as a residual.

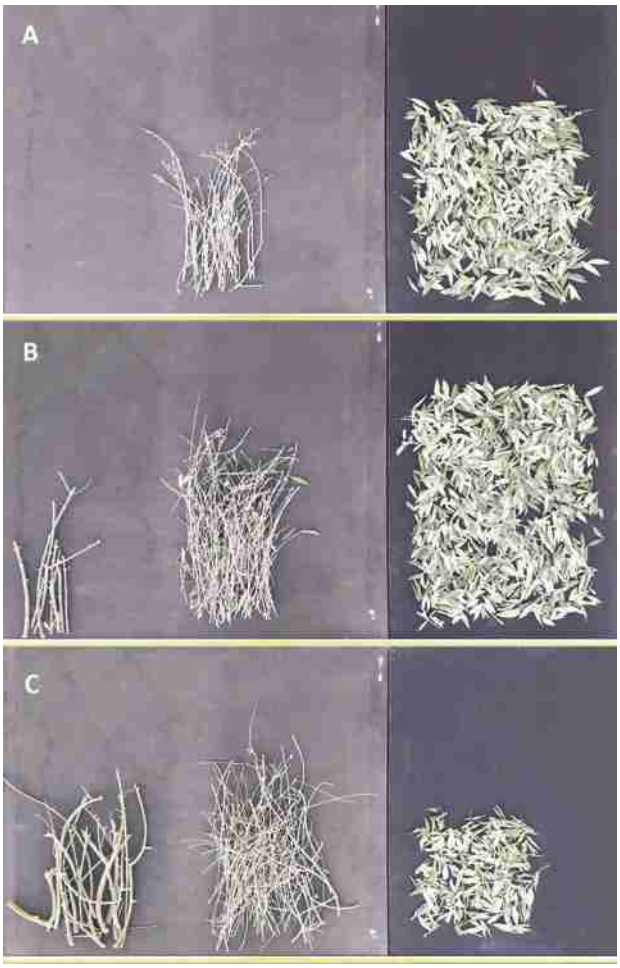



Fig. 7 - Example of partition of components (leaves, shoots, and branches) of the canopy transversal sections in a olive tree of cv. Arbequina (Tombolo farm, 2018) measured in a sampling units (1 unit = 1 m²), side West. A) Outer section (15 cm); B) Intermediate section (25 cm); C) Inner section (40 cm from the main tree axis).

## 4. Discussion and Conclusions

Mechanical winter pruning on adult hedges in superintensive plantations, unlike manual pruning, is a useful tool to control the size of the vegetative structure, thus decreasing its traditional role of bal-

ancer between vegetative growth and production (Ferguson *et al.*, 2002). In fact, by manual winter pruning, the aged, shaded and exhausted parts of the plant are selectively eliminated, to leave light and space for the parts destined to growth and to produce the following years (Peça *et al.*, 2002). Mechanical winter pruning, on the other hand, proceeds by vertical sections, indiscriminately eliminating the part exceeding the size limits imposed by the use of straddling machines; this leads, as immediate result, as pointed out by several Authors (Vivaldi *et al.*, 2015; Albarracín *et al.,* 2017), a sharp decline in productivity, a long unproductive period, due to the need to regenerate a fruiting canopy and, therefore, an economic damage that decreases the benefits offered by the mechanization of the harvesting (Peça *et al.*, 2002; Albarracín *et al.,* 2017).

In this work the authors tried for the first time to overcome the problem by verifying the effectiveness of a tool that combines the action of circular saws with a jet of air which push the shoots away from the cutting area, allowing to reduce the removal of plants young leafy parts. The main effect of the air flow is evidenced by the presence of two population (air On and air Off), totally different and distinct. The new air-jet system, compared to traditional pruning machines, preserves over 400% of the leaf surface and relative shoots length in the canopy zones where it has been applied, determining a proportional increase in production, already economically interesting the first year after the pruning.

The difference in olive produced resulted higher than 1 t $ha^{-1}$ using the air jet, demonstrating the true economic advantage of the new device, able to prevent an almost total fall in production in the winter pruning year. This improves the use of agronomic practices, keeping in mind that in superintensive olive groves, fertigation, soil and pests management are always to be applied, without exceptions (Vivaldi *et al.*, 2015). At the same time, the preservation of a larger leaf surface on the vegetation of the year, also guarantees a more suitable use of the solar radiation (Cherbiy-Hoffmann *et al.*, 2012), which allows both the activation and development of new growth points, and the growth of new potentially productive vegetative structures on the shoots elongations, able to guarantee an adequate continuity of the production (Fiorino and Marone, 2010).

Further research will be needed to improve the efficiency of this tool, and better understand the mechanisms and the evolution of the different buds present in the different parts of the canopy, which regulate the distribution of resources, also verifying the possible causes determining the growth differences due to the orientation East/West of the row canopy.

It is also important to determine the quality of the removed biomass which, in the case of "light" pruning, is exclusively composed of leaves and shoots, and could constitute a considerable amount of vegetal material to be used as a supplement/component of the livestock feed ration, or become an important source for the growing demand for phenolic antioxidants of nutraceutical interest (Talhaoui *et al.*, 2015; Castellani *et al.*, 2017).

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