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ANALYSIS OF QUALITY DEVELOPMENT IN BROAD-LEAVED TREE-FARMING PLANTATIONS IN NORTHERN-EAST ITALY

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Summary

Thanks to the financial incentives available through the EEC Regulation 2080/92, almost 250 hectares of tree-farming plantations have been established on previous agricultural lands in Gorizia province (northern-east Italy). The main reasons of such a policy were the excess of agricultural productions and the lack of local wood supply. The amount of subsidies was significant but the rules enforced were not sufficiently strict and properly defined; as a consequence, several management problems occurred already during the seasons after planting.

The aim of this study is to assess the present quality and the quality development of the tree farming plantations that were established in Gorizia province thanks to the public funds available through the EEC Regulation 2080/92.

This study has included field visits, collection of sample data representative of the entire population and primary data analysis. Two methods of stem quality assessment have been adopted, namely Nosenzo's classification (Nosenzo *et al*. 2008) and Canesin's classification (2006). Both methodologies demonstrated to be quickly applied in the field but a statistical test was carried out to compare their outcomes. The results show the significant difference between Nosenzo's and Canesin's classifications. In particular, the second one considerably overestimates the amount of timber belonging to the higher quality classes (A and B classes) because of the less restrictive and more subjective parameters used. On the other hand, Nosenzo's classification takes into account different degrees of some stem features (like 4 different classes for stem straightness); therefore, Nosenzo's methodology demonstrated to be more unbiased and should be preferred.

However, the results obtained with Canesin's classification were used to investigate the stem quality development through the comparison of the 2009 results with the corresponding data obtained in the same sample plots in a previous study (which adopted the same classification methodology). The results suggest that there was a considerable decrease of walnut stem quality, because of the huge drop of the higher stem quality classes. Dissimilar situation occurs in both cherry and ash populations; a significant difference of the 2006 and 2009 butt-log grade distributions was found also there, but the amount of the best stem quality class has remained constant, while the

others have changed; in particular, the reduction of the second best quality class (B class) has been compensated by the drop of the lowest class as well; therefore, the overall cherry and ash stem quality has decreased only slightly.

Furthermore, the comparison between the 2006 and 2009 stand parameters demonstrates a general decrease of tree growth increments in the relatively oldest plantations; this is mainly due to the increasing competitive conditions among trees, the unsuitable species planted, and, in some cases, the poor soil condition on which they were established. On the other hand, in the youngest plantations the DBH current annual increment (1-2 cm/year) is usually higher than the mean annual increment, meaning that the negative competition among trees has not been reached yet.

Lastly, tree-farming management in Gorizia province resulted to be scarce and inappropriate. Even in the thinned plantations the stem quality distribution has not improved due to the late and incorrect pruning operations that caused several butt-logs to fall in lower quality classes. Only in one-third of all plantations, the most valuable butt-logs represent more than 20 % of the total; this is the hypothetical value under which the profitability of a tree-farming plantation becomes questionable. This negative result is indicator of a general low interest in the active management of the tree-farming plantations established with the EEC Regulation 2080/92 and of low technical competences of the tree-farmers in Gorizia province.

1. Introduction

1.1 Background

The EEC Regulation 2080/92 was adopted to promote both sustainable farming and good silvicoltural practices. In those years, most EU countries (with the exception of France) registered a low local timber supply for their wood industries and high imports of commercial logs coming from tropical countries. As a result, the Regulation 2080/92 gave great impetus to the withdrawal of agricultural lands from food production in favour of trees able to produce high quality timber; in fact, planting trees on agricultural lands was one of the most important measures implemented. The aims were the reduction of current agricultural surplus and the increase of local timber availability.

Italian farmers have hardly planted trees on their lands for productive purposes, with the only exception of the highly mechanized poplar plantations in northern-Italy. The large amount of money suddenly available pushed some landowners to accept the presence of trees on their lands; unfortunately, only few farmers had the appropriate knowledge and capacity to undertake such a new activity and also research on tree-farming plantation was at its early stages. Moreover, the wood industry were in favour of only certain timbers and the market influenced the choice of tree species used; this is why most plantation designs considered only European walnut and wild cherry as principal species, even on unsuitable soil conditions.

1.2 Problem statement

Most of the tree farming plantations that have been established with the EEC Regulation 2080/92 have sometimes been managed in inappropriate ways or not managed at all.

The amount of subsidies was significant and included planting costs, seedlings establishment costs (for 5 years after planting), and a premium covering losses of income (for 20 years after planting) originated from the crop that was previously cultivated on the same land; unfortunately, the management rules to accomplish were not sufficiently strict and properly defined and the farmers that became suddenly “tree growers” had not the appropriate knowledge and experience to manage properly their new plantations. In some cases even abandonment or quasi-abandonment occurred; as a consequence, several management problems occurred already during the seasons after planting mainly due to the inappropriate set of tree species used, inappropriate plantation design, and lack of correct treatments like pruning, weed control, and thinning operations to be carried out at the right time.

The trees planted grew up but only in a few cases their trunks are capable of producing high quality timber for veneers or high quality sawn-wood (for example, timber for high quality furniture).

Grading the stem quality since the first stages is a proper way to monitor the quality development of a tree-farming plantation. Usually, commercial timber is graded visually by the personal experience of loggers and timber buyers, but estimating the quality of standing trunks is not always straightforward and a scientific methodology is needed, also to allow for unbiased comparisons.

1.3 Objectives and research questions

In this study two different stem quality classifications were adopted:

1. the classification delineated by Nosenzo *et al*. (2008) based on measurable stem features and different classes for some relevant defects (for example, 4 classes of stem straightness and 3 classes related to the presence of branches and knots);
2. the classification used in a previous study carried out to assess the structure and the quality of almost all tree-farming plantations established in Gorizia province with the EEC Regulation 2080/92 (Canesin 2006, Canesin & Pividori 2007a and 2007b).

Therefore, the specific research objectives are:

- comparing and testing the differences between the two stem quality classifications adopted, namely Nosenzo's and Canesin's stem quality classifications;
- estimating the present butt-log grade distribution and the stem quality development in a sample of all tree farming plantations established in Gorizia province with the EEC Regulation 2080/92.

1.4 Structure of the thesis

Chapter 1 introduces the reader with the background information that has motivated the present study. The research problems and objectives are stated.

Chapter 2 highlights the relevant theories behind the study including some relevant knowledge about tree-farming plantations in Italy, most used tree species and plantation designs, and most important management operations that are supposed to be carried out in order to get high quality timber at the end of the productive cycle.

Chapter 3 describes the research methodology including the description of the research approach, the description of the study area and sample plots, the instruments used for measuring the quantitative data, the data collection procedure and the final data analysis applied.

Chapter 4 reports the detailed results of the study divided according to the three most used principal species: European walnut, wild cherry, and European ash. In each sub-chapter, the results obtained are also discussed.

The detailed stand parameters and butt-log grade distribution obtained in 2009 for each sample plot are reported in Annex 4.

Finally, the general conclusions that have been extrapolated from the results of this study are reported in Chapter 5.

2. Theoretical background

The expression "tree-farming plantation" refers to the activity of growing trees with the purpose of producing commercial timber in a profitable way. These plantations are established temporally on agricultural lands and after the harvesting operations the land can be converted again into cropland without any restriction (Buresti & Mori 2003).

The Public administration fostered the implementation of tree-farming plantations to accomplish the following objectives:

- Reduce agricultural surplus;
- Increase local wood production, since EU countries and above of all Italy are heavy importers;
- Foster people to work and live also in marginal areas;
- Reduce the amount of CO_2 in the atmosphere, which is considered one of the main causes of the ongoing climate change;
- Improve the environment quality thanks to the positive effects that a population of trees intrinsically bears (phytodepuration, landscape diversification, increased biodiversity, constitution of acoustic green barriers, recovery of rare ecological niches for wildlife, new jobs opportunities) (Buresti & Mori 2000).

Also from the farmer point of view there are specific reasons that can lead toward the implementation of a tree-farming plantation:

- Availability of public subsidies;
- Diversification of both production and risks related to monocultures;
- Utilization of agricultural lands that have become marginal and not longer suitable for conventional agricultural crops;
- Production of renewable energy, like firewood and woodchips obtained after thinning that can be sold or used directly in the farm;
- Production of non-timber-forest-products like honey and small fruits.

Moreover, in the medium-long term it is forecasted a reduction of the incentives for agricultural crops and at the same time an increase of wood demand and wood prices (Buresti & Mori 2000).

The principal factors that can determine the success or the failure of a tree-farming plantation are: the productive objectives of the farmer/land owner, the ecological features, and the socio-economic environment in which the plantation will be established. Moreover, it is very important to entrust the project to a qualified tree-farming plantation designer; in fact, the investments protract over a long time span (10-15 years) and any mistake at the early stages should be avoided to maximize the production at the end of the rotation (20-40 years).

Therefore, before planting operations, the following aspects and activities should be considered and carefully evaluated:

- Data collection regarding owner perspectives and farm features;
- Analysis of the soil characteristics of the land that is going to be planted, including soil type, spontaneous flora, and exposure;
- Definition of a suitable plantation design;
- Evaluation of the need of accessories aimed to protect the seedling or to foster their growth, like dark plastic films, shelters, supporting poles, and fencing;
- Providing the necessary documentation to be presented to local authorities;
- Getting the project approval.

After the approval of a well described project, it is possible to proceed with the practical realization that include the main following steps:

- Ordering the seedlings (better with local provenances);
- Carrying out hydraulic works when needed;
- Carrying out soil preparation during summer time when the soil has the appropriate physical properties (neither wet nor very dry);
- "Squaring" the land in order to distribute at the specified distance the seedlings;
- Planting the seedlings at the right period according to climate and soil conditions (Buresti & Mori 2000).

The most common tree species that can produce high quality timber and get up to high prices in the European market are: wild cherry (*Prunus avium* L.), pear (*Pyrus* spp.), *Sorbus* spp., maple-trees (*Acer* spp.), chestnut (*Castanea sativa* Miller), European ash (*Fraxinus excelsior* L.) and European walnut (*Juglans regia* L.), which produces the most requested commercial timber in the Italian market (Buresti & Mori 2004).

However, the prices depend not only on the wood species but also on the wood mechanical quality; depending on the amount and type of defects found on a commercial log, the timber price changes accordingly and different quality classes can be delineated. Sometimes, the price for high quality timber is not divided into a specified number of quality classes but it is given as range; this is the case of "Camera di Commercio Udine" (2009), that reports the price of walnut timber in a range going from a minimum of 413 euro/m^3 to a maximum of 826 euro/m^3. Diversely, according to Buresti & Mori (2004), walnut industrial logs may be classified in three price classes as reported in Table 2.1.

Table 2.1**:** Prices of walnut logs belonging to different grades in 2003 (Buresti & Mori 2004)

	Euro/m³
1st class (A)	1100
2nd class (B)	350
3rd class (C)	160

To be classified as first class, logs should be at least 30-40 cm in diameter and 2.5 m long; they should have a straight and cylindrical shape, all knots and defects included in the 10 cm diameter central cylinder, homogeneous wood colour and regular annual-growth rings. The top quality timber (A class) can be used in the veneer industry (both sliced veneer and rotary-cut veneer). Depending on the presence and amount of the defects that affect the ideal features mentioned above, a log is downgraded to the second or third class (Buresti & Mori 2004).

Second class timber (B class) represents high quality sawn-wood, suitable for the production of high quality furniture, interior joinery, doors, turnery, etc. Third class timber (C class) represents low quality sawn-wood used only for exterior joinery, light construction, boxes, crates, etc.

Finally, a log is classified as D class when it does not fit into class C either, due to its bad mechanical defects; class D timber represents the lowest quality grade and only firewood (logs cut into peaces) or woodchips that are burned for energy purposes can be produced out of it. In any tree-farming plantation, woody biomass for energy purposes is also a by-product when produced from branches of principal trees, and from stems and branches of shrubs and accessory trees (Figure 2.1; Buresti & Mori 2006).

Figure 2.1: Timber assortments that can be obtained from tree-farming plantations (Buresti & Mori 2000, modif.).

2.1 Definitions

Several technical expressions are used to describe properly tree-farming plantations. First of all, it is important to clarify the difference between “principal tree species” and “accessory tree species”. ***Principal trees*** are the “crop trees” in a plantation, i.e. those trees that are planned to produce the high quality timber at the end of the productive cycle; their trunk can be sold at the highest prices and the final profit depends mostly on them. However, it is possible and strongly suggested by recent researches (Buresti & Mori 2007a) to plant also ***accessory tree*** species; in fact, it has been demonstrated that they favour the formation of a suitable stem and crown architecture of the principal trees thanks to the shading effect, and the improvement of soil fertility; in addition, with thinning operations they produce woody biomass that can be sold as firewood or woodchips representing an additional income for farmers; shrubs, shade tolerant species and all those species able to improve soil fertility through nitrogen fixation and leaf litter are preferred.

Both principal species and accessory species are planted following a precise ***plantation design,*** which is defined as the minimum unit of land surface including all tree species used and their relationship defined in the project design (like distance between trees of the same species and distance between trees of different species). The plantation design is able to reproduce on the entire land surface the whole plantation just rotating repeatedly itself by 180° on each side, without changing the relationship between species. The boundaries of each plantation unit pass through the centre of the trees located on the plantation design borders. Practically, thanks to the plantation design unit it is possible to know the amount of species needed, the number of trees of each species, the spacing distance and the spatial distribution of each tree species (Buresti & Mori 2000).

The easiest plantation design (***pure plantation***) uses only one tree species planted at a fixed spacing. When there are two or more principal species the tree population is defined as ***mixed plantation***.

A plantation with only one principal species and one or more accessory species is denominated as ***pure plantation with accessory species***, whereas, if there are two or more principal species plus the accessories species, the plantation is defined as a ***mixed plantation with accessory species*** (Figure 2.2 & Figure 2.3) (Buresti & Mori 2007b).

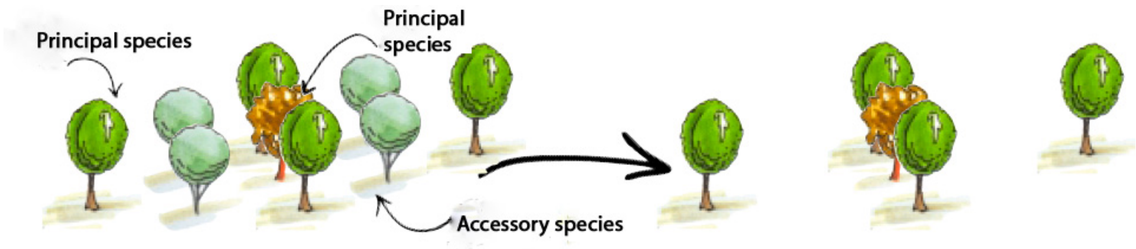


Figure 2.2: Example of a mixed plantation with accessory species: plantation design (left) and same plantation after removal of all accessory species (right) (Buresti & Mori 2000, modif.).

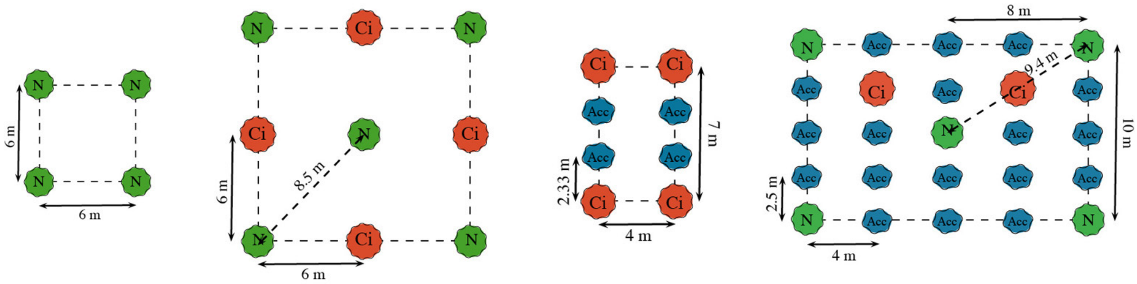


Figure 2.3: Types of tree farming plantations according to species composition. Starting from left: pure plantation (plot n° 7, see Annex 4), mixed plantation (plot n° 30), pure plantation with accessory species (plot n° 53), and mixed plantation with accessory species (plot n° 16.1).

2.2 Theoretical approaches

In order to get positive results at the end of the rotation, both qualification and dimensioning of all principal species should be carefully followed during the years.

According to Buresti & Mori (2000), the three phases at the base of high quality timber production are:

- Forming a well developed root system, that can be ensured through soil preparation, right selection of tree species, good quality seedlings, right plantation technique and suitable treatments during the first years after planting (emergency watering, weed control, replacement of dead seedlings);
- Forming a trunk sufficiently long (at least 2.5 m), cylindrical and free of knots thanks to the right tree species selection, a periodical monitoring of each single principal tree and correct pruning operations when needed;
- Fostering the formation of a cylindrical stem with homogeneous annual-growth rings in cross section, meaning a constant increment in size year by year (monitoring and thinning operation should be carried out at the proper time).

The utilization of accessory species together with a mix of principal tree species has been proved to have several positive effects on the plantation management:

- Faster soil cover and reduced soil erosion;
- Improvement of soil fertility and biodiversity;
- Positive modification of principal trees stem shape and architecture;
- Better tree selection thanks to planned thinning operations;
- Intermediate incomes derived from non timber forest products (honey, small fruits), firewood and small size sawn-wood obtained with thinning operations;
- Reduction of both treatment inputs and management costs: less use of fertilizers, easier weed control (especially when shrubs are planted), easier pruning operations carried out only on a restricted number of trees (only on principal trees and not on the accessory trees);
- Reduced pathogens' attacks;
- Diversification of production in terms of timber assortments and a consequent reduction of hazards due to market price fluctuations (Buresti & Mori 2000, Buresti & Mori 2003, Tani *et al.* 2007, Cutini & Giannini 2007).

To ensure the formation of suitable stems for high quality timber, pruning plays a very important role. Its main purpose is to guide the correct formation of a straight stem free of knots and branches and to concentrate all the defects in the ideal central cylinder of 8-10 cm diameter (Buresti *et al*. 2007, Brunetti & Nocetti 2007) (Figure 2.4).

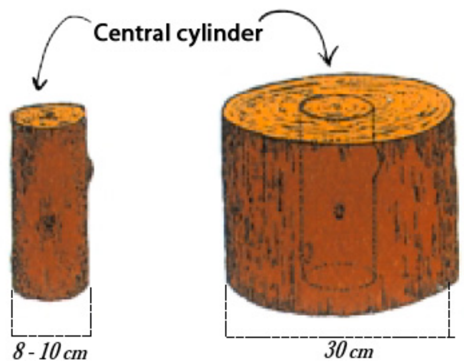


Figure 2.4: Ideal central cylinder containing all defects (Buresti & Mori 2000, modif.).

Thinning operations are also very important to be carried out at the right time when competition at the expenses of principal trees occurs (Pelleri *et al.* 2007; Marchino & Ravagni 2007). If thinning is delayed or not carried out, the entire plantation could be badly affected. In fact, all trees start to become weaker due to the increasing competition for nutrients and lights; this situation could also facilitate pathogens' attacks (fungi, insects and bacteria). Moreover there will be a delay in the productive cycle with respect to the original project design and the timber obtained could not be of the highest classes as planned (inhomogeneous annual growth rings). Thinning operations are still very expensive in young plantations because of the low amount of wood obtained and the low firewood quality that mostly comes from fast growing accessory species (like willow and alders) or accessory shrubs (like hazel). Research is trying to find a better market allocation for the timber harvested with thinning operations and some positive results have already emerged like: the profitable chairs production with plywood derived from small size walnut logs (Zanuttini *et al.* 2009) and the potential production of window frames with alder timber (Todaro *et al.* 2007).

To estimate the value of a tree-farming plantation is a hard job and currently there are few professionals able to do it properly. It is very important to have knowledge about wood in general, the growing patterns of each tree species and the wood technological characteristics demanded by the wood industry. At the moment of final harvesting different timber assortments will be available and to maximize profits it is crucial to allocate each log to the most valuable quality class even though this could cause a reduction in the amount of commercial timber sold. For example, if there is a third grade log four meters long but with the first 2.5 metres of A class, it is much profitable to cut it down to 2.5 metres and sell it as A class (higher price) instead of C class (much lower price).

As a conclusion, appropriate plantation design, pruning and thinning operations are key factors to get high quality timber at the end of the technical rotation (Buresti & Mori 2004).

3. Materials and methods

3.1 Research approach

In order to examine the quality development of broad-leaved tree-farming plantations in northern-east Italy, both secondary sources and primary data have been collected. The literature review allowed for a comprehensive understanding of the terminology used in the high quality tree-farming sector. Secondary data include the 2006 field data and results carried out to investigate the structure of all tree-farming plantations established in Gorizia province with the EEC Regulation 2080/92 (Canesin, 2006; Canesin & Pividori 2007a and 2007b).

The balk of the study is based on primary data that have been collected in spring 2009 to test the differences between the two stem classifications adopted; both quantitative and qualitative data collected have been subjected to statistical analysis to investigate the growth and quality trend of tree-farming plantations in Gorizia province.

To make reliable the comparison between the secondary data obtained in 2006 (Canesin, 2006) and the primary data obtained with the fieldwork carried out in 2009, the permanent plot approach was adopted.

3.2 Study area

Gorizia province extends over 466 km^2 and it is the most populated province in Friuli-Venezia Giulia region with about 296 inhabitants/km^2. It borders Slovenia to the east, Udine province to the west and the Adriatic see and Trieste province to the south (Figure 3.1).

The territory can be divided in five landscape units:

1) *Collio*, which is located to the north on low mountains with a dense river network;
2) *high plane*, which has been formed by coarse sediments transported by the rivers; therefore, the soil has low retention capacity;
3) *low plane*, located south of the "resurgences" and has been formed by fine and very fine sediments (clay and silt); both soil fertility and water availability reach high levels;

4) *Grado lagoon*, which is located to the south near the mouth of the Isonzo and Tagliamento rivers. Its origin is due to the redistribution of the alluvial sediments by the see. The salty water and the low nutrients in the soil are the main limiting factors for a well-developed vegetation cover. Most of the original salty and wet soils have been drained in the past to get more agricultural land available; the most significant example is the "Victoria drainage", completed at the end of the 50'.
5) *Carso*, which represents a unique landscape unit characterized by pure calcareous rocks able to form particular morphologies like sinkholes and *dolinas*. The high vegetation is poor due to the high pressure of the army during the first world war and the lack of conifers plantations that were common in others areas after the wars (AA.VV. 1998; Abramo & Michelutti 1998).

Figure 3.1: Map of Gorizia province (source: mondimedievali 2009, modif.)

The climate is mild thanks to the influence of the Adriatic See. The annual rainfall is higher in the interior part reaching even 1600 mm, while it hardly reaches 1000 mm on the coastal area. Also the mean annual temperature changes between the interior and coastal zones going from 12°C to 14°C respectively. The "Carso" area, the low plane and the lagoon are particularly affected by a very strong wind blowing from northeast and called "Bora" (AA.VV. 1995).

3.3 Sample plots

In 2006, Canesin (2006) carried out a study on the structure of almost all broad-leaved tree-farming plantations realised in Gorizia province with the EEC Regulation 2080/92 (about 250 ha). From the 147 homogeneous areas visited in 2006, a sub-sample of 21 sample plots has been selected choosing from the relatively best plantations spread on the entire province; therefore, the sample plot identification numbers correspond to those used in Canesin's study to allow for easier comparison; Table 3.1 lists the plots number and the municipalities in which they are located. Each sample plot was assumed to represent significantly either the whole plantation it is located in or only a homogenous area inside the plantation itself (in this case the plot number bears the homogeneous area number after the point). Most of the plantations are mixed with accessory species (14 plots); three are mixed, three pure with accessory species and only one is a pure plantation.

Table 3.1: List of the 21 plots sampled in 2009 with the respective species composition and municipality in which they are located.

Plot n°	Municipality	Composition
1	Romans d'Isonzo	Mixed
2.1	Cassegliano	Mixed with accessory species
2.2	Cassegliano	Mixed with accessory species
7	Grado	Pure
12A	San Canzian d'Isonzo	Mixed with accessory species
15A	San Lorenzo Isontino	Mixed with accessory species
16.1	San Pier d'Isonzo	Mixed with accessory species
16.2	San Pier d'Isonzo	Mixed with accessory species
22	Turriaco	Mixed
30	Mossa	Mixed
35	San Canzian d'Isonzo	Mixed with accessory species
37A	San Canzian d'Isonzo	Mixed with accessory species
41.1	Grado	Pure with accessory species
41.2	Grado	Pure with accessory species
51.1	Romans d'Isonzo	Mixed with accessory species
51.2	Romans d'Isonzo	Mixed with accessory species
53	Grado	Pure with accessory species
54A	Dolegna	Mixed with accessory species
61	Grado	Mixed with accessory species
77A.1	Romans d'Isonzo	Mixed with accessory species
77A.2	Romans d'Isonzo	Mixed with accessory species

Reading from Canesin's field data, it was possible to localize the trees already measured in 2006 through the combination of the recorded row number in the plantation and the assigned tree number along the row. Only in three cases it was not possible to find exactly the same tree measured due to missing data in the 2006 field papers (this applies to plots n° 7, 15A and 16.2).
The plot shapes and sizes are variable: 30 trees per each principal species have been measured in 2006 along the most representative rows of each plantation. These 30 trees per each principal species have been localized and measured in 2009 as well. Slight differences occur in those plantations where a recent thinning operation has been carried out (this applies to plot n° 2.1, 2.2, 16.1, and 16.2). In this case some trees in the nearest rows were sampled to reach totally 30 trees per each principal species in each plot.

3.3.1 Instruments for measuring

Both spacing and plantation designs were drawn measuring with a metric tape the minimum distance between trees and principal trees in each plot.
Then, for each sampled tree, a common tailor's tape was used to measure the girth at breast height, and a *metric pole* to measure the butt-log height and the deviation from the straightness. The tree total height was estimated using the Vertex hypsometer. Finally, the trunk quality features have been recorded following systematically the specific guidelines of both classification methodologies adopted.

3.3.2 Data collection

For each sampled tree the girth at breast height, the butt-log height, the total height and the trunk deviation from straightness were measured and the stem quality features were described filling in the field paper reported in Annex 2.
The deviation from the straightness was divided in 4 classes according to Nosenzo's classification (Nosenzo *et al.* 2008): class 0 means that there is no deviation (the butt-log is perfectly straight), class 1 means a deviation between 1 and 3 %, class 2 a deviation between 3 and 10 % and class 3 a deviation more than 10 %.
The stem inclination was divided into 2 classes: class 1 means a stem inclination between 10 and 20 % while class 2 means an inclination more than 20 %.

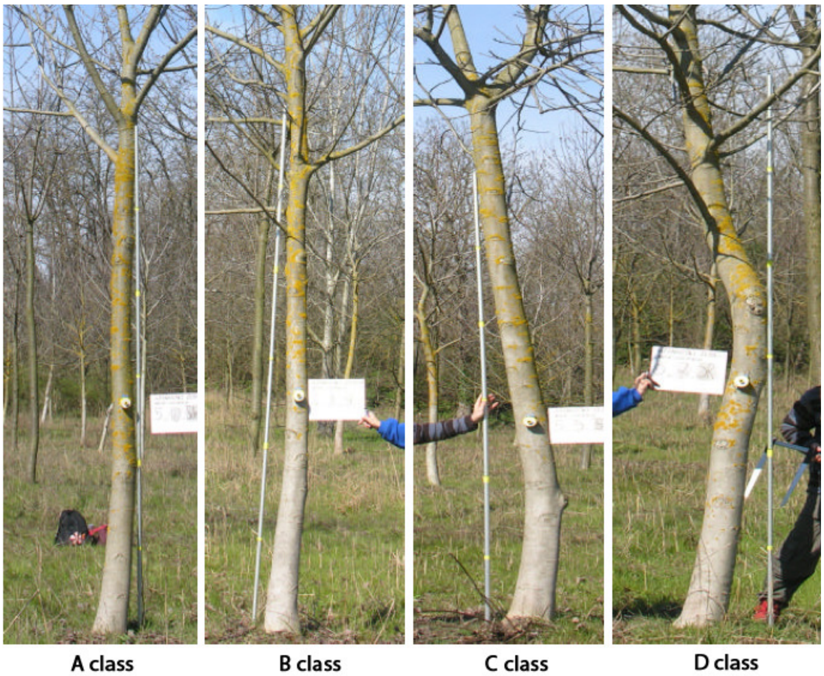


Figure 3.2: Stem straightness classes in Nosenzo's classification (Nosenzo *et al*. 2009, modif.)

It was also recorded, per each butt-log sampled, the presence of branches and knots with diameter more than 3 cm, covered knots, fresh knots and rotten knots.

The sum of the diameters of knots and branches was divided in 3 classes according to Nosenzo's classification: class 1 when the sum of all knots and branches diameters is more than 60 mm, class 0.5 when the sum is between 15 and 60 mm and class 0 when less than 15 mm. Protuberances caused by stubs were considered as knots with a diameter of 60 mm due to their negative effect on wood quality.

Figure 3.3: Some stem defects considered in this study. From left to right: biotic defects (insect holes, cancer and rot); a-biotic defects (knot diameter > 3 cm and base damage). The a-biotic defects in these examples could not be considered negligible because the stem diameter (at the height where the defect is found) was more than 10 cm.

Moreover, for each stem it was recorded the presence of sinuosity, fork, "saddle", base damage, rots, insects holes, frost cracks, ovality, signs on bark, "bottle neck", spiral

grain and others specific biotic or a-biotic defects reported in the notes (like dominancy, debarking, superficial insect holes, metal wires in the wood, etc.).
Some of the above defects were not found in the English literature and a word-by-word translation was applied; to avoid misunderstandings, the Italian translation and a short description of each stem defect treated in this study is reported in Annex 1.

3.4 Data analysis

The 2009 field data were analyzed using the Microsoft Office Excel software. At first, the raw field data of each sample plot have been recorded in an Excel sheet; then, a new excel sheet was created for each principal tree species found in the plot and the respective descriptive statistics have been computed.
To grade the butt-log of each sampled tree, two different methods were used: Nosenzo's classification (Nosenzo *et al*. 2008) and Canesin's classification. Both methods above divide the stem quality in 4 classes:

- A class, which is the most valuable one; the butt-logs belonging to this class have high quality features and can be used in the veneer industry;
- B class, which includes valuable timber that can be used for high quality furniture, for instance;
- C class, which includes butt-logs with low quality features and therefore capable of producing only low quality sawn-wood;
- D class, which is the lowest quality; the trunks belonging to this class can be used only as firewood or *bioenergy* (woodchips).

In both classifications adopted, a stem falls in D class whenever it is shorter than 2.5 meters, or it has got a deviation from the straightness above 10%, or its wood is affected by either serious biotic defects (insect holes, rot, serious debarking, etc.), or severe a-biotic defects (significant mechanical damages at the stem base able to facilitate disease attack). Superficial insect holes affecting only the bark and not the wood were considered negligible (Figure 3.4). Additionally, D class includes also stems of trees that show sinuosity or an inclination above 20 % in Nosenzo's classification, while, according to Canesin's classification, a stem is considered D class also when it has got both deviation and sinuosity. Whenever all the conditions above do not apply, a stem can be included in a class other than D.

Figure 3.4. Tiny insect holes that affect only the bark of some European ash stems. This defect has been considered negligible.

According to Nosenzo's classification, a stem belongs to C class when its deviation from the straightness is between 3 and 10 %, or the sum of the diameters of all branches and knots on the butt-log is more than 60 mm. Instead, according to Canesin's classification, a stem is considered C whenever it has got deviation or sinuosity (not both together), or both branches and knots with a diameter larger than 3 cm.

Table 3.2: Comparison between the 2 classifications adopted in this study. The occurrence of at least one feature listed in column 2 and 3 determines the corresponding grade in column 1.

Class	Nosenzo's classification	Canesin's classification
D	Stem length < 2.5 m	Stem length < 2.5 m
D	Deviation from the straightness > 10%	Both stem deviation AND sinuosity
D	Relevant biotic or a-biotic defects	Relevant biotic or a-biotic defects
D	Stem inclination > 20%	-
D	Stem sinuosity	-
C	Deviation from the straightness in the range of 3-10%	Stem deviation OR sinuosity
C	Sum of the diameters of all branches and knots > 60 mm	Presence of knots AND branches with a diameter > 3 cm
B	Deviation from the straightness in the range of 1-2%	Absence of stem deviation AND sinuosity
B	Sum of the diameters of all branches and knots in the range of 15-60 mm	Presence of knots OR branches with a diameter > 3 cm
A	Deviation from the straightness < 1%	Absence of deviation AND sinuosity
A	Sum of the diameters of all branches and knots < 15 mm	Absence of knots AND branches with a diameter > 3 cm

If the deviation from the straightness is between 1 and 3 %, and the sum of the diameters of all branches and knots on the butt-log is between 15 and 60 mm, the stem falls in B class in Nosenzo's classification. Instead, according to Canesin's, B class is reserved for butt-logs that show neither deviation, nor sinuosity, nor a contemporaneous presence of both branches and knots having a diameter more than 3 cm.

Finally, a stem is considered A class only if its deviation from the straightness is less than 1% and the sum of the diameters of all branches and knots on the trunk is less than 15 mm (Nosenzo's). Instead, according to Canesin's, it falls in A class whenever it is straight and free of both branches and knots with a diameter larger than 3 cm.

Table 3.2 lists the above conditions to be fulfilled in both classification methodologies.

The main implementation problem was the relatively subjective interpretation of the "stem deviation" in Canesin's classification.

Afterwards, pie charts showing both the butt-log grade distribution in each plot for each species and the overall butt-log grade distribution for each species have been drawn.

The statistical *Fisher exact test* was carried out to investigate both the similarity between the two stem classifications used and the development of the butt-logs quality in the period 2006-2009. In the first case, per each sample plot the number of trunks belonging to each quality class obtained through Nosenzo's classification was compared with the corresponding number of trunks obtained with Canesin's classification. In the second case, per each sample plot the number of trunks belonging to each quality class obtained through Canesin's classification in 2006 was compared with the number of trunks belonging to the same quality class obtained with the same classification in 2009. The corresponding probability values were computed using the online software provided by "College of Saint Benedict and Saint John's university" (Kirkman 1996). The *Fisher exact test* was required due to the high frequency of expected values less than 5, which is the minimum expected value found in the literature that allows for the accurate application of the *Chi-square test* (Fowler & Cohen, 2002). However, the *Chi-square test* was applied to investigate the statistical difference between the 2006 and 2009 results concerning the number of all butt-logs falling in a certain quality class and belonging to the same principal species (in this case, the expected values were much higher than 5 due to the sum of all butt-logs of a certain quality class in each plot); STATISTICA software was used to compute the *Chi-square* value and the corresponding probability of occurrence.

4. Results and Discussions

The fieldwork carried out in spring 2009 produced a consistent amount of raw data. A first analysis aimed at the computation of the stand parameters for each sample plot of this study (21); the detailed results are reported in Annex 4, where the reader can find information about the year of plantation, the species composition, and the specific plantation design. Per each principal species there is also a table reporting the growth increment, a table with the stand parameters and a table with the percentage of all stem defects found. Finally, the butt-log grade distribution obtained with both Nosenzo's and Canesin's stem classifications are presented in pie charts for ease of comparisons.

The most represented principal tree species in Gorizia province are European walnut, wild cherry, and European ash; the results concerning each principal tree species are described and discussed separately in 3 different sub-chapters focusing on:

1. the stand parameters estimated in 2009 and the current annual increment referred to the last three years;
2. the most relevant stem defects found;
3. the share of each stem quality classes obtained with Nosenzo's and Canesin's classifications and their statistical comparison through the *Fisher exact test*;
4. the stem quality development occurred between the years 2006 and 2009.

The percentage of each single stem defect referred to the total sample size of each principal tree species is shown for ease of comparison in Table 4.1; taking as example the first value, the table reports that 9 % of all walnut trees show at least one branch with a diameter larger than 3 cm. As one single butt-log could present even all defects listed, the values in Table 4.1 cannot be summed up inside the same tree species group. In all three principal species, *signs on bark* and *covered knots* are the most common defects followed by *stem straightness between 3 and 10 %* and *sum of all branches and knots diameters more than 60 mm (* $\sum(b+k) > 60$ mm). All defects except *signs on bark* (because considered a negligible defect) were divided into 5 groups according to the origin and the stem feature they affect (see Annex 1 for a detailed stem defects description).

Table 4.1: Percentage of each stem defect found on all sampled trees of each principal species and grouped according to the origin and the stem feature they affect.

	Stem defect	Walnut (%)	Cherry (%)	Ash (%)
Braches and knots	**Branch > 3 cm**	9	13	14
	Knot > 3 cm	31	12	3
	Covered knots	64	59	39
	Fresh knots	32	17	5
	Rotten knots	2	2	1
	∑(b+k) > 60 mm	57	45	30
	∑(b+k) 15mm < > 60 mm	3	11	7
Stem shape	**Stem straightness > 10%**	11	3	3
	Stem straightness 3% < > 10%	61	29	31
	Stem straightness 1% < > 2%	26	52	50
	Stem inclination > 20%	5	1	0
	Stem inclination 10% < > 20%	28	7	4
	Sinuosity	5	1	2
	Fork	3	4	2
	Saddle	21	12	21
	Bottle neck	2	4	0
	Ovality	0	1	0
Biotic	**Rot**	0	2	0
	Insect hole	5	0	8
A-biotic	**Base damage**	15	16	11
	Frost crack	2	2	1
Grain	**Spiral grain**	0	1	0
	Fluting	1	0.4	0
Negligible	**Signs on bark**	93	88	90
	Sample size (n°)	**447**	**570**	**300**

4.1 European walnut (*Juglans regia* L.)

All sample plots having walnut as principal species were divided in age classes and the corresponding mean tree height annual increment and mean diameter at breast height (DBH) annual increment were computed. Because of the very diverse management and ecological situations found (different plantation design, different soil conditions, different seedlings quality, different treatments) the expected DBH increase with age does not occur; in fact, one of the lowest mean DBH (10.7 cm) was found in the oldest plantations. However, the highest mean DBH (16.1 cm) was found in plantation number 7, which is the only pure walnut plantation of this study. The highest mean tree height was found in plot number 51.1 (12.31 m) instead, which is a mixed plantation with accessory species three years younger than the previous pure plantation.

The mean DBH annual increment is in the range of 0.7-1.4 cm/year with the highest value found in the 9 years old plots, while the tree height annual increment goes from 0.59 m/year in the oldest plots to 1.18 m/year in the 9 years old plots.

Afterwards, the current annual increment (CAI) referred to the last three years was computed: values lower than the mean annual increment are found mostly in the older plantations meaning that a negative competition occurred and the trees produced thinner annual growth rings during the last years. Same trend for the height CAI, which is higher than the mean height annual increment only in the 8 years old plantations (the youngest). The detailed data are reported in Table 4.2.

Table 4.2: Mean DBH, mean butt-log height (stem H), and mean tree height (H) for all walnut trees both in 2006 and 2009 divided in age classes. The last four columns report the mean DBH and height annual increment (I_m) and the mean DBH and height current annual increment (CAI, period 2006-2009).

			2006		2009			I_m		CAI	
Plot n°	**Age (y)**	**N°**	**DBH (cm)**	**H (m)**	**DBH (cm)**	**Stem H (m)**	**H (m)**	**Δdbh (cm/y)**	**Δh (m/y)**	**Δdbh (cm/y)**	**Δh (m/y)**
1	14	27	9.3	6.38	13.2	2.53	9.17	0.94	0.66	1.29	0.93
2.1	14	30	9.1	7.15	10.5	2.65	8.04	0.75	0.57	0.46	0.30
2.2	14	30	7.9	6.53	8.6	2.76	6.76	0.61	0.48	0.25	0.08
Mean	**14**	**87**	**8.8**	**6.69**	**10.7**	**2.65**	**8.28**	**0.76**	**0.59**	**0.64**	**0.53**
7	12	30	11.8	7.18	16.1	3.00	8.33	1.34	0.69	1.43	0.38
12A	12	30	11.1	7.90	14.9	2.61	10.31	1.24	0.86	1.28	0.8
Mean	**12**	**60**	**11.5**	**7.54**	**15.5**	**2.81**	**9.49**	**1.29**	**0.79**	**1.35**	**0.65**
16.1	11	30	10	6.57	11.9	2.37	6.85	1.08	0.62	0.65	0.09
16.2	11	30	8.4	5.87	11.6	2.37	7.24	1.05	0.66	1.07	0.46
Mean	**11**	**60**	**9.2**	**6.22**	**11.8**	**2.37**	**6.99**	**1.07**	**0.64**	**0.86**	**0.26**
22	10	30	8.8	7.32	12.1	3.59	8.39	1.21	0.84	1.11	0.36
30	10	30	6.3	4.05	11.7	1.99	6.67	1.17	0.67	1.78	0.87
Mean	**10**	**60**	**7.6**	**5.7**	**11.9**	**2.79**	**7.51**	**1.19**	**0.75**	**1.44**	**0.61**
35	9	30	8.6	6.42	12.3	3.61	9.06	1.36	1.01	1.24	0.88
37A	9	30	10.8	9.42	14.6	2.67	11.67	1.62	1.30	1.27	0.75
51.1	9	30	8.2	6.83	12.7	2.50	12.31	1.41	1.37	1.51	1.82
51.2	9	30	-	-	11.1	2.32	9.80	1.24	1.09	-	-
Mean	**9**	**120**	**9.2**	**7.56**	**12.7**	**2.78**	**10.58**	**1.41**	**1.18**	**1.34**	**1.15**
77A.1	8	30	5.7	4.92	11.0	2.36	9.22	1.38	1.15	1.76	1.43
77A.2	8	30	3.2	3.20	6.2	2.21	5.19	0.78	0.65	1.01	0.66
Mean	**8**	**60**	**4.5**	**4.1**	**8.6**	**2.29**	**7.94**	**1.08**	**0.99**	**1.38**	**1.29**

Figure 4.1 plots the mean DBH annual increment of each plot against the age and shows how the mean annual increment decreases when the plantations become older. The polynomial trendline that was drawn illustrates the phenomena. To keep constant the

mean annual increment, negative competition between trees should be controlled through appropriate thinning operations.

Some of the oldest plantations (plots 2.1, 2.2, 16.1, and 16.2) were thinned in the winter 2007/2008 (1 year before this study): mostly accessory species were affected and only very few walnut trees were felled. Consequently, more light and nutrients are currently available and a slight increase of both mean annual increment and CAI is expected to occur in these four plantations during next years.

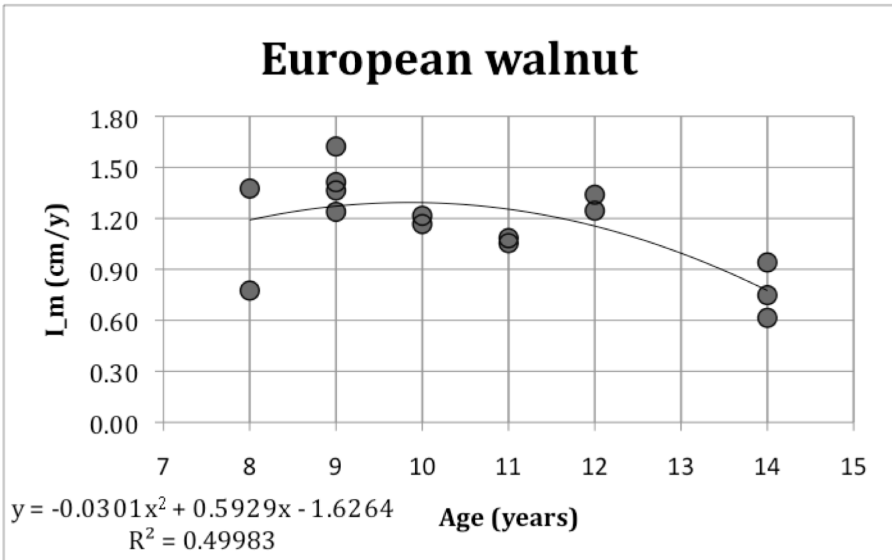


Figure 4.1: Mean DBH annual increment of walnut trees plotted against age.

The stem defects found in all walnut trees were divided into 5 groups as shown in Table 4.1. Signs on barks are very common (93%), but because they could be considered negligible at this stage, they are not included in further analysis. It was estimated that in average each walnut tree shows 4 different defects; this estimate should be carefully interpreted but suggests that the amount of defects found was quite huge. According to the results obtained, the most common stem defects are due to the presence of knots and branches and to the stem shape. In both cases a correct and constant pruning would have lowered very much the amount of this two defect groups. Biotic (insect holes and rot) and grain defects (spiral grain and fluting) share a much lower percentage of the total, while the a-biotic defects (base damage and frost crack) present a relatively low percentage but were found on 78 butt-logs (17% of the sample size); therefore, they cannot be considered irrelevant (Figure 4.2).

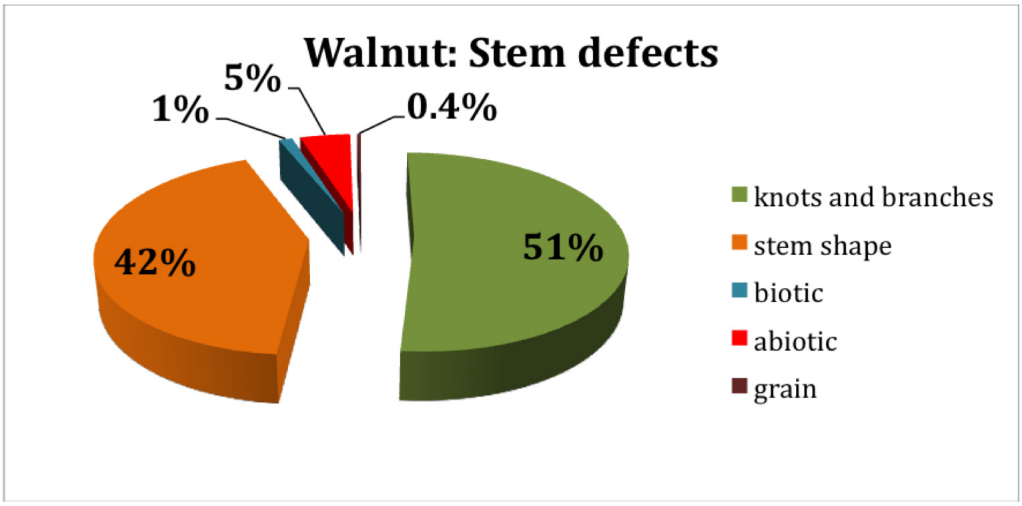


Figure 4.2: Stem defects found on all walnut butt-logs. See Table 4.1 for the list of stem defects included in each group.

Figure 4.3 shows the contribution of each single defect inside the defect group "knots and branches": the most common are *covered knots* followed by the *sum of branches and knots diameters more than 60 mm*, *branches and knots with diameter larger than 3 cm* and *fresh knots*. This demonstrates that pruning has not been carried out in the proper way and at the right time. *Rotten knots* share only 1 % of this defect group.

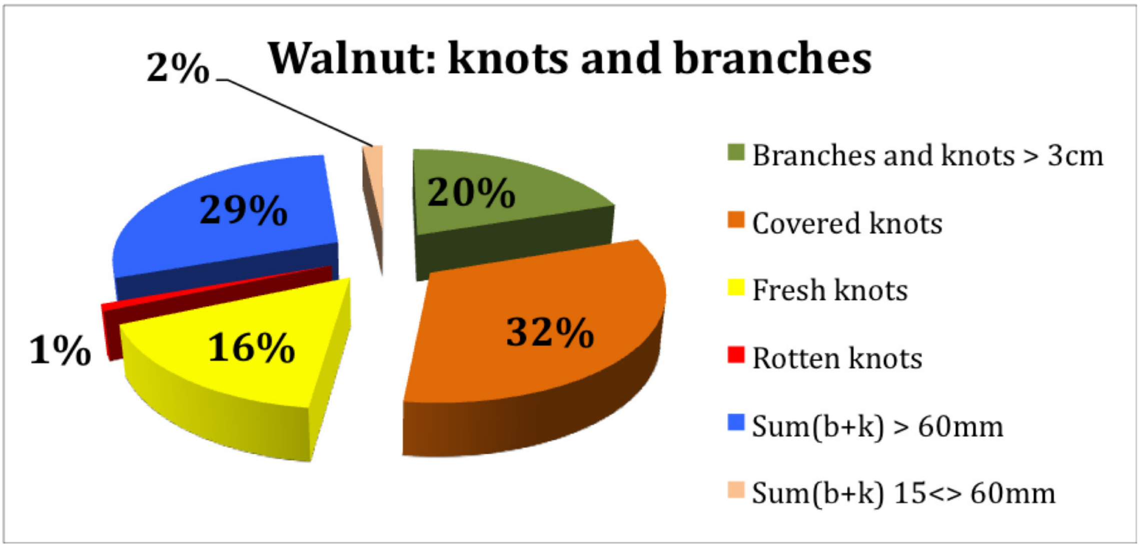


Figure 4.3: Stem defects due to the presence of knots and branches on all walnut butt-logs.

The detailed 2009 butt-log grade distribution in each sample plot having walnut as principal species are reported in Table 4.3, while the total percentage of A, B, C and D classes for the entire walnut population is reported in Figure 4.4.

In all plots, Nosenzo's classification produces lower percentage of higher quality classes (A and B) when compared with Canesin's classification, but the differences between the two classifications are significant only in two cases (plot 22 and 35) when applying the *Fisher Exact test*.

Table 4.3: Walnut butt-log assortments obtained in 2009 with Nosenzo's and Canesin's classification in the 15 sample plots having walnut as principal species. The last two columns show the *p* value and the equivalent significance level obtained with the *Fisher exact test* (*=little significant; **=significant; ***=very significant, **n.s.**=not significant)

		Nosenzo's classification				Canesin's classification					
Plot n°	**Age (y)**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**	***p* (Fisher)**	**Significance**
1	14	0%	11%	33%	56%	7%	0%	44%	48%	0.166	**n.s.**
2.1	14	0%	0%	37%	63%	3%	3%	33%	60%	1.000	**n.s.**
2.2	14	0%	7%	63%	30%	7%	10%	50%	33%	0.523	**n.s.**
7	12	0%	0%	43%	57%	3%	3%	40%	53%	1.000	**n.s.**
12A	12	0%	0%	53%	47%	0%	10%	50%	40%	0.324	**n.s.**
16.1	11	0%	7%	60%	33%	3%	3%	60%	33%	1.000	**n.s.**
16.2	11	0%	0%	40%	60%	0%	3%	37%	60%	1.000	**n.s.**
22	10	0%	20%	57%	23%	17%	0%	67%	17%	0.005	***
30	10	0%	3%	10%	87%	7%	0%	7%	87%	0.671	**n.s.**
35	9	0%	0%	60%	40%	3%	13%	43%	40%	0.098	*
37A	9	3%	7%	70%	20%	10%	0%	70%	20%	0.491	**n.s.**
51.1	9	0%	0%	57%	43%	3%	0%	60%	37%	0.792	**n.s.**
51.2	9	0%	0%	37%	63%	3%	0%	37%	60%	1.000	**n.s.**
77A.1	8	0%	3%	37%	60%	0%	0%	40%	60%	1.000	**n.s.**
77A.2	8	0%	7%	37%	57%	7%	0%	37%	57%	0.393	**n.s.**

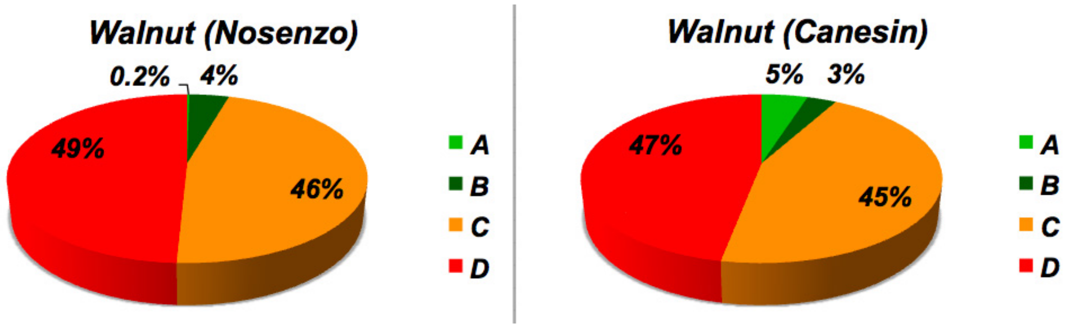


Figure 4.4: Walnut butt-log grade distribution according to Nosenzo's classification (left) and Canesin's classification (right).

"A class" timber is almost 0% of the total according to Nosenzo's classification and not more than 5 % according to Canesin's; "B class" ranges between 3 and 4%, while almost half of all walnut trees fall in "D class" according to both classifications used.

As a consequence, the amount of high quality timber that is still potentially suitable for veneers and high quality sawn-wood at the end of the rotation will be very little.

Therefore, the economical benefit will be strongly compromised. In fact, only in one case (plot 22) the amount of A and B classes together reaches 20 %; this is the threshold value found in the literature (Nosenzo *et al.* 2008) under which the economical benefit is no longer met and the future management of the entire plantation becomes questionable.

To investigate the stem quality development occurred in the period 2006-2009, the *Fisher exact test* was applied to the 2006 and 2009 quality classes obtained with Canesin's classification (Table 4.4). Plot 51.2 was not considered in this analysis because of the lack of 2006 data. In 85 % of the cases (12 plots out of 14) it was found a significant difference between the 2006 and 2009 values and even a very significant difference in 64 % of the cases (9 plots out of 14). These results suggest that the stem quality has changed consistently during the last three years.

Table 4.4: Walnut butt-log assortments obtained in 2006 and in 2009 with Canesin's classification in the 15 sample plots having walnut as principal species. The last two columns show the *p* value and the equivalent significance level obtained with the *Fisher exact test* (*=little significant; **=significant; ***=very significant, **n.s.**=not significant)

		2006 (Canesin's class.)				2009 (Canesin's class.)					
Plot n°	**Age (y)**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**	***p* (Fisher)**	**Significance**
1	14	10%	27%	7%	57%	7%	0%	44%	48%	0.000	***
2.1	14	13%	0%	20%	67%	3%	3%	33%	60%	0.256	**n.s.**
2.2	14	27%	7%	23%	43%	7%	10%	50%	33%	0.066	*
7	12	10%	13%	7%	70%	3%	3%	40%	53%	0.007	***
12A	12	30%	13%	17%	40%	0%	10%	50%	40%	0.001	***
16.1	11	20%	7%	10%	63%	3%	3%	60%	33%	0.000	***
16.2	11	10%	0%	3%	87%	0%	3%	37%	60%	0.000	***
22	10	33%	27%	17%	23%	17%	0%	67%	17%	0.000	***
30	10	33%	0%	3%	63%	7%	0%	7%	87%	0.028	**
35	9	7%	20%	27%	47%	3%	13%	43%	40%	0.617	**n.s.**
37A	9	17%	23%	10%	50%	10%	0%	70%	20%	0.000	***
51.1	9	3%	3%	3%	90%	3%	0%	60%	37%	0.000	***
51.2	9	-	-	-	-	3%	0%	37%	60%	-	-
77A.1	8	3%	0%	13%	83%	0%	0%	40%	60%	0.039	**
77A.2	8	3%	0%	7%	90%	7%	0%	37%	57%	0.006	***

A further analysis of the total amount of all butt-logs falling in the four quality classes in both 2006 and 2009 shows that there was a consistent decrease of the higher quality classes in favour of C class.

The *Chi-square test* was applied and a very significant difference between the 2006 and the 2009 butt-log grade distribution emerged (X^2 = 130; p value = 0.000). In fact, “A class” has decreased consistently from 16 to 5 % and “B class” from 10 to 3 %. The main causes are due to the presence of branches and knots with a diameter larger than 3 cm. On the other hand, the reduction of “D class” butt-logs is probably due to the trees-growth occurred during the very dynamic stem formation stage: for example, it could happen that butt-logs shorter than 2.5 m were considered D class in 2006 but they then developed in longer stems during the following years and were upgraded to class C in the 2009 inventory.

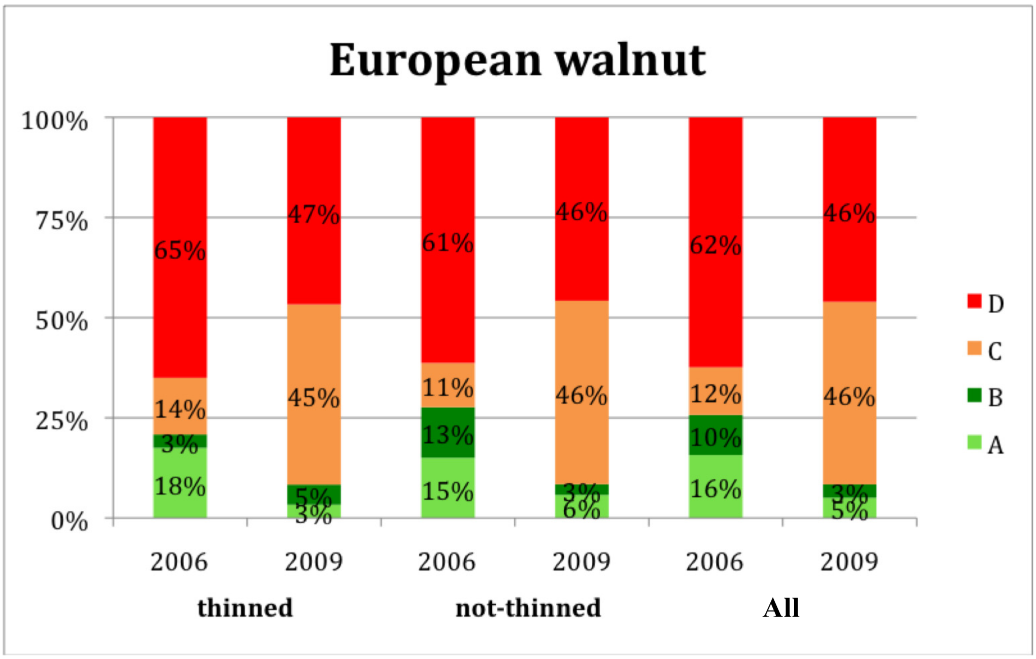


Figure 4.5: Walnut butt-log grade distribution in both 2006 and 2009 according to Canesin’s classification: thinned plots (4), not-thinned plots (10), and all plots (14). Plot 51.2 was not considered due to the lack of 2006 data.

Against any expectation, the amount of A class butt-logs drastically decreased also in the thinned plantations (from 18 down to 3 %). On the other hand B class trunks increased slightly (from 3 to 5 %), while D class dropped substantially from 65 to 47 % (Figure 4.5). This unexpected result could be due to the following reasons:

- The thinned plots (four) are located near the river banks on soils with low fertility and high percentage of pebbles; therefore, the trees are not facing the best growing conditions and the tree architecture has not developed naturally into the hypotetical valuable shape;

- They belong to the same owner and a similar management was applied: in particular, pruning operation have not been carried out in the proper way and at the right time; the small branches that were not recorded in 2006 grew bigger and took over the treshold of 3 cm considered in Canesin's classification; some of them were then pruned too late. Consequently, several knots and branches with diameter larger than 3 cm were recorded in 2009 and most of the previous A class butt-logs fell in lower quality classes;
- The subgective interpretation of both *deviation and sinuosity* could have caused several butt-logs to fall directly in C class. In fact, this is one of the limits of Canesin's classification. Nosenzo's classification solved partially this issue assigning different classes for the stem straightness and defining properly how to estimate the stem deviation from the straightness, the inclination and sinuosity.

4.2 Wild cherry (*Prunus avium* L.)

The stand parameters of all plots having wild cherry as principal tree species are reported in Table 4.5. The highest values of mean DBH (14 cm), mean tree height (10.1 m), mean DBH annual increment (1.55 cm/y) and mean height annual increment (1.21 m/y) in 2009 were recorded in the 9 years old plots. The lowest values were found in the oldest plots instead.

In the winter 2007/2008, thinning operations were carried out in plots 2.1, 2.2, 16.1, and 16.2 and some cherry trees were felled especially in the first two plantations; mostly damaged and weaker trees were felled. As a result, some trees different from those sampled in 2006 had to be measured to reach the fixed number of 30 trees per each principal species in each plot and this could have affected slightly the 2009 stand parameters (because of the less contribution of smaller diameters). Therefore, the comparison with the 2006 data should be carefully interpreted in thinned plots.

The DBH current annual increment (CAI) is generally in line with or even higher than the mean annual increment, especially in the youngest plantations where it reaches almost 1.5 cm/y. This suggests that the relatively young cherry trees have grown significantly during the last three years. Only in one case (plot 2.2) it was obtained an unexpected negative value for the DBH CAI. This could be due to the influence of the thinning operation when several cherry trees affected by diseases (especially rot) were removed in favour of the near ash trees. Mostly small diameters cherries remained and the mean DBH has decreased in 2009. The same explanation could be given also to justify the negative value of the height CAI in plot 2.1 and 2.2.

Table 4.5: Mean DBH, mean butt-log height (stem H), and mean tree height (H) for all wild cherry trees both in 2006 and 2009 divided in age classes. The last four columns report the mean DBH and height annual increment (I_m) and the mean DBH and height current annual increment (CAI, period 2006-2009).

			2006		2009			I_m		CAI	
Plot n°	**Age (y)**	**N°**	**DBH (cm)**	**H (m)**	**DBH (cm)**	**Stem H (m)**	**H (m)**	**Δdbh (cm/y)**	**Δh (m/y)**	**Δdbh (cm/y)**	**Δh (m/y)**
2.1	14	30	10.5	8.83	12.7	3.26	8.63	0.91	0.62	0.75	-0.07
2.2	14	30	8.5	7.23	8.1	3.00	7.12	0.58	0.51	-0.12	-0.04
Mean	**14**	**60**	**9.5**	**8.03**	**10.4**	**3.13**	**7.83**	**0.74**	**0.56**	**0.75**	**-**
12A	**12**	**30**	**8.8**	**6.75**	**10.7**	**2.61**	**8.58**	**0.89**	**0.71**	**0.66**	**0.61**
15A	11	30	5.1	6.25	6.0	2.85	6.22	0.50	0.52	0.30	0.00
16.1	11	30	9.1	7.12	11.0	2.61	7.56	1.00	0.69	0.64	0.15
16.2	11	30	9.1	6.92	10.0	2.92	7.50	0.91	0.68	0.31	0.19
Mean	**11**	**90**	**7.8**	**6.8**	**9.03**	**2.79**	**7.15**	**0.82**	**0.65**	**0.42**	**0.13**
22	10	30	9.5	7.13	12.1	3.95	8.46	1.21	0.85	0.86	0.44
30	10	30	8.3	5.85	13.8	2.65	7.26	1.38	0.73	1.83	0.47
Mean	**10**	**60**	**8.9**	**6.49**	**12.9**	**3.30**	**7.85**	**1.29**	**0.78**	**1.34**	**0.45**
35	9	30	10.7	7.82	15.9	4.46	10.68	1.77	1.19	1.72	0.95
37A	9	30	10.2	8.23	13.8	3.09	10.04	1.53	1.12	1.20	0.61
41.1	9	30	9.4	6.42	14.8	2.30	8.43	1.64	0.94	1.79	0.67
41.2	9	30	9.0	6.03	15.0	2.12	9.03	1.67	1.00	2.00	1.00
51.1	9	30	9.2	7.50	13.0	2.88	12.04	1.45	1.34	1.26	1.52
51.2	9	30	-	-	13.8	2.88	12.04	1.53	1.34	-	-
53	9	30	11.5	7.20	16.2	2.59	9.28	1.80	1.03	1.58	0.69
54A	9	30	6.5	6.43	9.4	2.64	6.82	1.05	0.76	0.98	0.13
Mean	**9**	**240**	**9.5**	**7.09**	**14.0**	**2.87**	**10.10**	**1.55**	**1.21**	**1.49**	**1.00**
61	8	30	6.7	5.50	12.8	2.95	7.25	1.60	0.91	2.03	0.58
77A.1	8	30	7.3	6.77	11.9	2.86	10.21	1.48	1.28	1.51	1.15
77A.2	8	30	4.5	4.91	7.1	2.75	6.69	0.89	0.84	0.88	0.59
Mean	**8**	**90**	**6.2**	**5.73**	**10.6**	**2.85**	**8.60**	**1.32**	**1.08**	**1.48**	**0.96**

Cherry trees manifest a clear reduction of mean DBH annual increment growing older. This phenomenon is shown by the straight curve in Figure 4.6 where the mean DBH annual increment is plotted against the age. The graph suggests that competition starts when the trees are 10 years old and since then it increases causing growth increment reduction. Most of the points to the right represent the thinned plantations; therefore, it is likely that those points will shift slightly upwards during the next years as more light has become available to the remaining cherry trees.

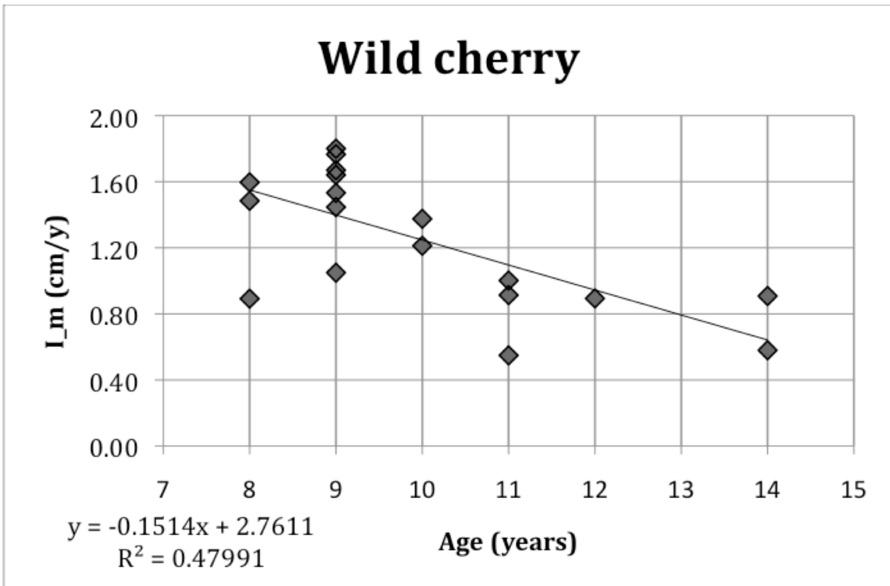


Figure 4.6: Mean DBH annual increment of cherry trees plotted against age.

The amount of stem defects recorded for cherry trees was less than that for walnut trees and the sample size is also higher (570 trees); as a result the average number of defects per each cherry butt-log (3 defects/trunk) is less than that found for walnut (4 defects/trunk). The two stem defects groups dealing with the presence of knots and branches and unsuitable stem shape are the most relevant (54 and 38 % of total defects respectively) (Figure 4.7).

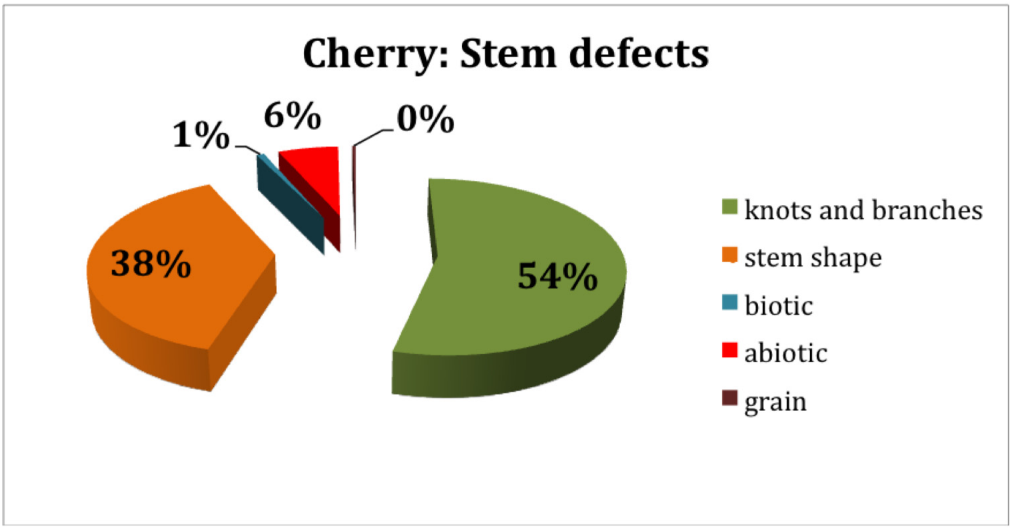


Figure 4.7: Stem defects found on all wild cherry stems. See Table 4.1 for the list of stem defects included in each group.

Inside the defect group "knots and branches", the most common are *covered knots* (37%), *sum of branches and knots diameters more than 60 mm* (28 %) and *branches and knots with diameter larger than 3 cm* (16 %).

It should be noticed the higher percentage of the defect "*sum of the diameters of branches and knots between 15 and 60 mm*" (7 %) compared to the value found in walnut trees (2 %); this and the inferior stem shape defects are the main reasons that allow more cherry butt-logs to fall in "B class" according to Nosenzo's classification or even in A class when adopting Canesin's classification (Figure 4.8).

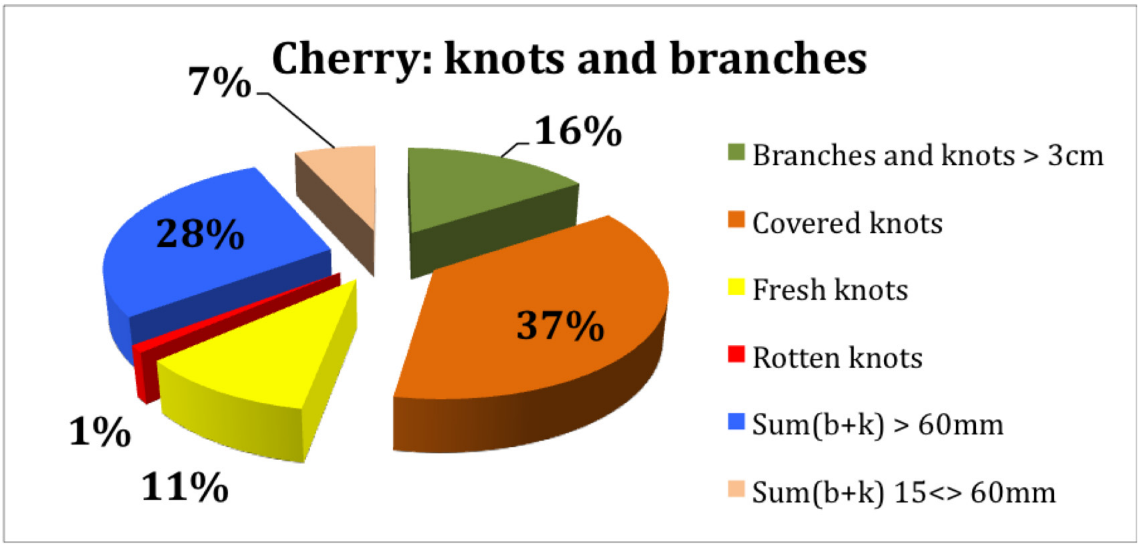


Figure 4.8: Stem defects due to the presence of knots and branches on all wild cherry butt-logs.

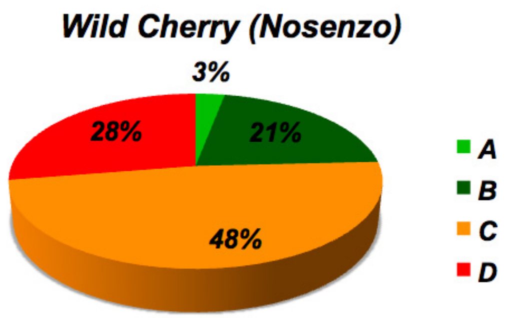
The detailed results about stem quality in each sample plot having wild cherry as principal species is reported in Table 4.6, while the total share of A, B, C and D classes for all walnut trees is reported in Figure 4.9. As in the walnut stem quality analysis, Canesin's classification produces higher percentage of the higher quality classes (A and B) when compared to Nosenzo's classification.

The *Fisher exact test* was applied to investigate the statistical difference between the number of stems that fall in each quality class with Nosenzo's classification and the number of stems in each quality class with Canesin's classification. The test resulted to be very significant in 63 % of the cases (12 plots out of 19), and not significant in only 21 % of the cases (4 plots out of 19). Therefore, the two stem classifications can be considered significantly different when applied on cherry stems.

The total amount of "D class" is similar and lower than that found in walnut trees, but the disparities between the two stem classifications adopted are relevant for the other quality classes. Very significant is the different percentage of butt-logs that fall in "A class": 3% (Nosenzo's) versus 35 % (Canesin's).

Table 4.6: Wild cherry butt-log assortments obtained with Nosenzo's and Canesin's classification in the 19 sample plots having wild cherry as principal species. The last two columns show the *p* value and the relative significance level obtained with the *Fisher exact* test (*=little significant; **=significant; ***=very significant, **n.s.**=not significant)

		Nosenzo's classification				Canesin's classification					
Plot n°	**Age (y)**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**	***p* (Fisher)**	**Significance**
2.1	14	3%	3%	80%	13%	27%	37%	23%	13%	0.000	***
2.2	14	0%	17%	30%	53%	17%	10%	20%	53%	0.104	n.s.
12A	12	0%	10%	53%	37%	13%	3%	47%	37%	0.206	n.s.
15A	12	10%	23%	40%	27%	30%	3%	40%	27%	0.057	*
16.1	11	10%	17%	47%	27%	33%	27%	13%	27%	0.018	**
16.2	11	0%	20%	47%	33%	20%	27%	20%	33%	0.021	**
22	10	3%	17%	73%	7%	63%	0%	30%	7%	0.000	***
30	10	0%	33%	40%	27%	53%	0%	20%	27%	0.000	***
35	9	0%	7%	83%	10%	27%	40%	27%	7%	0.000	***
37A	9	0%	37%	47%	17%	47%	3%	33%	17%	0.000	***
41.1	9	0%	7%	30%	63%	13%	3%	20%	63%	0.165	n.s.
41.2	9	0%	3%	20%	77%	3%	10%	10%	77%	0.404	n.s.
51.1	9	0%	20%	70%	10%	47%	3%	40%	10%	0.000	***
51.2	9	17%	33%	40%	10%	53%	3%	33%	10%	0.002	***
53	9	0%	10%	50%	40%	43%	3%	13%	40%	0.000	***
54A	9	10%	30%	30%	30%	40%	0%	30%	30%	0.001	***
61	8	0%	13%	70%	17%	20%	47%	17%	17%	0.000	***
77A.1	8	0%	57%	33%	10%	60%	7%	23%	10%	0.000	***
77A.2	8	3%	47%	33%	17%	53%	0%	33%	13%	0.000	***



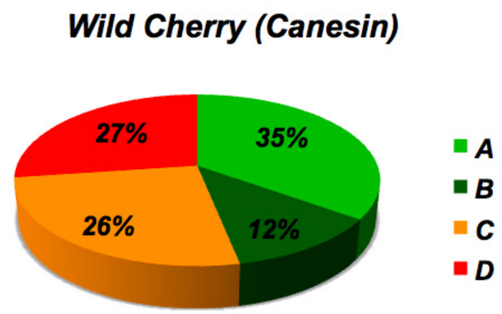


Figure 4.9**:** Wild cherry butt-log grade distribution according to Nosenzo's classification (left) and Canesin's classification (right).

However, Nosenzo's classification demonstrated to be more precise and objective; therefore it will be used to assess the 2009 stand quality; looking at the results, A and B classes together are more than 20 % of the total in 11 plots out of 19: the maximum amount of high quality timber is found in plot 77A.1 (57 %, but only B class) followed by plot 77A.2 and 51.2 (50 %, of which 17 % of only A class). If this is a better result compared to walnut trunks, the economic benefits will be quite low and questionable in 40 % of the plantations having cherry as principal species.

The *Fisher exact test* applied to compare the 2006 butt-log grade distribution with the corresponding 2009 quality classes obtained with Canesin's classification resulted very significant in 61 % of the cases (11 plots out of 18) and not significant in 28 % of the cases (5 plots out of 18) (Table 4.7). Plot 51.2 was excluded from this analysis because of the lack of 2006 data. Also the differences between the total number of stems in each quality class found in 2006 and 2009 resulted to be very significant (X^2= 69.1; p value = 0.000); only "A class" remained the same (34 %), while the other three classes changed significantly: "B class" decreased slightly, while "C class" has triplicated (from 8 to 26%) and "D class" decreased significantly (from 41 to 28 %) (Figure 4.10).

Table 4.7: Wild cherry butt-log assortments obtained in 2006 and 2009 with Canesin's classification in the 19 sample plots having wild cherry as principal species. The last two columns show the *p* value and the equivalent significance level obtained with the *Fisher exact test* (*=little significant; **=significant; ***=very significant, **n.s.**=not significant)

		2006 (Canesin's class.)				2009 (Canesin's class.)					
Plot n°	**Age (y)**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**	***p* (Fisher)**	**Significance**
2.1	14	73%	7%	13%	7%	27%	37%	23%	13%	0.002	***
2.2	14	33%	10%	7%	50%	17%	10%	20%	53%	0.303	n.s.
12A	12	30%	23%	10%	37%	13%	3%	47%	37%	0.003	***
15A	12	80%	7%	3%	10%	30%	3%	40%	27%	0.000	***
16.1	11	27%	23%	10%	40%	33%	27%	13%	27%	0.778	n.s.
16.2	11	40%	10%	0%	50%	20%	27%	20%	33%	0.009	***
22	10	50%	27%	10%	13%	63%	0%	30%	7%	0.003	***
30	10	43%	23%	7%	27%	53%	0%	20%	27%	0.022	**
35	9	17%	37%	23%	23%	27%	40%	27%	7%	0.322	n.s.
37A	9	20%	33%	17%	30%	47%	3%	33%	17%	0.003	***
41.1	9	10%	10%	3%	77%	13%	3%	20%	63%	0.182	n.s.
41.2	9	10%	7%	3%	80%	3%	10%	10%	77%	0.605	n.s.
51.1	9	30%	17%	0%	53%	47%	3%	40%	10%	0.000	***
51.2	9	-	-	-	-	53%	3%	33%	10%	-	-
53	9	13%	40%	7%	40%	43%	3%	13%	40%	0.001	***
54A	9	27%	13%	0%	60%	40%	0%	30%	30%	0.000	***
61	8	20%	7%	10%	63%	20%	47%	17%	17%	0.000	***
77A.1	8	23%	20%	10%	47%	60%	7%	23%	10%	0.001	***
77A.2	8	57%	7%	7%	30%	53%	0%	33%	13%	0.021	**

The *Chi-square test* became very significant also when comparing the 2006 and the 2009 values of the thinned plantations (X^2 = 18.1; p value = 0.000). In this case, all classes change significantly: A and D classes decreases, while B and C classes increases. Probably, most of the damaged trees that were considered D class in 2006 were removed by the thinning operation and this could explain the reduction of butt-logs in the lowest class. Nevertheless, the still high percentage of D class (32 %) is due to the high amount of very weak and dominated trees (graded as D) recorded in 2009. The strong reduction of butt-logs in the A class (from 43 to 24 %) is mainly due to the inappropriate and late pruning operations (all thinned plantations belong to the same owner and saw a similar management); branches less than 3 cm in 2006 grew larger and most of them were pruned in recent years leaving fresh knots with diameters larger than 3 cm. Therefore, the presence of only one knot > 3 cm has downgraded the whole butt-log in B class or even in C class when both branches and knots > 3 cm are present.

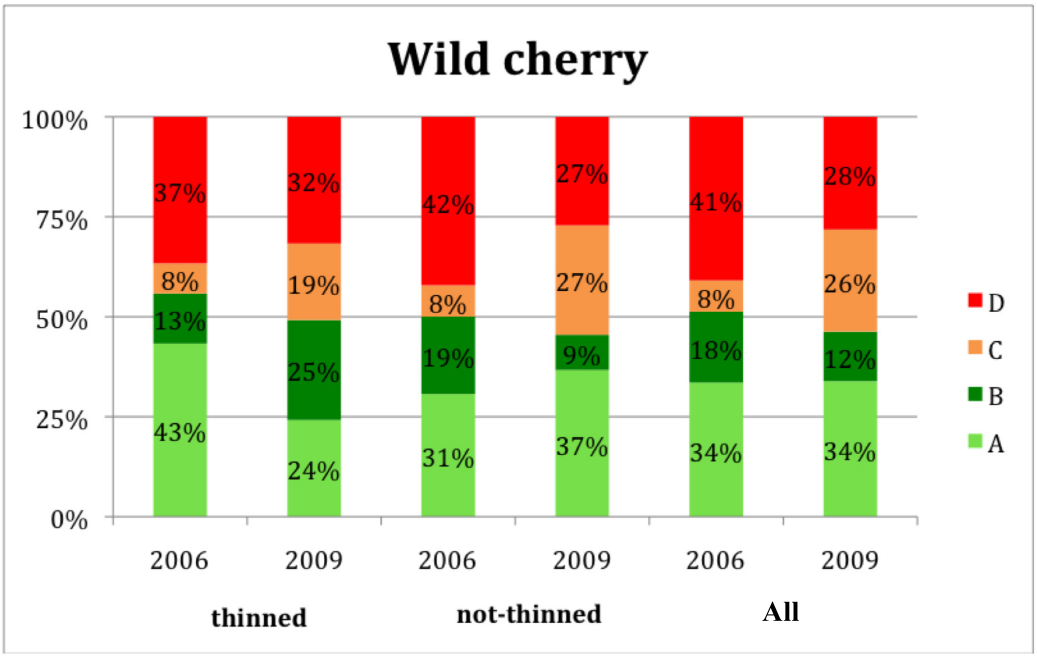


Figure 4.10: Wild cherry butt-log grade distribution in both 2006 and 2009 according to Canesin's classification: thinned plots (4), not-thinned plots (14), and all plots (18). Plot 51.2 was not considered due to the lack of 2006 raw data.

An additional sign of improper management is the presence of several epicormic shoots that were produced after the thinning operation when more light reached the ground. To avoid stem downgrading, epicormic shoots should have been pruned immediately after their appearance but this has not happened. However, their presence on the butt-logs affected mostly Nosenzo's classification; in fact, even 6 or 7 epicormic shoots with an average diameter of 1 cm can downgrade the entire butt-log in C class because the sum of all branches and knots diameters becomes higher than 60 mm (see Table 3.2).

4.3 European ash (*Fraxinus excelsior* L.)

The 2009 mean DBH of all European ash trees ranges between 8.8 cm (10 and 11 years old plots) and 14.4 cm (14 years old plots), while the mean annual increments are pretty similar in all age classes reaching a maximum of 1.19 cm/year (DBH) and 1.02 m/year (height) in the youngest plots (Table 4.8).

Table 4.8: Mean diameter at breast height (DBH), mean butt-log height (stem H), and mean tree height (H) for all European ash trees divided in age classes both in 2006 and 2009. The last four columns report the mean DBH and height annual increment and the mean DBH and height current annual increment (CAI, period 2006-2009).

			2006		2009			I_m		CAI	
Plot n°	**Age (y)**	**N°**	**DBH (cm)**	**H (m)**	**DBH (cm)**	**Stem H (m)**	**H (m)**	**Δdbh (cm/y)**	**Δh (m/y)**	**Δdbh (cm/y)**	**Δh (m/y)**
2.1	14	30	12.0	9.98	14.3	3.15	10.08	1.02	0.72	0.77	0.03
2.2	14	30	11.7	9.18	14.5	3.05	9.49	1.04	0.68	0.93	0.10
Mean	**14**	**60**	**11.9**	**9.58**	**14.4**	**3.10**	**9.77**	**1.03**	**0.70**	**0.85**	**0.06**
15A	11	30	8.4	8.67	9.4	3.17	8.53	0.86	0.78	0.34	-0.05
16.2	11	30	-	-	8.3	2.69	6.93	0.75	0.63	-	-
Mean	**11**	**60**	**8.4**	**8.67**	**8.8**	**2.93**	**7.71**	**0.80**	**0.70**	**0.3**	**-**
22	**10**	**30**	**6.1**	**5.83**	**8.8**	**3.54**	**8.09**	**0.88**	**0.81**	**0.90**	**0.75**
51.2	9	30	6.7	6.40	10.1	2.89	9.95	1.12	1.11	1.15	1.18
54A	9	30	5.5	6.12	8.6	2.81	7.42	0.96	0.82	1.03	0.44
Mean	**9**	**60**	**6.1**	**6.26**	**9.4**	**2.85**	**8.53**	**1.04**	**0.95**	**1.09**	**0.76**
61	8	30	6.2	5.31	8.9	2.71	6.46	1.12	0.81	0.92	0.38
77A.1	8	30	6.7	6.15	11.0	2.63	9.61	1.37	1.20	1.45	1.15
77A.2	8	30	5.1	5.13	8.6	2.70	7.50	1.07	0.94	1.15	0.79
Mean	**8**	**90**	**6.0**	**5.53**	**9.5**	**2.68**	**8.18**	**1.19**	**1.02**	**1.17**	**0.88**

The mean DBH annual increment decreases with age (Figure 4.11) with the exception of the 14 years old plots, that represent two of those plots that were thinned in winter 2007/2008. In plot 2.1 even 39 % of the previous ash trees were felled. Therefore, in the 2009 fieldwork, the felled trees measured in 2006 had to be compensated measuring 39% of additional ash trees in the adjacent rows. Mostly the smaller and weaker trees were removed; consequently, the mean DBH annual increment has not decreased significantly. An opposite trend characterizes plot 15A where the DBH current annual increment is much lower than the mean annual increment. This suggests that a

considerable negative competition occurred during the last three years. In fact, this is a very dense plantation with spacing distance of 1.5x3 meters. If the density reduced the increment in size, the competition favoured the formation of straight and knot-free stems thanks to self-pruning (see Table 4.9). The height current annual increment is surprisingly negative (-0.05 m/y): this could be due to the very slow height increment and the different trees sampled in 2009 (plot 15A is one of those three plots were it was not possible to apply the permanent sample approach because of missing data in the 2006 field papers).
With the exception of the previous plot, the current annual increment is in line with the mean annual increment in most cases. This means that, till now, they have not been affected by competition and they are producing quasi-homogeneous annual rings. In fact, most of the ash trees are becoming the dominant trees in the plantations suffering less the negative competition for light.
The current annual increment for plot number 16.2 could not be estimated because of the lack of 2006 data but it would have been necessary to compute a more unbiased estimate for the DBH CAI in the 11 years old plantations.

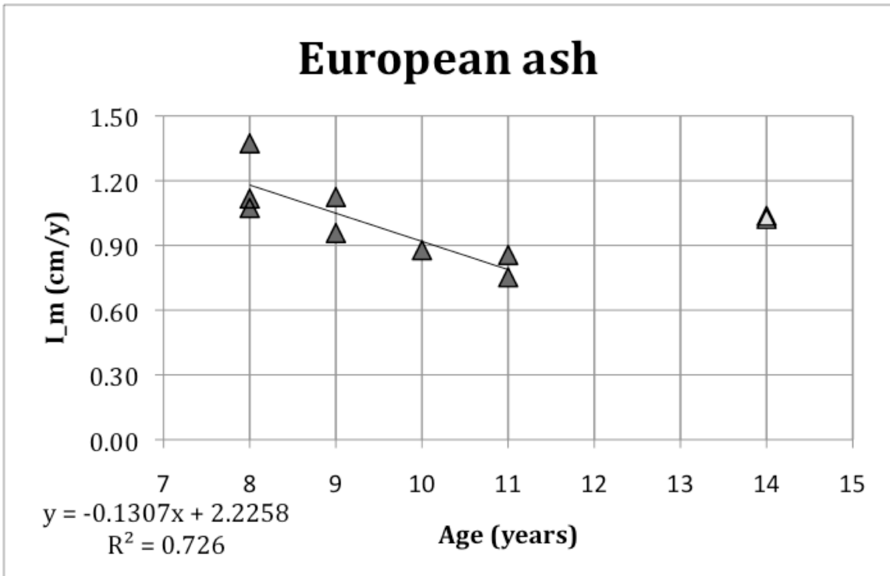


Figure 4.11: Mean DBH annual increment of ash trees plotted against age. The isolated points to the right represent two thinned plantations (plots 2.1 and 2.2).

The total amount of stem defects recorded on ash butt-logs was much less than that found in walnut and cherry trees. In fact, it was estimated that each ash trunk has about two defects, less than the average found for walnut trees (4 defects/trunk) and cherry trees (3 defects/trunk). No grain defects were found, while the biotic defects (insects hole and rot) share a higher percentage (4 %) than those found in walnut and cherry trees (only 1 % of the total defects) (Figure 4.12).

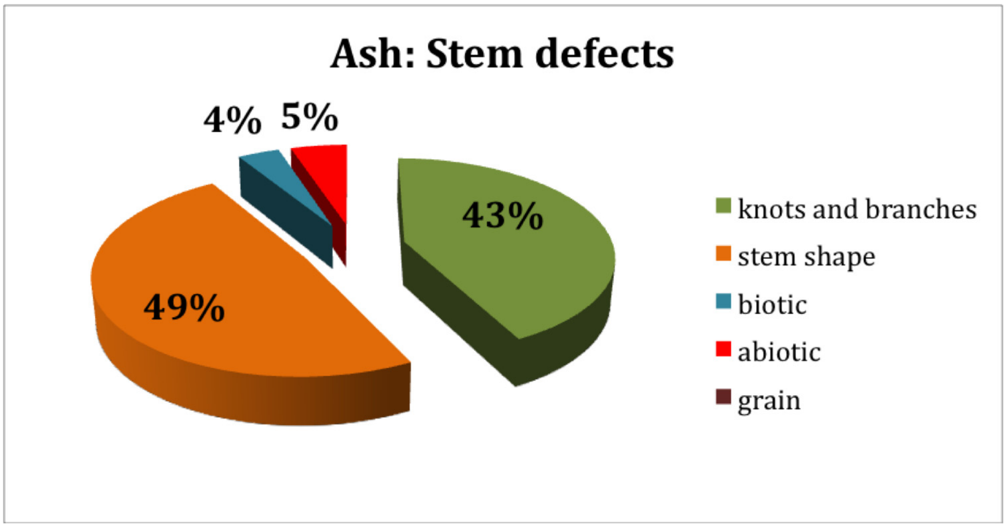


Figure 4.12: Stem defects found on all European ash butt-logs.

Inside the group "knots and branches", *covered knots* and *sum of branches and knots diameters more than 60 mm* are the most common. The higher percentage of *sum of branches and knots diameters between 15 and 60 mm* (7 %) allowed some ash trees to fall into "B class" with Nosenzo's classification or even in "A class" with Canesin's classification (Figure 4.13).

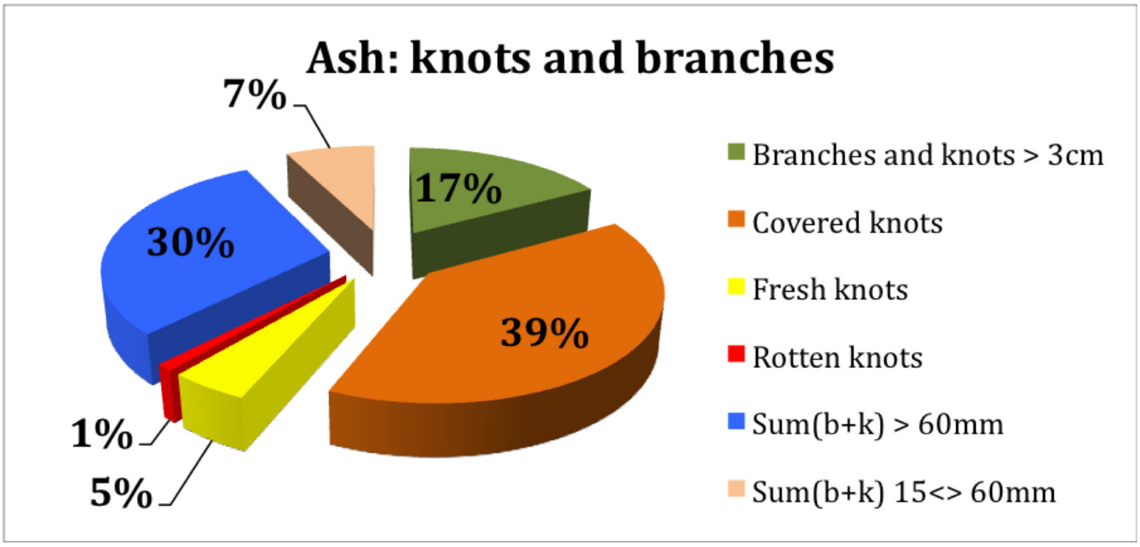


Figure 4.13: Stem defects due to the presence of knots and branches on all European ash butt-logs.

The results concerning the percentage of quality classes found with both Nosenzo's and Canesin's classification is listed in Table 4.9. According to both methodologies, plot 15A results to be the one with the highest percentage of high quality timber (23 % and

83% A class according to Nosenzo's and Canesin's classification respectively). This was probably due to the high density of trees planted that forced the trees to grow straight and favoured self-pruning.

Table 4.9: European ash butt-log assortments obtained with Nosenzo's and Canesin's classification in the 10 samples plots having European ash as principal species. The last two columns show the *p* value and the equivalent significance level obtained with the *Fisher exact test* (*=little significant; **=significant; ***=very significant, **n.s.**=not significant)

		Nosenzo's classification				Canesin's classification					
Plot n°	**Age (y)**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**	***p* (Fisher)**	**Significance**
2.1	14	0%	0%	83%	17%	30%	17%	37%	17%	0.000	***
2.2	14	3%	7%	47%	43%	10%	33%	13%	43%	0.005	***
15A	12	23%	60%	17%	0%	83%	0%	17%	0%	0.000	***
16.2	11	3%	20%	40%	37%	30%	10%	23%	37%	0.030	**
22	10	17%	33%	23%	27%	47%	3%	27%	23%	0.007	***
51.2	9	0%	37%	50%	13%	43%	0%	43%	13%	0.000	***
54A	9	10%	40%	37%	13%	53%	0%	30%	17%	0.000	***
61	8	0%	17%	37%	47%	20%	10%	23%	47%	0.053	*
77A.1	8	7%	27%	47%	20%	47%	0%	33%	20%	0.000	***
77A.2	8	7%	33%	23%	37%	40%	3%	20%	37%	0.002	***

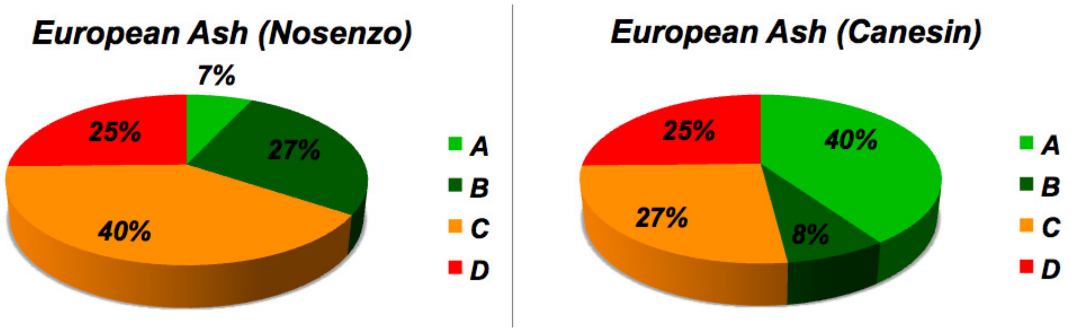


Figure 4.14: European ash butt-log grade distribution according to Nosenzo's classification (left) and Canesin's classification (right).

Even for European ash butt-logs, the most relevant differences between the two stem classifications used are found in the percentage of A, B, and C classes. The *Fisher exact test* confirmed the significant difference in all plots (in 8 plots out of 10 the statistical test was even very significant). Therefore, the two stem classifications can be considered statistically different when applied on ash trees.

Considering the whole ash population, the differences recorded in the higher quality classes are relevant: 7 % (Nosenzo's) against 40 % (Canesin's) for "A class" and 27 % (Nosenzo's) against 8 % (Canesin's) for "B class" (Figure 4.14).

Looking at Nosenzo's results (less biased), seven plantations out of 10 show a percentage of A and B classes (taken together) higher than 20 % of the total, which is the profitability threshold found in the literature (Nosenzo *et al.* 2008): plantation 15A resulted to be the best with 83 % of A and B classes together. Therefore, ash population is more valuable than cherry and walnut trees, but the amount of first quality timber is still modest and most of the plantations are close to the hypothetical threshold value of profitability.

Regarding the stem quality development occurred in the period 2006-2009, the differences between the 2006 and the 2009 results are not significant in 56 % of the cases (5 plots out of 9); therefore, it seems that the ash stem quality remained almost the same during the last three years. On the other hand, the statistical comparison of all ash trees (excluding those in plot 16.2) through the *Chi-square test* resulted in a very significant difference between the 2006 and 2009 butt-log grade distribution (X^2 = 19.5; p value = 0.000). The amount of ash butt-logs falling in "A class" remained constant (41%), while those falling in "B class" halved, those in C class increased (from 14 to 27%) and those in D class reduced (from 31 to 24 %) (Figure 4.15). Therefore, the reduction of B class was compensated by the reduction of D class as well and it can be concluded that the overall ash stem quality has decreased only slightly. Of course, the reduction of "B class" is not a positive sign.

Table 4.10: European ash butt-log assortments obtained in 2006 and 2009 with Canesin's classification in the 10 sample plots having European ash as principal species. The last two columns show the *p* value and the equivalent significance level obtained with the *Fisher exact test* (*=little significant; **=significant; ***=very significant, **n.s.**=not significant)

		2006 (Canesin's class)				**2009 (Canesin's class.)**					
Plot n°	**Age (y)**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**	***p* (Fisher)**	**Significance**
2.1	14	53%	23%	17%	7%	30%	17%	37%	17%	0.129	n.s.
2.2	14	37%	27%	7%	30%	10%	33%	13%	43%	0.104	n.s.
15A	12	40%	33%	10%	17%	83%	0%	17%	0%	0.000	***
16.2	11	-	-	-	-	30%	10%	23%	37%	-	-
22	10	63%	3%	17%	17%	47%	3%	27%	23%	0.693	n.s.
51.2	9	37%	13%	13%	37%	43%	0%	43%	13%	0.005	***
54A	9	43%	0%	13%	43%	53%	0%	30%	17%	0.053	*
61	8	23%	0%	10%	67%	20%	10%	23%	47%	0.140	n.s.
77.1	8	27%	20%	17%	37%	47%	0%	33%	20%	0.012	**
77.2	8	47%	3%	20%	30%	40%	3%	20%	37%	0.970	n.s.

Regarding the thinned plots the *Chi-square test* was significant (X^2 = 10.4; p value = 0.016), meaning a significant difference between the quality class distribution in 2006 and 2009. In particular, there was a considerable reduction of A class butt-logs and a significant increase of C and D classes. As for wild cherry trees, the inappropriate pruning operations during the last three years allowed several butt-logs to fall in B class or C class due to the presence of branches or mostly knots with diameter larger than 3 cm. The increase of D class butt-logs could be explained with new defects emerged during the last three years like insect holes (7 % of total ash stems in plot 2.1 and 10 % in plot 16.2) and rotten knots (10 % in plot 2.2) that downgraded the tree directly to D class. Base damage (13 % in plot 2.1 and 10 % in plot 16.2) caused also several stems to fall in D class mostly reducing the suitable butt-log length under 2.5 m. Probably these defects were not visible at the time of selection and these trees were left after the recent thinning operation.

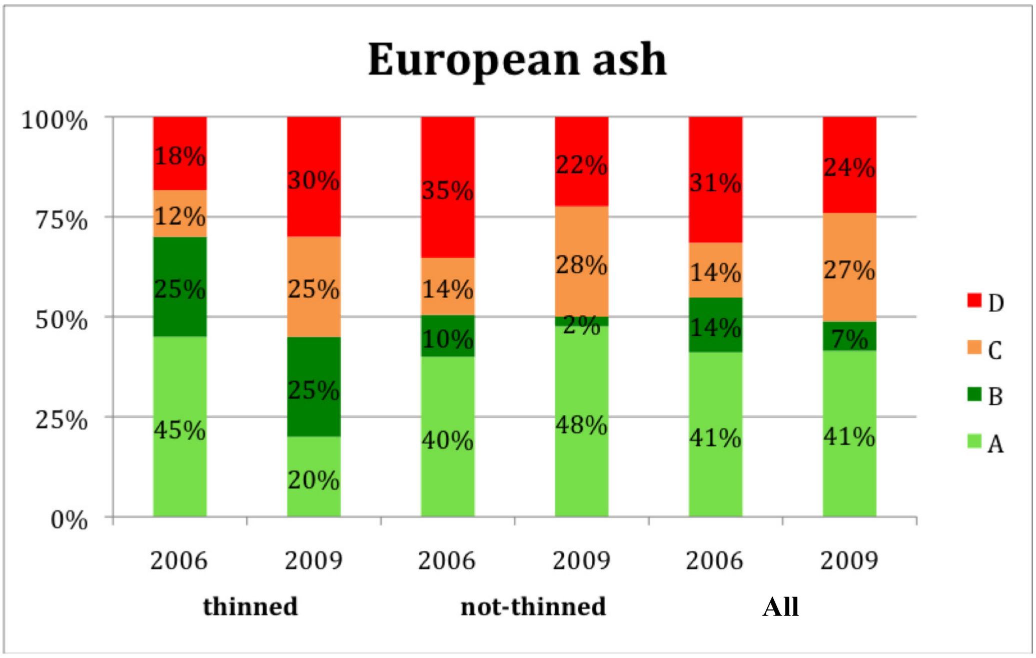


Figure 4.15: European ash butt-log grade distribution in both 2006 and 2009 according to Canesin's classification: thinned plots (3), not-thinned plots (6), and all plots (9). Plot 51.2 was not considered due to the lack of 2006 raw data.

5. Conclusions

Monitoring tree-farming plantations is a very important aspect that needs to be implemented and improved in order to understand the amount and type of stem defects able to downgrade the timber at the end of the rotation; in fact, especially during the stem formation stage some particular defects could be corrected without compromising the final stand quality.

A timber grading methodology is also needed to assess the timber quality before harvesting operations, so that the owners can have a clear idea about the amount of each quality class produced in their plantations. Timber quality has always been assessed through the personal experience of buyers and timber traders, but a detailed and scientific methodology is needed for more objective quality estimations.

In this study, two systematic stem classification methodologies have been adopted and compared, namely Nosenzo's classification (Nosenzo *et al.* 2008) and Canesin's classification. They are easy and quick to implement in the field but the results showed that they significantly differ and that Nosenzo's classification should be preferred because more precise and more unbiased. In fact, while the amount of D class (firewood and woodchips) is almost the same for both methodologies, Canesin's classification tends to significantly overestimate the amount of high quality timber (A and B classes); furthermore, the stem deviation is not defined by precise parameters or classes (as in Nosenzo's methodology) and it is exposed to subjective interpretations.

The similar outputs obtained only for walnut trunks can be explained with the consistent amount of trunks showing a deviation from the straightness more than 3 %; consequently, little amount of higher quality classes occurs and lower stem quality classes can match easily.

Broadleaved tree-farming plantations in Gorizia province (excluding poplar plantations) have been mostly established thanks to the public funds available through the EEC Regulation 2080/92. No strict silvicoltural rules were defined in this regulation and farmers realized their plantations mostly with the intent of getting the available subsidies rather than aiming at high quality timber production at the end of the rotation. Mixed plantations with accessory species are the most common in the study area and this was in line with the guidelines provided by the 1990's tree-farming research. Sometimes it was found that the plantation design was not strictly respected inside the same plantation; lack of experience and difficulties during planting operations could have been the most likely causes. The result was that the utilization of land surface was not maximized as some principal trees could be removed with future thinning operations when they do not fit the minimum distance required.

If the above problem could be considered not so relevant, the missing or incorrect pruning operations are the main causes of timber downgrading. In this study it was demonstrated that most of the defects found depend on the unsuitable stem shape and on the presence of branches and knots on the butt-logs outside the ideal 10 cm central cylinder; the defects above could be avoided or at least strongly reduced if pruning had been carried out properly and at the right time.

As a result, the general timber quality of the tree-farming plantations in Gorizia province is quite low. The worst principal species is walnut: according to Nosenzo's classification (Nosenzo *et al.* 2008) only 0.2 % and 4 % of all butt-logs fall in A and B class respectively, while almost half of the walnut trees will be only suitable for firewood or woodchips production (D class). Wild cherry and European ash trees manifest a better quality condition than that of walnut. Among them European ash resulted the best principal species of this study with 7 % and 27 % of ash butt-logs falling in A and B classes respectively and not more than 25 % in D class.

According to the literature (Nosenzo *et al.* 2008) the economical benefit becomes positive if the tree-farming plantation has at least 20 % of all butt-logs of all principal species falling in A and B classes together; under this critical threshold the future management should be questioned. In this study, only seven plantations out of 21 have the percentage of A and B classes (together) higher than 20 %. Among these, plot 15A and 54A have the highest amount of high quality timber: 58 % and 45 % respectively; in the other five "good" plantations, A and B classes together share not more than 32 % of the total. Nevertheless, the amount of A class solely is always very little: the maximum percentage is only 16.7 % (plot 15A).

In the remaining 14 tree-farming plantations, the amount of high quality timber at the end of the rotation will not be enough to compensate the costs; hence, the profitability of these plantations could be argued at present, but the mistakes of the past should be carefully studied and internalized in the system in order to avoid them in future managements.

In most plantations there was also a decrease of timber quality in the period 2006-2009; this negative trend could continue in the following years if urgent pruning or thinning operations will not be carried out especially in the youngest plots; the quality has decreased very significantly in walnut trees, where the best quality class drastically dropped. Cherry and ash butt-log grade distribution has also changed significantly during the last three years but the amount of A grade remained constant; B class decreased but this negative trend has been compensated by the decrease of the worst class as well. Therefore, the overall quality of both cherry and ash trees decreased only slightly; however, the general butt-log grade distribution leans mostly toward the lowest quality classes and the economic benefit will be at risk in most cases.

This negative result is mainly due to the scarce and inadequate management of these tree-farming plantations especially during the early stages when human input is required to foster the formation of valuable stems. Due to incorrect pruning operations, the stem quality distribution decreased in the thinned plantations too; there, the unsuitable stems have already formed and little could be done through tree selection; moreover, the poor soil conditions promoted the ongoing negative trend.

In the near future, the positive aspects of wood in general could rise up the timber demand both for industrial and energy purposes. In fact, wood is a natural resource, which has got several advantages with respect to others synthetic material used nowadays. It can be produced in a natural and sustainable way and has got very low environmental impacts both in the production and in the disposal stage. It requires low energy input to be transformed and can be easily reused. Hence, a gradual increase of wood prices is forecasted during the next years and the market is expected to pay back the work input necessary to produce high quality timber of big sizes, homogeneity and cylindrical shape; these positive signs give good opportunities to the implementation of tree-farming plantations, but, to maximize both ecological and economic benefits, the following key points should be improved:

- transferring knowledge about the ecology of local tree species and the timber they produce;
- fostering the implementation of the most suitable management able to maximize the production of veneer logs;
- transferring knowledge on the markets in which the timber is produced and the skill to sell it at the higher prices differentiating carefully between buyers of

high quality timber (they would underestimate the woody biomass) and buyers of woody biomass or low wood quality (they would underestimate the high quality wood if they are going to make pellets or particle boards out of it).

If subsidies are available, they should be used in a more efficient way than that used in the EEC Regulation 2080/92. Rather than providing money for losses of income in a long time span (20 years in the Regulation 2080/92), subsidies should be given for the implementation of the most efficient and correct treatments (like pruning and thinning operations). An additional public measure would be to provide free of charge the farmers with a professional figure who may lead the plantation for at least most of its rotation. In fact, as the investment costs spread on a long time span, a tree-farming expert could avoid or reduce any possible managerial mistakes that may influence negatively the total benefit of an entire plantation.

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Annex 1 - Stem defects considered in this study

Stem defects represent any abnormality or irregularity that decreases wood's working properties and value. The list of the stem defects considered in this study is reported in the table below where also the Italian translation and a brief description are provided.

English	Italian	Description
Base damage	Danno alla base	Debarking and serious wounds at the trunk base caused mostly by mechanical operations. The valuable butt-log begins above the damage
Fork	Biforcazione	Division of a bole into two or more stems.
Bottle neck	Collo di Bottiglia	Abrupt reduction of stem diameter, which usually occurs right above large branches
Covered knot	Nodo coperto	Part of a branch included in the wood not appearing on the bole surface
Fluting	Scanalatura	A groove or set of grooves forming a longitudinal surface decoration
Fresh knot	Nodo sano	Part of a branch included in the wood and visible on the bole surface
Frost cracks	Cretto da gelo	Long vertical cracks on the stem caused by frost or cold
Inclination	Inclinazione	Stem deviation from the vertical. The degree of such deviation is measured in percentage (maximum distance from the vertical line divided by the total stem length)
Insect hole	Foro di insetto	Bore hole in wood made by an adult insect or by a larva
Ovality	Ellitticità	Stem having a oval shape in the cross section
Straightness (deviation from)	Rettilinearità (deviazione dalla)	Stem deviation from the central axis. It is measured in percent (maximum distance from the main axis divided by the stem length interested by the deviation itself)
Rot	Carie	Wood decomposed by bacteria or fungi
Rot knot	Nodo marcio	Part of a branch included in the wood and visible on the bole surface but showing biotic alteration (rot)
Saddle	Sella	Abrupt deviation of stem straightness caused by the substitution of the apical bud by a lateral bud (occurred after a disturbance)
Signs on bark	Tracce sulla corteccia	Any wound visible on the bole surface affecting the bark
Sinuosity	Sinuosità	Stem showing two or more main axis
Spiral grain	Fibratura elicoidale	Wood conducting tissues arranged in a helical or spiral pattern
Stub	Moncone o Moncherino	An undesirable short length of branch remaining after an incorrect pruning cut

Annex 2 – Field paper used in the 2009 field data collection

Plot n° ______________ **Row n°** ______

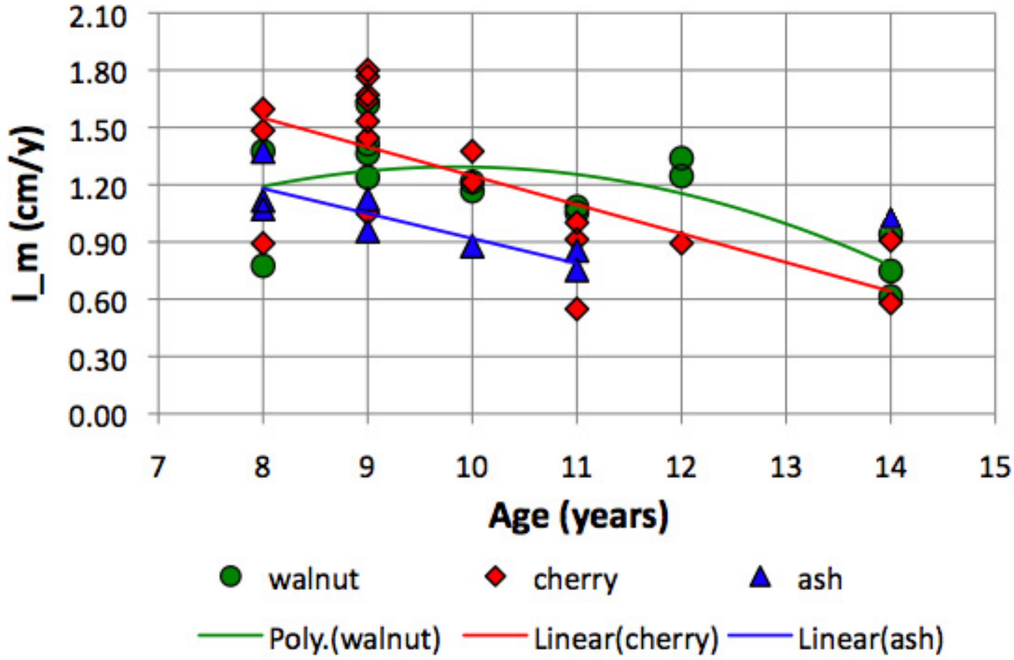
Stage: Qualification

Principal tree species:

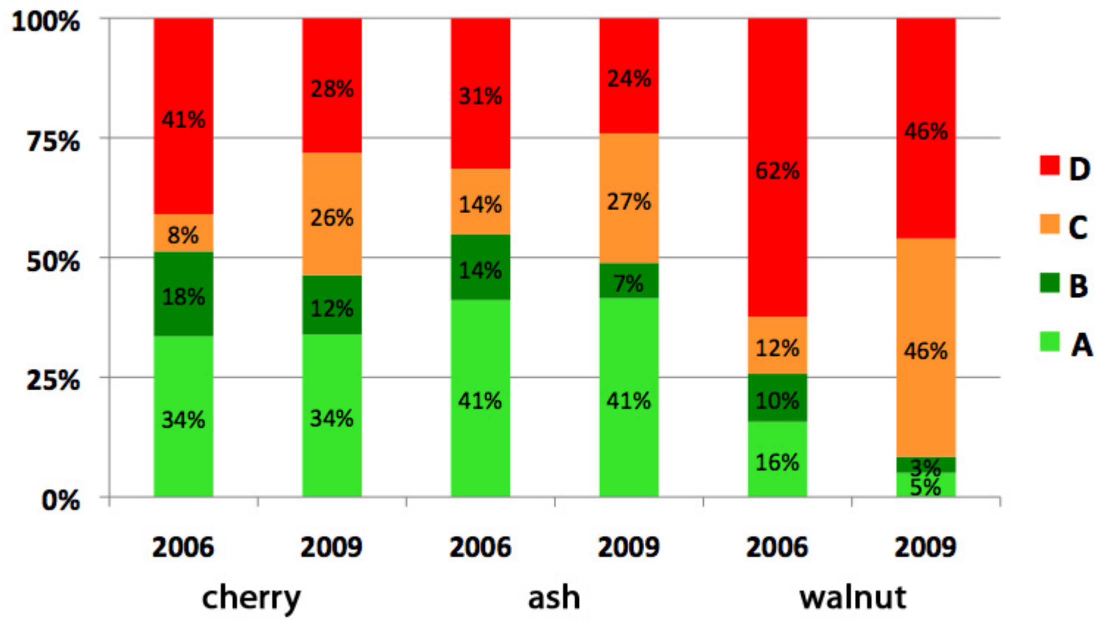
N°	S	G (cm)	Stem h (m)	Tree h (m)	Straig.	Incl. (%)	B>3	K>3	Cov. knots	Fresh knots	Rotten knots	Σ(b+k)	Class (Nos)	Sin.	Fork	Saddle	Base dam.	Rot	Insect hole	Frost crack	Oval.	Signs on bark	Bottle neck	Spiral grain	Notes

Abbreviations:
N°: tree number
S: tree species
G: girth at breast height (cm)
Stem h: stem (butt log) height (cm)
Tree h: total tree height (m)
Straig.: butt log straightness
Incl.: inclination (%)
B>3: branches with a diameter more than 3 cm
K>3: knots with a diameter more than 3 cm
Cov. knots: covered knots
Σ(b+k): sum of the diameter of all branches and knots on the stem divided in 3 classes (class 1: Σ(b+k) >60 mm; class 0.5: Σ(b+k) 15<>60 mm; class 0: Σ(b+k) <15 mm)
Class (Nos): butt log quality class according to Nosenzo's classification (Nosenzo et al. 2008)
Sin.: stem sinuosity
Base dam.: base damages
Oval.: stem ovality

Annex 3 – Additional graphs comparing walnut, cherry and ash results



Annex 3.1: Mean DBH annual increment of walnut, cherry and ash trees plotted against age. The graph represents a recapitulation of Figure 4.1, 4.6, and 4.11.



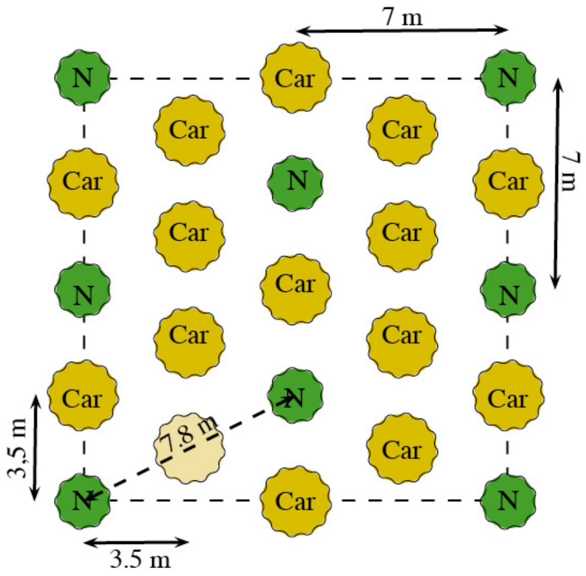
Annex 3.2: Comparison of cherry, ash, and walnut stem quality development; all butt-log grade distributions in this graph were obtained with Canesin's classification.

Annex 4 – Sample plots parameters

PLOT N° 1

Location: Romans d'Isonzo
Sampled rows: n° 1, 3, 5
Year of plantation: 1994
Date of data collection: April 4th 2009
Age (effective growth seasons): 14 years old

Species composition: Mixed
Principal tree species: European walnut (*Juglans regia* L.) and European hornbeam (*Carpinus betulus* L.)
Accessory tree species: none

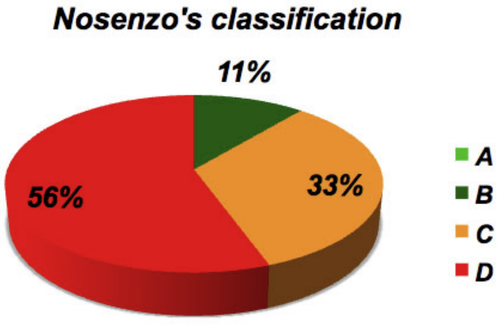


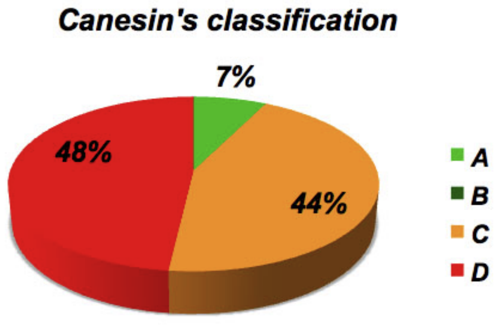
	Meters	Design
Spacing	3.5x3.5	Offset square
Plantation design		
- Walnut	> 7	Offset square
- Hornbeam	> 3.5	Offset square

Legend:
N = walnut;
Car = hornbeam.

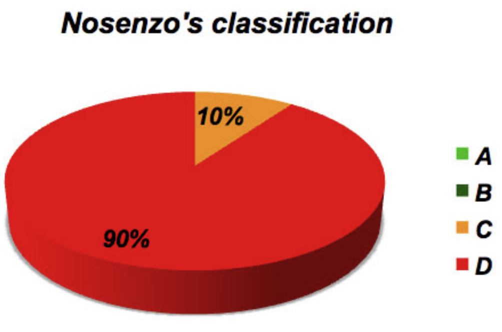
Growth rate	Walnut	Hornbeam
Mortality rate	69%	11%
Δdbh (cm/y)	0.94	0.94
Δh (m/y)	0.66	0.56

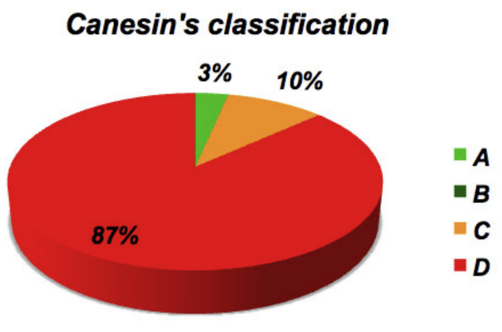
European walnut





European hornbeam





Annex 4 – Sample plots parameters

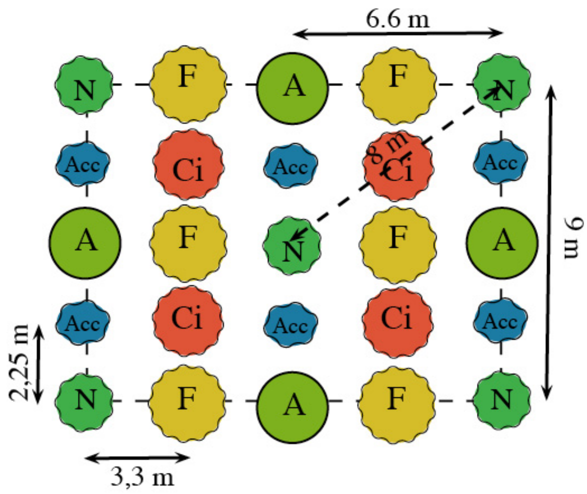
	European walnut				European hornbeam		
	DBH (cm)	Stem height (m)	Tree height (m)		DBH (cm)	Stem height (m)	Tree height (m)
mean	13.2	2.53	9.17		13.1	2.3	7.9
max	22.0	3.20	13.10		21.33	4.30	10.80
min	5.6	1.45	4.50		7.48	1.50	4.40
s^2	18.4	0.20	5.22		9.7	0.3	2.4
s	4.3	0.45	2.29		3.1	0.5	1.5

Stem defect	Walnut	Hornbeam	Stem defect	Walnut	Hornbeam
Branch > 3cm	0%	13%	**Sinuosity**	4%	27%
Knot > 3cm	26%	3%	**Fork**	11%	10%
Covered knots	70%	83%	**Saddle**	19%	10%
Fresh knots	33%	7%	**Base damage**	19%	7%
Rotten knots	0%	0%	**Rot**	0%	0%
∑(b+k) > 60mm	41%	37%	**Insect hole**	7%	0%
∑(b+k) 15<>60mm	3%	0%	**Frost crack**	11%	0%
Straightness > 10%	4%	33%	**Ovality**	0%	0%
Straightness 3<>10%	74%	37%	**Signs on bark**	93%	100%
Straightness 1<>2%	19%	27%	**Bottle neck**	0%	0%
Inclin. > 20%	7%	0%	**Spiral grain**	0%	0%
Inclin. 10<>20%	44%	7%	**Fluting**	7%	97%

PLOT N° 2.1

Location: Cassegliano (San Pier d'Isonzo municipality)
Sampled rows: n° 10, 9, 11, 12
Year of plantation: 1994
Date of data collection: March 22nd 2009
Age (effective growing seasons): 14 years old

Species composition: Mixed with accessory species
Principal tree species: European walnut (*Juglans regia* L.), wild cherry (*Prunus avium* L.), and European ash (*Fraxinus excelsior* L.)
Accessory tree species: *Acer spp., Crataegus monogyna* Jacq., and others thinned in winter 2007/2008.

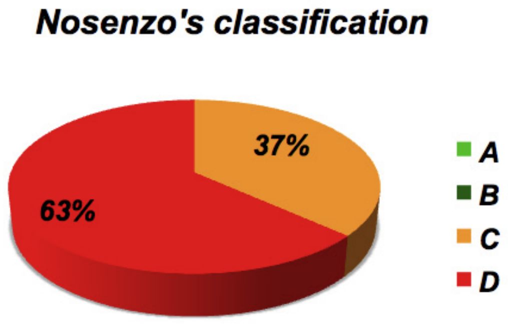


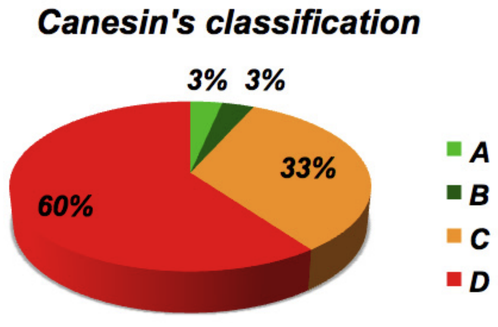
	Meters	Design
Spacing	3.3x2.25	Rectangle
Plantation design		
- Walnut & ash	> 8	Offset square
- Cherry	6.6X4.5	Rectangle

Legend:
N = walnut;
Ci = cherry;
F = ash;
Acc = accessory species.

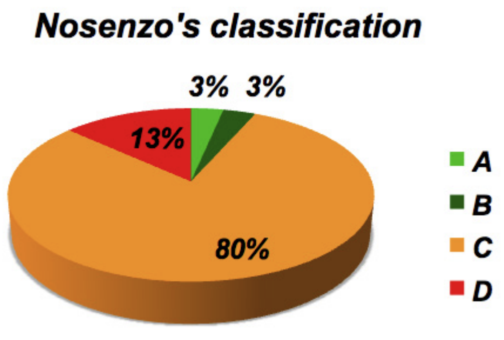
Growth rate	Walnut	Cherry	Ash
Mortality rate	8%	4%	5%
Thinned (winter 2007/2008)	17%	59%	39%
Δdbh (cm/y)	0.75	0.91	1.02
Δh (m/y)	0.57	0.62	0.72

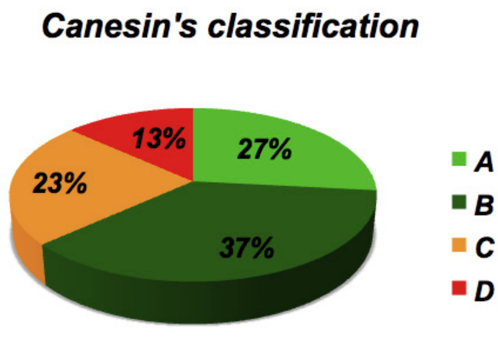
European walnut



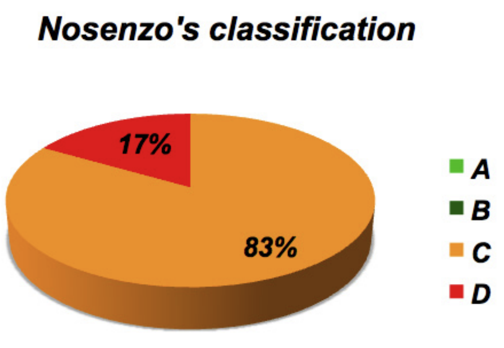


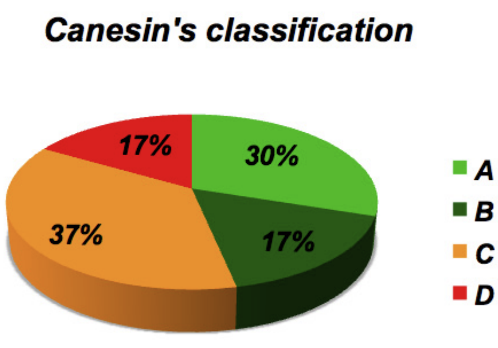
Wild cherry





European ash





Annex 4 – Sample plots parameters

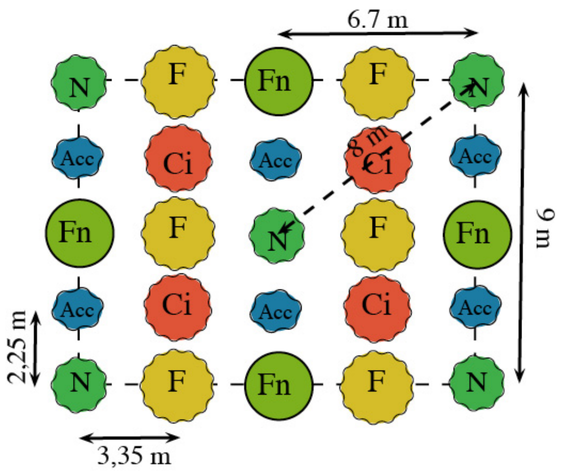
	European walnut			Wild cherry			European ash		
	DBH (cm)	**Stem height (m)**	**Tree height (m)**	**DBH (cm)**	**Stem height (m)**	**Tree height (m)**	**DBH (cm)**	**Stem height (m)**	**Tree height (m)**
mean	10.5	2.65	8.04	12.7	3.26	8.63	14.3	3.15	10.08
max	17.5	3.45	13.20	20.7	4.80	11.70	21.5	4.30	12.80
min	6.0	1.60	5.70	8.1	1.95	5.60	7.0	2.30	7.10
s^2	8.1	0.22	5.27	7.7	0.41	2.69	11.8	0.25	2.35
s	2.8	0.47	2.30	2.8	0.64	1.64	3.4	0.50	1.53

Stem defect	Walnut	Cherry	Ash	Stem defect	Walnut	Cherry	Ash
Branch > 3cm	30%	30%	23%	**Sinuosity**	7%	7%	3%
Knot > 3cm	7%	23%	0%	**Fork**	7%	0%	0%
Covered knots	53%	90%	93%	**Saddle**	20%	10%	20%
Fresh knots	3%	60%	0%	**Base damage**	33%	20%	13%
Rotten knots	7%	0%	0%	**Rot**	0%	3%	3%
∑(b+k) > 60mm	50%	90%	83%	**Insect hole**	10%	0%	7%
∑(b+k) 15<>60mm	0%	3%	0%	**Frost crack**	3%	0%	7%
Straightness > 10%	7%	0%	0%	**Ovality**	0%	0%	0%
Straightn. 3<>10%	70%	17%	30%	**Signs on bark**	100%	100%	90%
Straightness 1<>2%	23%	60%	53%	**Bottle neck**	7%	3%	0%
Inclin. > 20%	7%	0%	0%	**Spiral grain**	0%	0%	0%
Inclin. 10<>20%	47%	7%	4%	**Fluting**	0%	0%	0%

PLOT N° 2.2

Location: Cassegliano (San Pier d'Isonzo municipality)
Sampled rows: n° 2, 3, 4, 5, 6, 7, 8, 9
Year of plantation: 1994
Date of data collection: March 22nd 2009
Age (effective growing seasons): 14 years old

Species composition: Mixed with accessory species
Principal tree species: European walnut (*Juglans regia* L.), wild cherry (*Prunus avium* L.), European ash (*Fraxinus excelsior* L.), and pedunculate oak (*Quercus robur* L.)
Accessory tree species: *Crataegus monogyna* Jacq., and others thinned in winter 2007/2008

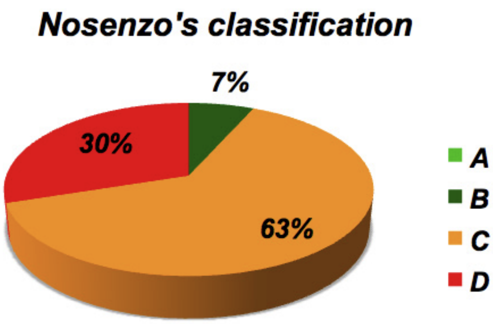


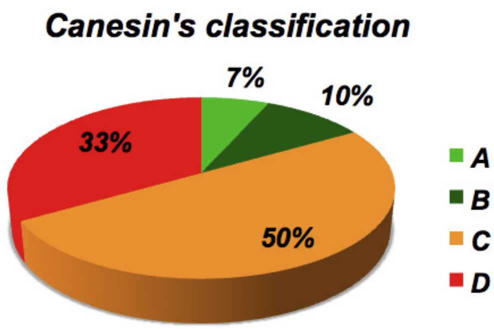
	Meters	Design
Spacing	3.35x2.25	Rectangle
Plantation design		
- Walnut, ash, oak	> 8	Offset square
- Cherry	6.7x4.5	Rectangle

Legend:
N = walnut;
Ci = cherry;
F = ash;
Fn = oak
Acc = accessory species

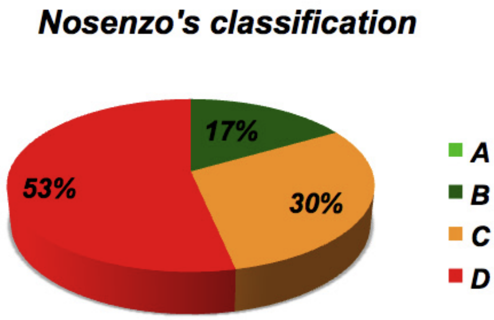
Growth rate	Walnut	Cherry	Ash	Oak
Mortality rate	8%	31%	15%	54%
Thinned (winter 2007/2008)	5%	26%	10%	-
Δdbh (cm/y)	0.61	0.58	1.04	0.42
Δh (m/y)	0.48	0.51	0.68	0.58

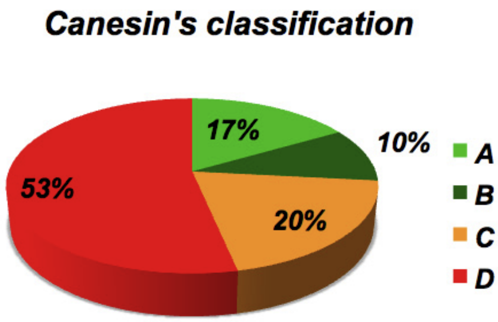
European walnut



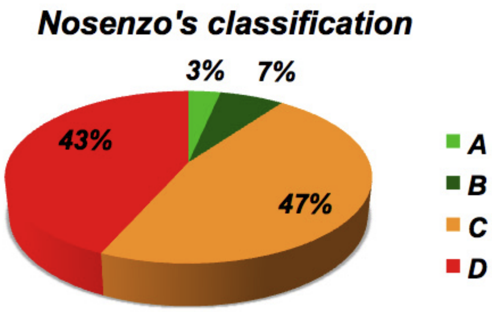


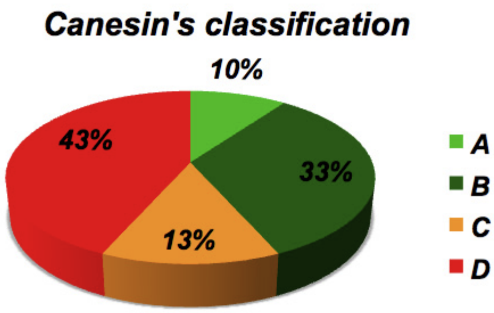
Wild cherry



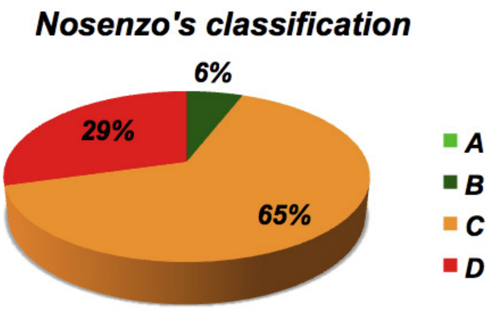


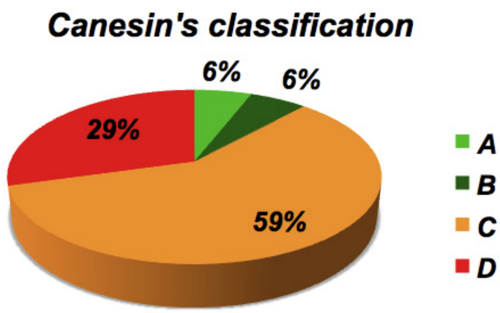
European ash





Pedunculate oak





Annex 4 – Sample plots parameters

	European walnut			Wild cherry		
	DBH (cm)	**Stem height (m)**	**Tree height (m)**	**DBH. (cm)**	**Stem height (m)**	**Tree height (m)**
mean	8.6	2.76	6.76	8.1	3.00	7.12
max	15.8	3.5	11.9	14.6	4.10	10.10
min	2.5	1.9	4.5	1.6	1.50	5.00
s^2	8.7	0.17	3.26	8.9	0.20	2.56
s	2.9	0.41	1.81	3.0	0.44	1.60

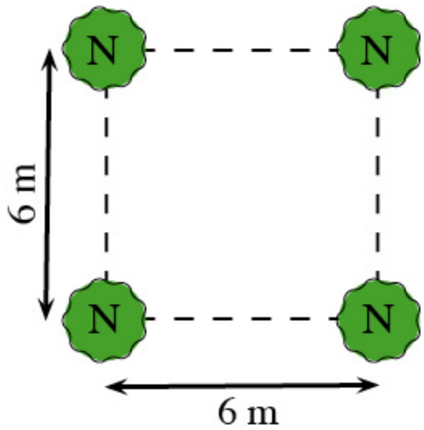
	European ash			Pedunculate Oak		
	DBH (cm)	**Stem height (m)**	**Tree height (m)**	**DBH (cm)**	**Stem height (m)**	**Tree height (m)**
mean	14.5	3.05	9.49	5.9	2.62	8.17
max	22.0	5	12.7	12.3	3.9	11.4
min	9.4	1.9	6.4	1.7	1.5	5
s^2	8.8	0.43	3.09	8.8	0.41	5.20
s	3.0	0.66	1.76	3.0	0.64	2.28

Stem defect	Walnut	Cherry	Ash	Oak
Branch > 3cm	27%	17%	77%	12%
Knot > 3cm	3%	0%	0%	0%
Covered knots	30%	23%	80%	12%
Fresh knots	10%	7%	7%	6%
Rotten knots	7%	7%	10%	0%
∑(b+k) > 60mm	30%	27%	83%	24%
∑(b+k) 15<>60mm	0%	0%	0%	0%
Straightness > 10%	0%	0%	0%	6%
Straightness 3<>10%	63%	20%	27%	71%
Straightness 1<>2%	37%	73%	63%	24%
Inclin. > 20%	0%	0%	0%	0%
Inclin. 10<>20%	3%	20%	3%	0%
Sinuosity	0%	0%	0%	0%
Fork	0%	0%	0%	0%
Saddle	17%	10%	10%	18%
Base damage	23%	23%	33%	6%
Rot	0%	7%	0%	0%
Insect hole	3%	3%	13%	0%
Frost crack	3%	0%	0%	0%
Ovality	0%	0%	0%	0%
Signs on bark	87%	77%	97%	76%
Bottle neck	7%	0%	0%	12%
Spiral grain	0%	0%	0%	0%
Fluting	0%	0%	0%	0%

PLOT N° 7

Location: Grado
Sampled rows: n° 2, 3 (after the third ditch from the road)
Year of plantation: 1996
Date of data collection: March 20th 2009
Age (effective growing seasons): 12 years old

Species composition: Pure
Principal tree species: European walnut (*Juglans regia* L.)
Accessory tree species: none

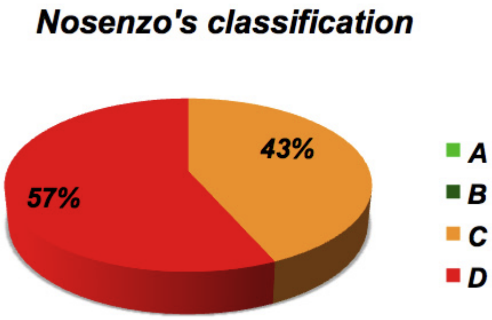


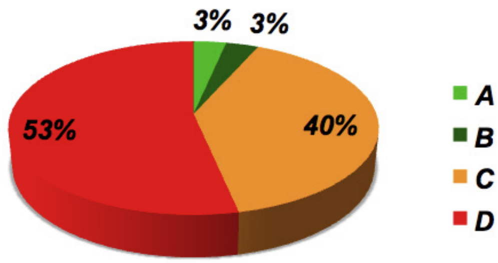
	Meters	Design
Spacing	6x6	Square
Plantation design		
– ***Walnut***	6x6	Square

Legend:
N = walnut.

Growth rate	Walnut
Mortality rate	**N.C.**
Δdbh (cm/y)	1.34
Δh (m/y)	0.69

European walnut





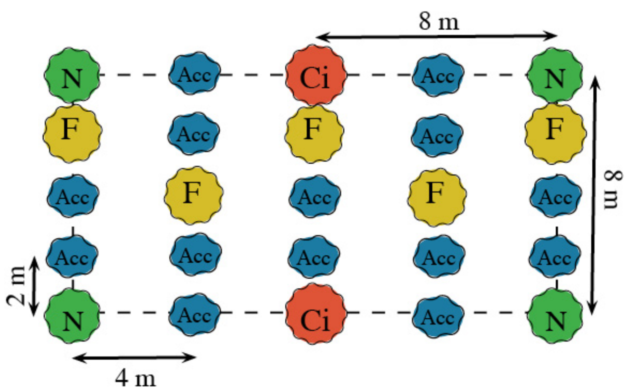
	European walnut		
	Diam. (cm)	**Stem height (m)**	**Tree height (m)**
mean	16.1	3.00	8.33
max	22.0	3.95	9.80
min	5.1	2.20	5.60
s^2	16.2	0.15	1.96
s	4.0	0.38	1.40

Stem defect	Walnut	Stem defect	Walnut
Branch > 3cm	23%	**Sinuosity**	20%
Knot > 3cm	83%	**Fork**	7%
Covered knots	87%	**Saddle**	33%
Fresh knots	43%	**Base damage**	47%
Rotten knots	7%	**Rot**	0%
∑(b+k) > 60mm	90%	**Insect hole**	3%
∑(b+k) 15<>60mm	0%	**Frost crack**	0%
Straightness > 10%	20%	**Ovality**	0%
Straightness 3<>10%	60%	**Signs on bark**	100%
Straightness 1<>2%	20%	**Bottle neck**	7%
Inclin. > 20%	0%	**Spiral grain**	0%
Inclin. 10<>20%	40%	**Fluting**	0%

PLOT N° 12A

Location: San Canzian d'Isonzo
Sampled rows: n° 10, 12, 16, 14
Year of plantation: 1996
Date of data collection: April 1st 2009
Age (effective growing seasons): 12 years old

Species composition: Mixed with accessory species
Principal tree species: European walnut (*Juglans regia* L.) and wild cherry (*Prunus avium* L.)
Principal "parachute" tree species: European ash (*Fraxinus excelsior* L.)
Accessory tree species: *Acer spp., Alnus. spp., Carpinus betulus* L. (most of them thinned)

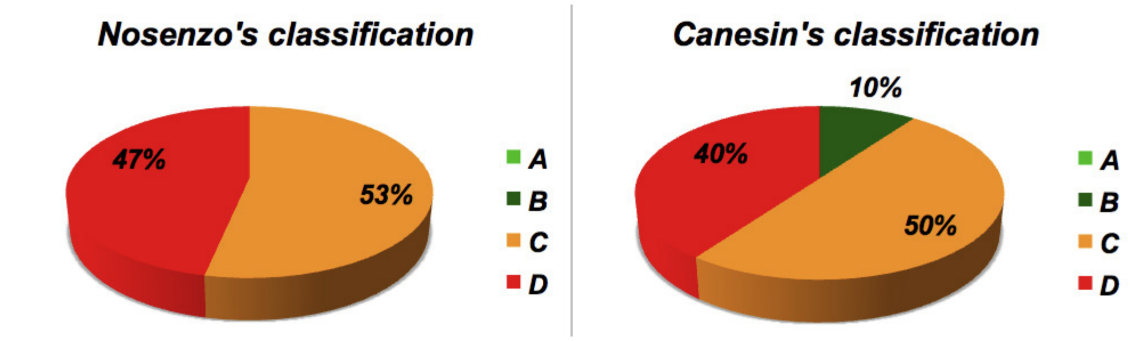


	Meters	Design
Spacing	4x2	Rectangle
Plantation design		
-Walnut & cherry	16x8	Rectangle

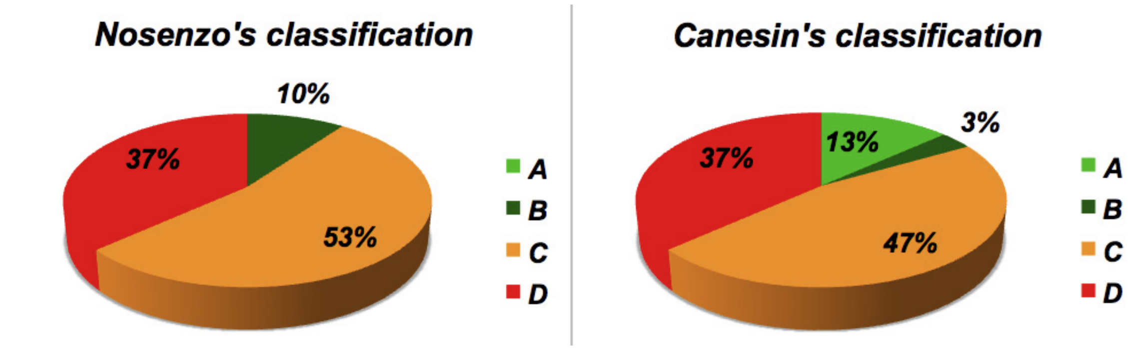
Legend:
N = walnut;
Ci = cherry;
F = ash;
Acc = accessory species.

Growth rate	Walnut	Cherry
Mortality rate	11%	18%
Δdbh (cm/y)	1.24	0.89
Δh (m/y)	0.86	0.71


European walnut



Wild cherry



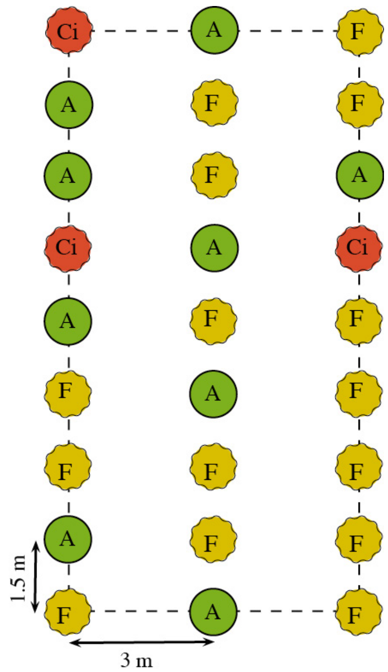
	European walnut			Wild cherry		
	Diam. (cm)	Stem height (m)	Tree height (m)	Diam. (cm)	Stem height (m)	Tree height (m)
mean	14.9	2.61	10.31	10.7	2.61	8.58
max	21.5	3.70	13.20	22.1	3.50	11.10
min	7.3	2.00	6.90	4.5	1.10	6.20
s^2	14.5	0.18	4.70	15.5	0.21	2.25
s	3.8	0.42	2.17	3.9	0.46	1.50

Stem defect	Walnut	Cherry	Stem defect	Walnut	Cherry
Branch > 3cm	3%	0%	**Sinuosity**	7%	0%
Knot > 3cm	77%	13%	**Fork**	7%	0%
Covered knots	90%	50%	**Saddle**	23%	17%
Fresh knots	80%	23%	**Base damage**	3%	20%
Rotten knots	0%	0%	**Rot**	0%	0%
∑(b+k) > 60mm	87%	37%	**Insect hole**	0%	3%
∑(b+k) 15<>60mm	0%	13%	**Frost crack**	0%	0%
Straightness > 10%	7%	3%	**Ovality**	3%	0%
Straightness 3<>10%	57%	53%	**Signs on bark**	97%	73%
Straightness 1<>2%	37%	37%	**Bottle neck**	0%	0%
Inclin. > 20%	7%	7%	**Spiral grain**	0%	0%
Inclin. 10<>20%	33%	10%	**Fluting**	0%	0%

PLOT N° 15A

Location: San Lorenzo Isontino
Sampled rows: n° 7, 8, 9, 10, 11
Year of plantation: 1996
Date of data collection: April 1st 2009
Age (effective growing seasons): 11 years old

Species composition: Mixed with accessory species
Principal tree species: wild cherry (*Prunus avium* L.) and European ash (*Fraxinus excelsior* L.)
Accessory tree species: field maple (*Acer campestris* L.)

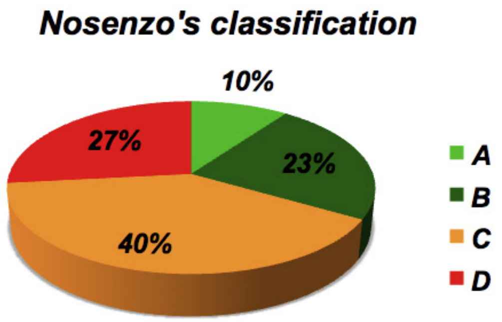


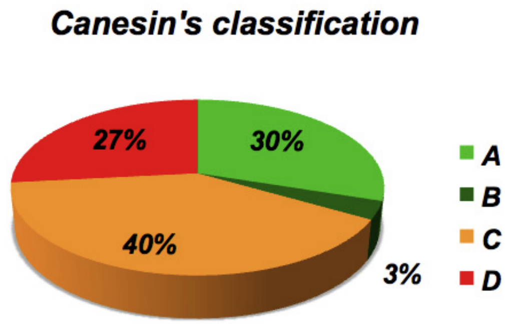
	Meters	Design
Spacing	3x1.5	Rectangle
Plantation design		
-Walnut, ash & oak	-	Free

Legend:
A = field maple;
Ci = cherry;
F = ash;

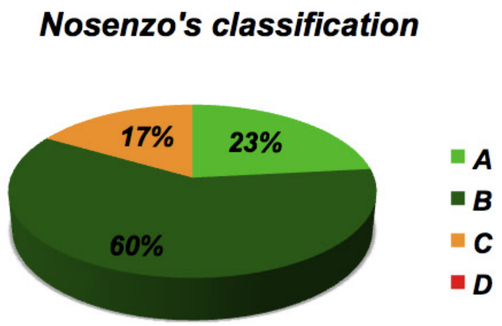
Growth rate	Cherry	Ash
Mortality rate	3%	-
Δdbh (cm/y)	0.50	0.78
Δh (m/y)	0.52	0.71

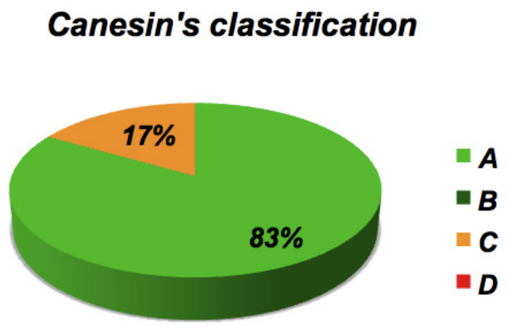

European walnut





European ash





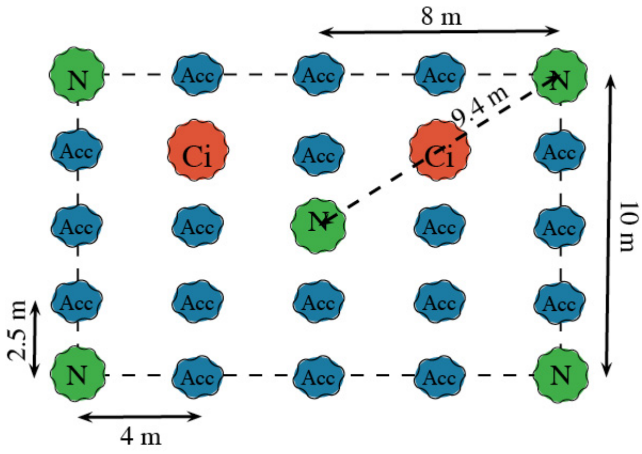
	Wild cherry				European ash		
	Diam. (cm)	Stem height (m)	Tree height (m)		Diam. (cm)	Stem height (m)	Tree height (m)
mean	6.0	2.85	6.22		9.4	3.17	8.53
max	11.3	3.73	9.00		14.6	3.72	9.90
min	2.2	2.32	3.80		3.5	2.50	4.90
s^2	5.8	0.11	2.34		7.4	0.18	1.70
s	2.4	0.33	1.53		2.7	0.43	1.31

Stem defect	Cherry	Ash	Stem defect	Cherry	Ash
Branch > 3cm	3%	0%	**Sinuosity**	3%	0%
Knot > 3cm	0%	0%	**Fork**	0%	0%
Covered knots	3%	20%	**Saddle**	20%	10%
Fresh knots	0%	0%	**Base damage**	0%	3%
Rotten knots	0%	0%	**Rot**	0%	0%
∑(b+k) > 60mm	7%	0%	**Insect hole**	0%	0%
∑(b+k) 15<>60mm	0%	17%	**Frost crack**	0%	0%
Straightness > 10%	0%	0%	**Ovality**	0%	0%
Straightness 3<>10%	50%	17%	**Signs on bark**	77%	80%
Straightness 1<>2%	33%	53%	**Bottle neck**	0%	0%
Inclin. > 20%	0%	0%	**Spiral grain**	0%	0%
Inclin. 10<>20%	13%	0%	**Fluting**	0%	0%

PLOT N° 16.1

Location: San Pier d'Isonzo
Sample rows: n° 8, 9, 10, 11
Year of plantation: 1997
Date of data collection: April 4th 2009
Age (effective growing seasons): 11 years old

Species composition: Mixed with accessory species
Principal tree species: European walnut (*Juglans regia* L.) and wild cherry (*Prunus avium* L.)
Accessory tree species: *Acer* spp., *Carpinus betulus* L., European ash (*Fraxinus excelsior* L.), Tilia sp., and others thinned in winter 2007/2008

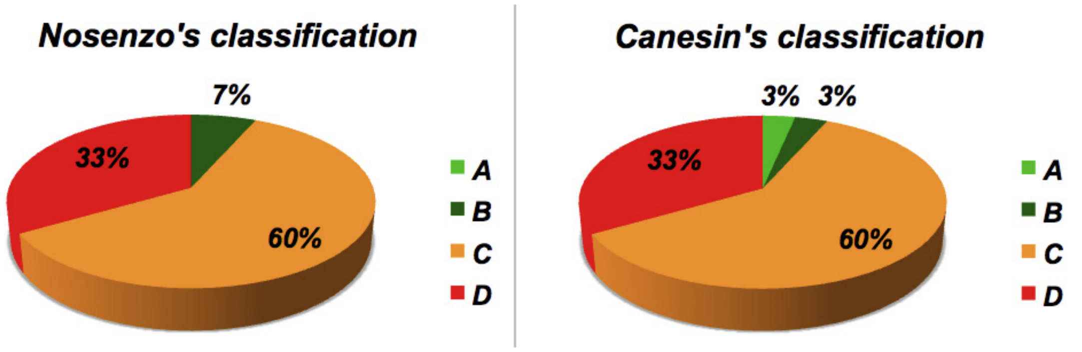


	Meters	Design
Spacing	4x2.5	Rectangle
Plantation design		
- Walnut	> 9.4	Offset square
- Cherry	8x10	Rectangle

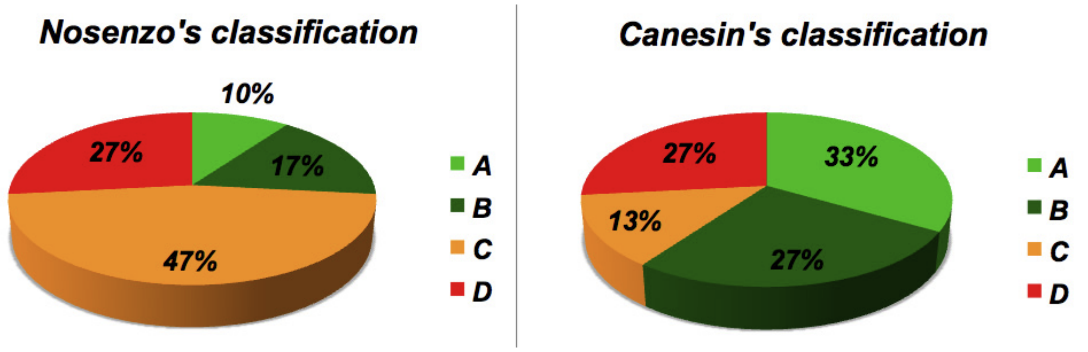
Legend:
N = walnut;
Ci = cherry;
Acc = accessory species.

Growth rate	Walnut	Cherry
Mortality rate	0%	5%
Thinned (winter 2007/2008)	28%	13%
Δdbh (cm/y)	1.08	1.00
Δh (m/y)	0.62	0.69

European walnut



Wild cherry



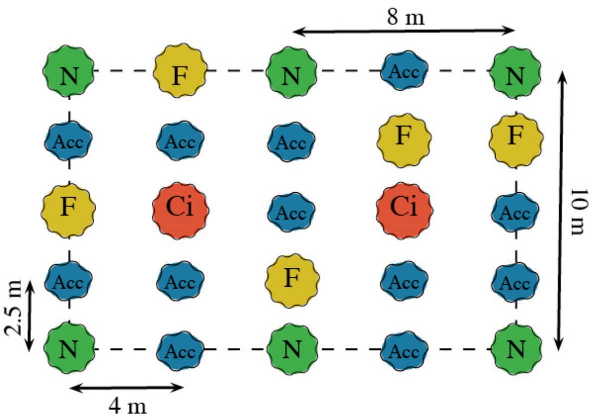
	European walnut				Wild cherry		
	Diam. (cm)	Stem height (m)	Tree height (m)		Diam. (cm)	Stem height (m)	Tree height (m)
mean	11.9	2.37	6.85		11.0	2.61	7.56
max	17.3	2.80	8.60		18.8	3.00	9.90
min	4.5	1.55	3.50		6.8	2.00	5.60
s^2	9.7	0.11	1.35		8.3	0.07	1.53
s	3.1	0.33	1.16		2.9	0.26	1.24

Stem defect	Walnut	Cherry	Stem defect	Walnut	Cherry
Branch > 3cm	20%	30%	**Sinuosity**	0%	0%
Knot > 3cm	73%	17%	**Fork**	0%	0%
Covered knots	80%	60%	**Saddle**	10%	3%
Fresh knots	70%	37%	**Base damage**	0%	37%
Rotten knots	0%	0%	**Rot**	0%	10%
∑(b+k) > 60mm	80%	57%	**Insect hole**	7%	0%
∑(b+k) 15<>60mm	0%	0%	**Frost crack**	3%	0%
Straightness > 10%	0%	0%	**Ovality**	3%	0%
Straightness 3<>10%	60%	13%	**Signs on bark**	90%	90%
Straightness 1<>2%	40%	53%	**Bottle neck**	0%	3%
Inclin. > 20%	0%	0%	**Spiral grain**	0%	0%
Inclin. 10<>20%	30%	0%	**Fluting**	0%	0%

PLOT N° 16.2

Location: San Pier d'Isonzo
Sampled rows: n° 8, 9
Year of plantation: 1997
Date of data collection: April 4th 2009
Age (effective growing seasons): 11 years old

Species composition: Mixed with accessory species
Principal tree species: European walnut (*Juglans regia* L.), wild cherry (*Prunus avium* L.), and European ash (*Fraxinus excelsior* L.)
Accessory tree species: *Fraxinus ornus* L., *Carpinus betulus* L., *Acer campestris* L., *Crataegus sp., Quercus pubescens* Willd. (most of them thinned in winter 2007/2008)

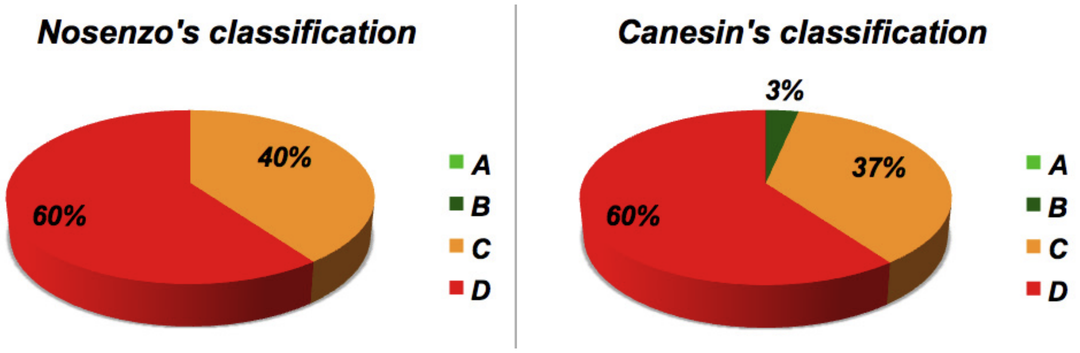


	Meters	Design
Spacing	4x2.5	Rectangle
Plantation design		
- Walnut & cherry	8x10	Rectangle
- Ash	-	Free

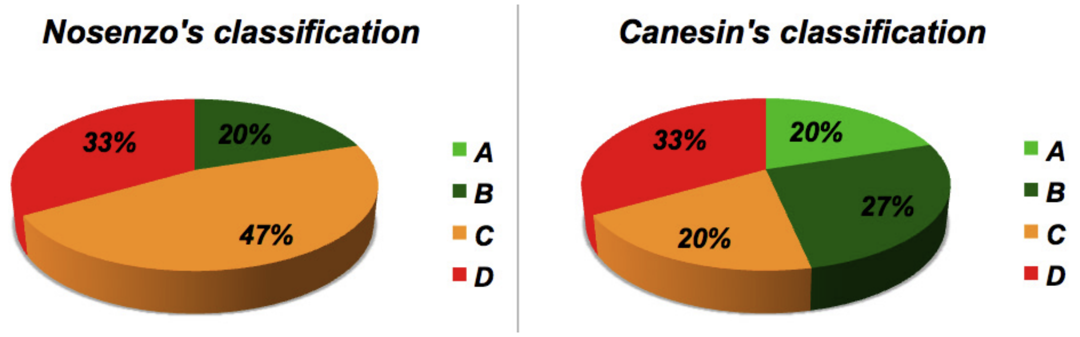
Legend:
N = walnut;
Ci = cherry;
F = ash;
Acc = accessory species.

Growth rate	Walnut	Cherry	Ash
Mortality rate	0%	5%	0%
Δdbh (cm/y)	1.05	0.91	0.75
Δh (m/y)	0.66	0.68	0.63

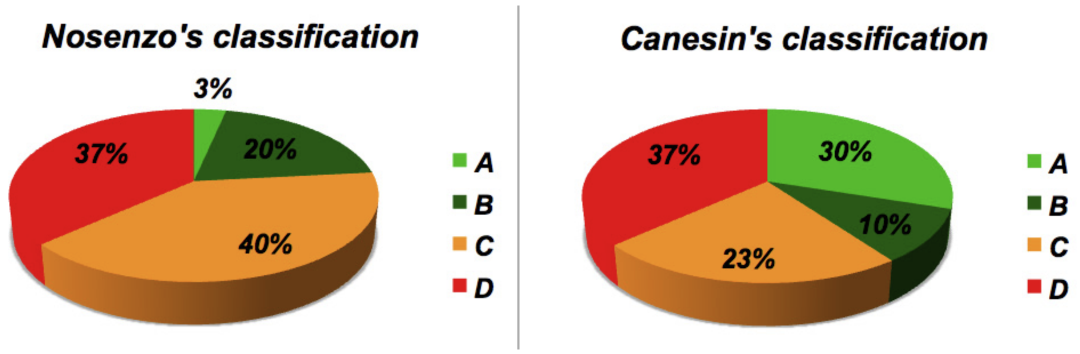
European walnut



Wild cherry



European ash



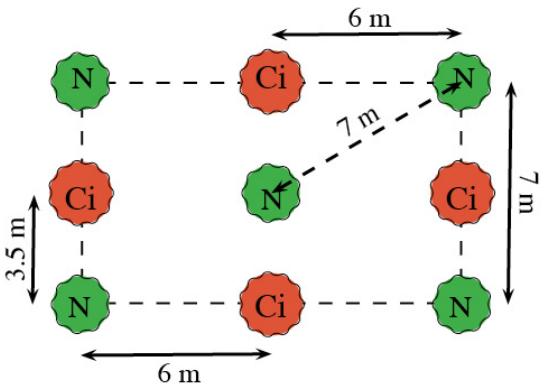
	European walnut			Wild cherry			European ash		
	Diam. (cm)	Stem height (m)	Tree height (m)	Diam. (cm)	Stem height (m)	Tree height (m)	Diam. (cm)	Stem height (m)	Tree height (m)
mean	11.6	2.37	7.24	10.0	2.92	7.50	8.3	2.69	6.93
max	20.8	3.50	11.70	20.2	4.40	11.30	17.2	4.00	11.70
min	4.6	1.88	3.15	2.9	1.50	3.20	3.5	1.90	3.50
s^2	16.2	0.13	5.18	19.2	0.42	5.00	11.1	0.22	4.84
s	4.0	0.37	2.28	4.4	0.65	2.24	3.3	0.47	2.20

Stem defect	Walnut	Cherry	Ash
Branch > 3cm	3%	0%	0%
Knot > 3cm	67%	47%	23%
Covered knots	67%	50%	30%
Fresh knots	67%	47%	30%
Rotten knots	3%	0%	0%
∑(b+k) > 60mm	63%	47%	30%
∑(b+k) 15<>60mm	0%	3%	0%
Straightness > 10%	0%	0%	0%
Straightness 3<>10%	53%	40%	20%
Straightness 1<>2%	40%	57%	63%
Inclin. > 20%	0%	0%	0%
Inclin. 10<>20%	27%	0%	10%
Sinuosity	0%	0%	0%
Fork	0%	3%	3%
Saddle	10%	13%	10%
Base damage	13%	27%	10%
Rot	0%	7%	0%
Insect hole	3%	0%	10%
Frost crack	0%	0%	0%
Ovality	0%	0%	0%
Signs on bark	93%	77%	83%
Bottle neck	0%	0%	0%
Spiral grain	0%	0%	0%
Fluting	0%	0%	0%

PLOT N° 22

Location: Turriaco
Sampled rows: n° 3, 4, 5, 6, 7, 8, 9, 10
Year of plantation: 1998
Date of data collection: March 27th 2009
Age (effective growing seasons): 10 years old

Species composition: Mixed
Principal tree species: European walnut (*Juglans regia* L.), wild cherry (*Prunus avium* L.), and European ash (*Fraxinus excelsior* L.)
Accessory tree species: none



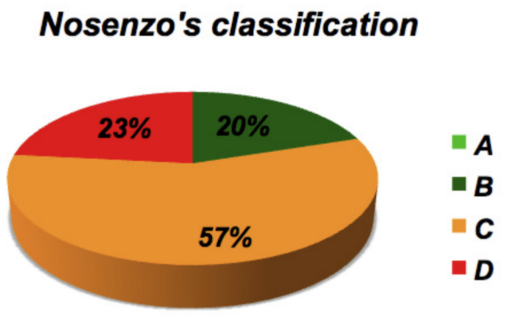
	Meters	Design
Spacing	6x3.5	Rectangle
Plantation design		
- Walnut & cherry	7	Hexagonal

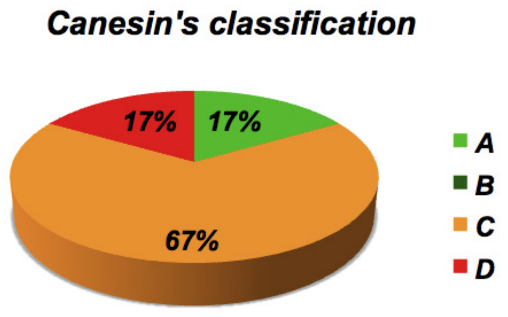
Legend:
N = walnut;
Ci = cherry.

Growth rate	Walnut	Cherry	Ash
Mortality rate	3%	2%	0%
Δdbh (cm/y)	1.21	1.21	0.88
Δh (m/y)	0.84	0.85	0.81

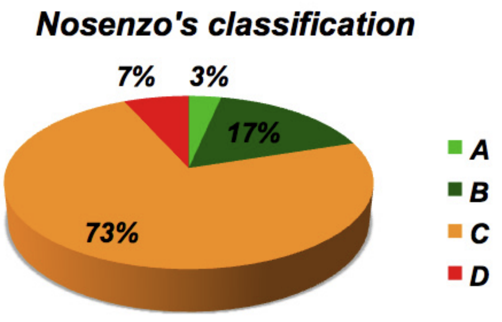
 

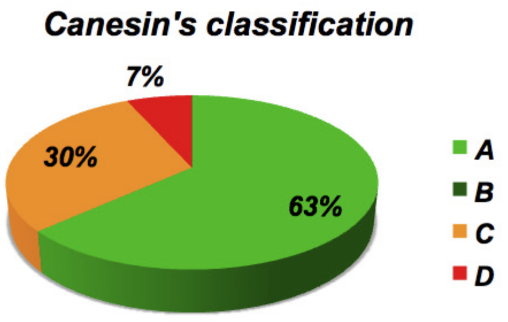
European walnut



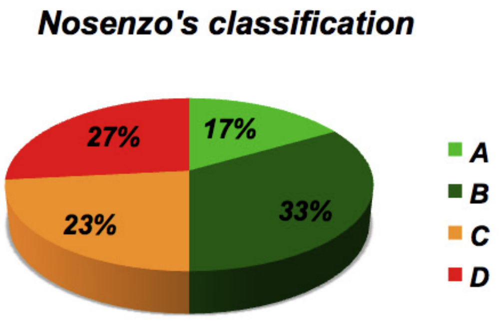


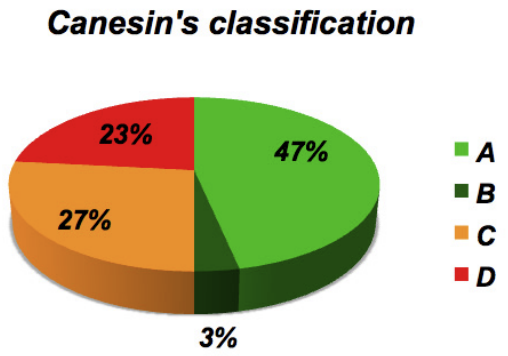
Wild cherry





European ash





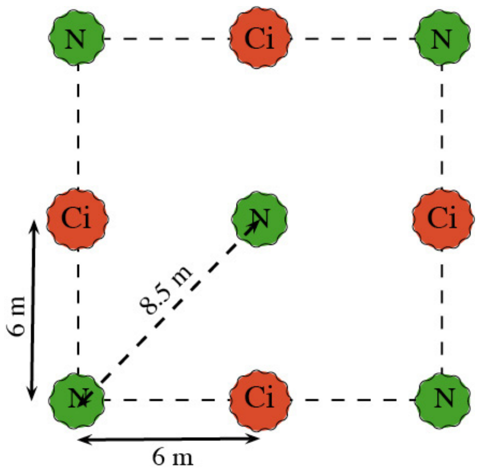
	European walnut			Wild cherry			European ash		
	Diam. (cm)	Stem height (m)	Tree height (m)	Diam. (cm)	Stem height (m)	Tree height (m)	Diam. (cm)	Stem height (m)	Tree height (m)
mean	12.1	3.59	8.39	12.1	3.95	8.46	8.8	3.54	8.09
max	15.9	4.50	9.60	19.9	5.60	11.10	12.4	4.40	9.20
min	6.0	2.00	5.10	2.5	1.60	3.50	4.8	1.70	6.30
s^2	4.7	0.49	1.30	17.0	0.63	2.18	2.8	0.43	0.69
s	2.2	0.70	1.14	4.1	0.80	1.48	1.7	0.66	0.83

Stem defect	Walnut	Cherry	Ash
Branch > 3cm	0%	0%	0%
Knot > 3cm	0%	0%	0%
Covered knots	57%	57%	3%
Fresh knots	3%	0%	0%
Rotten knots	0%	0%	0%
∑(b+k) > 60mm	50%	57%	3%
∑(b+k) 15<>60mm	3%	0%	0%
Straightness > 10%	7%	3%	0%
Straightness 3<>10%	43%	23%	27%
Straightness 1<>2%	50%	70%	53%
Inclin. > 20%	10%	0%	0%
Inclin. 10<>20%	47%	10%	3%
Sinuosity	7%	0%	7%
Fork	0%	0%	3%
Saddle	3%	13%	27%
Base damage	3%	10%	13%
Rot	0%	0%	0%
Insect hole	7%	0%	13%
Frost crack	0%	3%	0%
Ovality	0%	0%	0%
Signs on bark	100%	87%	93%
Bottle neck	0%	0%	0%
Spiral grain	0%	0%	0%
Fluting	0%	0%	0%

PLOT N° 30

Location: Mossa
Sampled rows: n° 3, 2, 4, 5
Year of plantation: 1998
Date of data collection: April 1st 2009
Age (effective growing seasons): 10 years old

Species composition: Mixed
Principal tree species: European walnut (*Juglans regia* L.) and wild cherry (*Prunus avium* L.)
Accessory tree species: none

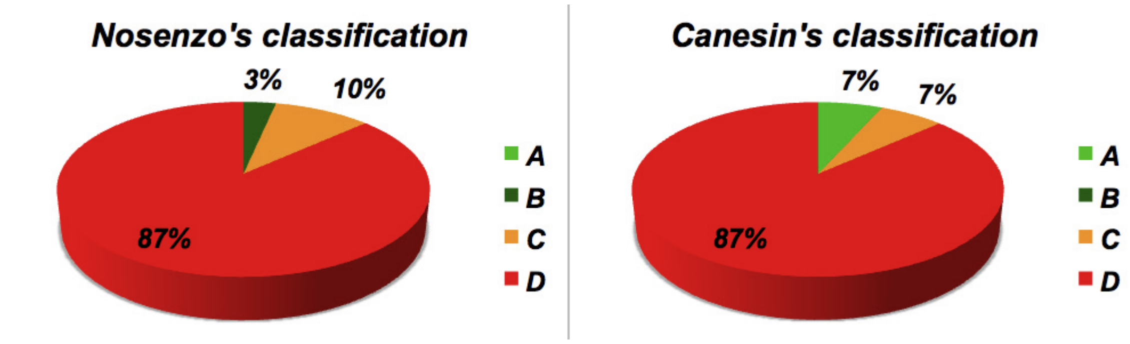


	Meters	Design
Spacing	6x6	Square
Plantation design		
- *Walnut & cherry*	> 8.5	Offset square

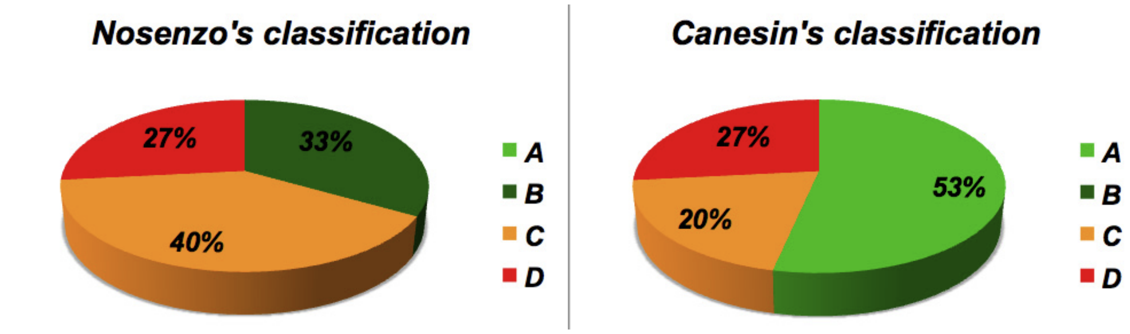
Legend:
N = walnut;
Ci = cherry.

Growth rate	Walnut	Cherry
Mortality rate	11%	14%
Δdbh (cm/y)	1.17	1.38
Δh (m/y)	0.67	0.73

European walnut



Wild cherry



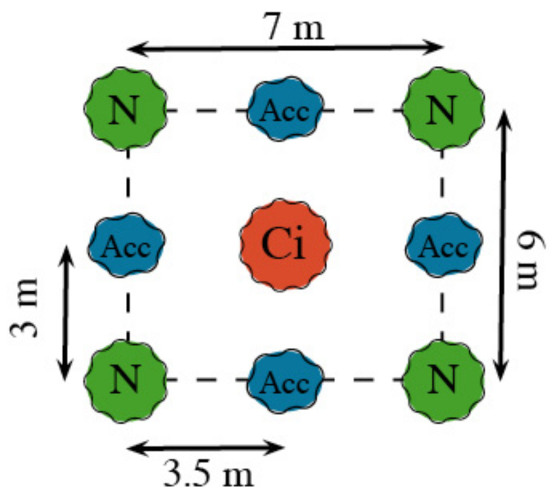
	European walnut			Wild cherry		
	Diam. (cm)	Stem height (m)	Tree height (m)	Diam. (cm)	Stem height (m)	Tree height (m)
mean	11.7	1.99	6.67	13.8	2.65	7.26
max	18.1	2.70	8.40	18.8	3.30	10.20
min	6.8	1.46	4.50	6.4	1.85	5.60
s^2	6.6	0.12	0.92	9.1	0.12	0.98
s	2.6	0.34	0.96	3.0	0.34	0.99

Stem defect	Walnut	Cherry
Branch > 3cm	0%	0%
Knot > 3cm	37%	0%
Covered knots	77%	80%
Fresh knots	43%	0%
Rotten knots	0%	0%
∑(b+k) > 60mm	67%	33%
∑(b+k) 15<>60mm	3%	30%
Straightness > 10%	3%	0%
Straightness 3<>10%	70%	30%
Straightness 1<>2%	27%	53%
Inclin. > 20%	0%	0%
Inclin. 10<>20%	23%	7%
Sinuosity	3%	0%
Fork	3%	0%
Saddle	17%	10%
Base damage	30%	33%
Rot	0%	3%
Insect hole	3%	0%
Frost crack	3%	0%
Ovality	0%	0%
Signs on bark	100%	93%
Bottle neck	0%	0%
Spiral grain	0%	0%
Fluting	0%	0%

PLOT N° 35

Location: San Canzian d'Isonzo
Sampled rows: n° 3, 4, 5, 6, 8, 10, 12
Year of plantation: 1999
Date of data collection: March 27th 2009
Age (effective growing seasons): 9 years old

Species composition: Mixed with accessory species
Principal tree species: European walnut (*Juglans regia* L.) and wild cherry (*Prunus avium* L.)
Accessory tree species: *Alnus spp., Fraxinus sp., Acer campestris* L.

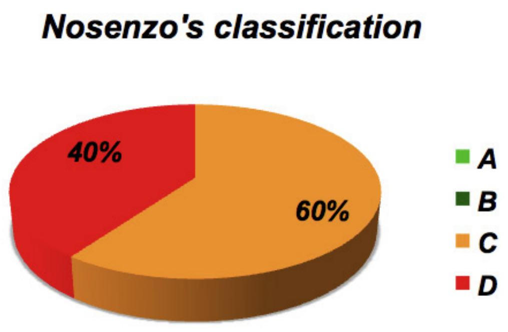


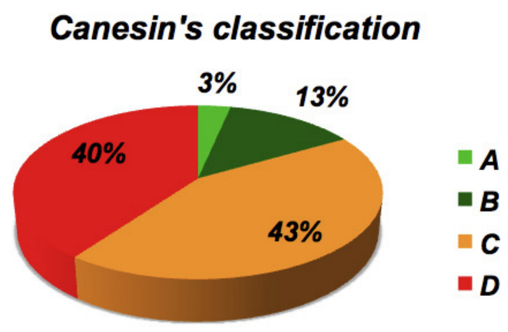
	Meters	Design
Spacing	3x3.5	Rectangle
Plantation design		
- Walnut & cherry	7x6	Rectangle

Legend:
N = walnut;
Ci = cherry
Acc = accessory species.

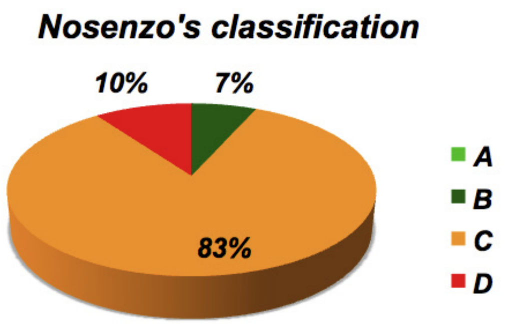
Growth rate	Walnut	Cherry
Mortality rate	4%	6%
Thinned	4%	-
Δdbh (cm/y)	1.36	1.74
Δh (m/y)	1.01	1.19

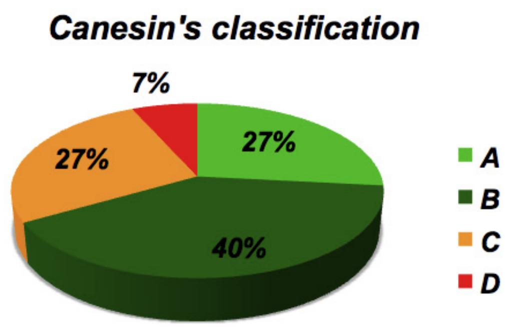
European walnut





Wild cherry





	European walnut			Wild cherry		
	Diam. (cm)	Stem height (m)	Tree height (m)	Diam. (cm)	Stem height (m)	Tree height (m)
mean	12.3	3.61	9.06	15.7	4.42	10.67
max	16.9	7.90	11.00	20.7	6.00	13.00
min	8.0	2.00	2.00	9.5	3.10	8.00
s^2	5.5	1.02	3.02	8.7	0.53	1.54
s	2.4	1.01	1.74	3.0	0.73	1.24

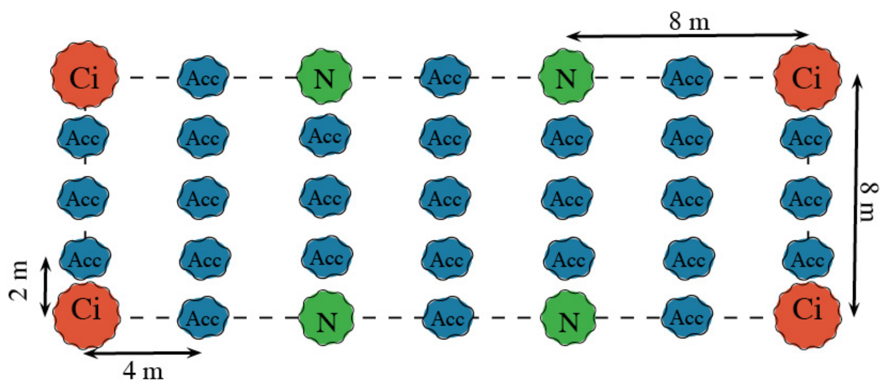
Stem defect	Walnut	Cherry	Stem defect	Walnut	Cherry
Branch > 3cm	3%	3%	**Sinuosity**	13%	0%
Knot > 3cm	53%	60%	**Fork**	0%	0%
Covered knots	80%	93%	**Saddle**	13%	3%
Fresh knots	63%	67%	**Base damage**	17%	0%
Rotten knots	7%	0%	**Rot**	0%	0%
∑(b+k) > 60mm	80%	90%	**Insect hole**	10%	0%
∑(b+k) 15<>60mm	0%	0%	**Frost crack**	3%	0%
Straightness > 10%	23%	3%	**Ovality**	0%	0%
Straightness 3<>10%	43%	20%	**Signs on bark**	97%	100%
Straightness 1<>2%	33%	57%	**Bottle neck**	0%	0%
Inclin. > 20%	13%	3%	**Spiral grain**	7%	3%
Inclin. 10<>20%	17%	10%	**Fluting**	0%	0%

PLOT N° 37A

Location: San Canzian d'Isonzo
Sampled rows: n° 7, 5, 3, 1
Year of plantation: 1999
Date of data collection: April 4th 2009
Age (effective growing seasons): 9 years old

Species composition: Mixed with accessory species
Principal tree species: European walnut (*Juglans regia* L.) and wild cherry (*Prunus avium* L.)
Accessory tree species: *Alnus spp., Crataegus sp., Platanus sp., Acer spp., Ulmus campestris* L.

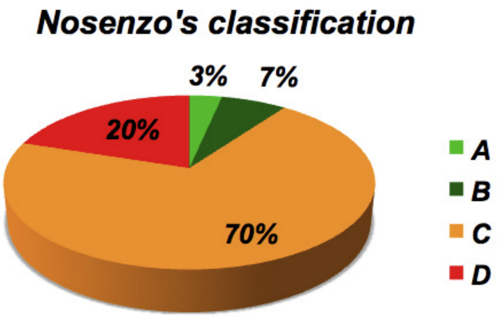
	Meters	Design
Spacing	4x2	Rectangle
Plantation design – Walnut & cherry	8x(8)	Square

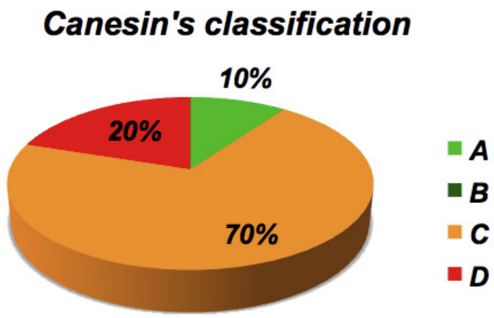


Legend:
N = walnut; **Ci** = cherry; **Acc** = accessory species.

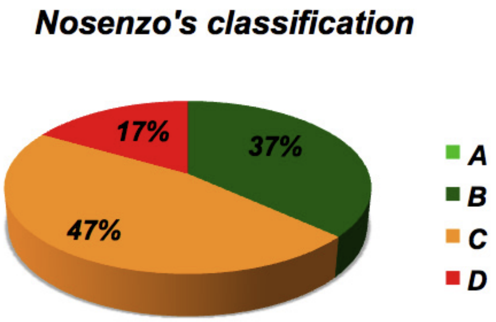
Growth rate	Walnut	Cherry
Mortality rate	0%	21%
Δdbh (cm/y)	1.62	1.53
Δh (m/y)	1.30	1.12

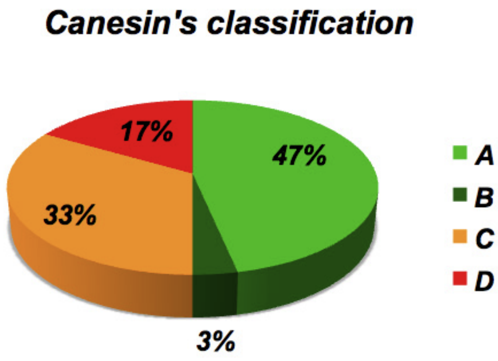
European walnut





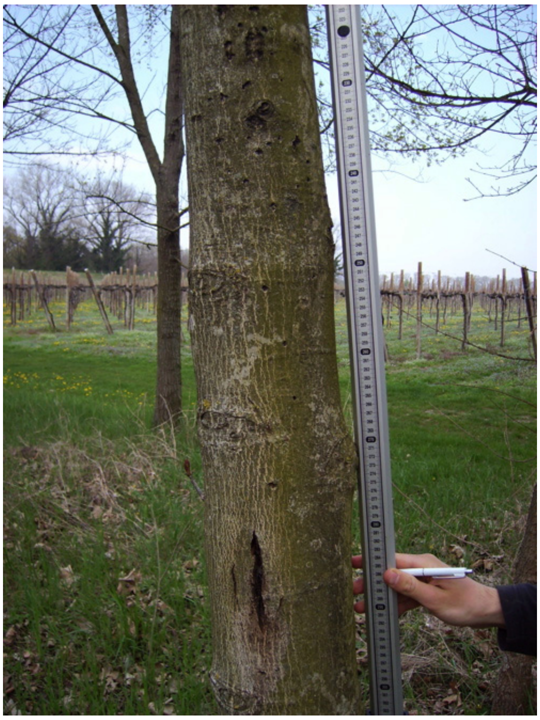
Wild cherry





	European walnut			Wild cherry		
	Diam. (cm)	Stem height (m)	Tree height (m)	Diam. (cm)	Stem height (m)	Tree height (m)
mean	14.6	2.67	11.67	13.8	3.09	10.04
max	20.7	3.90	16.10	20.7	5.00	14.00
min	7.2	1.78	5.50	5.1	2.20	4.90
s^2	14.8	0.24	7.84	22.0	0.42	4.41
s	3.9	0.49	2.80	4.7	0.65	2.10

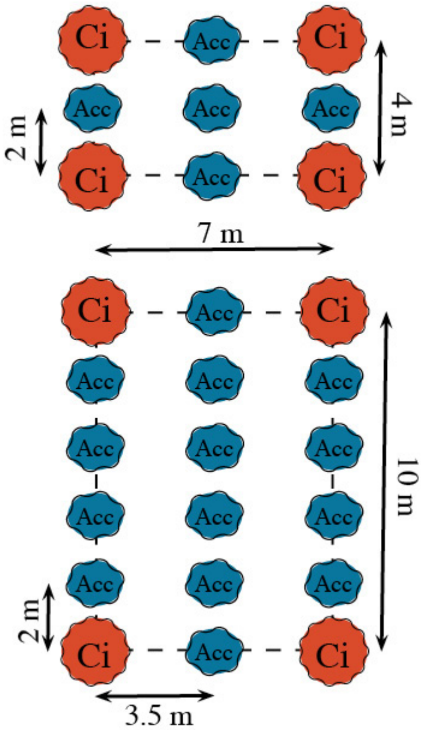
Stem defect	Walnut	Cherry	Stem defect	Walnut	Cherry
Branch > 3cm	0%	0%	**Sinuosity**	0%	0%
Knot > 3cm	0%	3%	**Fork**	3%	3%
Covered knots	67%	67%	**Saddle**	23%	3%
Fresh knots	0%	7%	**Base damage**	7%	7%
Rotten knots	0%	0%	**Rot**	0%	7%
∑(b+k) > 60mm	40%	43%	**Insect hole**	0%	0%
∑(b+k) 15<>60mm	23%	33%	**Frost crack**	3%	10%
Straightness > 10%	0%	0%	**Ovality**	0%	0%
Straightness 3<>10%	83%	37%	**Signs on bark**	90%	93%
Straightness 1<>2%	13%	50%	**Bottle neck**	0%	0%
Inclin. > 20%	0%	0%	**Spiral grain**	0%	0%
Inclin. 10<>20%	23%	3%	**Fluting**	0%	0%



PLOT N° 41.1

Location: Grado
Sampled rows: n° 3
Year of plantation: 1999
Date of data collection: March 23rd 2009
Age (effective growing seasons): 9 years old

Species composition: Pure with accessory species
Principal tree species: wild cherry (*Prunus avium* L.)
Accessory tree species: *Alnus spp., Fraxinus ornus* L., *Betula sp., Quercus sp., Cornus sanguinea* L., *Viburnum sp., Populus nigra* L.

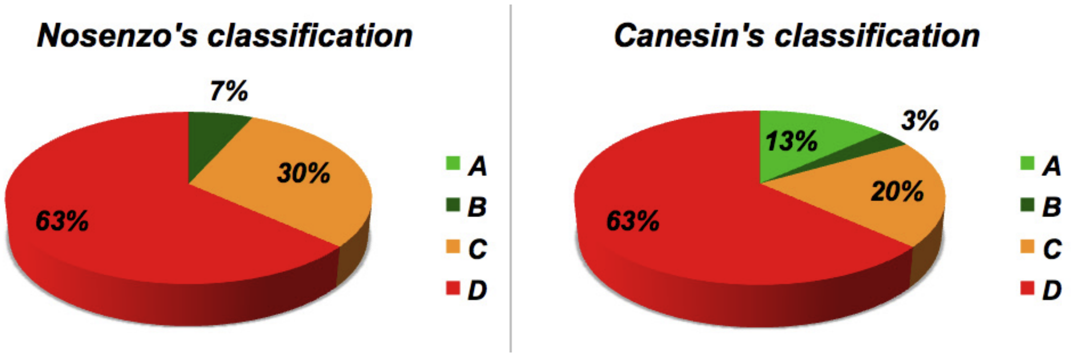


	Meters	Design
Spacing	3.5x2	Rectangle
Plantation design		
- Cherry	7x4 or 7x10	Rectangle

Legend:
Ci = cherry;
Acc = accessory species.

Growth rate	Cherry
Mortality rate	0%
Δdbh (cm/y)	1.64
Δh (m/y)	0.94

Wild cherry



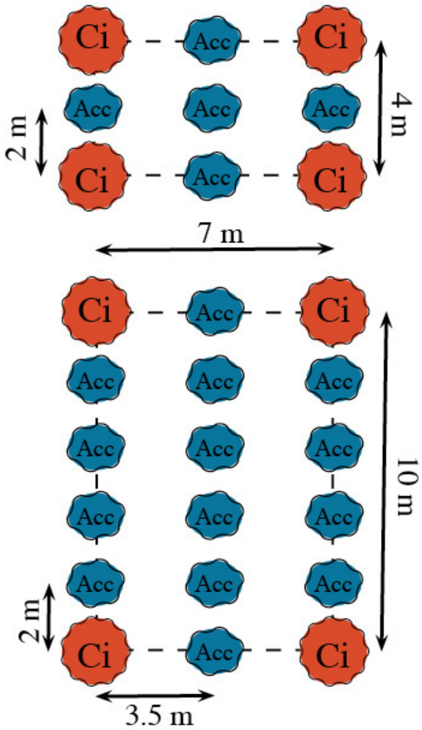
	Wild cherry		
	Diam. (cm)	**Stem height (m)**	**Tree height (m)**
mean	14.8	2.30	8.43
max	20.7	3.20	9.90
min	9.5	1.40	7.00
s^2	6.8	0.19	0.77
s	2.6	0.44	0.88

Stem defect	Cherry
Branch > 3cm	40%
Knot > 3cm	3%
Covered knots	90%
Fresh knots	0%
Rotten knots	7%
∑(b+k) > 60mm	73%
∑(b+k) 15<>60mm	3%
Straightness > 10%	10%
Straightness 3<>10%	30%
Straightness 1<>2%	37%
Inclin. > 20%	0%
Inclin. 10<>20%	0%
Sinuosity	0%
Fork	10%
Saddle	20%
Base damage	23%
Rot	0%
Insect hole	0%
Frost crack	0%
Ovality	7%
Signs on bark	100%
Bottle neck	27%
Spiral grain	3%
Fluting	0%

PLOT N° 41.2

Location: Grado
Sampled rows: n° 11
Year of plantation: 1999
Date of data collection: March 23rd 2009
Age (effective growing seasons): 9 years old

Species composition: Pure with accessory species
Principal tree species: wild cherry (*Prunus avium* L.)
Accessory tree species: *Alnus spp., Fraxinus ornus* L.*, Betula sp., Quercus sp., Cornus sanguinea* L.*, Viburnum sp., Populus nigra* L.*, Ulmus campestris* L.*, Acer campestris* L.

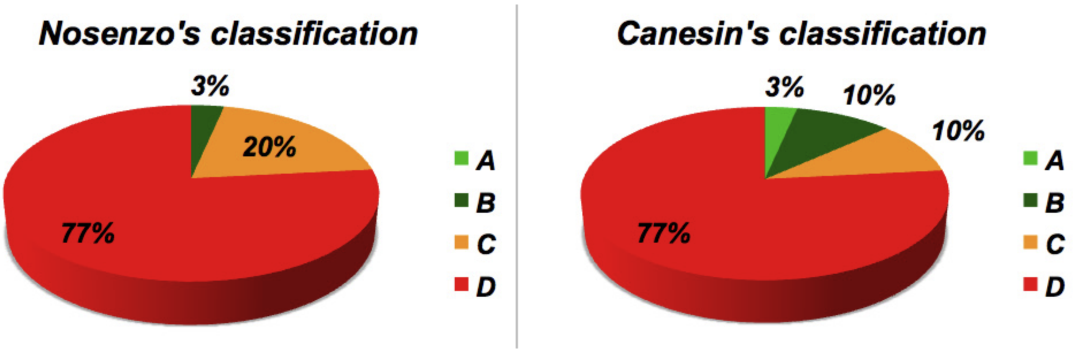


	Meters	Design
Spacing	3.5x2	Rectangle
Plantation design		
- Cherry	7x4 or 7x10	Rectangle

Legend:
Ci = cherry;
Acc = accessory species.

Growth rate	**Cherry**
Mortality rate	0%
Δdbh (cm/y)	1.67
Δh (m/y)	1.00

Wild cherry



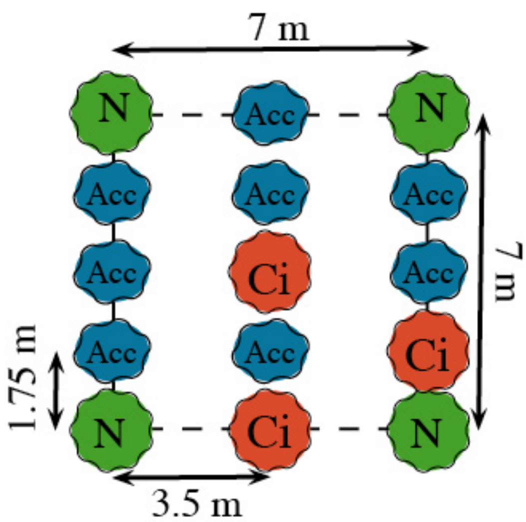
	Wild cherry		
	Diam. (cm)	Stem height (m)	Tree height (m)
mean	15.0	2.12	9.03
max	18.8	3.36	10.80
min	6.7	1.00	7.20
s^2	7.6	0.36	0.98
s	2.8	0.60	0.99

Stem defect	Cherry
Branch > 3cm	30%
Knot > 3cm	33%
Covered knots	87%
Fresh knots	27%
Rotten knots	13%
∑(b+k) > 60mm	50%
∑(b+k) 15<>60mm	3%
Straightness > 10%	7%
Straightness 3<>10%	33%
Straightness 1<>2%	30%
Inclin. > 20%	0%
Inclin. 10<>20%	3%
Sinuosity	0%
Fork	20%
Saddle	17%
Base damage	7%
Rot	0%
Insect hole	0%
Frost crack	3%
Ovality	3%
Signs on bark	100%
Bottle neck	17%
Spiral grain	3%
Fluting	7%

PLOT N° 51.1

Location: Romans d'Isonzo
Sampled rows: n° 4, 3, 5
Year of plantation: 1999
Date of data collection: March 31st 2009
Age (effective growing seasons): 9 years old

Species composition: Mixed with accessory species
Principal tree species: European walnut (*Juglans regia* L.) and wild cherry (*Prunus avium* L.)
Accessory tree species: *Alnus spp., Acer spp., Fraxinus excelsior* L.

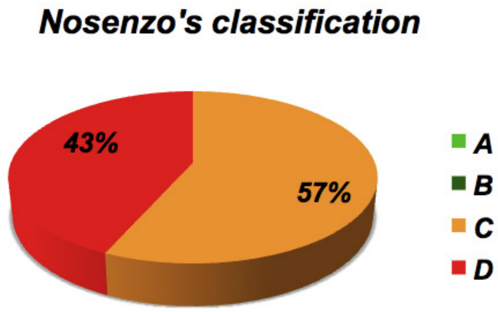


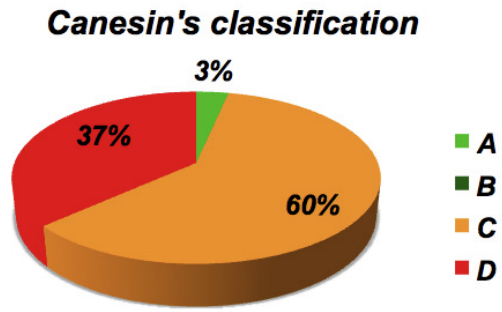
	Meters	Design
Spacing	3.5x1.75	Rectangle
Plantation design		
- Walnut	7x7	Square/free
- Cherry	-	Free

Legend:
N = walnut;
Ci = cherry;
Acc = accessory species.

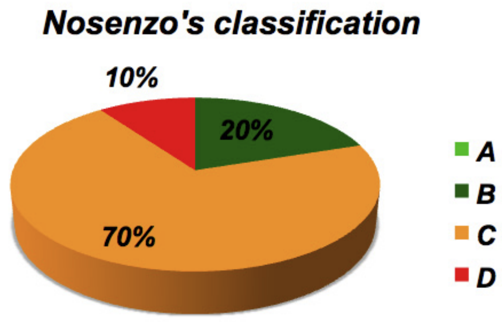
Growth rate	Walnut	Cherry
Mortality rate	3%	0%
Δdbh (cm/y)	1.41	1.45
Δh (m/y)	1.37	1.34

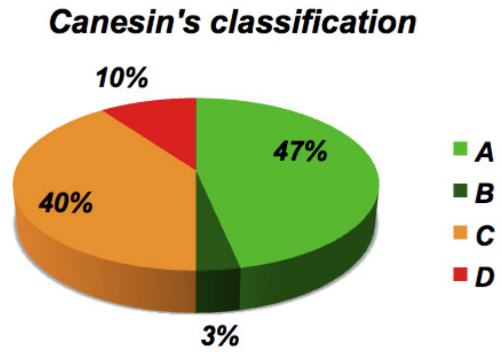
European walnut





Wild cherry





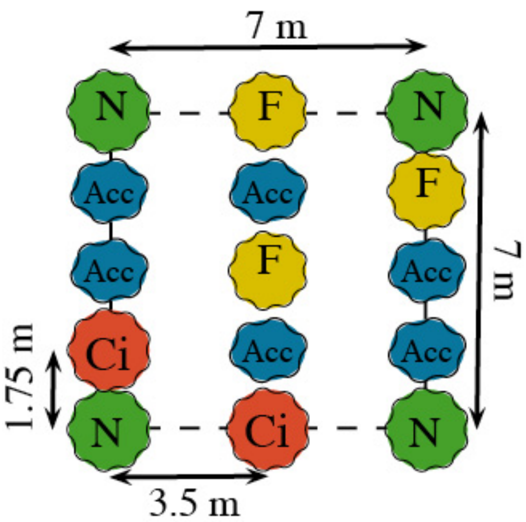
	European walnut				Wild cherry		
	Diam. (cm)	Stem height (m)	Tree height (m)		Diam. (cm)	Stem height (m)	Tree height (m)
mean	12.7	2.50	12.31		13.0	2.88	12.04
max	18.9	3.50	14.50		17.8	3.70	14.50
min	3.5	1.35	4.00		4.1	1.80	10.80
s^2	14.0	0.27	7.34		12.6	0.18	1.14
s	3.7	0.52	2.71		3.5	0.42	1.07

Stem defect	Walnut	Cherry	Stem defect	Walnut	Cherry
Branch > 3cm	3%	7%	**Sinuosity**	0%	0%
Knot > 3cm	10%	3%	**Fork**	0%	0%
Covered knots	73%	67%	**Saddle**	40%	3%
Fresh knots	20%	0%	**Base damage**	13%	10%
Rotten knots	0%	0%	**Rot**	0%	0%
∑(b+k) > 60mm	67%	57%	**Insect hole**	10%	0%
∑(b+k) 15<>60mm	0%	17%	**Frost crack**	0%	0%
Straightness > 10%	13%	3%	**Ovality**	0%	7%
Straightness 3<>10%	77%	30%	**Signs on bark**	93%	93%
Straightness 1<>2%	7%	50%	**Bottle neck**	0%	3%
Inclin. > 20%	10%	0%	**Spiral grain**	0%	0%
Inclin. 10<>20%	30%	20%	**Fluting**	0%	0%

PLOT N° 51.2

Location: Romans d'Isonzo
Sampled rows: n° 9, 10, 11, 12, 13
Year of plantation: 1999
Date of data collection: March 31st 2009
Age (effective growing seasons): 9 years old

Species composition: Mixed with accessory species
Principal tree species: European walnut (*Juglans regia* L.), wild cherry (*Prunus avium* L.), and European ash (*Fraxinus excelsior* L.)
Accessory tree species: *Alnus spp., Acer spp.*

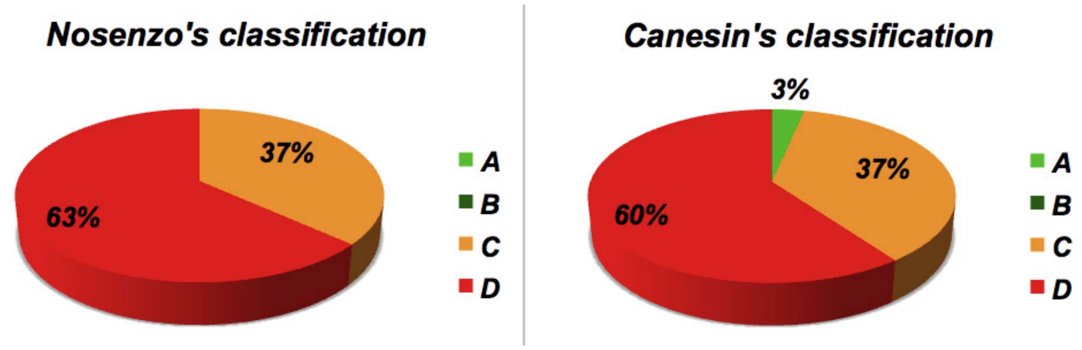


	Meters	Design
Spacing	3.5x1.75	Rectangle
Plantation design		
- Walnut	7x7	Square/free
- Cherry & ash	-	Free

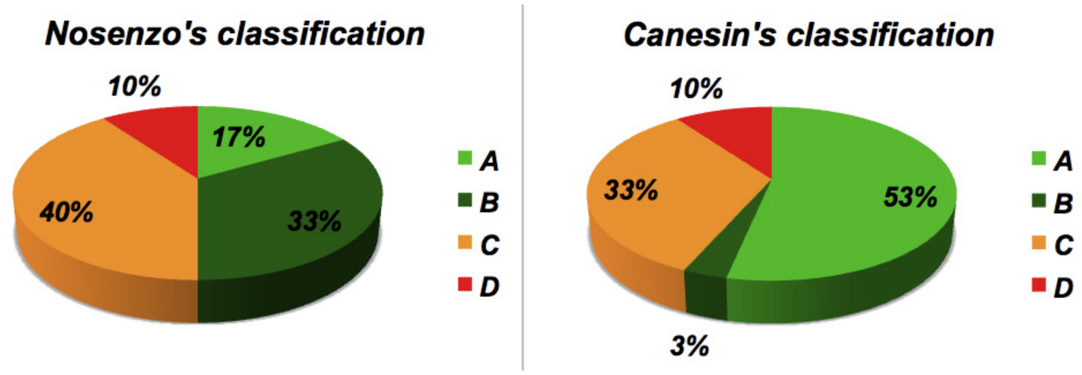
Legend:
N = walnut;
Ci = cherry;
F = ash;
Acc = accessory species.

Growth rate	Walnut	Cherry	Ash
Mortality rate	3%	0%	0%
Δdbh (cm/y)	1.24	1.53	1.12
Δh (m/y)	1.09	1.34	1.11

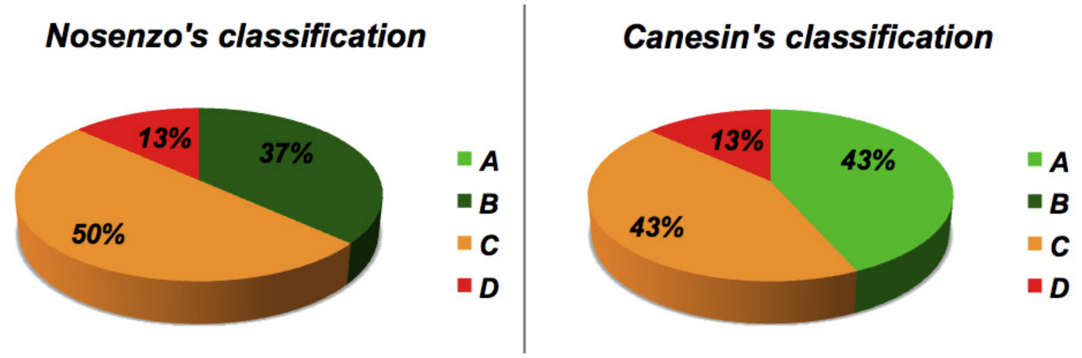
European walnut



Wild cherry



European ash



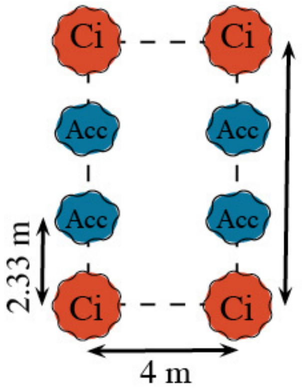
	European walnut			Wild cherry			European ash		
	Diam. (cm)	Stem height (m)	Tree height (m)	Diam. (cm)	Stem height (m)	Tree height (m)	Diam. (cm)	Stem height (m)	Tree height (m)
mean	11.1	2.32	9.80	13.8	2.88	12.04	10.1	2.89	9.95
max	21.5	3.05	15.40	23.7	3.60	14.80	13.7	4.00	13.70
min	3.5	1.30	4.50	2.9	1.30	5.30	6.4	1.65	6.60
s^2	22.6	0.23	9.78	23.9	0.22	4.81	3.2	0.23	3.50
s	4.8	0.48	3.13	4.9	0.47	2.19	1.8	0.48	1.87

Stem defect	Walnut	Cherry	Ash	Stem defect	Walnut	Cherry	Ash
Branch > 3cm	13%	3%	3%	**Sinuosity**	0%	0%	3%
Knot > 3cm	3%	0%	0%	**Fork**	0%	0%	0%
Covered knots	60%	47%	37%	**Saddle**	20%	0%	20%
Fresh knots	20%	7%	0%	**Base damage**	7%	0%	0%
Rotten knots	0%	0%	0%	**Rot**	0%	0%	0%
∑(b+k) > 60mm	47%	27%	20%	**Insect hole**	3%	0%	3%
∑(b+k) 15<>60mm	3%	33%	23%	**Frost crack**	3%	0%	0%
Straightness > 10%	20%	0%	7%	**Ovality**	0%	0%	0%
Straightn. 3<>10%	70%	30%	43%	**Signs on bark**	87%	80%	93%
Straightness 1<>2%	7%	33%	37%	**Bottle neck**	0%	0%	0%
Inclin. > 20%	10%	0%	0%	**Spiral grain**	0%	0%	0%
Inclin. 10<>20%	3%	7%	0%	**Fluting**	0%	0%	0%


PLOT N° 53

Location: Grado
Sampled rows: n° 16, 14
Year of plantation: 1999
Date of data collection: March 21st 2009
Age (effective growing seasons): 9 years old

Species composition: Pure with accessory species
Principal tree species: wild cherry (*Prunus avium* L.)
Accessory tree species: *Acer campestris* L., *Ulmus campestris* L., *Corylus avellana* L., *Quercus sp., Fraxinus angustifolia* Vahl, *Fraxinus ornus* L., *Alnus spp., Fraxinus excelsior* L.

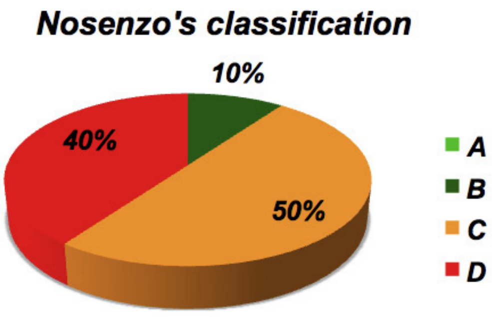


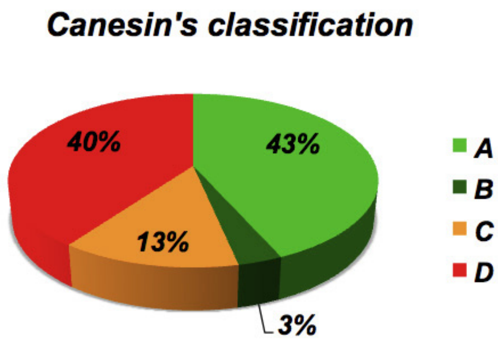
	Meters	Design
Spacing	4x2.33	Rectangle
Plantation design		
- Cherry	4x7	Rectangle

Legend:
Ci = cherry;
Acc = accessory species.

Growth rate	Cherry
Mortality rate	9%
Δdbh (cm/y)	1.80
Δh (m/y)	1.03

Wild cherry





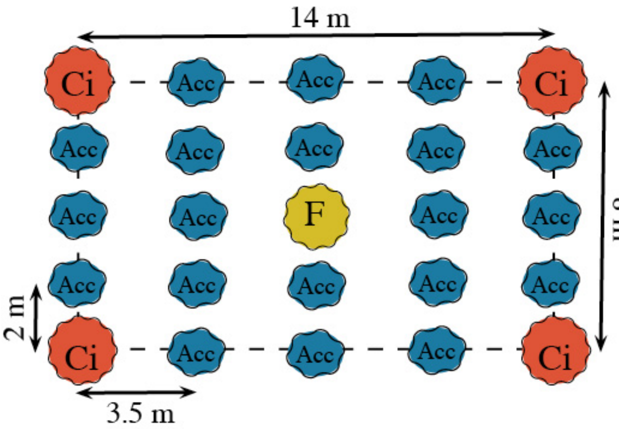
	Wild cherry		
	Diam. (cm)	Stem height (m)	Tree height (m)
mean	16.2	2.59	9.28
max	19.7	4.10	11.30
min	7.3	1.20	7.40
s^2	8.1	0.38	1.48
s	2.8	0.61	1.22

Stem defect	Cherry	Stem defect	Cherry
Branch > 3cm	3%	**Sinuosity**	3%
Knot > 3cm	7%	**Fork**	20%
Covered knots	87%	**Saddle**	17%
Fresh knots	17%	**Base damage**	27%
Rotten knots	3%	**Rot**	0%
∑(b+k) > 60mm	60%	**Insect hole**	0%
∑(b+k) 15<>60mm	7%	**Frost crack**	3%
Straightness > 10%	3%	**Ovality**	3%
Straightness 3<>10%	27%	**Signs on bark**	97%
Straightness 3<>10%	63%	**Bottle neck**	0%
Inclin. > 20%	0%	**Spiral grain**	3%
Inclin. 10<>20%	0%	**Fluting**	0%

PLOT N° 54A

Location: Dolegna
Sampled rows: n° 1, 3, 5, 7, 9
Year of plantation: 1999
Date of data collection: March 30th 2009
Age (effective growing seasons): 9 years old

Species composition: Mixed with accessory species
Principal tree species: wild cherry (*Prunus avium* L.) and European ash (*Fraxinus excelsior* L.)
Accessory tree species: *Alnus spp., Fraxinus ornus* L., *Acer campestris* L., *Carpinus betulus L.*

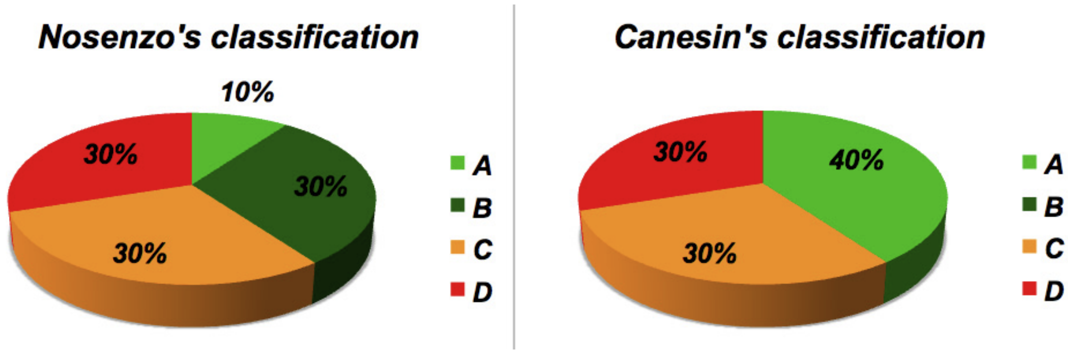


	Meters	Design
Spacing	3.5x2	Rectangle
Plantation design		
- Cherry & ash	14x8	Rectangle

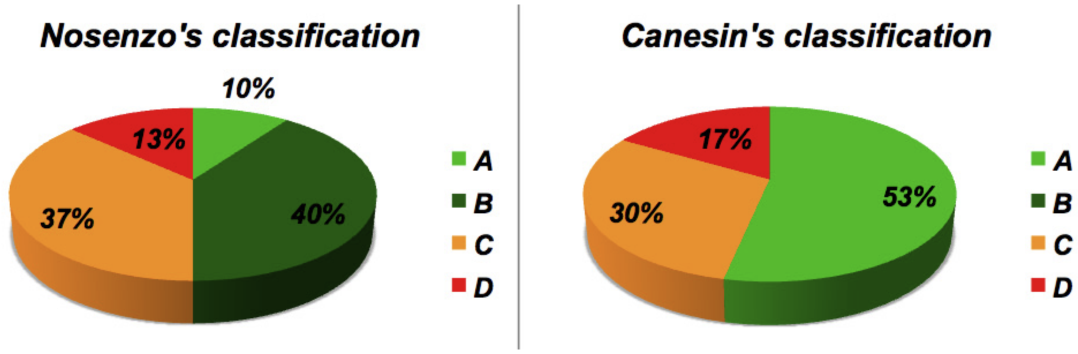
Legend:
Ci = cherry;
F = ash;
Acc = accessory species.

Growth rate	Cherry	Ash
Mortality rate	18%	0%
Δdbh (cm/y)	1.05	0.96
Δh (m/y)	0.76	0.82


Wild cherry



European ash



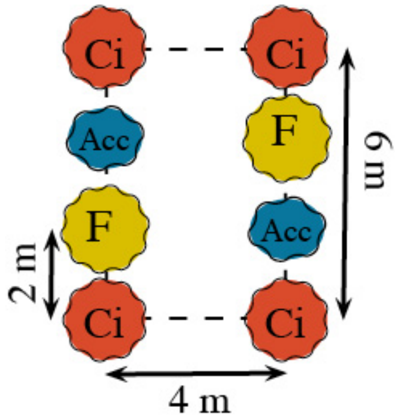
	Wild cherry				European ash		
	Diam. (cm)	Stem height (m)	Tree height (m)		Diam. (cm)	Stem height (m)	Tree height (m)
mean	9.4	2.64	6.82		8.6	2.81	7.42
max	14.5	3.80	9.00		12.1	3.40	9.20
min	1.6	1.55	2.00		4.5	2.05	4.50
s^2	14.7	0.26	4.73		2.3	0.09	1.69
s	3.8	0.51	2.18		1.5	0.31	1.30

Stem defect	Cherry	Ash	Stem defect	Cherry	Ash
Branch > 3cm	10%	0%	**Sinuosity**	0%	0%
Knot > 3cm	13%	3%	**Fork**	7%	0%
Covered knots	30%	10%	**Saddle**	27%	30%
Fresh knots	7%	3%	**Base damage**	20%	23%
Rotten knots	0%	0%	**Rot**	0%	0%
∑(b+k) > 60mm	20%	3%	**Insect hole**	0%	3%
∑(b+k) 15<>60mm	3%	0%	**Frost crack**	3%	0%
Straightness > 10%	7%	3%	**Ovality**	0%	0%
Straightness 3<>10%	23%	33%	**Signs on bark**	80%	87%
Straightness 1<>2%	53%	43%	**Bottle neck**	0%	0%
Inclin. > 20%	0%	0%	**Spiral grain**	0%	0%
Inclin. 10<>20%	3%	0%	**Fluting**	0%	0%

PLOT N° 61

Location: Grado
Sampled rows: n° 3, 4, 5
Year of plantation: 2000
Date of data collection: March 21st 2009
Age (effective growing seasons): 8 years old

Species composition: Mixed with accessory species
Principal tree species: wild cherry (*Prunus avium* L.) and European ash (*Fraxinus excelsior* L.)
Accessory tree species: *Ulmus campestris* L., *Alnus spp., Tilia sp., Acer campestris* L., *Carpinus betulus* L.

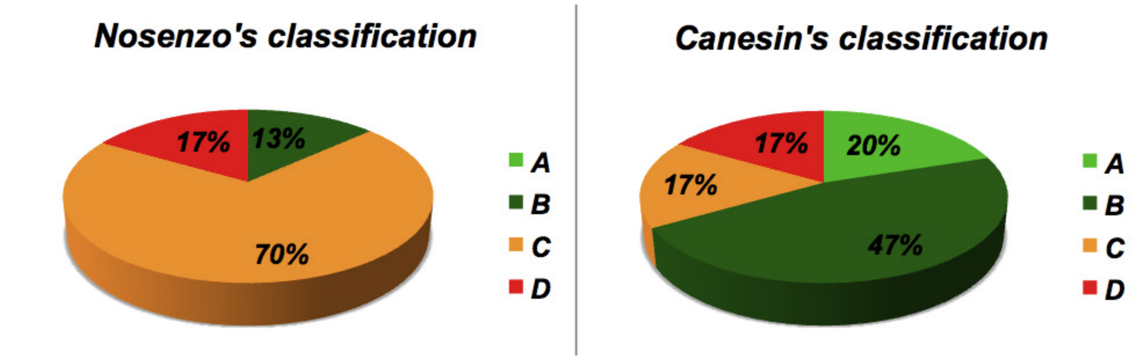


	Meters	Design
Spacing	4x2	Rectangle
Plantation design		
- Cherry	4x6	Rectangle
- Ash	-	Free

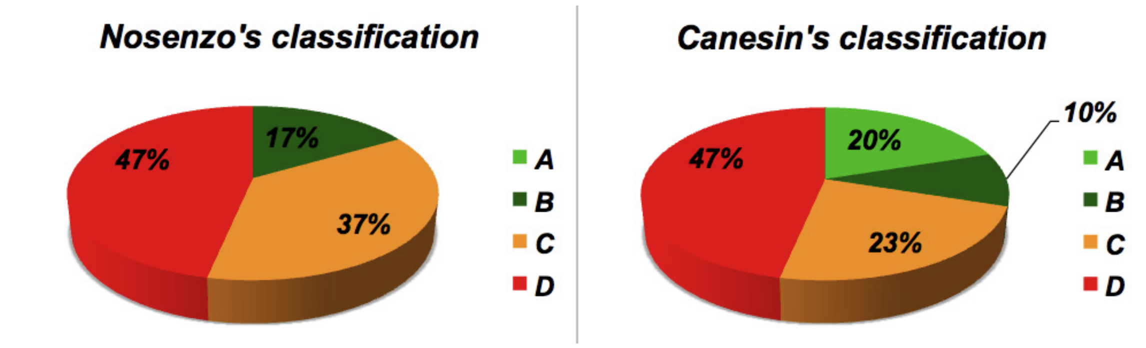
Legend:
Ci = cherry;
F = ash
Acc = accessory species.

Growth rate	Cherry	Ash
Mortality rate	39%	-
Δdbh (cm/y)	1.60	1.12
Δh (m/y)	0.91	0.81


Wild cherry



European ash



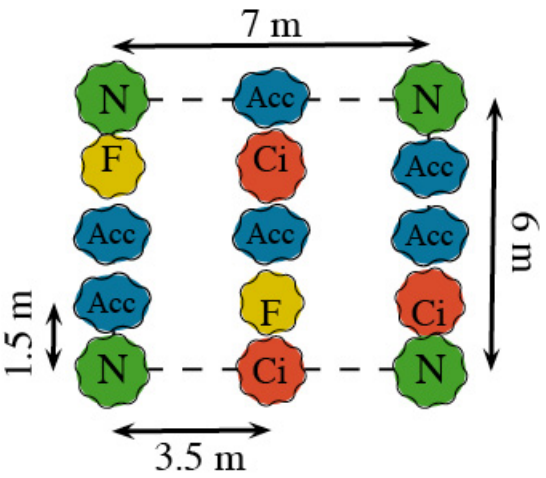
	Wild cherry				European ash		
	Diam. (cm)	Stem height (m)	Tree height (m)		Diam. (cm)	Stem height (m)	Tree height (m)
mean	12.8	2.95	7.25		8.9	2.71	6.46
max	17.5	4.40	8.60		14.0	3.70	7.60
min	5.7	2.45	5.70		1.9	0.50	4.70
s^2	13.3	0.25	0.82		6.8	0.39	0.86
s	3.7	0.50	0.90		2.6	0.62	0.93

Stem defect	Cherry	Ash	Stem defect	Cherry	Ash
Branch > 3cm	60%	33%	**Sinuosity**	0%	3%
Knot > 3cm	7%	0%	**Fork**	0%	3%
Covered knots	70%	47%	**Saddle**	13%	33%
Fresh knots	13%	7%	**Base damage**	33%	10%
Rotten knots	3%	0%	**Rot**	0%	0%
∑(b+k) > 60mm	70%	43%	**Insect hole**	0%	27%
∑(b+k) 15<>60mm	0%	0%	**Frost crack**	3%	0%
Straightness > 10%	10%	10%	**Ovality**	0%	0%
Straightness 3<>10%	13%	37%	**Signs on bark**	83%	83%
Straightness 1<>2%	60%	47%	**Bottle neck**	13%	3%
Inclin. > 20%	0%	0%	**Spiral grain**	0%	0%
Inclin. 10<>20%	3%	3%	**Fluting**	0%	0%

PLOT N° 77A.1

Location: Romans d'Isonzo
Sampled rows: n° 3, 4, 5
Year of plantation: 2000
Date of data collection: April 4th 2009
Age (effective growing seasons): 8 years old

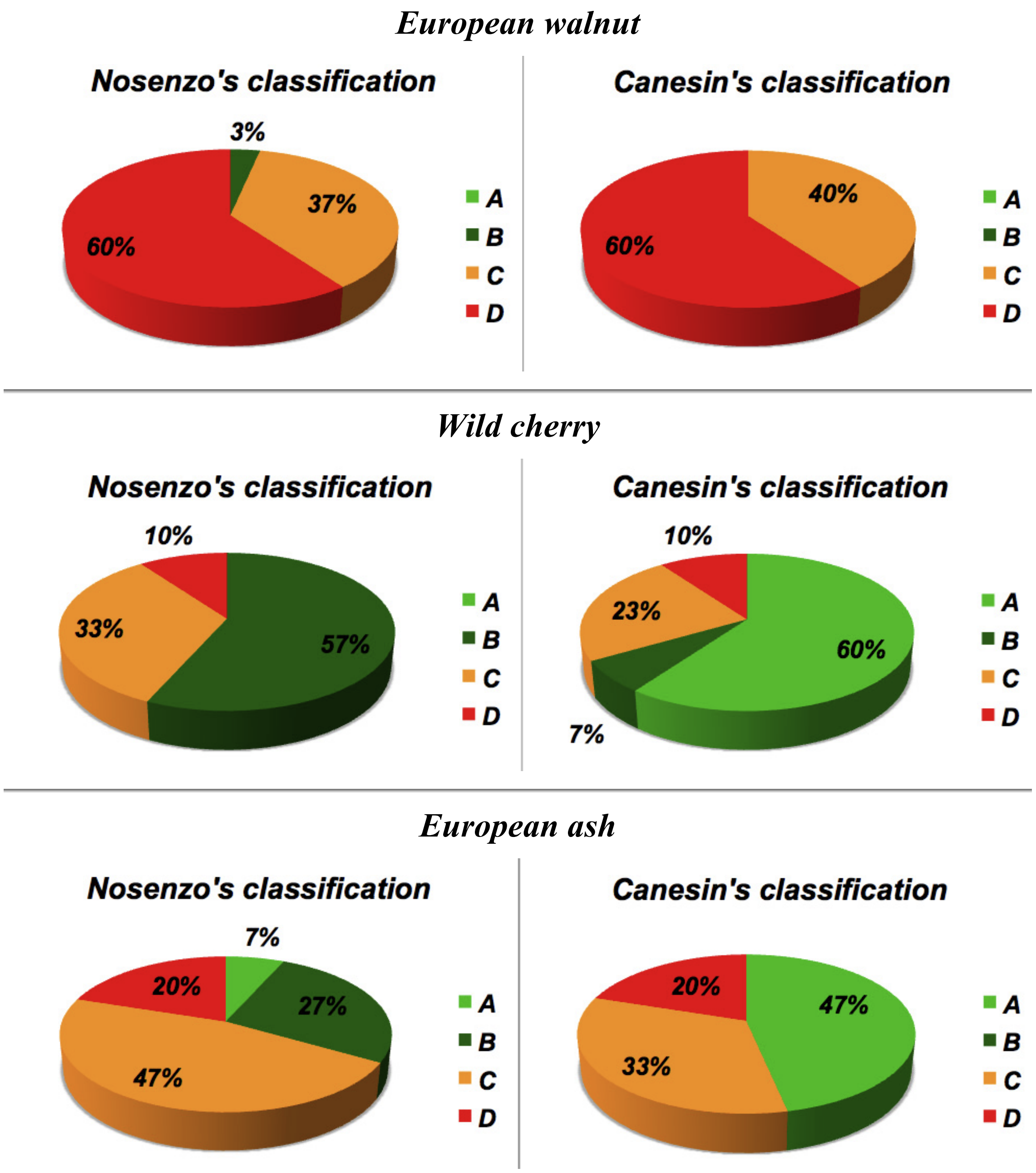
Species composition: Mixed with accessory species
Principal tree species: European walnut (*Juglans regia* L.), wild cherry (*Prunus avium* L.), and European ash (*Fraxinus excelsior* L.)
Accessory tree species: *Fraxinus ornus* L., *Acer campestris* L., *Acer sp.*



	Meters	Design
Spacing	3.5x1.5	Rectangle
Plantation design		
- Walnut	7x6	Rectangle/Free
- Cherry & ash		Free

Legend:
N = walnut;
Ci = cherry;
F = ash;
Acc = accessory species.

Growth rate	Walnut	Cherry	Ash
Mortality rate	-	2%	-
Δdbh (cm/y)	1.38	1.48	1.37
Δh (m/y)	1.15	1.28	1.20



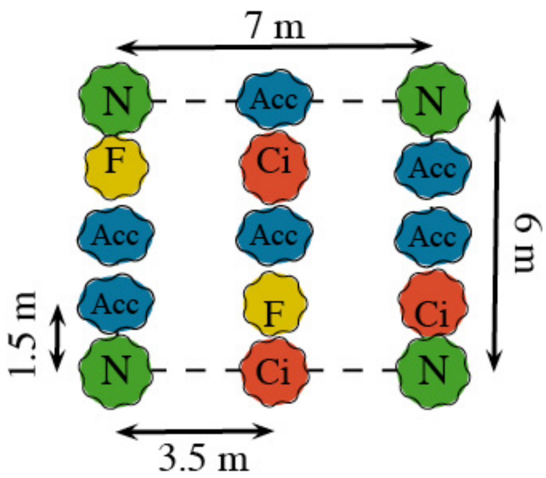
	European walnut			Wild cherry			European ash		
	Diam. (cm)	Stem height (m)	Tree height (m)	Diam. (cm)	Stem height (m)	Tree height (m)	Diam. (cm)	Stem height (m)	Tree height (m)
mean	11.0	2.36	9.22	11.9	2.86	10.21	11.0	2.63	9.61
max	15.9	3.00	11.80	16.9	3.80	12.40	13.5	3.15	11.40
min	3.8	1.30	4.50	5.7	2.20	8.20	7.3	2.05	7.00
s^2	9.6	0.18	3.65	7.6	0.14	1.20	2.1	0.07	0.86
s	3.1	0.42	1.91	2.8	0.38	1.09	1.4	0.26	0.93

Stem defect	Walnut	Cherry	Ash	Stem defect	Walnut	Cherry	Ash
Branch > 3cm	0%	3%	0%	**Sinuosity**	13%	0%	3%
Knot > 3cm	20%	7%	0%	**Fork**	0%	3%	7%
Covered knots	63%	63%	57%	**Saddle**	37%	7%	27%
Fresh knots	30%	7%	0%	**Base damage**	10%	10%	0%
Rotten knots	0%	0%	0%	**Rot**	0%	0%	0%
∑(b+k) > 60mm	60%	13%	23%	**Insect hole**	0%	0%	0%
∑(b+k) 15<>60mm	7%	57%	33%	**Frost crack**	0%	0%	0%
Straightness > 10%	40%	0%	3%	**Ovality**	0%	0%	0%
Straightn. 3<>10%	43%	23%	43%	**Signs on bark**	93%	93%	100%
Straightn. 1<>2%	17%	60%	30%	**Bottle neck**	0%	0%	0%
Inclin. > 20%	3%	0%	0%	**Spiral grain**	0%	0%	0%
Inclin. 10<>20%	30%	0%	0%	**Fluting**	7%	0%	0%

PLOT N° 77A.2

Location: Romans d'Isonzo
Sampled rows: n° 3, 4, 5, 2, 1
Year of plantation: 2000
Date of data collection: March 31st 2009
Age (effective growing seasons): 8 years old

Species composition: Mixed with accessory species
Principal tree species: European walnut (*Juglans regia* L.), wild cherry (*Prunus avium* L.), and European ash (*Fraxinus excelsior* L.)
Accessory tree species: *Fraxinus ornus* L., *Acer campestris* L., *Acer sp.*

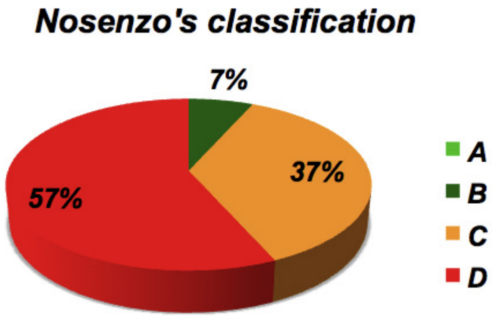


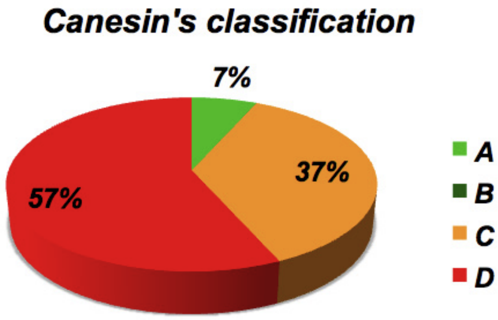
	Meters	Design
Spacing	3.5x1.5	Rectangle
Plantation design		
- *Walnut*	7x6	Rectangle
- *Cherry & ash*		Free

Legend:
N = walnut;
Ci = cherry;
F = ash;
Acc = accessory species.

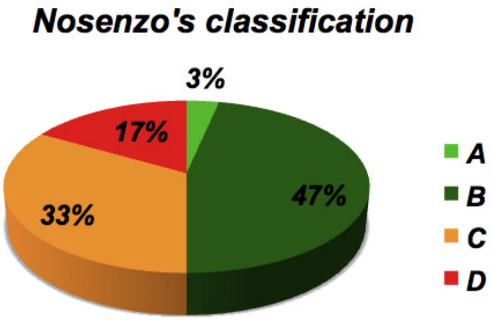
Growth rate	Walnut	Cherry	Ash
Mortality rate	2%	-	-
Δdbh (cm/y)	0.78	0.89	1.07
Δh (m/y)	0.65	0.84	0.94

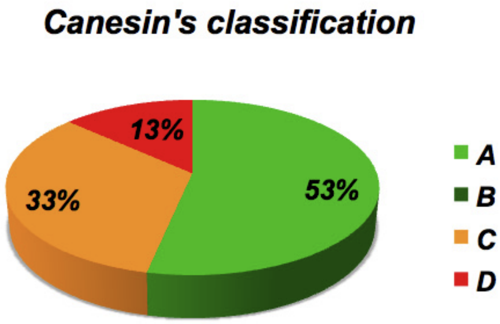
European walnut



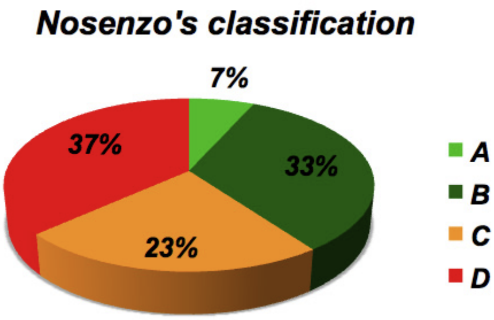


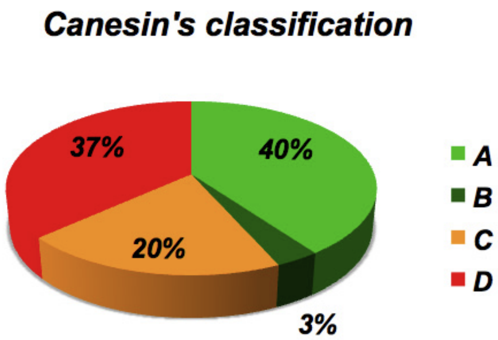
Wild cherry





European ash





	European walnut				Wild cherry				European ash		
	Diam. (cm)	Stem height (m)	Tree height (m)		Diam. (cm)	Stem height (m)	Tree height (m)		Diam. (cm)	Stem height (m)	Tree height (m)
mean	6.2	2.18	5.19		7.1	2.75	6.69		8.6	2.70	7.50
max	11.1	3.00	6.90		13.8	3.40	10.10		13.5	3.45	8.90
min	0.0	1.00	1.30		1.9	2.00	2.80		6.0	2.05	6.10
s^2	5.8	0.35	2.91		6.4	0.11	2.55		2.9	0.15	0.57
s	2.4	0.60	1.71		2.5	0.33	1.60		1.7	0.39	0.75

Stem defect	Walnut	Cherry	Ash	Stem defect	Walnut	Cherry	Ash
Branch > 3cm	0%	0%	3%	**Sinuosity**	0%	0%	0%
Knot > 3cm	0%	0%	0%	**Fork**	3%	3%	3%
Covered knots	0%	7%	10%	**Saddle**	33%	20%	23%
Fresh knots	0%	0%	0%	**Base damage**	3%	7%	0%
Rotten knots	0%	0%	0%	**Rot**	0%	0%	0%
∑(b+k) > 60mm	0%	3%	7%	**Insect hole**	3%	0%	7%
∑(b+k) 15<>60mm	0%	0%	0%	**Frost crack**	0%	3%	3%
Straightness > 10%	20%	3%	3%	**Ovality**	0%	0%	0%
Straightn. 3<>10%	57%	33%	30%	**Signs on bark**	80%	87%	90%
Straightness 1<>2%	23%	60%	53%	**Bottle neck**	3%	0%	0%
Inclin. > 20%	13%	0%	0%	**Spiral grain**	0%	0%	0%
Inclin. 10<>20%	13%	10%	3%	**Fluting**	0%	0%	0%

Notes:

Sampled rows: the plantation row number is given here in the order they have been sampled in both 2006 and 2009.

Δdbh: this is the DBH mean annual increment.

Δh: this is the tree height mean annual increment.

Inclin.: stands for "Inclination".