Annals of Silvicultural Research
47(1), 2022: 48-53
https://journals-crea.4science.it/index.php/asr

Concept note

Collection: "Precision tools to support poplar plantation forestry"

Poplar tree for innovative plantation models

Sara Bergante[1*]

Received: 11/01/2022 *Accepted: 9/02/2022* *Available online: 17/02/2022*

ABSTRACT The traditional poplar cultivation does not represent the only way to produce poplar wood: new market opportunities and new more sustainable cultivation models are appearing on the international scene. We are only reconsidering past solutions in a modern key and with new knowledges and technologies able to improve the productions through more sustainable, resilient, cultivation models for the adaptation to climate and market changes. In this note three alternative models (to traditional poplar growth) suitable for production of plywood, packaging, panels, pulp for paper, biomass and for environment services, are described and discussed: high-density model (HD), polycyclic plantation model (PP) and agroforestry (AF).

KEYWORDS: sustainability, resilience, new products.

Introduction

Poplar (*Populus* spp.) form one of the main resources for productive plantation forestry worldwide with thousands of hectares planted, about 31.4 million hectares (Marchi et al. 2022). The largest plantations occur in Canada and China, followed by Europe, with France and Italy being the Countries where these cultivations are mainly widespread. In Italy, about 43,400 hectares of poplar plantations are located in the Po valley (Corona et al. 2018), mainly issued for plywood and roundwood production. Specialized poplar plantations are characterized by a layout with a spacing of 36 m^2 for each tree, with a rotation period of 10-20 years. They have contributed to the development of important economic and productive sectors such as paper, wood-based plywood and furniture, by providing high-quality raw materials. Historically, specialized poplar plantations in Northern Italy have continued to be grown due to the cultural dependence of expert knowledge and tradition (Marchi et al. 2022). Currently, the production of poplar wood has a particular importance in the internal wood for furniture sector that ask for highest-quality material.

However, the traditional poplar cultivation does not represent the only way to produce poplar wood and the market is now interested in developing different types of products (mainly for packaging purposes) and new materials (bio-materials for plastic replacing). No less important is the need to develop innovative, more sustainable, resilient, cultivation models for the adaptation to climate and market changes.

Poplar is a fast growing pioneer tree, able of reproducing rapidly through vegetative way. This genus is represented by many species and hybrids covering the North hemisphere. For these reasons, it has been the object over the years of an intense breeding and selection activity (Bisoffi et al. 1996, Joshi et al. 2011) that has brought us today to ever shore genotypes with characteristics of high yields capacity and resistance to diseases (Carletti et al. 2016, Coaloa et al. 2020). These new clones are suitable both for traditional and innovative cultivation models, such as mixed, polycyclic and agroforestry models. In this paper we describe some alternative cultivation models suitable for poplar considering the new market opportunities and the advantages deriving from the choice of clones with High Environmental Sustainability (HES).

Brief introduction to High Environmental Sustainability (HES) clones

In recent years, in Italy, thanks to the activity of clonal selection, new poplar clones have been put on the market, mainly belonging to the species of *P.* ×*canadensis.*

These new clones are characterized by high resistance to the main fungal diseases typical of poplar (*Marssonina brunnea* (Ell. Ev.) Magnus and *Melampsora* spp.) and to woolly aphid (*Phloeomyzus passerinii* Sign.) and consequently to all the physiopathies deriving from weakness (Corona et al. 2018). This resistance allows to cultivate the new clones with a considerable reduction of chemical treatments responding to the objectives of greater sustainability (also provided for by the PEFC protocol); furthermore, they may have grown also in environments characterized by climatic conditions favorable to the development of diseases. However, the new clones are characterized by a high wood density, higher than 'I-214'. This character can represent a problem for the plywood industry mainly linked to the production of interiors for campers, caravans and ships, or in the production of pallets; however, it can represent an advantage in new areas such as construction or the production of innovative materials.

High Density Model (HD-model)

The traditional Short Rotation Coppice (SRC) (5-7 years rotation time) is a well-known model, as it was widely studied and recommended to produce biomass for energy purposes. In Italy over time, it has been preferred over the very High Density Model (vHD-model) with two-year coppicing, as it has numerous advantages including:

1 CREA – Research Centre for Forestry and Wood – Italy
*Corresponding author: sara.bergante@crea.gov.it

http://dx.doi.org/10.12899/asr-2344

(i) possibility of plantation,

(ii) coppicing and harvesting with the methods and machines used in traditional poplar cultivation,

(iii) easy weeds control and greater flexibility of coppicing times which allows to wait for favourable market periods,

(iv) possibility of producing different assortments even of higher quality than wood chips (such as packaging, OSB, paper pulp) and better quality of the wood chips due to a lower percentage of bark.

Some results obtained in experimental fields in Northern Italy (Fig.1), have also shown a greater wood production of the five-year HD-model, compared to the two-year vHD-model (Facciotto et al. 2020, Bergante and Facciotto 2015), and a higher ability in soil carbon storing, probably due to higher amount of annual litter and to fine roots inputs (Ferrè et al. 2021).

Figure 1 - Short Rotation Coppice, high density model (SRC, HD-model) with poplar clone 'Imola' in Casale Monferrato (AL – Italy).

This model is particularly suitable to produce wood for packaging, such as crates, food containers and pallets. Furthermore, currently wood is considered an interesting substitute for plastic, both used as it is, and as a raw material to produce innovative compounds, with advanced technological characteristics, but sustainable and biodegradable (Liao et al. 2020). It must also be considered that, if the target is reaching this market niche, this model allows to have assortments that can be sold in just 4-5 years, with all the advantages related to the shorter time of lands occupation and to risks due to climatic changes and extreme events. The introduction of HES clones would make possible to further lowering cultivation costs, by reducing the phytosanitary treatments required. However, it should be noted that these clones have greater wood basic density than the most popular genotype, clone 'I-214' (Bergante et al. 2013) and this aspect could represent a problem for certain types of assortment (packaging), but also an advantage for other types (pulp for paper or innovative components).

In an experimental trial grown in the 'Mezzi' farm of CREA- Forestry and Wood Research Centre, in Casale Monferrato with different poplar clones, we measured the girth at breast height each year during the cycle and at the end of five year we estimated the amount of total aboveground volume and the volume of main assortments (OSB/saw, pulp for paper, chips for energy). Results are reported in Figure 2 and 3.

Figure 2 - Casale Monferrato (AL- Italy). Girth trend of three poplar clones: Baldo *(P. deltoides),* Imola and Orion *(P. ×canadensis)* during five years of growth in SRC, HD-model.

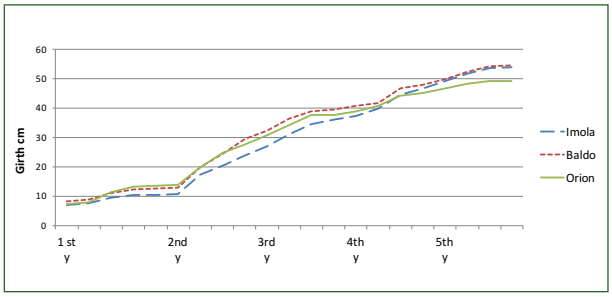
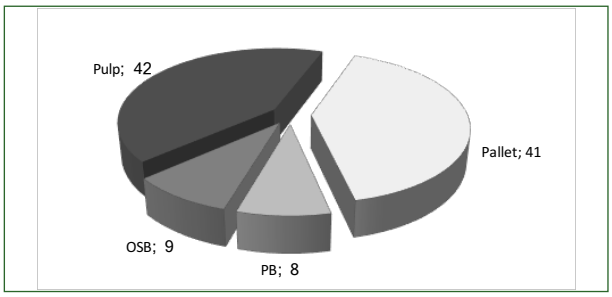


Figure 3 - Estimation of share of assortments (in percentage of total aboveground volume) in an experimental SRC, HD-model trial with poplar at the end of cycle.



At the end of five years the average girth for all clones reached 52.6 cm, corresponding to an average production per hectare at the end of cycle of 82 Mg of dry matter.

Polycyclic Plantation model (PP)

In recent decades, in some European Countries (Italy, France, Spain) and North America, many mixed-tree farming plantations have been established with walnut (*Juglans* spp.), poplar (*Populus* spp.) and other valuable broadleaved species combined with nurse species, mainly N-fixing trees or shrubs (e.g., *Alnus* spp., *Robinia pseudoacacia* L. and *Elaeagnus* spp.) (Rivest et al. 2010, Pelleri et al. 2013). With the introduction of Short Rotation Coppice (SRC) models, in such mixed plantations (Morhart et al. 2014) it is possible to grow noble hardwood species for high quality timber production with fast growing species for energy purposes, having the advantage of a periodical income from the harvest of SRC.

In Italy, these models are called "polycyclic plantations" (PP); is estimated that they cover between 200-400 ha (Pra et al. 2019) mainly in the areas of North and in the Po valley and have been defined as tree farming plantations where main crop trees with different cultivation cycles coexist in the same plantation (Buresti et al. 2014), (Fig. 4).

In such plantations, at least two types of the following kinds of crop trees must be present:

(i) very short rotation crop trees for biomass and ener-

Figure 4 - Polyciclyc Plantation (PP) in Meleti (LO-Italy).

gy production (corresponding to vHD-model and/or HD-model, from 2 to 5–6-year rotation), with the advantage of a periodical income. The more common species for biomass and energy production are poplar (*Populus* spp.), willow (*Salix* spp.), black locust (*Robinia pseudoacacaia* L.), elm (*Ulmus pumila* L.), plane (*Platanus* spp.) and hazel (*Corylus avellana* L.);

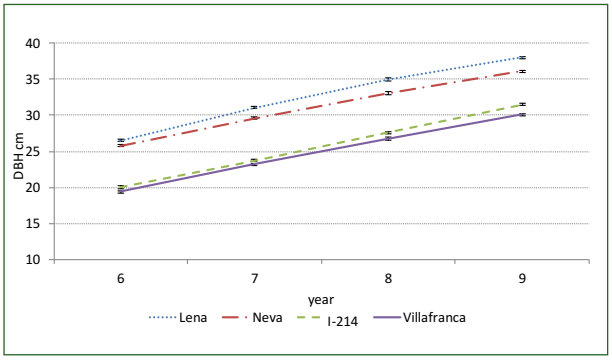
(ii) short-rotation crop trees for plywood production (poplar clones), 8-15 years;

(iii) medium-long-rotation crop trees (30-35 years) for valuable timber production (walnut, oak, or other valuable broadleaved species).

Crop trees are intercropped with nurse trees or shrubs (often N-fixing species) and with tree species playing a double role of nurse for main crop trees and production of biomass for energy purposes (Plutino et al. 2022). In such type of plantations poplar is one of the main species, dedicated to production of plywood and saw and can be harvested within 10 years, thus ensuring a first income for the farmer.

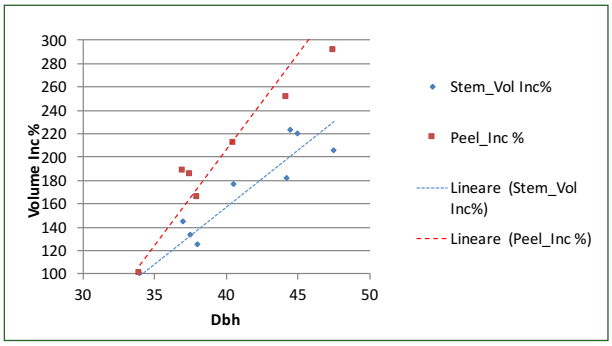
Some benefits are recognizable due to the consociation of several species and the dense cover due to the introduction of several shrubby species. For example, the presence of weeds is reduced, thanks to a rapid canopy coverage, the structure of the stems of the main plants has improved, with greater apical dominance and reduced ramifications, the cooler microclimate also reduces evapotranspiration to the soil, protecting it from erosion and decreasing water requirements (Paris et al. 2014). Probably due to higher spacing, poplar generally shows fast growth in PP model and reaches commercial volumes in 7-9 year, faster than in traditional model (Pra et al. 2019, Mori et al. 2017); in a trial conducted in San Matteo delle Chiaviche (Mantova, Italy), with poplar, walnut and other species, different poplar genotypes reached a commercial size between 7 and 9 years after plantation (Pelleri et al. 2013) (Fig. 5).

Figure 5 - Poplar genotypes in PP model trial in San Matteo delle Chiaviche (MN- Italy), DBH trend between 6th and 9th year. Graphic reworked from Pelleri et al. (2013).



This increased growth has multiple economic advantages, in fact Castro et al. (2013) demonstrates that the volume of veneers for plywood increases, in percentage more than proportionally compared with the increase of stem volume (Fig. 6).

Figure 6 - Veneers (from peeling) volume increment (%) compared with stem volume increment (%), based on Dbh (from Castro et al. 2016).



Also, in this model the introduction of HES clones would allow to avoid many chemical treatments, that in such design can be difficult due to the size of the machines, contributing to a more sustainable management of the plant also suitable for promoting biodiversity.

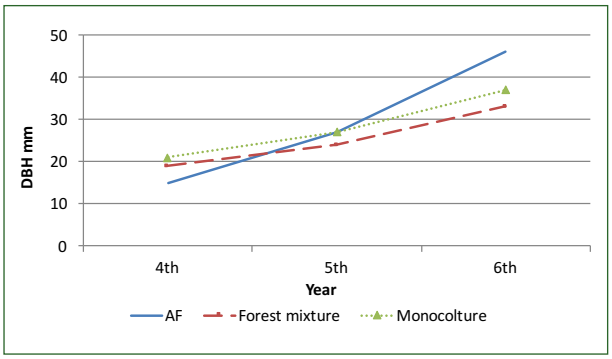
Agroforestry model (AF)

To address global climate change and food security whilst maintaining or improving the environment, international researchers and policy makers are increasingly promoting agroforestry. Agroforestry is a land use practice integrating woody perennials (trees or shrubs) with crops and/or animals on the same land unit (Fig. 7).

Figure 7 - Agroforestry model with poplar, walnut and shrubs rows.

In Europe, it is both a traditional land use and a focus for innovation (Paris et al. 2019). Italy has the fourth largest area of agroforestry in Europe and due to the variability of its pedo-climatic environments and its agricultural realities, it hosts different types of agroforestry systems, from sylvopastoral systems to the sylvoarable systems (Agnoletti 2013, Camilli et al. 2018). In this last model, poplar represent a solution for fast wood production in consociation with food-feed crops like corn (*Zea mais* L.), wheat (*Triticum* spp.), horticultural crops or others. It is generally planted with wide space (e.g. 8 × 8 m) or in rows along the edge of fields; some experimental plots on poplar-oak silvoarable systems, set up within the AGFORWARD project (www.agforward.eu), demonstrated that the initial timber quality of poplar trees is not negatively affected by the wide tree spacing required by agroforestry (Paris et al. 2016). The evaluations about poplar are at an early stage in Europe, but already in 2021 Thomas et al. (2021) have demonstrated, in an experimental plant conducted in France, the greater growth of poplar grown in agroforestry model compared to poplar in monoculture (Fig. 8).

Figure 8 - Trend of poplar DBH (mm) in three different cultural models: monocolture (traditional poplar stand), AF= agroforestry and forestry mixture (mixed plantation). Data are in mm because the trial started from poplar cuttings ad plantation material. Graphic reworked from Thomas et al. (2021).



The introduction of trees and particularly of poplar, as fast growing tree species in arable systems, requires addressing and solving some challenges, three of which are particularly important: *(i)* the effect of shade on annual crops, *(ii)* the competition for water and nutrients, *(iii)* the sensibility of poplar to chemical additions. In 2021 Rosso (Rosso et al. 2021) published a paper reporting old and new results of Italian trials with poplar consociated with rice (*Oryza sativa* L.), on rice fields edge rows and wheat and demonstrates that a correct orientation of rows of trees can reduce the shading of annual crops and that their eventual yield reduction, due to competition for light and nutrients, can be balanced with the wood income. Furthermore, in the future, a reduction in yield loss can be avoided through the selection of crop varieties more tolerant to shading.

Among the woody species, poplar, subject of genetic studies and intense selection, offers the possibility of selecting some physiological and phenological characteristics more suitable for cultivation in intercropping: for example, a crown with tapered shape or leaves with a small area or a clone with a short vegetative period to reduce the shading period.

As for its sensitivity to herbicide chemicals, up to now it has not been possible to carry out in-depth studies but only to record the many cases and the different reactions that have occurred on some occasions. Currently, this issue could be limited by reducing the use of chemical products, which is desirable in the future, or by developing suitable products, but poplar does not seem to represent a crop of interest for the industry of pesticides.

Conclusions

New market opportunities and new more sustainable cultivation models are appearing on the international scene. We are only reconsidering past solutions in a modern key and with new knowledges and technologies able to improve the productions. The poplar has spanned the centuries but continues to be the 'plant of the people' and thanks to its plasticity it continues to be an interesting opportunity in the wood production sector (Facciotto et al. 2014).

Some new cultivation models may apparently show more disadvantages than advantages, if we consider, for example, the costs and difficulties of planting and management, but if we want and must begin to affect environmental value in the calculation, the balance becomes positive: CO_2 absorption, soil protection, resource optimization, biodiversity and pesticide reduction are among the most important environmental advantages that these new models offer in the face of work, now in progress, of fine-tuning optimal cultivation methods and techniques.

References

Agnoletti M. 2013 - *Italian historical rural landscapes: dynamics, data analysis and research findings*. In: Agnoletti M. (ed) "Italian historical rural landscapes". Springer, Netherlands: 3–87.

Bergante S., Rosso L., Facciotto G. 2013 -*Wood characteristics of Poplar and Willow Clones Grown in 2 and 5-year SRC*. In: Proceedings of: '21st European Biomass Conference & Exhibition, Copenhagen, 3-7 June 2013: 182-185 [En].

Bergante S., Facciotto G. 2015 - *Yields of poplar SRC and VSRC grown with different fertilization and irrigation management.* Proceeding of: 23st European Biomass Conference & Exhibition Wien, Austria, 1-4 June 2015: 214-218 [En].

Bisoffi S., Gullberg U. 1996 - *Poplar breeding and selection strategies.* R.F. Stettler, H.D. Bradshaw Jr., P.E. Heilman, T.M. Hinckley (Eds.), "Biology of Populus and its Implications for Management and Conservation (Part I, Chapter 6)", NRC Research Press, National Research Council of Canada, Ottawa: 139-158.

Buresti E., Mori P., Ravagni S. 2014 - *The permanent polycyclic plantation: narrowing the gap between tree farming and forest*. In: Bozzano M., Jalonen R., Thomas E., Boshier D., Gallo L., Bordacs S., Smith P., Loo J. (eds). "Genetic restoration in ecosystem restoration using native tree species. State of the World's Forest Genetic Resources". Thematic Study. Rome, FAO and Biodiversity International: 188-194.

Camilli F., Pisanelli A., Seddaiu G., Franca A., Bondesan V., Rosati A., Moreno G.M., Pantera A., Hermansen J.E., Burgess P.J. 2018 - *How local stakeholders perceive agroforestry systems: an Italian perspective.* Agroforestry Systems https://doi.org/10.1007/s10457-017-0127-0

Carletti G., Carra A., Allegro G., Vietto L., Desiderio F., Bagnaresi P., Gianinetti A., Cattivelli L., Valè G., Nervo G. 2016 - *QTLs for woolly poplar aphid (*Phloeomyzus passerinii *L.) resistance detected in an inter-specific* Populus deltoides *x* P. nigra *mapping population.* PLoS One 11:e0152569. https://doi.org/10.1371/journal.pone.0152569

Castro G., Mori P., Zanuttini R. 2013 - *Produttività di sfogliato e diametro dei fusti. Indagini preliminari sui cloni di pioppo "I-214" e "Neva"*. [Veneer productivity and drum diameter. Preliminary investigations on "I-214" and "Neva" poplar clones]. Sherwood foreste e alberi oggi 192: 5-9 [IT].

Coaloa D., Chiarabaglio P.M., Giorcelli A., Pelleri F., Plutino M., Rosso L., Corona P. 2020 - *Redditività di pioppeti ad alto fusto e di piantagioni di latifoglie a legname pregiato in Italia.* Forest@ 17:101-108 https://doi.org/10.3832/efor3595-017

Corona P., Bergante S., Castro G., Chiarabaglio P.M., Coaloa D., Facciotto G., Gennaro M., Giorcelli A., Rosso L., Vietto L., Nervo G. 2018 – *Linee di indirizzo per una pioppicoltura sostenibile.* Rete Rurale Nazionale, Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Roma. ISBN: 978-88-99595-96-8

Facciotto G., Bergante S, Rosso L., Minotta G. 2020 - *Comparison between two and five years rotation models in poplar, willow and black locust Short Rotation Coppices (SRC) in North West Italy*. Annals of Silvicultural Research 45 (1): 12-20.

Ferré C., Mascetti G., Comolli R. 2021 - *High-Density Poplar SRC Accumulates More Soil Organic Carbon Than Very-High-Density SRC*. Agronomy 11(3): 584. https://doi.org/10.3390/agronomy11030584

Joshi C.P., DiFazio S.P., Chittaranjan K. 2011 - *Genetics, Genomics and Breeding of Poplar*. CRC Press: Boca Raton, FL, USA.

Liao Y. H., Koelewijn S. F., Van den Bossche G., Van Aelst J., Van den Bosch S., Renders T., Navare K., Nicolai T., Van Aelst K., Maesen M., Matsushima H., Thevelein J. M., Van Acker K., Lagrain B., Verboekend D. and Sels B. F. 2020 - *A sustainable wood biorefinery for low–carbon footprint chemicals production.* Science 367: 1385–1390.

Marchi M., Bergante S., Ray D., Barbetti R., Facciotto G., Chiarabaglio P.M., Hynynen J., Nervo G. 2022 - *Universal reaction norms for hybrid poplar clones in Italy for a sustainable cultivation under a changing climate*. iForest 15:47-55. doi: 10.3832/ifor3989-015.

Morhart C.D., Douglas G.C., Drupaz C., Graves A.R., Nahm M., Paris P., Sauter U.H., Sheppard J., Spiecker H. 2014 - *Alley Coppice—a new system with ancient roots*. Forest Science 71 (5): 527-542.

Mori P., Buresti Lattes E. 2017 - *I-214 and permanent polycyclic tree farms: relationships among diameter, productive area per plant and rotation cycle length.* Sherwood - Foreste ed Alberi Oggi 229. www.inbiowood.eu.

Paris P., Facciotto G., Tosi L., Nahm M., Morhart C., Douglas G., Lunny R., Dupraz C., Andre J., Graves A. 2014 - *Alley coppice: an innovative land use system-options of system design with experimental evidence.* 2. European Agroforestry Conference,

European Agroforestry Federation (EURAF). INT., Jun 2014, Cottbus, Germany. hal-02741338

Paris P., Camilli F., Rosati A. et al. 2019 - *What is the future for agroforestry in Italy?* Agroforest Systems 93: 2243–2256. https://doi.org/10.1007/s10457-019-00346-y

Paris P., Tosi L., Leonardi L., Ciolfi M., Della Valle C., Mezzalira G., Sangiovanni M., Lauteri M. 2016 - *Interspecific interactions on the light, water and nitrogen availability in a young poplar silvoarable system*. In: Gosme M. et al. (eds) "Celebrating 20 years of agroforestry research in Europe". Book of extended abstracts of the 3rd European agroforestry conference. European Agroforestry Federation, Montpellier: 232–235.

Pelleri F., Ravagni S., Bianchetto E., Bidini C. 2013 - *Comparing growth rate in a mixed plantation (walnut, poplar and other nurse trees) with different planting designs: result from an experimental plantation in northern Italy.* Annald of Silvicultural Research 37 (1): 13-21.

Pra A., Brotto L. Mori P., Lattes E.B., Masiero M., Andrighetto N., Pettenella D. 2019 - *Profitability of timber plantations on agricultural land in the Po valley (northern Italy): A comparison between walnut, hybrid poplar and polycyclic plantations in the light of the European Union Rural Development Policy orientation*. European Journal of Forest Research 138 (3):473 –494.

Plutino M., Bergante S., Facciotto G., Vitone A., Bianchetto E., Sansone D., Manetti M.C., Chiarabaglio P.M., Bidini C., Pelleri C. 2022 - *Short Communication about a study case on Polycyclic plantations (PP) as innovative models for sustainable combined production of noble hardwood and biomass.* Forest Systems 31 (1): eSC02. https://doi.org/10.5424/fs/2022311-18200.

Rivest D., Oliver A., Gordon A.M. 2010 - *Hardwood intercropping system: combining wood and agricultural production while delivering environmental services*. [Online] Available: http://www.agrireseau.qc.ca/Agroforesterie/documents/Hardwood_Intercropping_Systems_(1Mo).pdf [2020, April 2020]

Rosso L., Cantamessa S., Chiarabaglio P.M., Coaloa D. 2021 - *Competition effects and economic scenarios in an agroforestry system with cereal crops and wood plantations: a case study in the Po Valley (Italy)*. iForest - Biogeosciences and Forestry 14 (5): 421-425.

Thomas A., Priault P., Piutti S., Dallé E., Marron N. 2021 – *Growth dynamics of fast growing tree species in mixed forestry and agroforestry plantations*. Forest Ecology and Management 480: 118672.