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I-PAN

INNOVATIVE POPLAR LOW DENSITY STRUCTURAL PANEL

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Document information

Abstract

The possibility to make an engineered poplar light weight board in a sustainable manner depends on the quality the raw material. The I-214 poplar clone proved for along time to be the most convenient for many reasons, first of all the low specific weight and the rowing rave. We have examined in detail the caracteristics I-214 most relevant to the desired quality of the finished product and the factors that influence and strategies to control these factors opportune

Keywords

Poplar, I-214 clone, *Short Rotation Forestry* (Srf);

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LIST OF ABBREVIATIONS AND DEFINITIONS

DoW	Description of Work
EC	European Commission
PMQP	Project Management and Quality Plan
WP	Work Package
PMB	Project Management Board
TMB	Technical Management Board
PM	Project Manager
DM	Deliverable Manager
QM	Quality Manager
PR	Peer reviewer

INTRODUCTION

Poplar plantations are one of the most important timber supply resources in Europe for the primary processing industry, despite occupying a minimum surface area with respect to natural forests. In the case of Italy, a country that imports three quarters of the wood it consumes but where one of its strengths on the world market is actually the processing of timber for the production of furniture and furnishings, the production of poplar timber is of fundamental importance.

The tradition of poplar cultivation in the Piedmont region, where IBL's industrial history is rooted, has reached such levels of specialization that it actually represents the tradition of the cultivation and utilization of poplar wood, a model on which modern tree cultivation for wood production may be based worldwide. IBL possesses 2000 hectares of poplar plantations in Italy and Hungary and is constantly investing in the continual improvement of the quality of the plants.

Poplar cultivation not only has a significant economic value; the production of timber on agricultural land rather than forest land takes the pressure off the natural woods and forests and contributes to satisfying the environmental and landscaping benefits which are increasingly becoming the primary target of forests. Producing timber also means taking from the atmosphere part of the carbon jointly responsible for the greenhouse effect and capturing it in long-lasting products and artefacts. Cultivating poplars means using between 2 to 15 times less the amount of pesticides with respect to traditional agricultural cultivations and growing trees on land for ten years or more will enrich the soil with nutrients that the roots can absorb and deposit each year with the leaves in the top soil layers.

Highlighting the environmental benefits of poplar cultivation must not cloud the fact that further possibilities nevertheless exist to render cultivation even more eco-friendly, capable of providing further improvements to protect the quality of the air, water, soil, fauna and flora, primary resources that do not have community substitutes. It cannot be said of course that poplar cultivation plays the same environmental role as natural woods; that we are dealing with productions and systems that are not forestry is clear from the fact that the land used for poplar cultivation is agricultural land and that poplar cultivation does not give rise to all those typical restrictions that forestry land has. In most cases, this simply involves applying a sound cultivation practise throughout the various production cycle stages, from the choice of land on which the poplar wood is to be planted through to its felling, following the specifications of sustainable production (eco-poplar) which in fact already constitute a reference for primary forest certification schemes such as PEFC and FSC.

In the details that follow, it may be noted that in most cases the environmental benefits gained from the application of an eco-sustainable cultivation practise can be added to the economical benefits relating to decreased production costs without impacting on product quality.

1 HISTORY AND EVOLUTION

1.1 ENVIRONMENTAL VALUE OF POPLAR CULTIVATION

Supply chains based on the utilization of poplar wood and its by-products represent the superiority of an agricultural and industrial Italy, widely acknowledged on an international scale. Italian poplar cultivation in fact has promoted the development of both the paper industry and plywood industry for decades as well as furniture in general, supplying top quality raw materials, obtained from a skilled clone selection procedure, vegetation propagation, experiments and disclosure of rational cultivation techniques.

Moreover, the poplar cultivation carried out in accordance with "sustainable" cultivation methods has never given rise to any kind of environmental impact issues, but has helped to maintain good biodiversity levels and to reach the targets set by the Kyoto Protocol.

Man's alteration of the carbon cycle (C) has given rise to evident issues but also to new environmental and economical prospects for the agricultural-forestry sector, with interesting repercussions on poplar cultivation. The increase in carbon dioxide (CO_2) emissions into the atmosphere is mainly due to man's use of fossil fuels, the combustion of which releases fossil carbon into the atmosphere which would otherwise remain trapped in the oil, carbon and gas etc. deposits. Another significant emission of fresh carbon into the atmosphere is due to deforestation, mainly in the equatorial/sub-equatorial zone, caused by topsoil fires with the consequent oxidization of the soil's organic matter.

Forest management and the reforestation of agricultural land are two widely acknowledged strategies adopted to fight the increase in the level of atmospheric carbon by:

- Storing carbon in the biomass of plantations, woods and forests and in the soil's organic matter;
- Producing wood-based raw materials to replace materials requiring high energy levels for their production (e.g. concrete and iron);
- Use of wood-based biomass as fuel; this is characterised by the fact that its impact on carbon accounting in the atmosphere is virtually nil, and can help reduce the greenhouse effect by replacing fossil fuels.

The Kyoto protocol (1997), an international treaty to reduce levels of CO_2 in the atmosphere explicitly acknowledges the positive role of woods, forests and wood-based cultivations.

If specific reference is made to the Italian poplar cultivation, both in terms of a manufacturing business as well as in terms of prospects for the use of biomass as a fuel, it may be said that:

- Supplying around 50% of the timber from domestic production will greatly contribute to the utilization of timber in the furniture industry (plywood), as an alternative to fossil based materials (plastics);
- The production of wood outside the forest takes the pressure away from natural woods, consenting the latter to focus on its function as a carbon reservoir;
- The poplar is currently the main tree species used in biomass plantations for fuel purposes, commonly called *Short Rotation Forestry* (Srf); it is logical that it should continue to have such an important role, both in terms of crop advantages (rapid growth, easily propagated and genetically improved, easy to harvest), as well as for aspects mainly related to the production of wood-based biomass for energy purposes (easy to harvest mechanically and process, excellent pellet quality achieved). On a European scale, a clear shift of biomass production for fuel purposes is foreseen from the forestry sector to the agricultural sector (fuel cultivations: first and foremost biodiesel, bio-ethanol, Srf).

The positive environmental role of poplar cultivation has not received the attention it deserves to date from the European and national institutions, due especially to the failure to acknowledge Carbon credits to the poplar farmers and operators in the agricultural-forestry sector. Carbon Credits are similar to financial markets where countries, industries or private operators can freely buy or sell Carbon Credits, depending on their requirements/potentiality, or in other words, the proved and certified capacity to absorb CO_2; it is estimated in 2006 that the value of the carbon credits fluctuated between 10-35 € per ton of absorbed CO_2 (*International Emission Trading Association-The World Bank*).

Lines of research have been addressed to determine the contribution of poplar cultivation to rebalance carbon accounting, also in relation to the utilization of land for other purposes (agriculture, long cycle forestry: 30-100 years). Such research has contemplated both the traditional 10 year cycle poplar cultivation as well as the SRF of poplar trees, with permanent experimental devices in the course of international research projects. The results obtained from the research groups (National Research Council, University of Tuscia -Viterbo, Common Research Centre Ispra -Varese) show that the carbon accounting for poplar cultivation is always positive, despite the fact that carbon capture in the long term, depends on the use of the wood produced, as well as on the management of the soil and organic matter in both its *pre*- and *post*- plant profile. A 12-year-old poplar plantation in particular in the Ticino regional park, has demonstrated that it is a high carbon (C) absorber, with an annual carbon capture of around 5.7 t C ha^{-1}, allocated in the above-ground wood biomass. Below ground (0-45 cm deep), this has depleted the soil of carbon by 25% with respect to a nearby natural wood (Ferrè et al., 2005). In contrast, planting poplar trees on land used for agricultural purposes (corn, rice and other agricultural crops), typically having a low carbon content in its soil, can determine a significant increase in the stock of organic matter and consequently of carbon.

With the application of suitable cultivation measures, like those employed in disciplining sustainable poplar cultivation (eco-poplar) it is possible to guarantee long term conservation. Less processing of the soil in particular, mitigates oxidation of the organic matter accumulated in the surface layers of the soil, helping, amongst other things, to maintain an elevated fertility of the soil. This aspect becomes even more relevant if we consider that while, in the case of poplar and tree cultivation for timber purposes, as in the case of natural woods and forests, the leaves of the plant’s crown fall annually to the ground and are absorbed into the ground, in most of the agricultural cultivations these are generally removed or burned, like the rest of the cultivation residue, thus impoverishing the soils or making it necessary to use large amounts of fertilizers.

Consequently rapidly growing plantations like poplar cultivations feature amongst the most efficient agricultural-forestry systems for maintaining and storing organic matter in the soil and for absorbing greenhouse gases, and will become even more so in the future, as demonstrated by a recent European project EUROFACE, coordinated by the University of Tuscia and by the CNR. In this project, by simulating the future composition of the atmosphere ([CO_2] 550 ppm, around the year 2050), an increase of approximately 20-25% has been estimated in the capacity of these plantations to produce biomass and capture carbon (Scarascia-Mugnozza et al., 2006; Liberloo et al., 2006).

The knowledge acquired so far on the role of the agricultural-forestry ecosystems, both natural and more intensive, in the carbon cycle suggest that:

- The carbon C account for poplar cultivation is more than positive. The productions from poplar cultivation, as raw material for industrial purposes as well as biomass for fuel purposes, can help mitigate the emission of gases with a climate altering effect related to the use of fossil fuels;
- Long term reforestation of agricultural land can greatly increase the *stock* of organic matter in the soil, thus helping to maintain its fertility;
- The production of timber outside forests can relieve the pressure on natural woods, thus permitting the latter to fully develop its function as a carbon reservoir;
- Poplar cultivation adapts well to the scenarios of *global changes*, increasing productivity with a greater concentration of CO_2 in the atmosphere.

Other particularly important actions from an environmental point of view are related to the use of poplar plantations as buffer strips as well as for phyto-remedy operations and to protect the hydro-geological stability. The buffer strips, like linear systems, diversify the agricultural-forestry environment, creating ecological niches for animal and vegetable organisms, whilst acting at the same time as a wind barrier and controller of soil erosion. The biofilter plantations as well as the decontaminating plantations can carry out their ecological function perfectly, producing at the same time significant quantities of raw wood material, absolutely necessary both at a national and European level.

In all these phyto-remedy technologies, the poplar tree, together with other *Salicaceae*, have ample possibilities of application, thanks to its rapid growth and high transpiration rates which convert into interesting amounts of absorbed and stored contaminants in a sustainable manner in the various parts of the plant (trunk and branches, leaves, stumps and fine roots).

Basically we can distinguish three increasing levels of application of the phyto-remedy in the field of poplar cultivation:

- To absorb heavy metals, although it is necessary to define on a case to case basis how to intervene and to quantify the phyto-extraction capacity of the poplar plantations;
- As buffer strips, where it has been possible to obtain results that demonstrate the efficiency of such systems even though a *scaling up* assessment would be appropriate*,* to allow an assessment of the actual benefits of these systems on a territorial level as well;
- To dispose of livestock waste in short and medium long rotation poplar plantations.

Moreover, the semi-extensive cultivation models for poplar plantations, which provide for limited cultivation operations and maintaining grassy undergrowth, can also reinforce the important function of defending the soil and regulation of water to permit a regular flow. Right from the 1970s (Benini et al. 1979) surveys have been conducted to study the effect of the tree and poplar cultivations for wood, in floodplain areas, following the occurrence of floods. In a survey conducted by CRA-PLF of Casale Monferrato, immediately after the Piedmont territories were seriously flooded in November 1994, it was found that the poplar cultivations as well as other tree plantations had helped to limit soil erosion and maintain the hydro-geological stability to the same extent as the natural formations located along the river bands (Chiarabaglio P.M. e Coaloa D., 2000).

These important environmental functions of poplar plantations should be objectively acknowledged and could convert into direct operations to promote the realization of new plantations to include in the agricultural-forestry management plans as well as other operations on a European, national and/or regional level aimed at ensuring a future for tree cultivation for timber purposes, for the environment and for the territory, to the advantage of the community.

For this reason it would seem essential that:

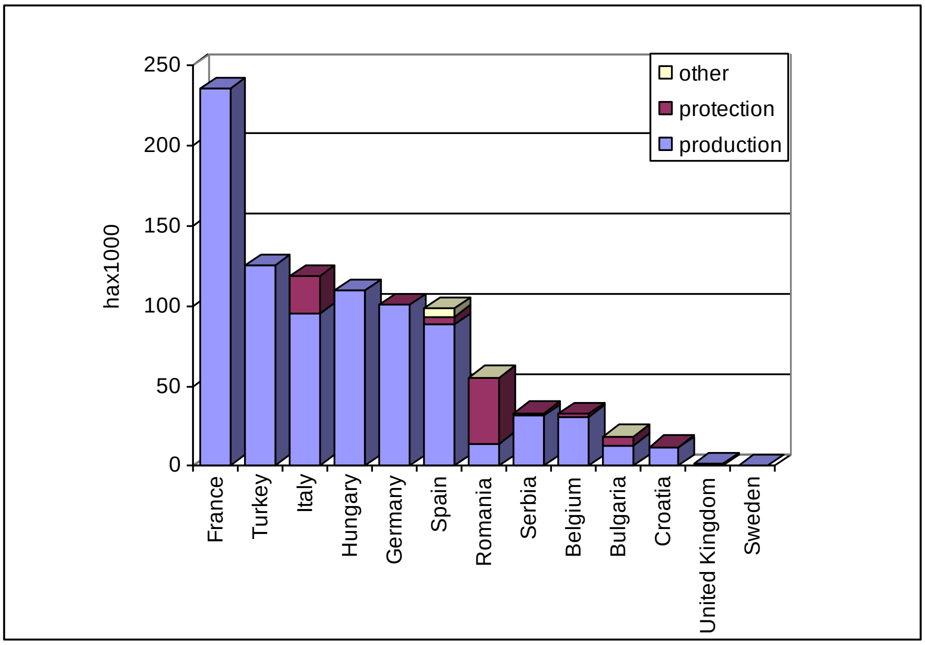
- Reforestation policies for agricultural land must permanently include poplar plantations, conducted on the basis of sustainable practise;
- Carbon Credits are to be acknowledged for poplar farmers and operators in the agro-forestry sector, equivalent to the annual capacity to capture greenhouse gases as well as the host of actions to the advantage of the environment and community.

1.2 CURRENT SITUATION AND PROSPECTS FOR EUROPEAN POPLAR CULTIVATION

Poplar is a fast growing species, economically important for wood productions for several industrial purposes (plywood, sawlogs and pulpwood, fuelwood and biomass for energy) and other environmental roles such as soil protection, regeneration of waste land, restoration of natural river-bank environments, phyto-remedy, and to reduce the effects of climate change and air pollution.

Leaving aside the very important role of poplar in the context of natural forests, specialized plantations have been classified, depending on their purpose, as ‘wood production’ or ‘protection’. So the statistical data on poplar cultivation available worldwide are referred to different cultural models, adopted in the different countries on the basis of their specific needs. The data set out below have been taken from “FAO-FRA 2010, Global Forest Resources Assessment” and from “IPC Country progress reports, summary statistics 2008”.

In Europe poplar plantations cover a total area of 940,200 hectares - of which 236,000 are in France, 125,000 in Turkey, 118,500 in Italy, 100,000 in Germany, 98,500 in Spain, 109,300 in Hungary and 55,300 in Romania (graph 1). The area planted with poplar in Italy has reached its historical minimum thus confirming the negative trend registered in the last two decades (Coaloa and Chiarabaglio 1996, Coaloa 2007). According to the new national forest inventory (INFC, 2009), poplar plantations for wood production amount in Italy to 70 thousand hectares. The poplar available still fails to meet the demand of the timber industry that produces high-quality plywood; the deficit in domestic production is covered by massive imports of round wood from other European countries and Eastern Europe.

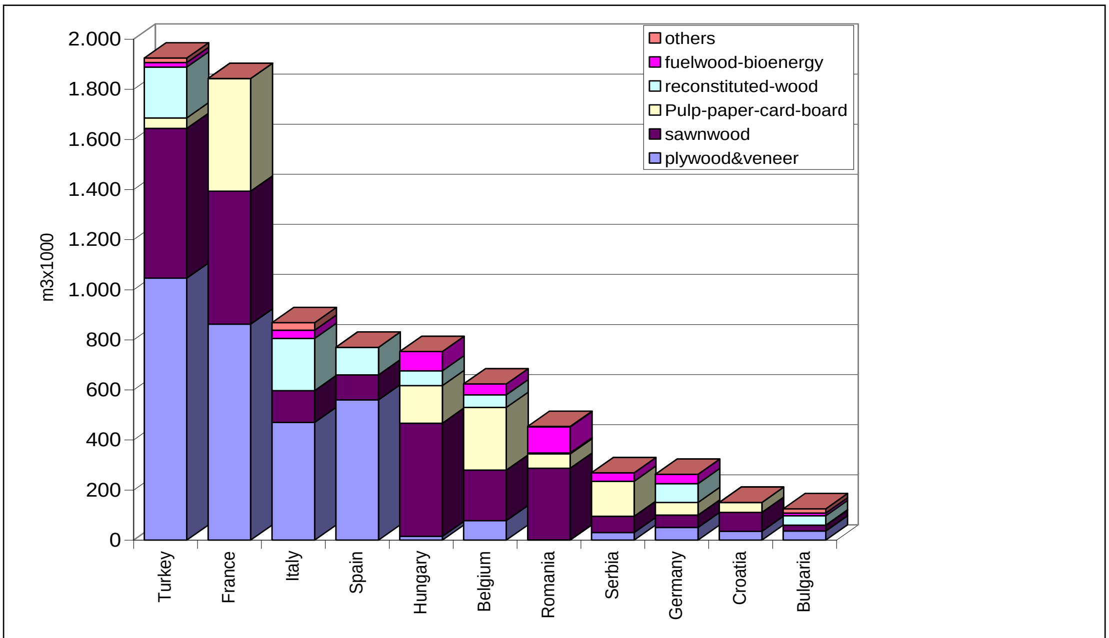


Graph 1 – Poplar planted in Europe by purpose.

Even if 80,000 ha (8%) of poplars are reported as being used for various protective systems, wood production remains the main purpose. The poplar roundwood available annually in the European countries amounts to an average of 8,044,000 cubic metres, destined to the production of plywood/veneers (40%) and sawn timber (31%) (table 1). Among the most productive countries are France (1,800,000 m^3), Turkey (3,500,000 m^3, of which 1,925,000 m^3 for industry), Italy (868,000 m^3) and Spain (770,000 m^3) (graph 2).

	m^3x1000	%
Plywood & veneer	**3183**	**40**
Sawn timber	**2510**	**31**
Pulp-paper-card-board	**1180**	**15**
Reconstituted-wood	**746**	**9**
Fuelwood-bioenergy	**359**	**4**
Others	**67**	**1**
TOTAL	**8044**	**100**

Table 1 – Poplar wood production by product from poplar plantations



Graph 2 - Availability of poplar wood from plantations, by product.

The present consumption of wood-based panels in Europe reaches 50 million m^3. As regards plywood, the production amounts to 3 million m^3, imports reach 6 million m^3 and exports 3.5 million m^3. The most important countries exporting poplar round wood are France, Hungary and Belgium; they export, on average, respectively 217, 214 and 208 thousand cubic meters every year (table 2). The major importers are Italy (massive imports by the wood industries), Belgium and Bulgaria with respectively 457, 228 and 34 thousand cubic meters per year.; in Europe the total exported and imported volumes are almost equivalent (777.000 m^3 and 742.000 m^3 respectively).

In Italy the overall demand for poplar round timber for the industry is around 3.1 million tons (3.9 million cubic metres): 53% plywood, 20% wooden pallets, 13% wooden crates for fruit and vegetables, 11% paper pulp. The demand for poplar timber can actually be met by felling 14,000 hectares/year of poplar plantations.

	Import x 1000 m^3	Export x 1000 m^3
Belgium	228	209
Bulgaria	34	0
Croatia	18	18
France	0	217
Italy	457	0
Serbia	0	106
Spain	5	13
Hungary	0	214
TOTAL	742	777

Table 2 – Poplar wood import / export in Europe.

Even if poplar wood demand is higher than the offer and in Europe is due to increase, several critical aspects must be considered in the most representative poplar countries.

The average price of poplar wood currently varies from 45 to 53 € per cubic meter; the highest prices are in Spain, the lowest in France where prices are different according to plant diameter. The average price for poplar logs has fallen by 20% in real terms since the 1980s and there seems no prospect for real price increase in long term perspective.

Since the definition of poplar production varies between the EU member state, being considered in some countries as agriculture and in others as forestry, the measures for funding vary too in the Common Agricultural Policy (CAP). The measures can be divided into three categories: forestry measures, agro-forestry measures and bioenergy production measures.

As the debate about the CAP after 2013 is open, member states have to clearly define the legal status of poplar plantations to know which measures can be applied for the different poplar cultivation. Even if the further "greening" of the CAP including rural development are under discussion, tendencies for the future agriculture policy are:

1. maintaining or increasing measures dealing with sustainability and environmental aspects;
2. payments for environmental services to poplar farmers and forest owners.

Forestry measures will very likely further be included in the rural development pillar of the CAP, even if there are no guarantee for a dedicated budget, which also depends on EU member co-financing.

In Italy the price of poplar plants and poplar wood (around 45 € per cubic meter), complex laws and no state funding to support poplar cultivation, are decreasing new plantations (by 50% of new plantations from 1970), with a progressive reduction in the number of operators in the poplar sector.

As in Italy poplar cultivation is seen as an agricultural practice rather than forestry, many environment-oriented laws and regulations, particularly ZPS (*Special Protection Zone*) SIC (*Site of Community Importance*) and Natural parks have banished poplar cultivation from the lands more suitable for poplar growing, such as flood plains and river beds.

As lack of consideration for the environmental role of poplar, forest certification can help improve both the social perception of poplar and its environmental role; coordinated action are taken for a better knowledge of poplar cultivation also with a strong (R&D) research and development activities.

Following the studies carried out by the Intensive Wood Production Research Unit (CRA-PLF), with a research project funded by the Piedmont Region, with the collaboration of a large working group (University, farmers and environmental organizations), protocols were defined for sustainable poplar cultivation, which limit the use of chemical products (pesticides and manures) and reduce ordinary tillage, especially for environmentally sensitive areas. Based on these results, the technical guidelines for sustainable management of poplar cultivation, allowed to start the application in Italy of two forest certification schemes for poplar cultivation: the FSC (Forest Stewardship Council) scheme and the PEFC (Programme for Endorsement of Forest Certification) scheme, both of which are based on internationally-recognised requirements. Since 2007, about 4500 hectares of poplar plantations have been certified, through certification groups of smallholders, in Piedmont, Friuli Venezia Giulia and Lombardy, in about 140 farms.

1.3 QUALITY AND PROPERTIES OF POPLAR WOOD, WITH PARTICULAR REFERENCE TO CLONE I-214

It is common knowledge by now that the quality of poplar wood, intended as all of its physical, mechanical and technological properties as a whole, is strictly dependent on genetic factors as well as on the soil and climatic conditions of the site and the cultivation techniques applied.

Poplar wood, and clone I-214 in particular, generally possesses the following characteristics:

- An ample whitish sapwood or with slightly yellowish hues;
- The heartwood, which is not always visible, is a greenish-brown colour which becomes much lighter when dry. In addition to an often irregular border, it may also have abundant yellowish rubbery secretions on the edge ;
- Regular growth rings, normally between 25 and 30 millimetres in breadth, clearly distinguishable also due to the presence of a thin band of terminal parenchyma with generally little colour to it;
- Fine to averagely coarse webbing;
- Generally straight and not very pronounced grain in the longitudinal sections.

In over 50 years of cultivation clone I-214 has demonstrated that:

- it adapts easily to the soil and climatic conditions of the various plantation environments;
- it grows rapidly;
- it easily takes root;
- it is able to withstand the principal adversities.

From the technological point of view, the density of the wood produced is low compared to most other cultivated clones (fig. 2), there is a significant presence of light coloured sapwood with respect to the smaller size of the heartwood, which is not generally very dark, not very branchy thus facilitating pruning and restricting flaws related to knots. In comparison, in recent years less tolerance to some biotic adversities has been noted such as browning, rusting and woolly aphid which may easily be controlled by taking suitable cultivation measures.

Figure 1 - Transversal section of the I-214 clone trunk

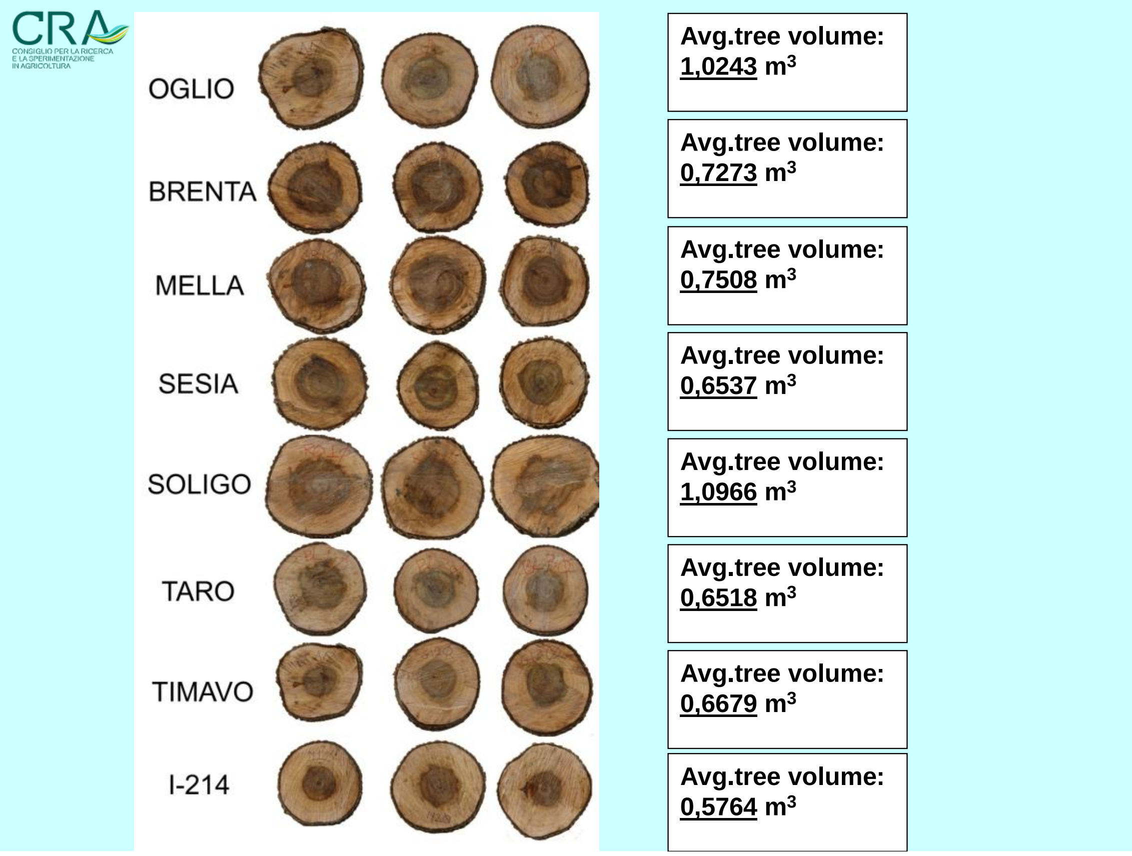


Fig 2 – mass volume of various poplar clones

The histological analysis conducted on some poplar wood samples taken from specialized plantations have highlighted the presence of mainly elliptic vessels, rarely round, distributed over the whole growth ring but with different frequency and dimensions between the zones, following the vegetative season. The vessels may be isolated but are more frequently arranged in radial chains consisting of 3-6 tangential elements forming irregular alignments, dendrites or streams. The number of vessels can vary from 125 to over 250 every 10 mm2, whereas their dimensions fall within the following ranges: radial diameter between 30 and 220 microns, tangential diameter between 25 and 120 microns. The transversal vessel walls have simple perforations, without spiral thickening and have oval areolar dots mainly arranged in a quincunx pattern, with oval orifice or sometimes having an irregular edge. On the vessel walls touching the parenchymatic cells of the beams, the dots, which are still oval shaped, are large and simple.

The radial parenchyma consists of uniseriate and homogenous rays, straight, very fine, between 3 and 30 high (approximately 300 micron), exclusively formed from procumbent cells. They form tiny mirrors in the radial section, barely visible to the naked eye, the same colour as the surrounding tissue but much brighter. Beam homogeneity constitutes an important classification element as it allows the poplar tree to be distinguished from other similar species with heterogeneous parenchymatic beams.

The axial parenchyma is of the apotracheal type, rarely diffused, and is mainly grouped into 2-3 tangential rows to the limit of the latewood area. The fibres are not very abundant, between 400 and 2000 microns long with an average of less than 950 microns.

The average data for the physical properties of poplar wood are:

- Mass volume in the fresh state between 0.6 and 0.9 g/cm3, with an average of 0.76 g/cm3;
- Mass volume at normal humidity between 0.26 and 0.52 g/cm3, with an average of 0.34 g/cm3;
- Base density between 0.28 and 0.42 g/cm3, with an average of 0.29 g/cm3;
- Axial shrinkage 0.1%, radial shrinkage 2.8%, tangential shrinkage 6.3%, volumetric shrinkage 9.8%.

Mechanical resistance at 12% wood moisture content are as follows:

- Resistance to axial compression from 21.5 to 41 MPa, with an average of 31.5 MPa;
- Module of elasticity with a flexion from 6350 to 9150 MPa, with an average of 7850 MPa;
- Shear resistance from 2.1 to 4.9 MPa, with an average of 3.4 MPa;
- Resistance to dynamic bending and surface wear, with average fissility.

The table below summarizes the average values of the mechanical-physical properties of the poplar I-214 wood clone taken during research conducted by Castro and Paganini (1994

Mechanical-physical properties of the poplar I-214 wood clone	**Number of samplings**	**Average value**	**Variation coefficient**
Mass volume (g/cm3)	60	0.318	8.5
Equilibrium moisture content (%)	15	13.2	5.4
Total radial shrinkage (%)	45	2.72	14.0
Total tangential shrinkage (%)	45	5.44	7.1
Module of bending elasticity (GPa)	60	6.55	14.7
Resistance to static bending (MPa)	60	46.7	16.8
Bending resilience (kJ/m2)	60	22.6	30.8
Parallel compression (MPa)	120	23.7	11.1
Perpendicular compression (MPa)	30	2.9	16.2
Shear resistance (MPa)	30	4.6	7.4
Static axial hardness (N)	30	2432	11.3
Tangential static hardness (N)	30	1204	22,1
Static radial hardness (N)	30	1341	26,5

Table 3 – mechanical-physical properties of the poplar I-214 .

The main drawbacks of poplar wood, such to impact seriously on quality are:

- Irregular shape of the trunk and tendency to sinuosity, generally related to genetic, environmental and cultivation factors;
- Alteration in the base portion of the trunk with more or less deep cracks due to damage caused by utensils during mechanical processing or other cultivation operations in general;
- Presence of tension wood mainly due to soil and climatic conditions of the land and genetic factors;
- Splits and/or cracks of various sizes due to internal wood tension occurring during growth. This generally affects plants with large diameters, larger and older plants;
- Cracks from frost and/or cortical necrosis due to afflictions such as “brown spots” and /or wood eating insects whose larvae produce large tunnels with consequences that will affect the possible utilization of the wood;
- Excessive “nerving” of the sapwood and heartwood resulting in tangential and radial shrinkage of the wood after stripping;
- Deep and irregular colouring of the heartwood which affects the yield in “white” sheets;
- Knots of various sizes present along the trunk due to improper pruning or poor cultivation treatment.

2 POPLAR GROWTH AND PANEL MANUFACTURE

2.1 STRATEGIES TO CONTROL DEFECTS AND FACTORS WHICH CAUSE THEM

The preliminary strategies to be adopted to improve defect control in the raw wood material utilized for the production of engineered wood-based panels (OSB) are related to the assessment of the site features of the land allocated for growing poplar plantations, specifically dedicated for the purpose, in addition to the choice of cultivation techniques applied.

The first factors to take into account are consequently climate, land, and availability of water for the soil. Other factors including plantation density, pruning, pest control, phyto-sanitary defence and crop rotation, are just as important in terms of productivity yield and technological properties of the wood, as well as in terms of factors related to the energetic balance of the entire cultivation.

With regard to climate, it is necessary to know the temperature and average annual rainfall at least and possibly snowfall frequency and early or late frosts. The latter factors are closely related to the risk of flaws in the wood such as cracks and alterations of trunk wood and cracks caused by frost.

On the same level as climate, the land plays a fundamental role both in terms of optimal growth "performance" as well as in terms of quality and health of the plants with the evident positive effects on economic and environmental sustainability of the entire production cycle. In this respect fertility, structure, chemical composition acid/alkaline (pH) reaction, presence of limestone and soluble salts and the depth of the water table must all be taken into account. Lastly, it may be useful to make a careful analysis of the spontaneously growing vegetation, by making direct surveys or using phyto-sociological maps which may indicate particular situations, like for example the presence of permanent water stagnation (sedges, reeds, horsetail reeds) or soil acidity (bracken, heather).

A more detailed description of the strategies which may be adopted to optimise the principal cultivation factors of the I-214 poplar clone will follow.

2.2 CHOICE OF LAND

Despite being suitable for cultivation in the various temperate regions of the globe ((Europe, Asia, North and South America), growth capacity of the I-214 poplar clone is strictly related to the physical-chemical properties of the soil and to its nutritional values and availability of water. Consequently it is preferable to grow the plantations on deep soil (at least 70-100 cm), permeable and with a good supply of water: the ideal level of the water table is at a depth of 100-150 cm. Soils which are to be avoided are those with stagnant surface water where the water, with a low oxygen content, would prevent the roots from growing from the very first year the tree is planted. The best soils are those containing a sandy-limey and sandy-clay composition, not too loose or too compact, with a uniform profile and a pH value from sub-acid to moderately alkaline. If the soil is uniform and well structured, the young poplar will grow roots along the whole length; otherwise, the roots will only grow where the more favourable layers of soil are. High proportions of gravel (gravel stones larger than 2 mm) and large sand particles (between 0.2 and 2 mm) can lead to undue permeability resulting in a low water supply during the summer months. Such stress conditions expose the plant to primary parasite attacks (*Marssonina brunnea*, *Melampsora* spp. (rust) and parasites due to weakness (*Discosporium populeum*, Melanophila, Agrilo) or the appearance of physiological disorders ('brown spots') and wood-eating insects and defoliators with the consequent technological and quality depreciation of the timber produced. On the contrary, a soil which is too heavy with a high clay content can suffocate the plant, decreasing root growth and causing premature browning of the inner parts of the wood (heartwood and sapwood) foregoing quality. Other land to avoid is land with a high limestone content and salty soils which are not suitable for cultivating the I-214 poplar clone. In fact, an active limestone content of more than 6-8% favours the formation of iron chlorosis, whereas concentrations of 0.1% of sodium chloride are already able to provoke phytotoxicity phenomena, especially when the young poplar plants start taking root.

Consequently, on the basis of the criteria for identifying the suitability of the land for poplar cultivation, also provided for in methods disciplining sustainable cultivation, well-structured soil is preferable with a good supply of water and nutritional elements to ensure rapid growth, with evident benefits both in productive and environmental terms for a better storage of climate-altering gases.

2.3 PREPARING THE LAND

The cultivation operations to be conducted in the pre-planting stages includes some main preparatory work (ploughing and loosening of the soil clods) and complementary work (harrowing milling and weeding). The task of the former is to roughly break up and loosen the soil which has more or less settled, whereas the task of the latter is to refine the uppermost surface layer.

The need to encourage the poplar roots to grow down as deeply as possible and the availability of increasingly powerful farming machinery has meant that deep ploughing has become the main operation for preparing the land. Ploughing, which can go as deep as 70-100 cm or more, permits the control of spontaneous vegetation, facilitates the storage of water and helps the organic matter and/or phosphate and potassium fertilizers to sink and spread into the ploughed layer. Weeding usually involves a 10-20 cm layer of soil and may be carried out immediately or just after the summer ploughing. In the latter case, the refining of the soil is facilitated by the weather. In the case of replanting the poplar plantation and above all, when cases of root decay occurred in the previous plantation, weeding may contribute effectively to reducing the clods of soil, to bringing the roots and large wood residue from the previous plantation to the surface, thus reducing also the risks of telluric diseases.

The type of land and its moisture content will determine the choice as to when the operation is carried out. Generally, the best period for carrying out work on land which is destined for poplar cultivation is autumn. Ploughing on the other hand must be done in summer for heavy soil with a high clay content, when the soil is in a temperate condition. In addition to having a beneficial effect on the structure, this also encourages the mineralization of the organic substances, thus improving fertility and hence the growth of the plants and the efficiency with which it captures atmospheric carbon.

2.4 POPLAR PLANTING METHODS

The choice of investment is extremely important in terms of productivity and quality of the wood, both in terms of the straightness of the trunk and branches. Spacing depends on the properties of the site (climate, soil) as well as on the end use of the raw material (veneer logs, peeling veneer, chips, pulpwood or biomass for energy purposes). In the case of wood-based panel production (OSB) experiments conducted to date using the various clones, amongst which the I-214 clone, demonstrate that to reduce the sinuosity of the trunk and excessive branching, the preferred investments are those of average density (500 – 1100 trees per hectare) with spacing ranging from 3 x 3 to 5 x 4 metres between the rows and on the row, and crop rotation every 5 – 7 years.

It is preferable to use young poplars of about one year old for the plantation, well developed and lignified, of the correct shape, free from parasites, lesions and any other kind of defect. Young poplars with the following must not be used:

a) Unhealed wounds, except for shear cuts made to get rid of surplus shoots;
b) Partial or total dieback of the trunk;
c) Excessive bending of the trunk;
d) Multiple trunk;

e) Trunk with several terminal shoots;
f) Incomplete lignification of the trunk and branches;
g) Damage to collar or other serious damage caused by live organisms;
h) Signs of heating, fermentation or moulding due to improper storage in the nursery.

It is good practise to choose plants that are similar in diameter to reduce any unevenness in the development of the plants and to ensure a better regularity in diameter and straightness of the end product.

Year old poplar plants in addition to possessing a better rooting capacity and hence establishment, are relatively cheap to purchase, are easier to transport but need to be pruned at least twice a year to form its trunk.

The poplar plantation must be made using poplar plants that are fully dormant, avoiding particularly frosty periods when opening and refilling the holes may prove difficult. The period for planting in the Po valley normally goes from the middle of November right through to the end of March. At any rate, it is good practise to minimize the time between uprooting and planting to avoid dehydration. It is advisable to water the young poplar plants for at least ten days prior to planting.
In fresher and well-structured soil, the young poplars must be planted to a depth of at least one fifth of their height (normally 70 cm at least) into the soil.
The careful execution of all the planting operations is not always sufficient to ensure the full establishment of the poplar plants. The death rate however must not exceed 5% otherwise the irregular spacing of the plants determines heterogeneous development and shape with a deterioration in the quality of the wood and a lower yield on the level of industrial transformation.

2.5 Pruning

Pruning is an indispensable operation to improve the quality and technological properties of the wood. This reduces the number of knots present in the wood, gives the trunks a more cylindrical shape and consequently a better yield in the industrial transformation.
Poplar pruning mainly consists in the gradual removal of branches that have grown at the bottom of the trunk. The aim of pruning is to achieve the very best quality without impacting too much on the growth and development of the plant. Removing part of the crown in fact, decreases the leafy surface, where photosynthesis takes place and temporarily slows down the growth rate. It is therefore an extremely delicate operation which will impact on the output and technological quality of the end product. Trunks from properly pruned plantations are able to provide top quality assortments for which a minimum of healthy knots is acceptable (healthy knot: knot without any defect i.e. signs of alteration or rotting) and small in size (less than 1 knot with a diameter of less than 35 mm per linear meter of trunk). A higher number of knots and/or larger knots will determine a technological deterioration of the product and assortments with numerous defects are destined for the production of wood pulp or for energy purposes.

It is advisable to prune up to at least 4 metres from the ground to produce quality material. Pruning the trees higher up would mean an increase in costs which would not be proportional to an increase in production quality or quantity. There are two types of pruning: trunk forming and cleaning. The first type of pruning eliminates forking and branches which, since they are vertical in shape and tend to swell, could compete with the leader. The aim of these operations is to ensure that the trunk grows into the right shape and must be carried out in a timely manner within the first two years of planting. With the trunk cleaning cuts, all the branches are removed from the trunk up to a suitable height (4-5 metres); this is to be done gradually, when the branches are still small, less than 6 cm in diameter if possible. The branches are to be cut right down to the trunk to achieve a better quality and to avoid leaving stubs. A summary of the pruning procedures may be found below and illustrated graphically in Fig. 3.

The most suitable period of the year for pruning normally coincides with the period that the plant is dormant, excluding the severely cold periods with risk of frost.

The operations during the first year are easily carried out from the ground with hydraulic or pneumatic shears and pruners. Platforms or cherry pickers may be used to carry out pruning operations afterwards.

Summary of the pruning operations.

Year 1 - During the dormant period, forking is to be eliminated, the more vigorous sterile branches, as well as all the branches up to a height of 1.5 m off the ground (the latter may also be removed in the vegetative season).

Year 2 - During the dormant period the more vigorous sterile branches on the second whorl are to be eliminated and the ones on the first whorl are to be thinned out further, removing the larger ones; in addition all the branches up to a height of 2 m off the ground are to be removed.

Year 3 - During the dormant period the sterile branches on the second whorl are to be thinned out by removing the larger branches as well as the branches below the first whorl up to a height of 3 m off the ground.

Year 4 - During the dormant period the branches on the second whorl are to be thinned out again by removing the larger and more upright ones, up to a height of about 4 m from the ground.

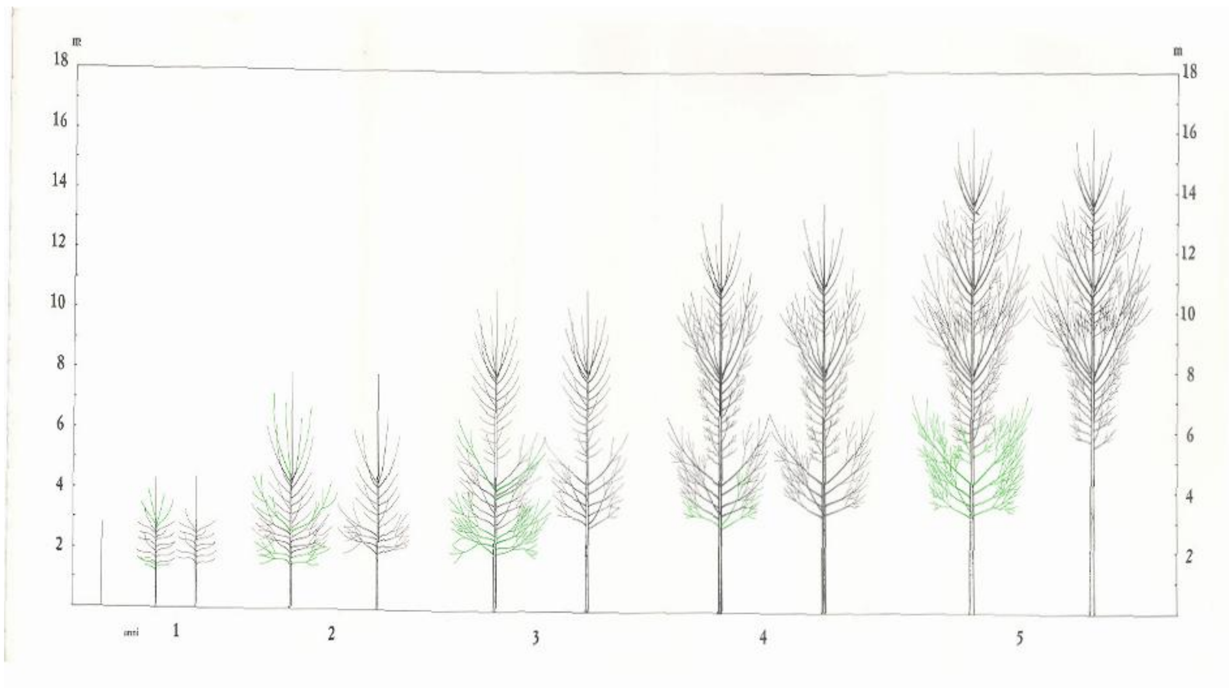


Fig. 3 – Pruning

2.6 Processing

The aim of the surface processing of the ground is to reduce the evaporation of the soil, to contain weed competition and optimize photosynthesis efficiency and hence plant growth rate. In the first two years from planting, it is appropriate to intervene two or three times over the whole surface of the poplar plantation, taking care to avoid the growth of weeds in the warmer months in particular, when plants require more water. Normally disk harrows equipped with straddle are used or, in the autumn, a plough to make channels towards the centre of the space between the rows and help to drain off surplus rainwater. The consequent cutting of the surface roots may be regarded as a positive operation as it stimulates the plant's roots to grow deeper into the soil.
Generally routine operations exert a positive action in the first few years as they permit an efficient weed control. Weeds in fact compete strongly for water and nutrients, especially in the first few years when the crown is not yet fully grown or able to shade the ground and aid the growth of a very intrusive heliophilous type herbaceous flora. After that, from the fourth year on, the shade gradually increases and the undergrowth evolves towards a less competitive sciophilous species. Despite this, experimental tests have shown that it is possible to use, as an alternative to mechanical operations, mowing to produce a mulching action of the weeds, from the second year of planting. The difference in growth between the two systems was not statistically significant but the energetic and environmental advantages of the layer of grass were considerable. The application of the layer of grass with trimmings or grinding of the grass as an alternative to disking from the second year or third year after planting is a particularly advantageous operation especially in the open floodplains or at the bottom of the valleys as it protects the soil against erosion. Furthermore, in the event of brief but heavy showers, typical of summer storms, there is less surface runoff water.

2.7 Irrigation

In most temperate environments, irrigation, although it is not absolutely indispensable, can improve the quantity and quality of the timber produced. To prevent it from becoming uneconomical, it is to be carefully controlled by supplying suitable quantities of water at the right time to avoid plant stress.

Water consumption may be estimated on the basis of the amount of water transpired to calculate the unit of dry substance. In the case of the *Populus ×canadensis* 'I-214' clone, it has been calculated by trial and error that 350 litres of water are needed to produce 1 kg of dry substance. This value, which may be taken as a reference value, if multiplied by the presumed annual yield, may be used to calculate the seasonal water requirements of the cultivation. The establishment of a correct water equilibrium will help to optimize an efficient use of the water, the establishment of the right time for irrigation with the evident benefits both in terms of production and the environment.
The most common methods of irrigation applied in poplar cultivation are essentially two: channels for the water to flow in and under canopy sprinklers. The method chosen depends on how the land is arranged, on the availability of irrigation water and on the equipment available. The first method requires large flow rates (around 800 – 1000 m3/ha) and is limited where the soil is too loose or the ground is not flat enough. Sprinkling requires lower flow rates (300-400 m3/ha) and can be used on land which is not flat.

2.8 Nutritional aspects

The analysis of the nutritional requirements of the plant and the potential need for the supply of nutritional elements is essential to ensure a rapid and regular growth and to avoid excesses which would have a negative effect on the environment as well as on production. For this reason it is necessary to know the composition of the land and the crops that have been removed. Nevertheless, in order to keep the soil fertile and to ensure a good production, it is not sufficient to put back in what has presumably been removed. Soil in fact is not an inert sub-layer but a site of complex biotic and chemical activity and it is necessary to take into account losses due to non-cultivation, transformation and runoff, phenomena which will vary depending on the season, on the type of soil and fertilizer used. In particular, in the floodplains areas, affected by periodic flooding and frequently characterized by loose, deep and fresh soil, it is possible to achieve a good timber production without resorting to chemical fertilizers. The addition of fertilizers is necessary on the other hand to increase the productivity of the poplar plantation on land with a low exchange capacity and deficient in nutritional elements. The effects of the fertilizers, including nitrogen based fertilizing can be lost if the water is not readily available. Organic fertilization with manure or leguminous manure has proved to be successful, for maintaining the fertility of the soil as well. As an example, plantations on a 5 – 7 year rotation, as estimated, to avoid any uptake of the nutritional reserves of the soil, a nitrogen addition of not more than 90 kg/ha for the first two years is recommended and not more than 120 kg/ha for the following years, whereas recommendations for phosphorous and potassium are overall 120 kg/ha of P205 and 250 kg/ha of K2O. These levels should not be exceeded to avoid the risk of contaminating the water table or excessive enriching of the plants with consequent sinuosity of the trunk and/or greater incidence of biotic or abiotic adversities. Nevertheless, in order to avoid polluting the water bed, the nitrogen based fertilizers must be fractioned into amounts not exceeding 60 kg/ha per dosage.

In the case of proven mineral deficiencies following an analysis of the soil, target fertilizers need to be used, when the crop is planted and in the first 3-4 years of rotation.

2.9 CONTROLLING THE BIOTIC ADVERSITIES

Insects and disease of the poplar tree are responsible each year for losses estimated at around 30% of the value of the potential timber production. The economical loss would be much higher without a suitable phytosanitary defence, the cost of which in both economical and environmental terms must be carefully assessed also from the perspective of satisfactory profitability from the cultivation, conserving at the same time, the technological properties of the timber. This is also in consideration of the fact that poplar plantations are mainly located in floodplain areas or “sensitive” areas from an environmental point of view.

In compliance with current phytosanitary provisions in effect in various European countries, only specifically authorized products may be utilized (consequently in this particular case these must be verified to see if “poplar” appears on the label) and that the product may only be used to protect against the adversities listed on the relative label. An equally important aspect is related to the equipment used to apply the pesticides over the crop. To protect the trunk against weevils, saperda and aphid it is advisable to use spraying machines with vertical bars or beams to wet the target thoroughly and restrict scattering the product. The crown on the other hand needs to be sprayed with atomizers to atomise the pesticide solution so that it covers the leafy surface as evenly as possible. Lastly, it must be remembered that all necessary precautions must be taken to protect the operator’s health and safety and of course to protect the environment when using this equipment: only use the quantities given for the active ingredients and instructions as to the amount of water required, avoid spraying the pesticide when it is windy or during the hottest part of the day, choose low toxic products, service the equipment regularly, especially pumps and nozzles as well as all the hydraulic plant to prevent leakage and malfunctions, always wear suitable protective clothing.

Planting resistant clones is definitely the best way of controlling adversities, as this would exclude the application of active chemical ingredients. The I-214 clone has a fairly good resistance to some diseases such as spring defoliation, leaf disease caused by *Venturia populina* (Vuill.), bacterial canker caused by *Septoria musiva* and the virus. On the other hand, there are problems related to poor rust tolerance (*Melampsora larici-populina* Kleb.e *Melampsora allii-populina* Kleb.) and it is prone to browning caused by *Marssonina brunnea* (Ell. et Ev.) P. Magn.) as well as to insects such as the poplar woolly aphid (*Phloeomyzus passerinii* Signoret), the large poplar longhorn (*Saperda carcharias* L.) and weevil (*Cryptorhynchus lapathi* L.)

Browning in particular is a fungal disease, able to cause, in particularly favourable years, more or less premature defoliation, which can continue throughout the entire vegetative season. The loss of foliation slows down the annual growth and, if it happens towards the end of the summer, the plant may go into an unnatural dormant state. This can lead to an incomplete lignification of the apical parts of the annual shoots with a consequent risk of being damaged by frost and difficulty for the buds to regenerate the following spring. In order to limit the damage, it is essential to carry out a first preventive treatment, irrespective of the seasonal trend, when most of the leaves are fully open, usually in the second or third ten days of April, with highly resistant active ingredients. The first treatment is generally able to protect the vegetation for at least a month, and if the climatic conditions are not particularly favourable for the growth of the fungus, attacks can be limited for a good part of the vegetative season (end of June). If climatic conditions on the other hand are particularly favourable (average temperatures between 9° and 25°C and above all if the relative humidity of the air is high), it may be advisable to carry out a second treatment in the second 10 days of May (about a month after the first). The addition of adhesive/wetting substances improves the application of the solution over the leaves, reduces evaporation and consequently increases the efficiency of the fungicide. On the contrary, the indiscriminate addition of insecticides with broad spectrum (especially pyrethoids) should be avoided when there is no real risk of damage caused by defoliator insects.

Rusts as well (*Melampsora larici-populina* Kleb.e *Melampsora allii-populina* Kleb.) have become particularly dangerous parasites both for the proliferation of the different species which have virtually colonized the various areas of the European poplar plantations, as well as for the serious consequences of the attacks on the plantations. It has in fact been demonstrated that, as well as reducing the annual growth rate, plants which have suffered premature defoliation in the summer are weaker and more likely to suffer attacks from weakness parasites, especially the *Discosporium populeum* fungus. It is therefore essential to adopt a careful monitoring and control strategy. The number of treatments to be carried out is determined by the precociousness of the infections which, in turn, determine the intensity of the attacks. In order to ensure that the treatment is successful, the first treatment must be carried out in time, and must be done when the first uredospores appear on the underside of the leaves (in years that are particularly favourable for the parasite, hot and humid summers, this can occur at the end of June). Subsequent treatments, which will be required if new attacks are noted on the leaves, are to take place 10-15 days from the first one, up to and not after the middle of September.

For those adversities for which there is no truly efficient chemical protection, the danger may be limited by adopting rational cultivation practises such as the choice of the plantation site and the type of nursery material used. Amongst these, root rot caused in particular by *Rosellinia necatrix* Prill., although not very frequent, can destroy and kill the plants affected; this can occur in particular where the soil is loose and are favoured by conditions where periods of drought alternate with wet periods. This may be controlled by resting the land for a certain period of time or using it for alternative crops (cereals or fodder). Furthermore, in order to keep the soil healthy for the next cultivation, after the plantation has been cut down, part of the wood biomass produced (leaders, stubs and root residue) is to be eliminated with shredding operations. Stubs may be removed with special tools (stump extractors) or ground down with grinding drills. Roots nearer the surface may be removed afterwards with weeders.

Also the fungus causing cortical necrosis, amongst which the most dangerous is *Discosporium populeum* (Sacc.) Sutton, are particularly harmful as they significantly depreciate the quality of the timber. This may be controlled by using healthy and vigorous nursery material, choosing a favourable site and applying suitable cultivation techniques. The same measures are useful for containing the “brown spot” disease as well, an alteration of physiological origin which affects weak or suffering plants and also causes bark necrosis.

In the case of some parasitic insects such as jewel beetles, with species like *Agrilus suvorovi populneus* Schaefer and *Melanophila picta* Pall, harmful during the year of transplantation on suffering plants and the red caterpillar (*Cossus cossus* P.) control is based on the application of rational cultivation techniques, whereas with regard to the poplar wasp moth, harmful above all in the nursery but sometimes in the plantation as well, the chemical protection of the poplar plantation is difficult to accomplish. Consequently, for technical and economical reasons, it is advisable to promote natural limiters, and to avoid treating the crowns with non selective insecticides.

The case of the weevil is different (*Cryptorhynchus lapathi* L.), widely found in all the area of the poplar cultivation, and which is capable of breaking the trunk of the young poplars. Controlling the parasite, which is extremely slow moving, starts with the planting of healthy nursery plants, from suitably controlled nurseries and disinfested when uprooted. The chemical battle in infested plantations is essential up to the third year, whereas it is not normally acceptable from the fourth year on when the insect, moving along the crown branches, is no longer able to cause economical damage to the crop. A single insecticide treatment, if done properly, will eliminate the young larvae nesting in the bark, thus preventing damage: the ideal moment for this is when the poplar recommences vegetation, when the buds begin to open.

The large poplar longhorn (*Saperda carcharias* L.) is an extremely dangerous insect due to the serious decline in quality of the timber caused by the tunnels which the larvae dig. Poplar plantations growing in unfavourable sites are particularly at risk, where the diminished vegetative vigour does not provide the plant with a suitable defence from the insect's attack.

As a result, the plantations need to be protected against the Saperda throughout the entire cultivation cycle, the only exception being the first year, when any eggs which may have been laid in the nursery at the foot of the poplar shoot will die off when the bottom part of the trunk is planted in the ground. In cases of severe infestation in young plantations, it may be useful to spray the bottom portion of the trunk (where the laid eggs are mainly found) when the larvae open, which in the Po valley is around the end of May beginning of June. As in the case of the weevil, a suitably fine mist sprayed over the trunk is necessary to achieve a satisfactory result.

The woolly aphid can cause extremely serious damage (killing the plant, breaking the trunk), especially in years when the climate is particularly favourable. Plantations between the 4^{th} and 5^{th} year of age run the greatest risk, since the micro-climatic conditions created inside are particularly favourable for the development of aphid colonies (elevated humidity, little wind and limited irradiation). Careful supervision of these plantations during the risk period (end of May-August) is the prerequisite for a timely resort to defence should the need arise: the infestation in fact may be easily thwarted at the onset by carefully spraying the affected portions of the trunk with a white mineral oil (500 g/hl), whereas it becomes more difficult to control with abundantly developed colonies.

The only defoliator which is capable of provoking intense and repeated defoliation of the poplar tree over the years is the American Hyphantria, a butterfly which came from America about 20 years ago, whose young larvae engulf the leaves in a silky web. Normally only the second generation of the parasite, the summer one, can cause damage of economical importance to the poplar cultivation. In the event of an attack, microbiological solutions based on *Bacillus thuringiensis kurstaki* (100-150 g/hl) (Bt) should be preferred to the traditional insecticides or the insect growth regulators (IGR), like for instance hexaflumuron (3-6 g/hl), which control the parasite by interfering to a limited extent with its numerous natural enemies. Treatment with IGR is to take place a little before (first half of August) treatment with Bt or traditional insecticides (usually the middle of August).

3 CLUSIONS

The application of suitable poplar cultivation techniques, in addition to consenting the pursuit of the targets of environmental and economical sustainability of the plantation, guarantees a better technological quality of the timber produced. From an approximate assessment of the morphological characteristics of the I-214 clone plants present in the plantation it is possible to express an opinion on cultivation management procedures and hence distribute the volume of the potential selections available as a percentage. To optimize the yield in particular for the production of engineered panels, it is necessary to produce plants with straight cylindrical trunks, free from evident wood defects (cracks, brown spots, dry knots or alterations caused by biotic or abiotic adversities) or with a slightly oval transversal section of the trunk at the most. The sinuosity of the trunk means of course that it will be less efficient to process, as well as an heterogeneous consistency and density of the wood, due to the nerving or the knotting of the trunk. Poorer quality trunks and plant waste may be ground to produce fibre panels or chips for energy purposes.