Project number: 6275
Funding source: DAFM / Teagasc / ERA Net- Bioenergy
Date: May 2019
Project dates: Jan 2013 – Jan 2018

Maximising timber & energy biomass production in agroforestry (alley coppice)

Key external stakeholders:

DAFM, COFORD, Advisors, Consultants, Nurseries, Forest researchers farmers,

Practical implications for stakeholders:

Agroforestry is the 'integration of farming activities with tree growing on the same land unit'. We investigated a novel agroforestry system of growing short rotation coppice willow (SRC) for the production of wood for energy generation in combination with growing trees for high value timber production i.e. 'alley coppice' (Morhart *et al*., 2014). Results from three alley coppice systems are reported in which the high value timber trees such as wild cherry and poplar were grown in the headlands or in rows within fields and the biomass energy crop (willow) was grown in the tree alleys. The early stage results indicate the potential and limitations of growing high value hardwood trees in combination with a biomass crop such as willow.

Main results:

1. Selected varieties of wild cherry (*Prunus avium*) produced superior growth in height and stem diameter compared to unselected cherry trees when grown in alleys among a newly established willow crop and also in headland alleys bordering an established biomass crop of 4 yr. old willows.
2. The width of the alleys for growing trees affected trees growth; 4m wide alleys within the willow crop gave significantly taller trees than narrow, 2m wide alleys.
3. The height and diameter growth of all willow varieties, were negatively affected when planted in alleys of 16 yr old poplar trees.
4. There were significant differences among 23 varieties of wild cherry trees for growth traits when grown in headland allys next to an established 4 yr. old willow crop.
5. Modelling of the alley coppice systems showed that combining trees with short rotation coppice (SRC) is more profitable than pure short rotation coppice (SRC) in optimal growth conditions but under suboptimal conditions, pure SRC is more cost-effective. In addition, simultaneous planting of the tree and biomass components is more desirable because delayed planting of the biomass component can result in decreased SRC yields due to shading by the established trees' canopies.

Opportunity / Benefit:

Results have shown that establishing trees in combination with willow cropping is feasible in Ireland but optimizing the productivity of the total agroforestry system depends on the careful consideration of the varieties of the tree and biomass components deployed as well as land quality and appropriate management. Wood production for bioenergy and high value logs can be enhanced in rural areas under favourable growth conditions in the alley system investigated. It is important to carefully choose the site for an alley coppice system; additional demonstration sites are desirable and more field data is required to model the biophysical and economic behaviour with greater precision over time for a given location.

Collaborating Institutions:

AFBI, INRA, CNR, IWW, FVA

Contact Gerry C. Douglas Email: Gerry.Douglas@teagasc.ie.

Teagasc project team: G. C. Douglas, R. Lunny, J. Mc Namara (Teagasc), J. Mc Adam (AFBI), UK.
External collaborators: M. Nahm & U. Sauter For Res Inst (FVA), Germany; C. Mohart & Prof. H. Spiecker Univ Frieburg (IWW), Germany; C. Dupraz (INRA), France and P. Paris (CNR- IBAF), Italy.

1. Project background:

The demand for woody biomass as well as high quality timber exceeds its current availability and projected future needs. This project has initiated new land use concepts by establishing trials which combine the production of high value timber trees such as wild cherry wood (*Prunus avium)* and poplar wood together with woody biomass crops such as willows on the same land units. This novel system of alley coppice involves growing the timber trees in alleys / headlands of fields which grow the commercial biomass crops. The project was part of a larger ERA-NET Bioenergy project with four other countries which already had well established alley coppice systems in place so they could undertake studies on modeling their systems. Trials in Ireland were newly established in 2013 and results provided are from the end of the third growing season i.e. 2015.

2. Questions addressed by the project:

- Can viable agroforestry systems be established in Ireland in an alley coppice form, which combine willow biomass production with the production of high value timber trees?
- Which willow varieties perform best when grown together with wild cherry?
- What is the optimal alley width for positive interactions between five varieties of wild cherry timber trees, when intercropped with a range of five varieties of biomass willow?
- Can viable biomass plantations be established in alleys with mature 16 yr old poplar trees? and which willow varieties interact positively or negatively when grown in alleys with such poplars
- Which wild cherry varieties, (among 24 commercial ones) perform best when planted in linear fashion on the headland periphery of an established 4 year old willow plantation?

3. The experimental studies:

Well established alley coppice experiments were evaluated from trials in Germany, France and Italy. The biophysical and economic behaviour of alley coppice systems has also been modelled. In these models, two options were examined and presented in summary form below i.e. the simultaneous planting of the biomass crop (SRC), together with the valuable timber trees and also the effects of the delayed planting of SRC among timber trees which were already well established.

In Ireland, the alley coppice trials were newly established in May / June 2013; they consisted of a biomass crop (willow) grown in alleys in combination with timber trees, wild cherry (*Prunus avium*) and poplar to determine the growth potential of each component and their interactions. Three experiments were established and results given are for growth to 2015, so results should be considered as preliminary since the rankings of components will vary as trees develop. All willow was planted at commercial density, in double rows 0.75m apart; spacing between double rows was 1.5m. All wild cherry trees were planted 2.5m apart within all treatment alleys.

The first experiment was at AFBI, Armagh using selected varieties of wild cherry timber trees established simultaneously with the crop of biomass willow SRC to determine the growth and physiological interactions of five cherry varieties (+ one unselected seedling control) with five willow varieties and the effects of tree alley widths (2.0m and 4.0 m). Selected varieties of wild cherry trees, in the 'Tested' genetic category, were developed in Germany and sold as SilvaSELECT®. We tested individual genotypes in this variety i.e. Concordia, Neso, Pluto, Hermes and Saturn. The five commercial willow varieties were: Olof, Endeavour, Terra Nova, Resolution and Beagle.

The second experiment at AFBI was to establish and investigate an alley coppice growing system consisting of the seven willow treatments i.e. six varieties of willow (those mentioned 5 above) + the variety Tora and a mixture of all six varieties; planted in alleys (14m wide) of poplar. Poplar trees were 16 yrs. old and were spaced 5m apart within the tree rows; poplar varieties were: Beaupre, Trichobel, Gebecq and Hoogworst.

Contact Gerry C. Douglas Email: Gerry.Douglas@teagasc.ie.

The third experiment was established at Gurteen Agricultural College in 6m wide headland alleys within a 4 yr. old crop of commercial willow. The tree component consisted of unselected cherry saplings as controls and 22 selected varieties of wild cherry from SilvaSELECT®, Germany and two genotypes from France (Ameline and Gardeline). Trial format was linear, randomized 15 blocks, around the periphery of the 8 acre field. Each randomized block contained a set of each of the cherry varieties.
The variables studied for each component (biomass production and tree growth) in the alley coppice systems were: total plant heights and stem diameters at the root collars, volumetric soil moisture (%) and photosynthetic active radiation (PAR). Data analysis was by Analysis of Variance to establish significant differences in and among the various treatments. Details of experimental results are given in Lunny (2016).

4. Main results:

Results from the Irish experiments are given firstly followed by a summary of the main findings of the modeling studies carried out by the European project partners.

In the first experiment of willow established simultaneously with wild cherry trees, the cherry varieties Saturn and Concordia both grew significantly taller (P>0.05) with the willow variety Olof (289cm, and 320cm, respectively) than with Endeavour (254cm and 283cm, respectively) and Resolution (254cm, and 279cm, respectively). In contrast to this the cherry control grew significantly taller together with willow varieties Resolution (199cm), Beagle (194cm) and Terra Nova (185cm) than with Olof (149cm) and Endeavour (150cm). There were no significant differences in the mean height of cherry variety Hermes and Pluto across all willow variety treatments. There was a significantly higher (P<0.001) growth recorded for cherry varieties Concordia (298cm), Neso (294cm) and Pluto (287cm) compared to Hermes (263cm), Saturn (262cm) and the Control (176cm) with all alley width treatments. For all varieties, cherry heights were significantly higher (P<0.05) in alleys of 4m in width compared to alley widths of 2m. Also, regarding root collar diameter, the cherry varieties Neso (27.67mm), Pluto (25.76mm), Concordia (25.20mm) and Saturn (25.16mm) had significantly (P<0.001) greater diameters than Hermes (20.90mm) and the Control (17.11mm) with both alley widths.

The second experiment showed the strong negative effect of mature poplar trees on the willows growing within their alleys. The heights of each willow variety at each position in the 14m wide poplar alley showed that, willow height growth was significantly higher (P<0.01) and stem diameter significantly greater (P<0.01) towards the center of the alley when compared to the positions nearer the poplar trees (Figure-page 1). Willow varieties Endeavour and Tora performed best; Terra Nova and Resolution were poorest and the mixture of all six varieties was intermediate in shoot growth. Willows grew taller (P<0.001) under the poplar varieties Beaupre and Hoogvorst compared to the poplar varieties Gebec and Trichobel. The willow plant position had a very highly significant effect (P<0.001) on mean willow height, mean stem diameter, and soil moisture level. The highest mean volumetric soil moisture and PAR was noted the furthest distance from the tree line (6.625m).

Results from the third experiment showed variability for growth among 23 selected varieties of wild cherry as timber trees, when grown in headland alleys of a well-established 4 yr. old crop of willow biomass. Ten SilvaSELECT®, varieties of wild cherry grew to significantly greater height (P<0.001) than either the unselected sapling controls and the two French varieties Gardeline & Ameline. The ten best performong varieties were: Neso, Deo, Triton, Vulkan, Neptune, Favonius, Janus, Pluto, Tiberius, and Demeter. The variety Neso was tallest (1.9m) followed by Triton, Vulcan and Deo (1.65m); Ameline performed poorest (1.0m), and was similar to controls. The variety Deo had the greatest stem diameter (17mm), followed by Neso(16mm) Vulcan and Neptune (15mm); Ameline performed poorest (8mm) even when compared with the controls (9mm).

The models developed by the European project partners showed that under optimal growth conditions, the alley coppice system, combining trees with biomass cropping (SRC) is more profitable than pure SRC.
However, under suboptimal conditions, pure short rotation coppice is more cost-effective. In addition, delayed planting of the biomass component can result in further decreased coppice yields due to shading, especially when the coppice crop is growing under and between older timber trees with large crowns. It was concluded that, the delayed planting strategy of the biomass component, can only be recommended when the timber trees are still young, or when only a limited number of trees are present so as to prevent extensive shading of the biomass crop. The system of establishing a minimal alley coppice crop in which the valuable timber trees are planted only at the headlands of the fields is viable in terms of tree growth and quality and

Contact Gerry C. Douglas Email: Gerry.Douglas@teagasc.ie.

can even be adopted by farmers who are reluctant to plant trees on their open land areas.

5. Opportunity/Benefit:

This is the first scientific study which combined the growing of high value timber broadleaved trees, in combination with biomass crops, at trial sites in Ireland, as a novel viable system of land use. The trial sites are still operational for future data collection and analyses to further validate the initial results and outputs of the components of the systems as well as total output fom the land areas. The research results help to identify the most appropriate willow variety(s) for growing as an intercrop with the most suitable variety(s) of poplar or wild cherry in an alley coppice system in Ireland. The knowledge generated on the optimal combinations of willow and wild cherry varieties may stimulate the adoption of these combinations by farmers who wish to diversify production into various systems of agroforestry.
Transferring the technology effectively will require more sets of demonstration sites on farmers' lands to validate these initial results, especially to optimise the management of the tree component of the system.

Operations such as species selection, thinning and pruning are provided in the 'Management guidelines', which were elaborated in the project and cited below. One example concerns the strong relationship between trees with big crowns and trees with big stem diameters, for all species. It is easy to estimate tree spacings and to calculate the final distance whihc should be allocated between the future crop trees in an agroforestry system. Assuming an aimed for stem diameter of 60cm (at a height of 1.3m above ground i.e. dbh); the final distance between the hardwood trees is computed as: the aimed for stem diameter in (cms) e.g. 60 X 25 = 1500cm (15m). This example indicates a minimum distance to each neighbour tree as 15m in all directions, resulting in a density of 44 final crop trees per hectare.

6. Dissemination:

Main publications:

Morhart C., Douglas G.C., Dupraz C., Graves A., Nahm M., Paris P., Sauter U.H., Sheppard J., Spiecker H. (2014). Alley Coppice - a new system with ancient roots. Annals of Forest Science, 71, 527-542. https://link.springer.com/article/10.1007/s13595-014-0373-5

Lunny R. 2016 PhD. Title: Tree crop interactions in alley coppice- **a** novel land uses system. Queens University Belfast, N. Ireland.

Popular publications:

Morhart C., Sheppard J., Douglas G.C., Lunny R., Paris P., Nahm M. (2015) Management guidelines for valuable wood production in agroforestry systems.
https://www.teagasc.ie/media/website/crops/forestry/research/Management-Guide-for-Valuable-Wood-Production-in-Agroforestry.pdf

Lunny R., McAdam J.H., Douglas G. (2014). Alley Coppice: Combining Willow SRC with Poplar and Cherry trees. In: JHN Palma (ed.), Proceedings of the 2nd European Agroforestry *Conference* in Cottbus, Germany. EURAF, pp. 255-256

Project website: http://www.agrocop.com/

7. Compiled by: Gerry C. Douglas and Rory Lunny

Contact Gerry C. Douglas Email: Gerry.Douglas@teagasc.ie.