# Research and Development Protocol for Weed Management in Mediterranean Silvoarable Group in France

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| **Project name** | AGFORWARD (613520) |
| **Work-package** | 4: Agroforestry for arable farmers |
| **Specific group** | Mediterranean silvoarable systems in France<br>Weed study in silvoarable alley cropping |
| **Milestone** | Milestone 16 (4.3) Part of experimental protocol for WP4 |
| **Date of report** | 9 June 2015 |
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AGFORWARD (Grant Agreement N° 613520) is co-funded by the European Commission, Directorate General for Research & Innovation, within the 7th Framework Programme of RTD. The views and opinions expressed in this report are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.

## 1 Context

The AGFORWARD research project (January 2014-December 2017), funded by the European Commission, is promoting agroforestry practices in Europe that will advance sustainable rural development. The project has four objectives:

1. to understand the context and extent of agroforestry in Europe,
2. to identify, develop and field-test innovations (through participatory research) to improve the benefits and viability of agroforestry systems in Europe,
3. to evaluate innovative agroforestry designs and practices at a field-, farm- and landscape scale,
4. to promote the wider adoption of appropriate agroforestry systems in Europe through policy development and dissemination.

This report contributes to the second objective. It contributes to the initial research and development protocols (Milestone 16; (4.3)) for the participative research and development network focused on agroforestry for arable farmers. It forms a second protocol which should be read alongside Gosme and Desclaux (2015).

The initial stakeholder group, which focused on silvoarable systems, mentioned weeds as an issue for crop management, and unravelling the impact of trees on weed infestations in silvoarable systems has been identified as one of the key researchable topics for the WP4 (Burgess et al. 2014; Gosme 2014). Because of an obvious lack of knowledge about weed communities in these systems, diagnosis is first required. Thus we describe here the initial research protocol which aims to characterise the weed communities and quantify their effect on arable crops in alley cropping systems compared to conventional cropping systems.

## 2 Background

Farmers mentioned weed management as an issue in silvoarable systems (Gosme 2014). Some studies has been conducted to characterize weed composition and abundance in alley cropping, however they mostly focused on the understorey vegetation and rarely on the arable weeds in crops (e.g. Burgess et al. 2003). Thus references are needed to assess the impact of trees on weed communities and their effect on arable crops in alleyways. It is expected that the weed community in silvoarable systems are modified because of i) the tree understorey to the sides of cropped alleys, and ii) competition for light and water from the trees. Consequently the effects of weeds on crops may be different compared to a weed community of arable crops without trees.

## 3 Objective of trial

The objective of the trial is to assess the effect of tree rows on weed community of the crop alleyways in alley cropping. Key questions include:

- Is the weed community of arable crops different (species, abundance, distribution) in silvoarable systems compared to conventional arable systems?
- Is the understorey vegetation responsible for increasing weed infestation in crops of the alleyways?
- Are the shading conditions responsible for changes in weed composition and abundance?
- Does weed pressure for crops change in silvoarable systems compared to arable systems?

Alongside these objectives, the hypotheses are:

- Arable weed community in silvoarable systems is different in terms of species composition and richness (more shade-tolerant species, more perennials in agroforestry, increased species richness) and abundance (similar to field border, where abundance is generally increased, because of the presence of understoreys).
- Weeds in agroforestry are adapted to shading conditions (e.g. sciaphilous species).
- Species of the understoreys are present in the crop alleys.
- The different structure of weed community in silvoarable systems results in a different effect on the crop.

## 4 System description

The trial is set up in two fields, at the Restinclières experimental site, 15 km north of Montpellier (43°43'N, 4°1'E, 54 m a.s.l.), in South-East of France. Figure 2 shows the localisation of the fields in the Restinclières site. The trial will be focused on two fields (A and B) as described in Table 1.

**Field A** is a 6 ha field (Figures 1 and 2), divided in two parts (crop management has remained constant for the past 20 years, previous crop was durum wheat (*Triticum durum*)). The field comprises 4 ha of alley cropping part, with 20 years-old hybrids of walnuts (*Juglans x intermedia*), and barley (*Hordeum vulgare*)(13 m across tree rows), and a 2 ha pure cropping part with barley.

**Field B** is a 1 ha field (Figures 1 and 2) divided in two parts (crop management has remained constant for the past 20 years, previous crop was durum wheat (*Triticum durum*)). The field comprises 0.5 ha of a well-shaded alley cropping part, with 15 years–old poplars (*Populus spp*.), and pea (*Pisum sativum*) (13 m across tree rows), and 0.5 ha of an unshaded area with poorly-developed 20 year-old sorb trees (*Sorbus domestica*) and pea.

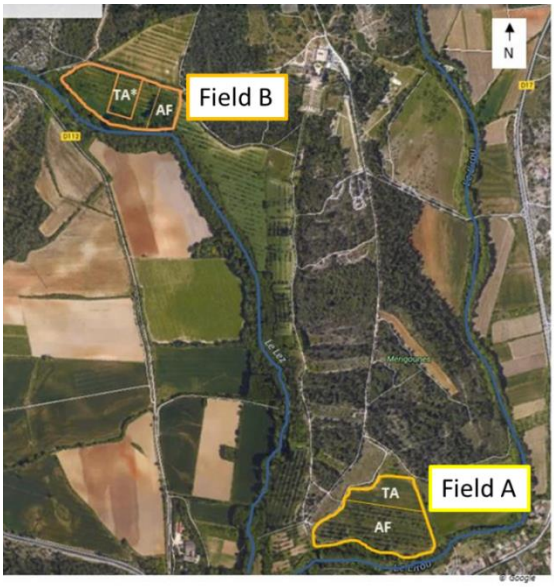


Figure 1. Location of Field A and Field B on the Restinclières estate. Field A: TA=pure barley system, AF=Walnut/barley agroforestry system; Field B: TA*=Sorb/pea agroforestry system (poor shade), AF=Poplar/pea agroforestry system (dense shade). (Map: Google)

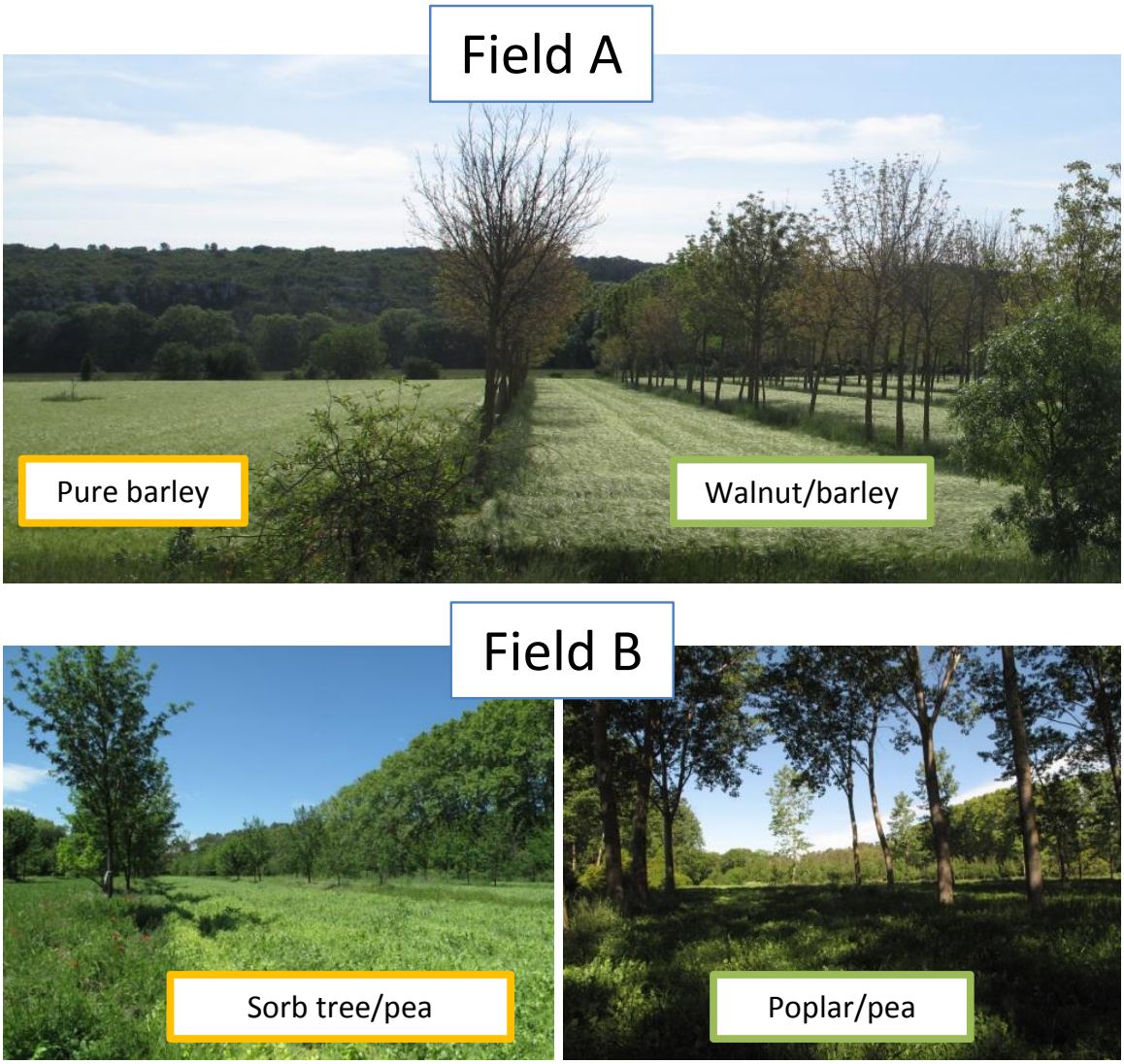


Figure 2. View of Field A and Field B (Pictures: D. Mézière, May 2015)

Table 1. Description of the site, with soil, tree, understorey, and climate characteristics

| Site characteristics | |
|---|---|
| Area: | 6ha+1ha |
| Co-ordinates: | 43°43' N, 4°1' E |
| Site contact: | Lydie Dufour |
| Site contact email address | dufourl@supagro.inra.fr |

| Soil characteristics | |
|---|---|
| Soil type (WRB classification) | |
| Soil depth | Deep |
| Soil texture | Deep silty clay limestone |

| Tree characteristics | | |
|---|---|---|
| FIELD A | Agroforestry system | Pure crop reference system |
| Tree species | Hybrid walnut (*Juglans x intermedia*) | None |
| Tree density (spacing) | 100 trees $ha^{-1}$ (13 m across lines, about 4 to 8 m along tree line) | None |
| Tree protection | None | None |
| Additional details | Uncultivated 1.5 m strip at tree base with spontaneous vegetation | |
| FIELD B | Highly shaded agroforestry system | Low shaded agroforestry system |
| Tree species | Poplar (*Populus spp.*) | Sorb (*Sorbus domestica*) |
| Variety/rootstock | - | - |
| Tree density (spacing) | 100 trees $ha^{-1}$ (13 m between rows, about 4 to 8 m within row) | 50 trees $ha^{-1}$ (13 m between rows, about 4 to 12 m within tree row because of a lot of mortality) |
| Tree protection | None | None |
| Additional details | Uncultivated 1.5 m strip at tree base with spontaneous vegetation | Uncultivated 1.5 m strip at tree base with spontaneous vegetation |

| Crop characteristics | | |
|---|---|---|
| FIELD A | Agroforestry system | Crop reference system |
| Species | Winter barley (*Hordeum vulgare*) | Winter barley (*Hordeum vulgare*) |
| Coverage | Complete | Complete |
| Previous cropping | Durum wheat (*Triticum durum*) / pea (*Pisum sativum*) /durum wheat /durum wheat /pea | Durum wheat *(Triticum durum)* / pea (*Pisum sativum)* /durum wheat / durum wheat /pea |
| FIELD B | Shady agroforestry system | Sunny agroforestry system |
| Species | Pea (*Pisum sativum*) | Pea (*Pisum sativum*) |
| Coverage | Complete | Complete |
| Previous cropping | Previous years: Durum wheat (*Triticum durum*) / durum wheat/pea (*Pisum sativum*)/durum wheat | Previous years: Durum wheat (*Triticum durum* )/ durum wheat/pea (*Pisum sativum*)/durum wheat |

| Climate data | |
|---|---|
| Climate type | Mediterranean |
| Mean monthly temperature | 14.2 °C |
| Mean annual precipitation | 851 mm |
| Details of weather station | Data from 2011-2013 (Campbell station on site) |

# 5 Trial design

## 5.1 Conceptual design

The primary objective of the research study is to characterise weed community of arable crops in alley cropping systems, in terms of specific composition, specific abundance, spatial distribution, and crop competition. A secondary objective is to determine whether shade and/or the presence of spontaneous vegetation under tree lines can explain any differences of weed community structure.

## 5.2 Description of design

Field A was chosen because of the presence of a reference crop area in the field, adjacent to the agroforestry area. Field B has no reference crop area but it presents two alley cropping systems with different levels of shade intensities. The sorb trees produce little shade due to poor tree development and survival. By contrast the poplar agroforestry area consists of a very dense stand resulting in greater light reduction from May to October (Table 2).

Table 2. Description of the four surveyed systems

| **Field A** | | **Field B** | |
|---|---|---|---|
| Pure crop | Walnut agroforestry | Sorb agroforestry | Poplar agroforestry |
| Barley | Barley | Pea | Pea |
| No tree | Tree: hybrid walnut (7 surveyed lines) | Tree: sorb (7 surveyed lines) | Tree: poplar (6 surveyed lines) |
| No alley cropping (the whole field is surveyed) | Alley cropping (6 surveyed alleys) | Alley cropping (5 surveyed alleys) | Alley cropping (5 surveyed alleys) |
| Full light | Moderate shade when the trees have leaves | Low shading when the trees have leaves | High shading when the trees have leaves |

# 6 Measurements

The planned measurements to be taken in each of the four surveyed systems are summed up in Table 3. In each of the four systems, measurements (except for biomass) will be recorded within 1 m x 1 m quadrat plots placed regularly (at distances of 1.17 m) along three transects in each treatment (Figure 3). In both fields, the transects are placed perpendicularly to the tree lines. In Field A, the transects extend from the crop reference into the agroforestry area (Figure 4).

The distances from trees are not exactly the same at the cross between transect and tree lines as some trees were cut to reduce tree density in 2003. Five quadrats will be sampled for each crop alley in the agroforestry field, which enables us i) to measure the light radiation variability in alley cropping induced by trees and ii) to sample at different distances from grass strips of the tree understoreys. Given the absence of trees in the reference crop, each group of five plots are separated by an empty zone (corresponding to the tree line in the agroforestry field). Otherwise the protocol is the same.

Because of other trials on the same fields (pollarded tree trial in Field A, participatory durum wheat breeding in Field B), some crop alleys are not sampled in the agroforestry field. Hence six crop alleys will be surveyed in Field A, and 5 crop alleys will be surveyed in Field B.

Table 3. Planned measurements and the number of sampled quadrats[2]

| Measurements | Field A | | Field B | |
|---|---|---|---|---|
| | Pure barley | Walnut/barley | Pea/Sorb | Pea/Poplar |
| Weed sampling in alley crop | 90 quadrats x 3 dates | 90 x 3 dates | 75 x 3 dates | 75 x 3 dates |
| Weed sampling in understorey | - | 21 x 3 dates | 21 x 3 dates | 18 x 3dates |
| PAR[2] | 20 (extremity of the pure crop part) x 3 dates | 111 x 3 dates | 93 x 3 dates | 93 x 3 dates |
| Weed/crop biomass | 9 x 1 date | 9 x 1 date | 9 x 1 date | 9 x 1 date |

[1]In the table, when 90 quadrats, it means 5 quadrats/alley* 6 alleys*3 transects. 75 quadrats = 5 quadrats/alley* 5 alleys*3 transects; 21 quadrats = 1 quadrat*7 understoreys*3 transects; 18 quadrats = 1 quadrat*6 understoreys*3 transects; 111 quadrats = 90 plots in alley crop + 21 in understoreys; 93 quadrats = 75 plots in alley crop+18 in understoreys. Only 20 quadrats for PAR in the pure barley as in the middle of the field, it is full light (and we do not need take photos alongside all the transects).

[2]Photosynthetically Active Radiation

Figure 3. A transect indicated by blue markers (quadrat places) within field A. The reference crop can be seen in the foreground; the walnut-barley agroforestry system can be seen in the background.

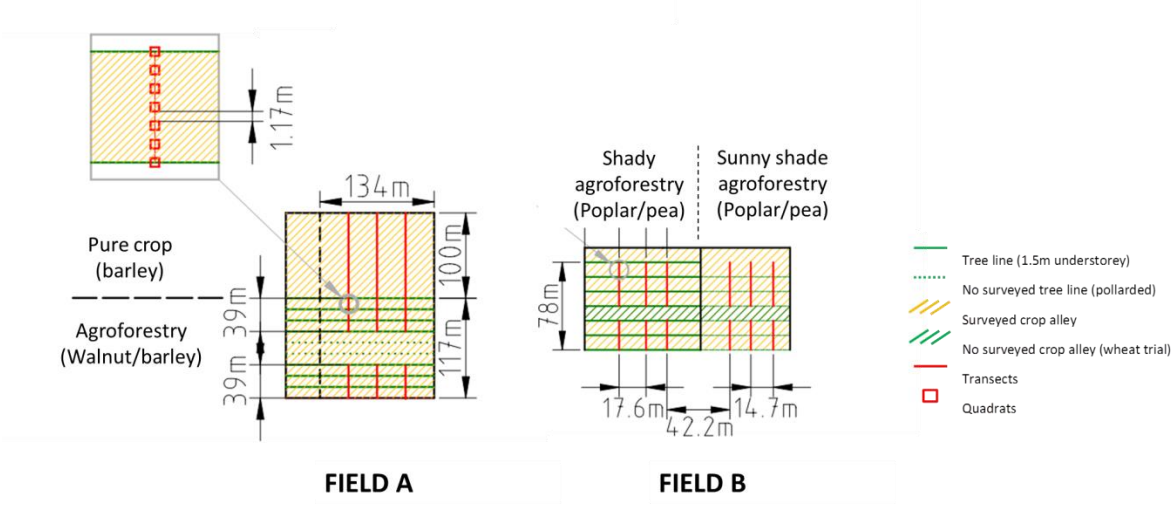


Figure 4. Location of the transects and the quadrats in each field

**Weed sampling**

For the crop alleys, all weed species and their specific abundance (number of individuals for each species) will be recorded within each 1 m² quadrat. For the quadrats of the tree understorey, specific abundance will be related to an abundance class following the scale of Barralis: 0, 1 if 1 individual, 2 if 2-3 individuals, 3 if 4 to 20 individuals, 4 if 21 to 50 individuals, 5 if more than 50 individuals. If there are problems with species identification (due to juvenile stage), individuals will be recorded and identified later (e.g. when flowering).

**Light radiation assessment**

Hemispherical pictures will be taken at the centre of each quadrat, on the same three dates as weed sampling. By using Winscanopy software, the photosynthetically active radiation (PAR) will be calculated from the pictures.

**Weed competition**

Crop competition caused by the weeds will be expressed by the following ratio: dry mass of weeds/dry mass of crops (Valantin-Morison, 2004; Weiner et al. 2010). Thus, in each system, nine 1 m² quadrats (3 in the middle of the alley, 3 in the north part of the ally, and 3 in the south part of the alley) will be completely harvested. The total harvested biomass will be separated between crop biomass and total weed biomass. The harvests will be carried out some days before crop harvest (anticipated to be 10 June 2015 for barley and pea), dried at 70°C and weighed.

**Sampling date**

Composition, abundances and total PAR under canopy are measured three times in the same quadrats during the campaign:

- Before tree budbreak (30 March-3 April), which corresponds to the situation with minimum shade.
- Some weeks after budbreak when tree leaves are quite well developed and provide shade, as well as when crops are flowering (22-26 May). Crop flowering is a critical period for yield build-up of wheat.

- Two weeks after 1st post-harvest tillage (16-19 July), when tree Leaf Area Index (LAI) is near its maximum, and weed seedlings have largely emerged.

## 7 Acknowledgements

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