Research and Development Protocol for the Intercropping of Olive Orchards in Italy

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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, and
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 protocol (Milestone 10 (3.3)) for the participative research and development network focused on the use of agroforestry in high value tree systems.

2 Background

In Italy over one million ha of olive (*Olea europea*) orchards risk large scale abandonment, since the removal of trees is prohibited, the olive oil price is relatively low and the de-coupling of subsidies from production have made harvesting unnecessary. The economic gain could be improved by intercropping olive trees with other viable crops grown beneath the canopy (Rosati et al. 2012, Daoui and Fatemi, 2014). This may provide additional income, and promotion of the advantages of agroforestry practices may increase farmer interest in olive groves (Tsonkova et al. 2012, Pisanelli et al. 2014). However selection of the appropriate species and the development of targeted and innovative agronomic practices are important to improving the efficiency of agroforestry practices and the maximisation of ecosystem services (Tsonkova et al. 2012). Among the wide range of perennial species evaluated, wild asparagus (*Asparagus acutifolius*) holds high potential as a new crop, in combination with the olive tree (Mantovani and Rosati 2014). Since the plant naturally grows in abandoned olive orchards, and the market for its spears is already established, its cultivation appears profitable. To optimise the land use and further diversify the outputs, other crops could be added to asparagus production in olive orchards. Bulb crops appear to be an interesting alternative to arable crops, since they are perennials like the asparagus (i.e. no soil tilling necessary), but their vegetative cycle occurs in winter and spring, leaving the soil bare during the summer and the olive harvest time in the fall.

The stakeholder group meeting, held in Spoleto Italy on 27 June 2014, was attended by 16 participants. The meeting introduced farmers and other stakeholders to a new agroforestry practice, integrating olive trees with other crops/animals, particularly with the wild asparagus. The group indicated that other crops should also be investigated, and for the reasons mentioned in the previous paragraph, flowers were chosen as a possible crop.

For the trial, the perennial bulbous species narcissus (*Narcissus poeticus* L. var. Tete a Tete, Johann Strauss, King Alfred, Ziva Paper white, Poeticus Recurvus) and tulip (*Tulipa kaufmanniana* Regel, var. Giuseppe Verdi) have been selected. At the moment, there are no data available describing the agroforestry design of olive-asparagus-flower systems. CRA will test this innovation to evaluate the

resource (i.e. light and water) availability under the canopy of different olive orchard systems (traditional and hedgerow), to identify way of optimising resource-use efficiency and therefore crop performance. Given the evergreen perennial, but crawling nature of the wild asparagus, plants were planted along the tree rows, in order to leave the inter-row space accessible to machinery and for the cultivation of the flower species selected. The trial design includes a control plot where the wild asparagus, narcissi and tulips are growing in open field (i.e. no trees).

The field trial will evaluate the microclimatic conditions and the light availability in different olive orchard systems (i.e. traditional 5 m by 3.5 m and very-high density 4 m by 1.5 m). The suitability of the selected intercropped species will be tested, taking into account the agronomic practices for each crop. In addition, since there is minimal information about the eco-physiology of wild asparagus, a pot experiment will also be carried out under controlled conditions to evaluate the responses of plant growth to light and water availability. These data will be integrated into an ecological model (van der Werf et al. 2007, Graves et al. 2010) to describe the growth dynamics of the olive-asparagus agroforestry system.

3 Objective of trial

The trial aims to assess the technical feasibility of the olive-asparagus-flower system, and testing its efficiency as compared with the asparagus-flowers system growing in open field or the pure olive grove. Key questions include:

- How do the light spatial and temporal variations, the soil moisture dynamic and the microclimatic conditions differ under the two olive orchard systems and in the open field?
- Is the asparagus-flower system less productive in combination with the olive trees?
- Are the crop cycles of the intercropped species compatible with olive tree cultivation?
- Is there any management practice for the olive orchard jeopardizing the asparagus and flower production?
- Are narcissus and tulip suitable for the olive-asparagus-flower system?
- If tulip and narcissus are suitable for the olive-asparagus-flower system, which are the more appropriate varieties?
- What is the eco-physiological response of wild asparagus to light and water availability?
- What are the morphological and physiological adaptations and the yield response of wild asparagus to light constraints under the trees?

4 System description

The field trial is carried out at Colle Cecco, near Spoleto, central Italy. Climate, soil characteristics and species selection is shown in Table 1. The two different olive orchards systems, namely high density system (HD), and traditional system (T), are showed in Figure 1a and Figure 1b respectively. The 8 year old olive trees in the HD system are spaced 1.5 m along the row, and 4 m between rows. While in the traditional system, the 20 years old olive trees are spaced 3.5 m along the row and 5 m between the rows. Two year old asparagus plants have been transplanted along the tree rows. Between olive rows, instead, three rows of narcissi and tulips were planted. As a control plot the asparagus-flowers system was also established in an open field (Figure 1c). Detailed information of the plot design is given in Tables 1 and 2 and Figure 2.

Figure 1. Experimental plots at Colle Cecco: a) olive-asparagus system in high density system, b) olive-asparagus system in a traditional system and, c) asparagus as a control. The tulips and narcissi have not been planted yet.

Table 1. Description of the site: location, soil, climate, and crop characteristics

Field experiment site characteristics	
Co-ordinates:	42°48'34.4"N 12°39'39.7"E
Site contact:	Adolfo Rosati
Site contact	adolfo.rosati@entecra.it

Field experiment soil characteristics	
Soil depth	>120 cm
Soil texture	Silty clay
Bulk density	1.5 g cm^{-3} (20 cm depth), 1.6 g cm^{-3} (40 cm depth)
Aspect	North-South
Slope	10%

Field experiment climate data	
Mean min temperature	7.4 (± 5.4 SD) °C, T
Mean max temperature	18.8 (±7.7 SD) °C
Mean annual precipitation	816 mm
Details of weather station	Data from 1985-2014 from stazione metereologica di Perugia (Perugia weather station).

Field experiment species selection		
Tree species	Intercrop along the trees row	Intercrop between tree rows
Olea europea	*Asparagus acutifolius*	*Narcissus* L. var. *Tete a Tete* var. *Johann Strauss* var. *King Alfred* var. *Ziva Paper withe* var. *Poeticus Recurvus* *Tulipa kaufmanniana* R. Var. Giuseppe Verdi

5 Trial design

5.1 Conceptual design

The field trial entails two treatments related to the olive orchard system, plus the control (Table 2). For the pot experiment two treatments in relation to the light availability are planned (Table 3).

5.2 Description of design for the field trial

Wild asparagus, narcissi and tulips, are grown under two different olive grove systems, namely traditional (TR), high-density (HD) and an open field control (C). The experiment design consists, for each treatment, of one plot of three rows of olive-asparagus with two inter-row spaces, each with three rows of bulbs, for a total of 5 rows of narcissus and one row of tulip. Each plot is divided into 4 consecutive subplots of 2.5 m for all the systems. The experiments are included in a broader olive grove.

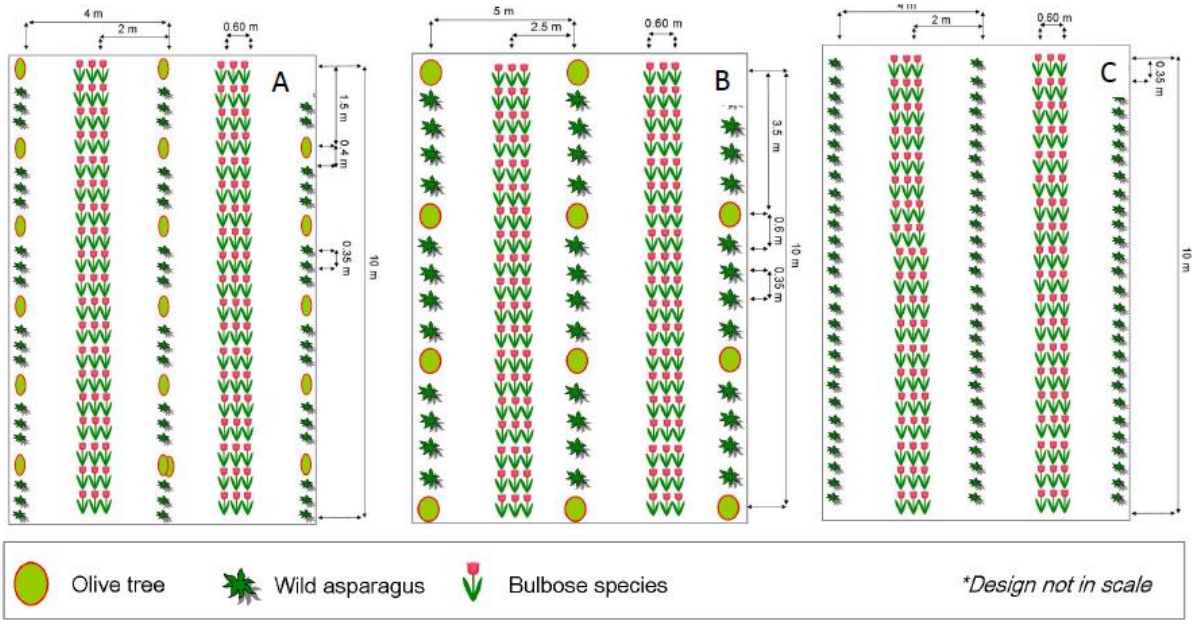

Figure 2. Diagram of the trial plots at Colle Cecco: a) olive-asparagus system in high density system, b) olive-asparagus system in high density system and, c) asparagus as a control

Table 2. Description of treatments chosen for the field experiment

Field experiment plot dimension				
Treatment	Agroforestry system	Plot dimension	Sub plot dimension	Subplot n.
High density	Olive-asparagus-flower	4 m x 10 m	4 m x 2.5 m	4
Traditional	Olive-asparagus-flower	5 m x 10 m	5 m x 2.5 m	4
Control	Asparagus-flower	4 m x 10 m	4 m x 2.5 m	4

Field experiment plant system			
Treatment	Olive trees inter-row distance	Olive trees in-row distance	Asparagus in-row distance
High density	4 m	1.5 m	0.35 m
Traditional	5 m	3.5 m	0.35 m
Control	-	-	0.35 m

5.3 Description of design for the pot experiment

For the pot experiment two treatments have been planned, in relation to the incident photosynthetic active radiation (PAR), namely shaded and unshaded plants (Table 3). Two year old wild asparagus plants (n = 24), were transplanted into 11 L pots, filled with sand and organic compost (1:1), which were fertilised and kept well-watered. During the vegetation period 2015, half of the plants (Shaded treatment) will be maintained under a polyethylene shade cloth. Therefore they were constantly shaded, subjected only to 50% of the total PAR reaching the ground. The unshaded treatment plants will be maintained uncovered and receive 100% sunlight for all the vegetation period. During the winter (October 2014 to February 2015) to avoid frost damage, the plants were overwintered in a glasshouse without climate-control. From March 2015 the plants were re-established outside of the glasshouse and were well-watered.

Table 3. Description of treatments the chosen for the pot experiment

Pot experiment design		
Treatment	Photosynthetically Active Radiation (PAR)	Replicas (n)
Shaded plants	50% PAR	12
Unshaded plants	100% PAR	12

6 Measurements

6.1 Field experiment measurements

The planned measurements to be taken in the two treatments for the field experiment are described in Table 4.

6.2 Objectives

- Evaluation of the microclimatic condition and dynamic over time of soil water availability and light availability in the different olive grove systems.
- Assessment of the tree growth (i.e. trunk diameter and weight of pruning materials and of fruit production) each vegetation period.
- Assessment of the wild asparagus aboveground biomass production over time.
- Evaluation of the survival rate and the vegetative cycles of the flower species over time.
- Evaluation of the light use and water use by the wild asparagus.

Table 4. List of measurements to be taken in the two treatments and control for the field experiment

High density	Traditional	Control
Recording air temperature, relative humidity and soil moisture (20 and 40 cm depth).	Recording air temperature, relative humidity and soil moisture (20 and 40 cm depth).	Recording air temperature, relative humidity, incident PAR and soil moisture (20 and 40 cm depth).
Measuring tree basal diameter and height at the beginning of each year.	Measuring tree basal diameter and height at the beginning of each year.	
Recording periodically the incident and the transmitted PAR spatial and temporal variation across the row and in the row.	Recording periodically the incident and the transmitted PAR spatial and temporal variation across the row and in the row.	
Estimate periodically the wild asparagus biomass production.	Estimate periodically the Wild asparagus biomass production.	Estimate periodically the Wild asparagus biomass production.
Measuring periodically the Wild asparagus net photosynthesis and water use efficiency.	Measuring periodically the Wild asparagus net photosynthesis and water use efficiency.	Measuring periodically the Wild asparagus net photosynthesis and water use efficiency.
Recording the sprouting and flowering time from each floral species/cultivar and bulb survival.	Recording the sprouting and flowering time from each floral species/cultivar and bulb survival.	Recording the sprouting and flowering time from each floral species/cultivar and bulb survival.
Recording biomass development (e.g. number of flowering stems and average height)	Recording biomass development (e.g. number of flowering stems and average height)	Recording biomass development (e.g. number of flowering stems and average height)

6.3 Pot experiment measurements

Through the plot experiment we will evaluate the wild asparagus adaptation to light reduction and its eco-physiological response to water limitation. The planned measurements are listed in Table 5.

6.4 Objectives

- Assessment of the wild asparagus growth performance under different light availability.
- Evaluation of the wild asparagus morphological and eco-physiological adaptation to light limitation.
- Evaluation wild asparagus eco-physiological response to water limitation and temperature variation.

Table 5. List of measurements to be taken on the two treatments for the pot experiment

Shaded plants	Sunny plants
Estimate periodically the wild asparagus biomass production. Evaluate the light response curve and CO_2 response curve under different temperature, and soil moisture content.	Estimate periodically the wild asparagus biomass production. Evaluate the light response curve and CO_2 response curve under different temperature, and soil moisture content.

7 Ecological modelling

The second part of this protocol describes attempts to model the system using the YieldSAFE biophysical model. The YieldSAFE model has been previously parameterised for intercropped apple orchards (Vylupek 2010). Hence, the modelling objectives are:

- Modification, calibration and validation of the existing growth model (Vylupek 2010) and additional calibration as required for olive trees.
- Parameterisation/calibration of the understory component (i.e. wild asparagus).

These objectives will be pursued in collaboration with, and to the extent decided by, the WP6 leader (Table 6). Measurements of tree height, diameter, crown dimensions, and olive yield and PAR interception will be taken, and supported by data from the literature.

Table 6. Possible measurements to improve current parameterisation of the YieldSAFE model

Measurement	Method
Height	Physical measurement of trees.
Diameter at breast height (D_{bh}), diameter above graft (D_{40})	
Crown dimensions	
Olive yield	Physical counts, calculation based on total yield and tree density.
Aboveground biomass	Estimated with biometrics from published data.
Maximum leaf area	Destructive sampling/defoliation: determination of total wet leaf mass, and leaf area, and moisture content of a sub-sample.
Wood density	Destructive sampling or measurements of prunings.
Proportion of shoots removed per prune	Currently this was estimated, but the value may be better informed by expert judgement/measurement from prunings.

The photosynthetic performance of the asparagus and consequently its potential biomass growth can be based on a radiation-use-efficiency model approach (Rosati et al. 2003, 2004). Since this bimodal pattern of grass growth beneath the trees may have interesting interactions with tree growth, and implications for grazing, the YieldSAFE model may also be parameterised for olives with a grass understorey.

8 Acknowledgements

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