Research and Development Protocol for Silvoarable Agroforestry in the UK

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Work-package	4: Agroforestry for arable farmers
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Milestone	Milestone 16 (4.3) Part of experimental protocol for WP4
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Approved	Paul Burgess 28 April 2015

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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 protocols (Milestone 16) for the participative research and development network focused on agroforestry for arable farmers.

2 Background

Silvoarable systems are currently rare in the UK. The few systems that exist are usually based on an alley cropping design with arable crops in the alleys. The tree component consists either of top fruit trees (apples, pears and plums), timber trees, or coppice trees for woodfuel. Agroforestry systems present novel cropping environments with greater variability in growing conditions where competitive interactions between the crop and tree rows need to be optimised to ensure greatest productivity. Crop varieties better suited to growing in these environments may need to be developed to secure the viability of agroforestry systems. The development of agroforestry-adapted arable crops was identified by the UK silvoarable stakeholder group as an innovation for further development at the workshop held on 18 November 2014 (Smith et al. 2014).

Field trials were conducted at Wakelyns Agroforestry, Suffolk, UK in 2014. The trial plots were drilled on the 19 March 2015 in two cropping alleys (alleys 2 and 4) in a willow agroforestry system. Plots measured 1.2 m x 10.2 m, seed was sown in 20 cm row widths and seed rates were adjusted based on thousand grain weights to achieve 425 seeds m^{-2}. Trial entries included a spring oat variety (Canyon), a spring barley variety (Westminster), a spring triticale variety (Agrano), two spring milling wheat varieties (Paragon and Tybalt), an equal mixture of Paragon and Tybalt and a spring wheat Composite Cross Population (CCP). The trial in each alley was drilled in six beds across each 10 m wide alley. Trial plots were arranged so that plots of the same entry were adjacent across all six beds and were repeated twice in each alley. Alley 4 included all wheat entries and oats whilst alley 2 included the wheat CCP, barley and triticale. Both willow tree rows in alley 2 and the tree row on the west side of alley 4 were coppiced in Jan 2014. The tree row on the east side of alley 4 was left standing throughout the season. Assessments of crop emergence were made at growth stage 11 and each plot was harvested with a plot combine to measure grain yield.

3 Results and discussion of 2014 research

Analysis of variance revealed significant differences among crop yields (F_{48} = 80.65, P<0.001) although the performance of wheat varieties and the mixture did not significantly differ from each other. There was a highly significant effect of bed position in each alley (F_{48} = 53.91, P<0.001) with the alleys nearest the tree rows yielding lowest (Figure 1 and 2). Wheat yields in the bed nearest the standing hedge were on average 62% lower than in the highest yielding bed near the centre the alley 4. Whereas, the wheat yields in the bed next to the coppiced hedge in alley 4 were 18% lower than the highest yielding bed. In alley 2, wheat yields in the east and west beds next to the coppiced hedges were 46 and 31% lower than the highest yielding bed respectively. This yield loss near to the tree rows was greatest for the standing tree row in alley 4 which had not been coppiced. This could suggest that the un-coppiced tree was providing greater competition than the coppiced trees with shading likely to be a key effect. Moreover, the results showed no evidence of a yield loss in oats next to the tree row that was coppiced.

No crop variety by bed interaction was found indicating that the wheat varieties, mixture and population demonstrated a comparable yield loss due to trees. Therefore, these results do not support the hypothesis that greater within crop diversity per se can help to stabilise yield in the more marginal environments close to the trees. However, this may be due to the limited number of replicates. Trials over several years and in other tree systems could reveal clearer results.

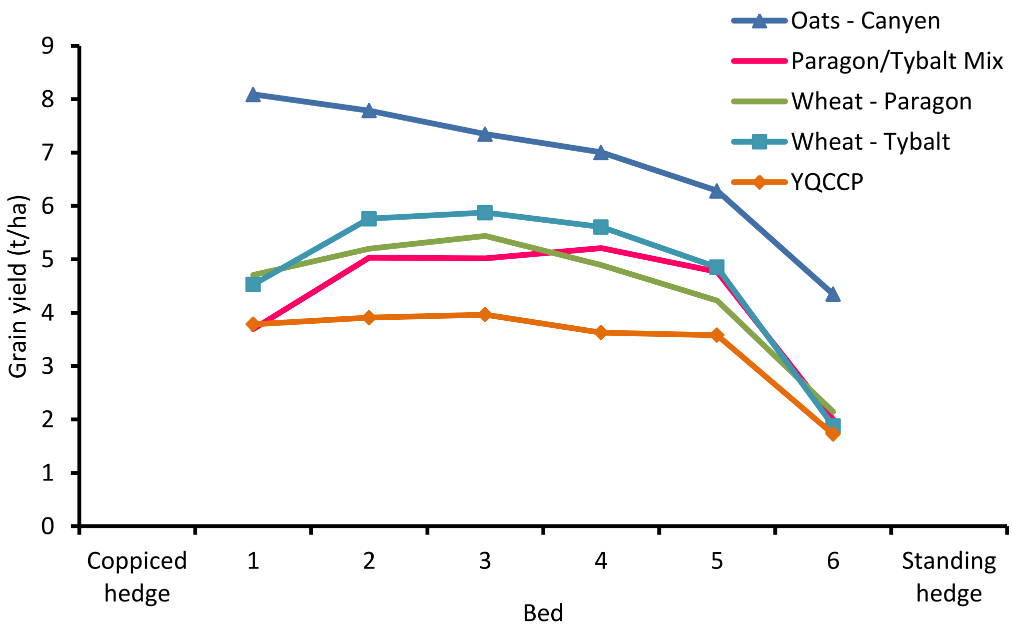

Figure 1. The mean grain yield (n=2) of a spring oat and wheat varieties, mixture and composite cross population (YQCCP) in six positions across a ten m wide agroforestry cropping alley (Alley 4) between a coppiced and standing willow tree rows.

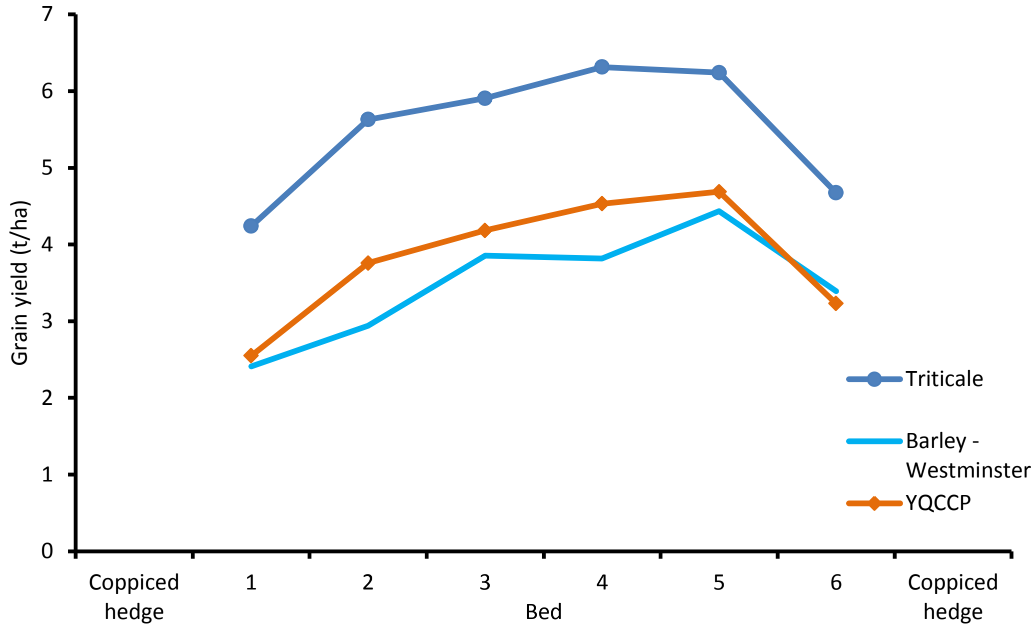

Figure 2. The mean grain yield (n=2) of spring triticale and barley varieties and a composite cross population (YQCCP) in six positions across a 10 m wide agroforestry cropping alley (Alley 2) between coppiced willow tree rows.

Crop emergence rates were also lower in beds next to the trees in alley 2 (F_7 = 13.64, P<0.001) and alley 4 (F_6 = 20.61, P<0.001). Linear regression indicated that this lower crop emergence resulted in lower yields in wheat (P<0.001) and triticale (P<0.01) but not oats or barley (Figure 3). These results suggest that crop yields, particularly of wheat and triticale, are reduced as a result of poorer crop establishment when sown in plots adjacent to the tree rows. This may be a direct effect of poorer soil conditions when drilling as well as increased competition for resources with tree roots.

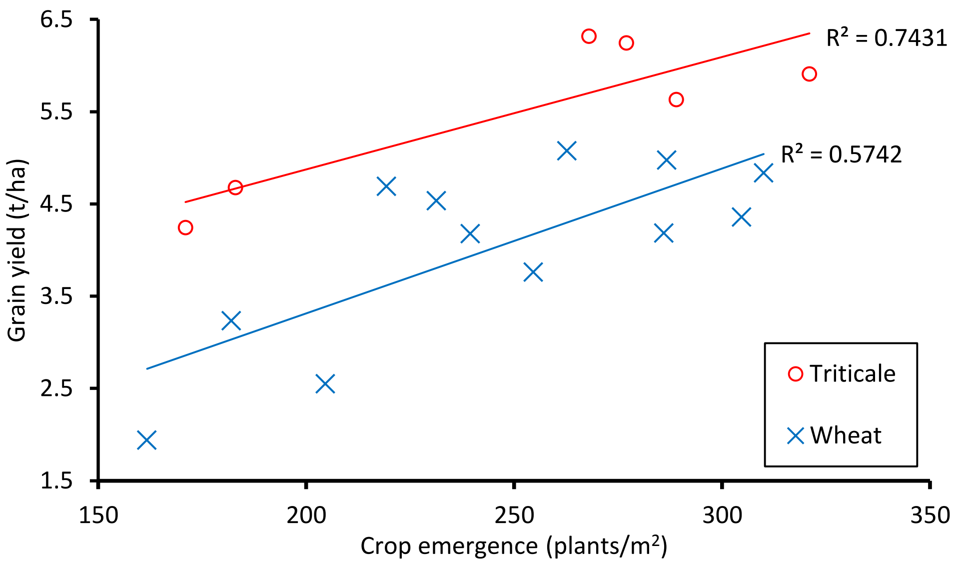

Figure 3. The relationship between grain yield and crop emergence for a spring triticale variety and wheat varieties, mixture and population.

Results from this trial have implications for designing and management of agroforestry cropping systems including optimum alley width and crop choice. Oats seem to be best suited to this system as they are less affected by competition with trees when the shading effect is removed by coppicing. It may, therefore, be advisable to grow spring rather than winter cereals in willow agroforestry so that tree rows can be coppiced in winter and the shading effect of the trees on the crop are minimised.

Results reported here can only indicate the negative effects of the tree rows on crop yields compared to yields in the centre of the alley. The overall crop yields, when compared to an open field may be greater due to the positive effects of agroforestry such as microclimate regulation, soil nutrient availability, increased organic matter and beneficial biodiversity. However, these advantages cannot be quantified in this study.

4 Objective of experiments

Going forward, the experiments to be carried out in 2015 and 2016 aim to assess the competitive effects of the agroforestry tree rows on the cereal growing in the alley and how these competitive interactions can be optimised through evolutionary plant breeding to develop varieties that are particularly well adapted to growing in close proximity to trees. The principle is to let natural selection act on these diverse crop populations to select the plants that are best suited to the prevailing conditions i.e. develop an ‘alley-edge’ population and an ‘alley-centre’ population.

5 System description

Wakelyns Agroforestry is a diverse organic agroforestry system in eastern England which incorporates four silvoarable systems; short rotation coppiced (SRC) willow, SRC hazel, mixed top fruit and nut trees, and mixed hardwood trees with 10-12m-wide crop alleys between tree rows (Figure 4).

Figure 4. Harvesting the wheat population in the willow silvoarable system at Wakelyns Agroforestry.

The reasons behind establishing such a diverse system were manifold: to reduce pest and disease pressure by increasing the distance between individuals of the same species; to increase biodiversity including beneficials such as pollinators and natural enemies; to provide resilience to a changing climate; and to diversify production and reduce the risks associated with farming single commodities.

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

Site characteristics	
Area (ha): Co-ordinates: Site contact: Site contact email address	22.5 52.361489°N; 1.3559639°E Nick Fradgley nick.f@organicresearchcentre.com

Soil characteristics	
Soil type (WRB classification)	
Soil depth	
Soil texture (sand%, silt%, clay%)	Clay to clay loams normally (58% clay, 20% silt, 22% sand)
Additional soil characteristics	

Tree characteristics		
System	Agroforestry system	Reference system*
Tree species	Hazel (*Corylus avellana*)	NA
Variety/rootstock		NA
Tree density (spacing)	Staggered double rows 1.5m between rows and trees	NA
Tree protection	None; mypex weed control barrier	NA
Additional details	Managed as short rotation coppice for bioenergy – coppiced every 5 years, single row only	

Crop characteristics		
System	Agroforestry system	Reference system*
Species	Wheat	NA
Coverage	Seed rate 425 m^2	
Additional details	Composite cross population	

Climate data	
Mean daily minimum temperature	6.1°C (Met Office Scole 1981-2010 averages).
Mean daily maximum temperature	14.4°C (Met Office Scole 1981-2010 averages)
Mean annual precipitation	620 mm
Details of weather station (and data)	Scole met office weather station Location: 52.365, 1.160 Altitude: 27 m above mean sea level

* To which the agroforestry system is compared
NA: not applicable

6 Experimental design

An experiment will be established to test material selected in contrasting environments near to and away from the agroforestry tree rows. A replicated cross-over experiment will allow a comparison of performance of selected material in each environment based on the hypothesis that wheat lines will perform best in the environment from which they were selected (i.e. 'alley edge' selected lines will perform better in the 'alley edge' plots than 'alley-centre' lines).

Table 2. Treatments: environments in which spring wheat lines were selected

Treatment A	Treatment B	Treatment C
East of trees selected lines (EOT selection)	West of trees selected lines (WOT selection)	Centre of alley selected lines (COA selection)

A spring wheat composite cross population (CCP) was grown in plots across a willow system agroforestry alley in 2014. Single ears were selected before harvest from different plots in the centre and either side of the alley and were categorised according to their position (Table 2). Each line was sown as a single 1 m ear row in March 2015 to bulk up seed for further comparative replicated trials. Plots of bulk CCP were harvested separately from plots on either side of the alley. These have enough seed to sow 12 m^2 plots in a replicated cross-over trial to test the effect of the population adapting under natural selection to each environment (Figure 5).

7 Measurements

Large plots of selected CCPs will be assessed for crop establishment yielded using a small plot combine. Other yield components such as thousand grain weight and tillers m^{-2} will also be measured before harvest.

8 Acknowledgements

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EOT sel. pop	= East of trees selected population			
WOT sel. pop	= West of trees selected population			
COA sel. pop	= Centre of alley selected population			
Spr. Pop. Filler	Spr. Pop. Filler	Spr. Pop. Filler	Spr. Pop. Filler	Spr. Pop. Filler
P701 WOT sel. pop.	P710 Spr. Pop.	P719 EOT sel. pop.	P728 W. Pop.	P737 COA sel. pop.
P702 COA sel. pop.	P711 W. Pop.	P720 WOT sel. pop.	P729 Spr. Pop.	P738 EOT sel. pop.
P703 EOT sel. pop.	P712 Spr. Pop.	P721 COA sel. pop.	P730 W. Pop.	P739 WOT sel. pop.
P704 WOT sel. pop.	P713 W. Pop.	P722 COA sel. pop.	P731 Spr. Pop.	P740 EOT sel. pop.
P705 EOT sel. pop.	P714 Spr. Pop.	P723 WOT sel. pop.	P732 W. Pop.	P741 COA sel. pop.
P706 COA sel. pop.	P715 W. Pop.	P724 EOT sel. pop.	P733 Spr. Pop.	P742 WOT sel. pop.
P707 WOT sel. pop.	P716 Spr. Pop.	P725 COA sel. pop.	P734 W. Pop.	P743 EOT sel. pop.
P708 COA sel. pop.	P717 W. Pop.	P726 EOT sel. pop.	P735 Spr. Pop.	P744 WOT sel. pop.
P709 EOT sel. pop.	P718 Spr. Pop.	P727 WOT sel. pop.	P736 W. Pop.	P745 COA sel. pop.
Spr. Pop. Filler	Spr. Pop. Filler	Spr. Pop. Filler	Spr. Pop. Filler	Spr. Pop. Filler

Figure 8. Schematic map showing the layout of the treatments

9 References

Smith J, Wolfe M, Crossland M, Howlett S (2014). Initial Stakeholder Meeting Report: Silvoarable Agroforestry in the UK. 21 November 2014. 8 pp. Available online: http://www.agforward.eu/index.php/en/silvoarable-agroforestry-in-the-uk.html