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AGROFORESTRY: INTEGRATING APPLE AND ARABLE PRODUCTION AS AN APPROACH TO REDUCING COPPER USE IN ORGANIC AND LOW INPUT APPLE PRODUCTION

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SUMMARY

Integrating top fruit production into an agroforestry system, where trees are integrated with arable crop production may have a beneficial effect on the control of plant pathogens such as scab (*Venturia inaequalis*). Apple yields and pest and disease levels were assessed in a novel apple/arable agroforestry system in Suffolk, and compared with a modern local organic orchard in 2012. Despite 2012 being a very bad year for apple production in the UK, apple yields in the agroforestry system appeared to be comparable with standard figures when scaled up from 2.5% land area under apple production to 100% apples, and even at just 2.5% cover, out-performed the organic orchard used for comparison. Initial indications are that scab levels were over twice as high in the organic orchard than in the agroforestry, indicating that this approach may offer some potential in reducing copper use in organic apple production. However, further research will be required to confirm these early results.

INTRODUCTION

Novel land use systems that integrate woody species into the agricultural landscape have the potential to balance productivity with protection of the environment and the maintenance of ecosystem services (Jose, 2009). An emphasis on managing rather than reducing complexity promotes a functionally biodiverse system with both ecological and economic interactions between trees and crops and livestock (Lundgren, 1982). Although the potential of agro-forestry based agricultural systems has been demonstrated in principle (Quinkenstein *et al*., 2009), information of usefulness in the context of European low-input production systems is lacking. Also, the introduction of such systems into European high-yielding traditional apple production systems will meet substantial obstacles as the approach affects not only agronomic performance but also well-established fruit production traditions. As part of the European FP7-funded project 'Innovative strategies for copper-free low-input and organic farming systems (CO-FREE)', we have been evaluating an innovative apple/arable agroforestry system as a potentially sustainable strategy for reducing copper inputs in organic and low input systems. The aim is to provide information on the potential of agro-forestry in the European context.

Integrating top fruit production into an agroforestry system, where woody species are integrated with crop production may have a beneficial effect on the control of plant pathogens such as scab (*Venturia inaequalis*) due to a number of mechanisms:

- A greater distance between tree rows in agroforestry systems, with crops in the adjoining alleys, is likely to reduce the spread of pathogens.
- Lower densities of trees favour increased air circulation which has been shown to reduce

the severity of scab by reducing leaf wetness duration (Carisse and Dewdney, 2002).

- Regular cultivations within the crop alleys will incorporate leaf litter into the soil, thus enhancing decomposition and reducing the risk of re-inoculation from overwintered scabbed leaves the following spring.

Wakelyns Agroforestry, an organic silvoarable research site was established in 1994 on 22.5 ha in eastern England, (52.4ºN, 1.4ºE). Within the apple/arable agroforestry system, a diverse mix of 21 varieties of apple trees on MM111 rootstock are interspersed with 7 timber species (small-leaved lime *(Tilia cordata),* hornbeam *(Carpinus betulus),* wild cherry *(Prunus avium),* Italian alder *(Alnus cordata),* ash *(Fraxinus excelsior),* oak *(Quercus petraea),* sycamore *(Acer pseudoplatanus),* in north/south rows with 12 m-wide crop alleys between adjacent rows (Figure 1). Cereals, potatoes, field vegetables and fertility-building leys are grown in rotation within the alleys. The apple trees cover 2.5% of the land area in the 2 ha system. This design offers the opportunity to increase the spacing among individual trees of a particular species in two dimensions. First, the alley itself separates the rows of trees by 12 m. Second, the tree rows contain eight different tree species, including apple, which are planted as randomised blocks, but with two trees of each species at each planting position. The average distance between adjacent pairs of tree species is about 5 m, so that a single pair of apple trees is represented only once in a 40 m line of trees. This arrangement was designed to mimic the spatial patterns obtained in a mixture of cereal varieties, which has been shown to be a major factor in reducing the rate of spread of fungal diseases among plants (Chin and Wolfe, 1984; Wolfe, 1985). Theoretically, therefore, the apple tree arrangement at Wakelyns should delay the spread of a range of pathogens, and, indeed, pests, relative to a conventional orchard arrangement where the apple host trees are packed more closely in all directions. A local modern 0.6 ha organic orchard acts as a benchmark for comparison (Clarkes Lane Orchard). A new orchard was planted on 0.2 ha of the site in 2004/05, which included plums, pears and 19 varieties of apples, planted on M9 rootstock. Trees are spaced 1.5 m within rows and 3 m between rows; rows vary in length up to a maximum of 45 m. Neither system uses copper to control for scab.

Research has focused on two factors that are likely to be affected by an agroforestry system approach to non-copper use: (i) Yield and quality of apples; (ii) Emergence of primary and secondary pests and diseases.

MATERIALS AND METHODS

The experimental design at Wakelyns consists of 4 plots, each plot including two tree rows and the crop alley in between, with 7-10 apple trees in each plot interspersed with timber trees. In the organic orchard, assessments were carried out in four plots, each plot consisting of two tree rows and the narrow grass alley in between. In autumn 2012, all apples harvested from each site were graded as Class I/Class II/processing/waste and weighed per class and variety. Pests and diseases were assessed in the plots at two points before harvest: small fruits in July 2012 and large fruits in August 2012. One sample consisted of 100 plant units chosen randomly from all trees in the plot area (100 small developing fruits; 100 large fruits pre-harvest). Each plant unit was thoroughly inspected for eggs, insects or insect damage and diseases.

Figure 1: Mixed apple and timber silvoarable system at Wakelyns Agroforestry, Suffolk

RESULTS

Apple Yields and Quality

Apple production in England in 2012 was severely affected by heavy rain from April to June and late frosts, with some fruit farmers reporting losses of up to 90% of their crop (McCarthy, 2012). In the agroforestry and orchard sites, some varieties failed to set fruit (e.g. Cornish Gillyflower at Wakelyns; Spartan and Winter Gem at the orchard), or had very low fruit set. In addition, high levels of scab impacted on yields at the orchard (see below) and so the resulting total apple yields were very low (Figure 2). Yields within the agroforestry were higher than in the orchard, even when taking into account the fact that apple trees cover only 2.5% of the area (tree plus understory). Comparing yields with standard figures from the Organic Farm Management Handbook (Lampkin *et al*., 2012) by scaling up the agroforestry tree area from 2.5% to 100% (i.e. multiplying yield by 40), the yields from the agroforestry compare favourably (Class I & II: 15.7 t/ha from the agroforestry vs. 14 t/ha from orchards at peak production).

Emergence of Primary and Secondary Pests and Diseases

Please note, that due to the low fruit set experienced in 2012, sample sizes within plots were highly uneven, making statistical comparisons inappropriate. Neither the agroforestry apple trees or orchard trees are sprayed for scab and so there were high levels of scab in both systems (Figure 3). However, scab levels of both small and large fruits were over twice as high in the orchard compared with the agroforestry site.

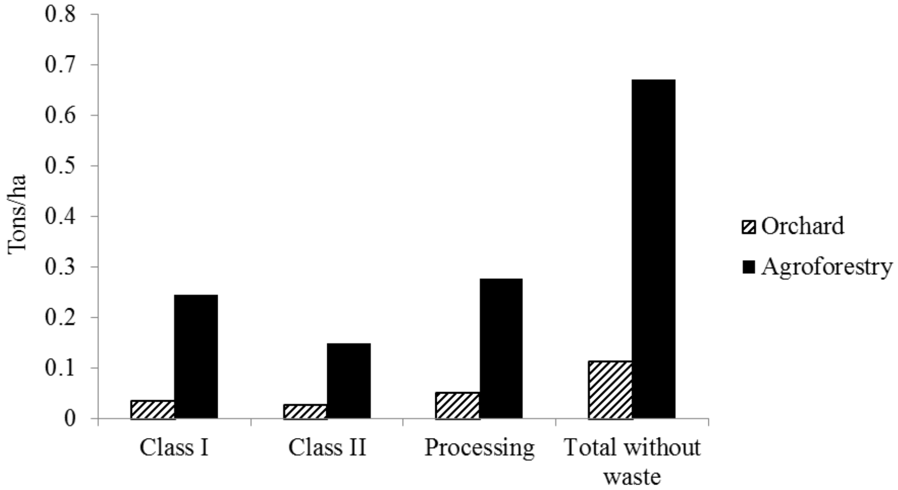

Figure 2: Total apple yields (t/ha) from the agroforestry (black bars) and orchard (striped bars) sites in 2012. NB. Apple trees account for 2.5% of land area in the agroforestry system

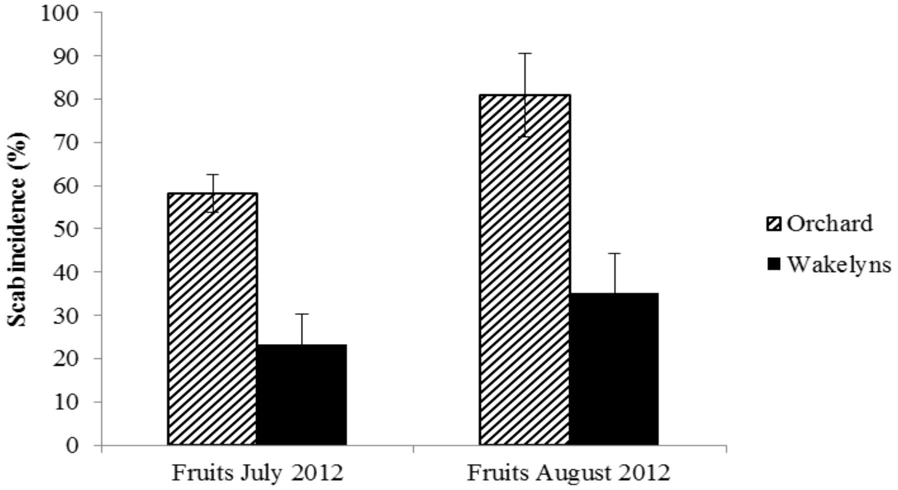

Figure 3: Mean scab incidence per plot (+/- se, *n*=4) in the agroforestry and orchard sites in 2012

Secondary pest and disease damage was also recorded (Figures 4 and 5). A preliminary consideration of the data indicates that cracks in the apples were more abundant at the orchard, perhaps reflecting an erratic supply of water there. There was a higher incidence of insect damage to small developing fruits by sawflies and codling moths in the agroforestry system compared with the orchard. In contrast, codling moth damage was then higher in the orchard in the pre-harvest apples, which may have been due to differences in the phenology of the moth between the systems.

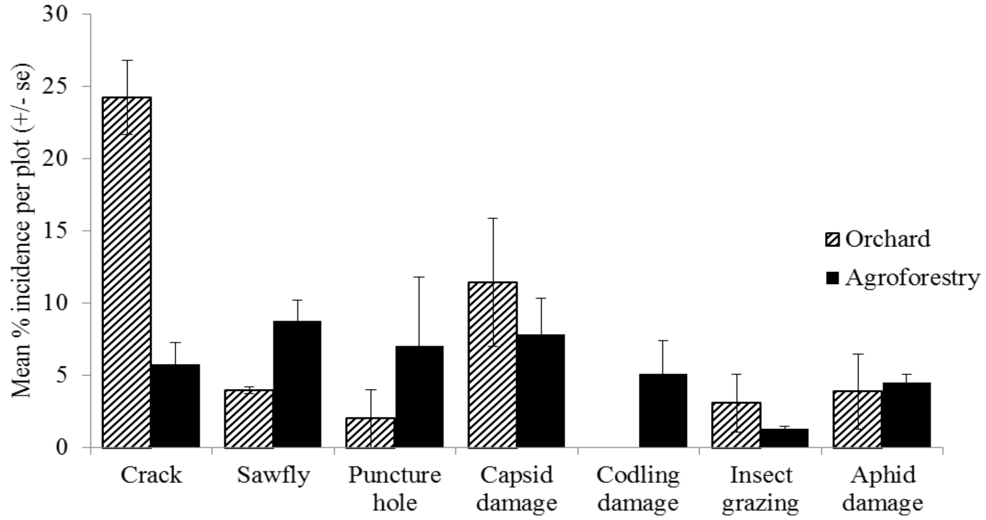

Figure 4: Pest and disease damage per plot (+/- se, *n*=4) to small developing fruit in July 2012

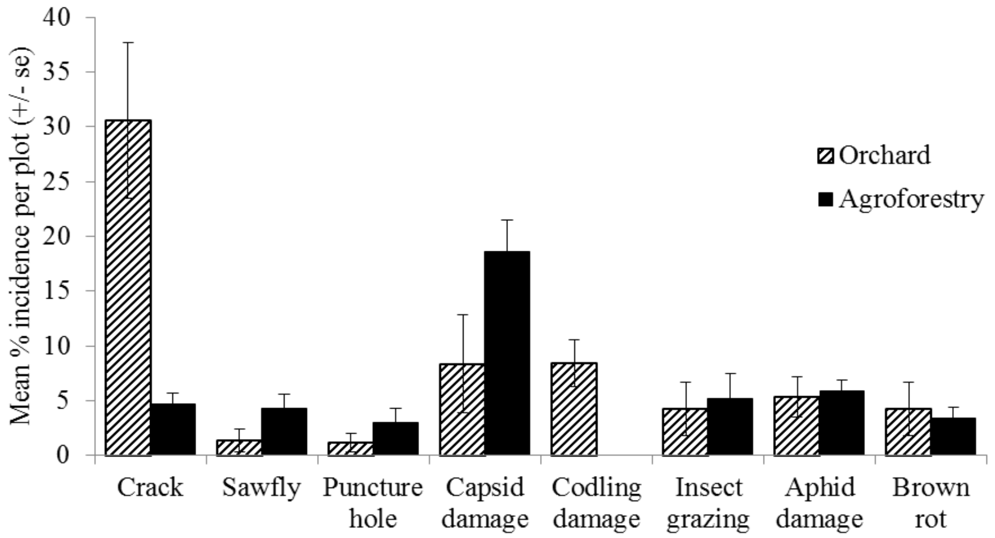

Figure 5: Pest and disease damage per plot (+/- se, *n*=4) to pre-harvest fruit in August 2012

DISCUSSION

Apple yields in 2012 were adversely affected by the weather, with low fruit set due to late frosts and heavy rain. Despite this, the yield from the agroforestry system was comparable with standard figures when scaled up from 2.5% land area under apple production to 100% apples, and even at just 2.5% cover, appeared to out-perform the organic orchard used for comparison. It must be taken into account that the trees within the agroforestry system are on vigorous rootstock and 18 years old, while those in the orchard are on dwarfing rootstock and 8 years old, but it could be argued that both of these systems are in the peak production phase for their rootstock (from 8 years for MM111 and 5 years for M9) and so the comparison at the system level (i.e. agroforestry vs. modern orchard production) is valid. Although no firm conclusion can be drawn from the results to date, it appears as if there may be indications of a potential positive impact on reducing scab levels within the agroforestry. This could be due to the very low densities of apple trees. Also, that while some varieties may fail to set fruit or have high levels of scab, the high diversity of apple varieties within the agroforestry means that other varieties will have compensate and so buffer against extreme losses of yields. However, further research will be required to confirm this theory.

While there appears to be a number of potential benefits to integrating apple production within a diverse agroforestry system in terms of production and reduced disease pressure, there are management considerations associated that need to be taken into account. The apple trees cover just 2.5% of the land area, and so are a minor part of the system, and this would probably not be acceptable for large scale apple producers who rely on economies of scale. However, this approach could work well in a diverse, potentially small-scale system such as a market garden, where apples could contribute to direct marketing channels such as vegetable box schemes or farm shops. Having such a wide range of varieties within the system means that harvesting would occur over a longer period. This requires careful planning and may be a challenge for selling to wholesalers if only small amounts are ready at any one time. New approaches to marketing could address this problem, for example, creating mixed bags of varieties, categorizing by taste, e.g. ‘sweet’ apple bag, or ‘sharp’ apple bag; or by making more of a feature of the varieties if going into vegetable box schemes, e.g. ‘apple of the week’.

In addition to the potential benefits of agroforestry for reducing the need of inputs such as copper for disease control in apples, there may be wider positive impacts on other ecosystem services such as biodiversity support, buffering the microclimate and soil fertility (Jose, 2009), particularly when compared with an arable-only system. In this case, the challenge is all about how best to **manage** complexity rather than aiming to **reduce** complexity.

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