

NEW ALLEY CROPPING TRIAL IN THE MID-WESTERN US WITH MULTI-LAYER NUT AND FRUIT TREE ROWS

Wolz KJ^{1*}, Branham B², Guest J³, Paulson N⁴, Revord RS², Wander M², Yang W⁵, Lovell ST²

* Correspondence author: wolz1@illinois.edu

(1) Program in Ecology, Evolution, and Conservation Biology, University of Illinois at Urbana-Champaign, Urbana, IL, USA (2) Department of Crop Sciences, University of Illinois at Urbana-Champaign, Urbana, IL, USA (3) Department of Civil & Environmental Engineering, University of Illinois at Urbana-Champaign, Urbana, IL, USA (4) Department of Agricultural Economics & Policy, University of Illinois at Urbana-Champaign, Urbana, IL, USA (5) Department of Plant Biology, University of Illinois at Urbana-Champaign, Urbana, IL, USA

Introduction

Alley cropping systems are one of the most common agroforestry applications around the world. Simple and scalable, alley cropping systems integrate rows of woody crops with an 'alley crop' in the intervening 'alleys'. The archetypal alley cropping system contains a single timber-producing tree species within the rows (e.g. walnut or poplar trees) and an herbaceous crop in the alleys (e.g. wheat or hay). This setup allows the producer to focus on and continue to mechanically harvest the alley crop while the timber crop matures over the long run. Despite the effectiveness of alley cropping to date, two major gaps exist in the current research and application of alley cropping systems, both of which show great promise in improving these systems and should be a top priority for the agroforestry community.

The first gap is the diversification of the woody crop rows by leveraging multiple species and/or multiple canopy layers within the rows. Despite the potential benefits of multispecies systems being well documented (Malézieux *et al.* 2009, Piotto 2008), the typical alley cropping system still contains monospecific, single-layer tree rows. In this scenario, the trees are spaced within the row at a distance determined by mature canopy width (often 10-25 m), leaving a substantial amount of unutilized space between trees within the rows. Additional crops utilized in this space could add to the productivity of the system without interfering with either the primary tree crop or the alley crop.

One of the simplest implementations of tree row diversification in alley cropping systems is either via within-row diversification or between-row diversification of the existing canopy tree layer. Within-row diversification would leverage a strong niche complementarity effect between the two tree species. Between-row diversification would be preferred, however, if management efficiency was much higher with monospecific rows (e.g. with some types of mechanical harvesting). Further diversification approaches exist due to the three-dimensional nature of woody systems. Rather than diversifying the original canopy tree layer, a diversified alley cropping system can be implemented with the addition of an 'undercrop': an additional woody crop that grows within the same row as the primary tree crop but occupies a lower canopy layer. For example, planting shade-tolerant shrubs in between the canopy trees could increase the space utilized, light captured, and yields obtained early in the succession of the system. Diversity can be further increased by adding undercrops in other canopy layers or by adding additional species to each undercrop layer.

The second gap is the utilization of food-producing fruit and nut trees rather than timber/biomass species within the woody crop rows. Food-producing tree crops of all kinds have longstanding global markets and have garnered increased investment in the US and Europe by both industry and academia over the past two decades (Molnar *et al.* 2013). Beyond specialty/niche markets, some woody crops even have potential as staple food crops. Chestnut (*Castanea* sp.) and hazelnut (*Corylus* sp.), for example, could functionally replace maize (*Zea mays*) and soybeans (*Glycine max*), respectively, as industrial sources of starch, oil, and protein (e.g. Smith 1929, Benitez-Sánchez *et al.* 2003). Another important benefit of food-producing tree crops compared to timber crops is that, once established, they produce marketable products each year, thereby diversifying farmers' revenue streams and potentially providing a quicker return on establishment costs.

Here, we describe and discuss a new, large-scale field trial that aims to explore not only these two major gaps in alley cropping research and application, but also the potential of combining the two strategies. These two strategies have rarely been applied together and have almost never been considered as viable options for temperate food production. Combining the separate benefits of diversified woody rows and food-producing tree crops into diverse food-producing alley cropping systems could create a transformative temperate agroforestry model.

Study site

In May 2015, a new 12-hectare multi-layer alley cropping field trial was established in Urbana, IL, USA at the University of Illinois at Urbana-Champaign (**Figure 1**). The trial contains four replicate plots each of seven treatments, arranged in a randomized complete block design. Each plot is approximately a 0.4 ha square containing eight tree rows spaced 9 m apart with an alley crop of grass-clover hay. The site experiences a temperate, continental climate with a mean annual temperature of 11°C, an average of 18.5 days that reach greater than 32°C, and an average of 122 days that reach lower than 0°C. Mean annual rainfall is 1050 mm, with mean annual snowfall adding an additional 590 mm of equivalent rainfall. The dominant soil type at the site is a silt loam to silty clay loam, with 0-2% slope across the site. The land-use history has been conventional row-crop agriculture (recently, a maize-soybean rotation) for over 100 years, making region-wide comparisons possible.



Figure 1: Site layout of the multi-layer alley cropping field trial at the University of Illinois at Urbana-Champaign.

The main goal of the field trial is to explore the potential of and synergy between the alley cropping strategies of (1) multispecies woody crop rows and (2) food-producing woody crops. Consequently, the primary treatment variable in the trial is the composition and arrangement of species within the woody crop rows. The four primary woody crops used in the trial are Chinese chestnut (*Castanea mollissima* 'Qing'), European hazelnut (*Corylus avellana* 'Yamhill'), semi-dwarf apple (*Malus domestica* 'Liberty'), and black currant (*Ribes nigrum* 'Blackcomb'). Chestnut and hazelnut were selected due to their functional similarity to maize and soybean, apple because it is the most common fruit crop of the region, and black currant due to its relatively high shade tolerance. The treatments are as follows:

Maize-soybean rotation – A 'control' treatment to compare the new agroforestry systems to the dominant surrounding land-use.

Component monocultures of woody crops – Industry-standard monoculture plantations of the four major component woody crops (**Figure 2**, treatments 2C, 2A, 2H, and 2U)

Simple two-species alley cropping – Alternating, mono-specific rows of chestnut and hazelnut (**Figure 2**, treatment 3).

Addition of a single undercrop – The same as treatment 3, but with the addition of an undercrop of black currant as a second canopy layer (**Figure 2**, treatment 4).

Double density canopy nut trees – The same as treatment 3, but with the canopy nut trees at double density (**Figure 2**, treatment 5).

Addition of a second undercrop – The same as treatment 4, but with the addition of a second undercrop of apple as a third canopy layer (**Figure 2**, treatment 6).

Hyper-diverse woody rows using native species – Serves as diversity extreme that mimics the same alley cropping structure but has a species composition acceptable to most conservation strategies. Utilizes the same structural composition (i.e. the density/arrangement of each

canopy layer) as treatment 4, but includes 8 native fruit/nut-producing species: pecan (*Carya illinoensis*), American persimmon (*Diospyros virginiana*), American plum (*Prunus americana*), pawpaw (*Asimina triloba*), saskatoon serviceberry (*Amelanchier alnifolia*), American hazelnut (*Corylus americana*), American elderberry (*Sambucus canadensis*), and black chokeberry (*Aronia melanocarpa*) (not illustrated in Figure 2).

In each of these treatments, within-row spacing of canopy nut trees follows regional recommendations for monospecific plantations. Successive undercrop diversity was added only within rows to maintain the productivity and manageability of the alley crop. All of the plants in the field trial were installed over two days using a mechanical tree planter, and the 1-m band of tree rows was sprayed with pre-emergent herbicide to minimize weed pressure. Irrigation was neither necessary nor used. Tree tubes were installed on the apple trees to protect them from small mammals. The entire field site was enclosed in a simple three-wire, double-depth fence to keep out deer. The hay alley crop was drilled in the spring prior to tree planting and mowed regularly during the establishment year. In future years, the alley crop will be cut and removed as hay, and the 1-m within row bands will continue to be kept free from weeds using herbicide.

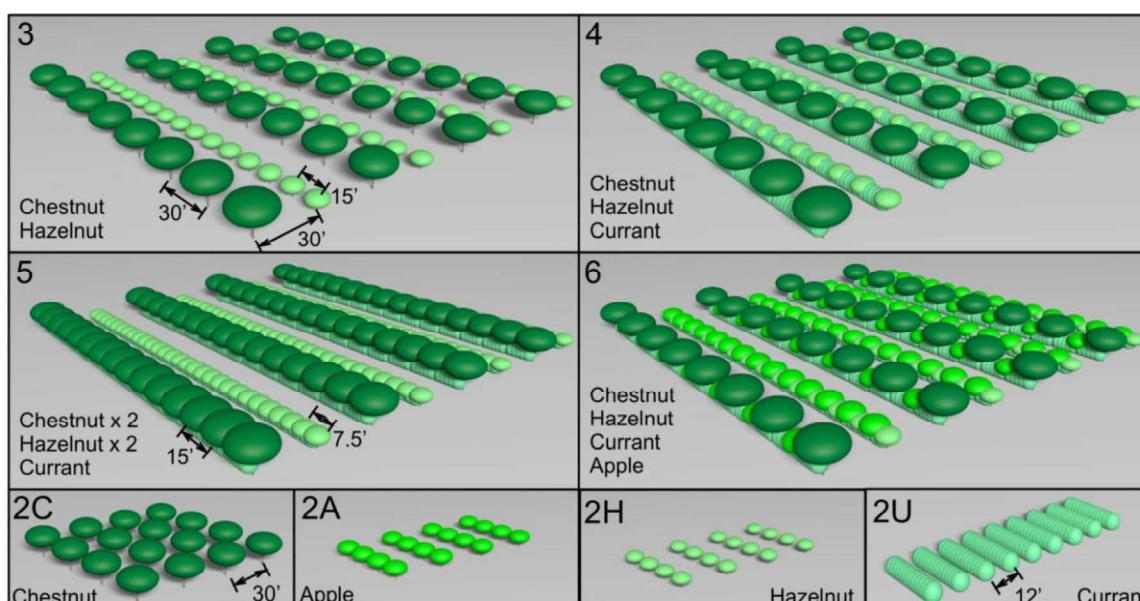


Figure 2: Hypothetical three-dimensional geometry of experimental treatments at maturity.

Conclusion

The two major innovations that are the focus of this new field trial, multispecies woody crop rows and food-producing woody crops, are significant existing gaps in temperate alley cropping research and application in both the US and Europe. It is our aim that this new field trial will provide a major opportunity to explore these strategies over the next 20+ years and will provide significant results that are applicable across the temperate zone. Since the agroforestry paradigm is much more widely accepted and implemented in Europe than it is in the US, we look forward to developing strong collaborations with European agroforestry allies in the years to come.

References:

- Benitez-Sánchez PL, León-Camacho M, Aparicio RN (2003) A comprehensive study of hazelnut oil composition with comparisons to other vegetable oils, particularly olive oil. *European Food Research and Technology* 218:13–9.
- Malézieux E, Crozat Y, Dupraz C, Laurans M, Makowski D, Ozier-Lafontaine H, Rapidel B, de Tourdonnet S, Valantin-Morison M (2009) Mixing plant species in cropping systems: concepts, tools and models: a review. *Agronomy for Sustainable Development* 29:43–62.
- Molnar T, Kahn P, Ford TM, Funck CJ, Funk CR (2013) Tree crops, a permanent agriculture: concepts from the past for a sustainable future. *Resources* 2:457–88.
- Piotto D (2008) A meta-analysis comparing tree growth in monocultures and mixed plantations. *Forest Ecology and Management* 255: 781–6.
- Smith JR (1929) *Tree Crops: a Permanent Agriculture*. Harcourt, Brace and Company, New York.