ARABLE WEEDS IN ALLEY CROPPING AGROFORESTRY SYSTEMS – RESULTS OF A FIRST YEAR SURVEY

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Introduction

Interest for agroforestry, i.e. association of trees and crops in the same fields, is growing in Europe. Among the agroforestry systems, the alley-cropping systems combine parallel tree rows and cropped alleys, which are large enough to allow mechanization. For these systems, one of the issues addressed by French farmers concerns weed management (Cirou and Hannachi, 2014; Wartelle 2014). Indeed, weeds could induce important yield losses (Oerke, 2006). Moreover since seeds can persist for a long while in the soil, a single bad weed control a given year could have long-term repercussions (Barralis et al., 1988). In the alley cropping agroforestry systems, one particularity is the presence of herbaceous vegetation on the strip of the tree rows. In the manner of field boundaries, this vegetation could be a source of potential weeds for the crops of the interrow if the species of the strip spread towards crop alleys (Marshall, 1989; Marshall and Moonen, 2002). These uncropped strips take up a big part of the field, as they are settled on 3 to 8% of the field area according to tree row spacing (about 13 to 30 m), which justifies the fear of farmers. Additionally the trees could modify the microclimatic conditions of the field under the canopy (e.g. available light radiation for crops, temperature, soil moisture). These modifications of environmental conditions, associated with the tree understory at the edge of cropped alleys might thus result in a different effect of weeds on crops, both because of different species and different competitive ability of weeds in agroforestry systems compared to pure crop systems. To this day very few surveys have studied the impact of alley cropping agroforestry system on weed communities (e.g. Burgess et al., 2003), and, to our knowledge, none of them have been carried out on more than 10-years-old agroforestry plantations. If the challenge of weed management is first the reduction of the harmfulness of weeds towards crop, it is now well-established that weeds play a key-role for biodiversity conservation (Petit et al., 2011). In order to design sustainable weed management options that are adapted to agroforestry, it is first necessary to better know the weed communities in these agroecosystems. Thus, the objectives of the present study were (i) to compare the arable weed communities in agroforestry vs. pure crop control, in terms of species composition, richness, and abundance, and (ii) to assess the effect of the distance to the under-tree vegetation on the structure of weed communities within the crop alleys.

Material & Methods

Weed survey was carried out in 2015 in a mature 20-years-old experimental field of INRA Montpellier. The cropping system carried out on the field has remained quite constant during the past 20 years. Crop management is conventional and typical of the region, with a pea/winter durum wheat/winter barley rotation. Tillage is superficial and mouldboard ploughing is done every three years. This 6 ha field was cropped with winter barley in 2015. The field is divided in two parts: a control part (TA), consisting of pure crop, and a medium-shaded agroforestry system (AF), with 20 years-old hybrid walnut trees. In the AF system, alley crops are 12 m width and the under-tree strips is 1 m width and composed of spontaneous vegetation, mowed once every 5 or 6 years. Weeds were surveyed at 3 dates: (1) at the onset of vegetation in spring but before tree budbreak (March), (2) one month after tree budbreak when leaves were well developed (May), and (3) at the end of summer, two months after crop harvest (September, no tillage was carried out during the summer). Species and specific abundance were recorded within 1 m² quadrat plots placed regularly (at distances of 1.17 m) along three transects that were perpendicular to the tree rows, resulting in 5 quadrats per alley and 1 quadrat per under-tree strip. Six alleys were studied. In the pure crop control, the same number of quadrats were made along three transects we placed in the middle of the control part (sufficient distance to avoid boundary effects of field margin or AF part on the control) in the prolongation of the agroforestry transects. In total, 603 quadrats were studied in the 2 treatments for all the survey sessions. In each quadrat and for each session, the photosynthetically active radiation was calculated from hemispherical photos taken in each quadrats, which were analyzed with WINSCANOPY software (**Figure 1**).

The comparison between agroforestry and pure crop control, as well as the effect of distance to the under-tree vegetation strip, were analyzed with a generalized linear mixed model (GLMM) (Onofri et al., 2010). The composition was analyzed through a Principal Coordinates Analysis (PCoA) carried out on the Jaccard (presence/absence) similary index (Kenkel et al., 2002)

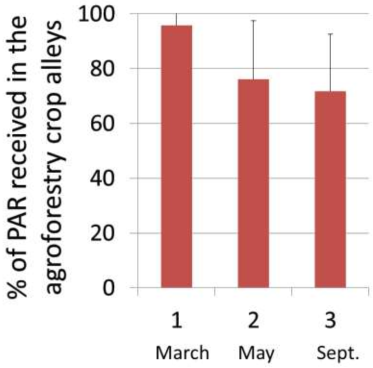

Figure 1. Evolution of the Photosynthetically Active Radiation (PAR) received under the tree canopy in the crop alleys compared to pure crop control situation.

Results

Pure crop control vs. agroforestry

The total number of weed species over all samples of a given field (system diversity) was significantly higher in agroforestry (without accounting for the species present in the strip) than in the pure crop field, with about 35 vs. 25 species per session respectively. At the quadrat level (alpha diversity), the results show a similar number of species per quadrat in agroforestry and pure crop control (about 5 to 6 species/m²) for the two spring sessions, but a significantly higher diversity in agroforestry plots two months after crop harvest (about 8 species/m² in AF vs. 5 species/m² in the control, respectively). The same results were found when analyzing the composition (i.e. assemblage of species within a quadrat): the frequent species were the same and showed similar relative abundance in the communities in AF than in control plot for the two spring sessions whereas quite different compositions (species and relative abundance per species) were observed at the end of summer between AF and control plot (**Figure 2**). In terms of abundance, there was significantly more individuals/m² in the pure crop control than in agroforestry, except at the end of summer (**Figure 2**)

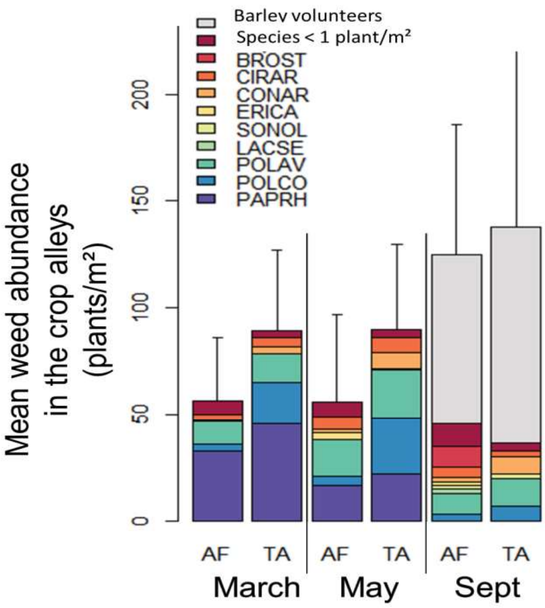

Figure 2. Specific and total abundances of flora at quadrat scale for the three sessions.
AF=agroforestry system, TA=pure crop control. BROST: *Bromus sterilis*, CIRAR: *Cirsium arvense*, CONAR: *Convolvulus arvensis*, ERICA: *Conyza canadiensis*, SONOL: *Sonchus oleraceus*, LACSE: *Lactuca serriola*, POLAV: *Polygonum aviculare*, POLCO: *Fallopia convolvulus*, PAPRH: *Papaver rhoeas.* Different letters above the bars indicate significant difference between groups (α=1%, general linear mixed models performed for each session).

Effect of under-tree vegetation strip on weed communities

Composition of vegetation was similar between pure crop control and crop alleys of the AF system and differs from the composition of the AF strip vegetation (results of PCoA, not shown here). About 33% of the species present in the strip were never found in the crop alleys (22 species on 65 species observed in the entire agroforestry plot). For each of the spring sessions, there were significantly more species in the crop alley quadrats that subtended the strip (at 2.17 m in the crop alley from the middle of the strip), than in the other quadrats (4.34 m and 6.51 m from the middle of the strip) (Figure 3). However we did not observe increased weed abundance close to the herbaceous strips during these two spring sessions. On the opposite, abundance at the end of summer (September) was significantly higher in the quadrats places at 2.34 m from the strip than in the other ones.

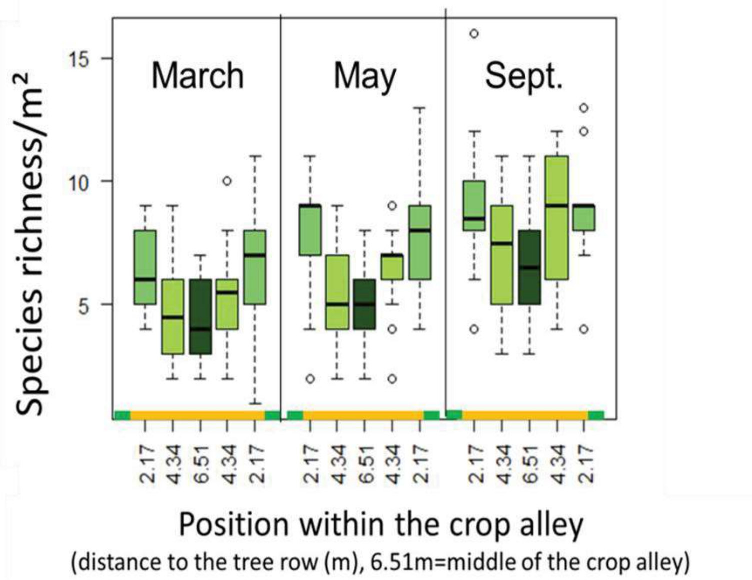

Figure 3. Distribution of species richness at quadrat scale (1 m²) as a function of the position in the crop alley (interrow) in the agroforestry part. Each boxplot is the distribution of the richness for 18 quadrats (6 alleys x 3 transects).

Our results were consistent with the observations of Marshall (1989) focused on the impact of field margin vegetation on weed distribution in pure crop field, who showed a positive effect of margin on species richness along the first meters of the field. In the single weed survey in temperate AF we found (Burgess et al. 2003), the authors also showed a greater diversity of weeds in agroforestry crops than in pure crops. However, they observed a greater cover of weeds in the agroforestry alleys (spring survey) whilst our results showed the opposite. Nonetheless their weed survey was made in fields where the strips were sown one year before the monitoring, maybe due to more ruderal species in their fields than in ours (i.e. species able to settle in disturbed habitat such as the young-sown strip or the arable crop alleys). In spring when the crop is growing and is sensitive to weed competition, the total abundance of species was lower in agroforestry system what was explained by the lower abundance of the most frequent weed species in AF compared with TA (*Papaver rhoeas, Fumaria officinalis, Fallopia convolvulus, Polygonum aviculare*). One hypothesis could be that these species, which are very much adapted to arable crop conditions, might be a little triggered by the microclimatic conditions of AF plot. At the end of the summer, which was warmer and drier in 2015 than standard conditions in the region, the weed community in AF was composed of new species that emerged after harvest and were likely to be favored by the conditions of AF. The higher abundance close to the strip at the end of summer, which was not observed when crop were growing (spring sessions), showed that the most diverse community close to the strip we observed in spring might have been triggered by the competition with crops in spring (when higher diversity but no higher abundance was observed). In summer, when there is no crop in the field and as a consequence no competition with crops, more weed individuals could emerge and grow. The increased number of species in AF plot could be a source of ecosystem services, on condition that abundance, and above all biomass of weeds, does not increase too much (as shown in this first year survey), to avoid higher crop:weed competition. Our results lead to the conclusion that the cropping system carried out in the experimental fields is efficient to control weeds that developed in summer, not to have increased populations during crop growth. However some of the common species of the alleys and the strips are potentially difficult to manage (e.g. *Galium aparine, Lolium rigidum, Papaver rhoeas*). Thus weed management should include considerations of the strip margins in order to avoid problematic situations at long-term.

As for all studies on the effect of cropping systems on weed communities, the survey need to be carried out th next year, to have results all along the crop rotation. Moreover, these first results might be site-specific. Thus the survey will be completed by future surveys in farmers' fields to follow the study of the effect of the crop management and the strip management (sown vs. spontaneous vegetation) to control weed harmfulness in agroforestry (e.g. weed seed production, weed biomass and consequence in terms of yield losses,..) while promoting their contribution for biodiversity (e.g. for seed-eating organisms).

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