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# Wheat/clover temporary intercropping for weed management. An on-farm study from Central Italy

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**Summary**

Intercropping, the simultaneous cultivation of two or more crops, is often proposed as a promising tool for low-input arable cropping systems. By using ecological processes and agro-biodiversity, intercropping is able to provide a wide range of agro-ecosystem services. Yet farmers' knowledge is crucial if effective innovation has to take place, and their involvement in the research process can lead to very positive research outcomes. We tested a wheat/clover temporary intercropping system against two control treatments, in two farm trials in the growing season 2016/2017. Weed samplings were performed at the wheat steam elongation phase, and subsequently weed relative density and diversity indexes calculated. We found that intercropping was able to reduce weed relative density at both sites, whereas it had a site-specific effect on weed diversity indexes. At the site where the situation was most reliable, we found that intercropping decreased weed diversity indexes, indicating a less even weed community than in the other two control treatments. Reduced weed density in intercropping is most probably linked to higher competition for resources, e.g. light, and surely represents a beneficial effect of intercropping. A less even and diverse community, nonetheless, may lead in the long-run to a specialized weed community where perennial weed species are favoured, if other weed management tools are not employed by the farmer. We conclude that intercropping represents an effective tool in the hands of low-input and organic arable crop farmers, and it should be employed together with other measures in order to achieve effective weed management.

**Key words**: Intercropping, on-farm, weed, Shannon, Simpson, living mulch, agro-biodiversity

## Introduction

Organic and low-input arable cropping systems need novel ways to manage weed communities. Intercropping, the simultaneous cultivation of two or more crops, has proved to be a promising tool to enhance weed control without reducing crop yield (Verret *et al.*, 2017). Intercropping is part of a bigger shift in agricultural systems referred to as ecological intensification (Doré *et al.*, 2011), where ecological processes and the use of biodiversity are intensified for the provision of specific agro-ecosystem services. Research in Italy has been carried out on intercropping systems involving large-seeded legumes (Tosti & Guiducci, 2010; Antichi, 2013), but little is known about small-seeded legumes like clover (Campiglia *et al.*, 2014) with rows 15cm apart (same row). Surprisingly enough, despite a good body of knowledge produced on the effect of intercropping on weed biomass, still scant information can be found on weed diversity and composition. Tittonell

(2014) noted that making use of the regulating functions of nature is only a part of the greater food system change envisioned by agroecology. In fact, agroecology entails also new forms of knowledge production that put at the centre the role of farmers, as active participants in the research process. Our aim was to study the effect of a wheat/clover temporary intercropping system on the weed community, in terms of plant density, species richness and diversity, in a real farming context, by involving farmers in an on-farm trial where both ecological and farming control treatments were tested against intercropping.

## Materials and Methods

We set up two farm trials, hereafter referred as to Valtriano 2017 and Santa Luce 2017. We aimed to compare an intercropping system (PCWpr) (Persian clover and common wheat) with two sole crop wheat control treatments (CONTROLSTRIP and CONTROL). Treatments were decided, together with the farmers, during two participatory focus groups held on 17 September 2015, and 28 September 2016. Crops in PCWpr were sown in paired rows on the same day (1 November 2016). The inter-row distance was 16 cm, while the inter-strip distance was 48 cm. The two crops co-existed until March 2017 (wheat BBCH GS 31), when the clover crop was incorporated into the soil by means of a rotary hoe. From then onwards, wheat grew alone until harvest (June 2017). CONTROLSTRIP was an unfertilized wheat sole crop, sown in paired rows and managed like in the intercropping, but without the clover crop. CONTROL was a wheat sole crop, customarily sown in single rows and fertilized with organic poultry manure. The preceding crop was millet in the case of Valtriano 2017, and oilseed rape in the case of Santa Luce 2017.

The weed species (all species that were not seeded) were identified and the number of individuals for each species (density) was assessed on 29 March 2017 at Valtriano, and on 5 April 2017 at Santa Luce, at wheat BBCH GS 31. The sampling area was 0.075 $m^{-2}$ (0.25 m × 0.30 m) at both sites.

Weed abundance was calculated as a relative density value compared to the reference treatment, represented by CONTROL, as follows:

Relative density = actual weed density (plants $m^{-2}$)/average CONTROL weed density (plants $m^{-2}$). Relative densities were then analysed statistically using a mixed effects modelling procedure, as described by Zuur *et al.* (2009). Treatment and relative density were considered as fixed effects, whereas Location, Block (nested in Location) and Subplot (nested in Block) were considered as random effects. The significance of the explanatory variables was tested by using a likelihood ratio test, i.e. two mixed models were compared in terms of AIC and log likelihood, with a Maximum Likelihood (ML) estimation, and probabilities equal to or less than 0.05 were considered significant. The model was then refitted with Restricted Maximum Likelihood (REML) estimation, to correct the estimator for the variance. The significance of differences among treatments was estimated by using multiple comparison of means, and probabilities equal to or less than 0.05 were considered significant. In order to test the model assumptions (normality, homogeneity of variances, violation of independence), Shapiro-Wilk test, and Levene test were performed, as well as graphical assessments. Data on species richness, Shannon diversity and Simpson diversity were interpolated and extrapolated based on Hill numbers (q = 0 for species richness, q = 1 for Shannon diversity, q = 2 for Simpson diversity), using the iNEXT package (Chao *et al.*, 2014; Hsieh *et al.*, 2016).

## Results

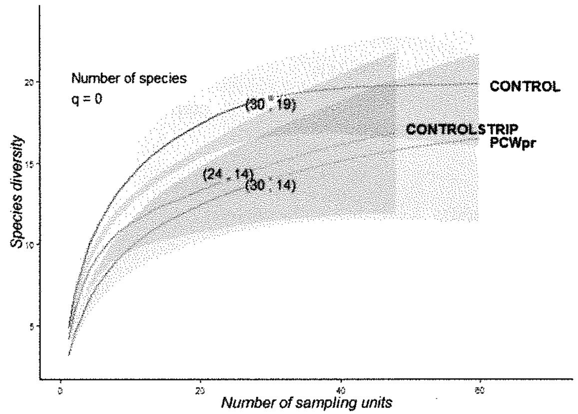
Overall, the presence of the companion clover crop in PCWpr was effective at decreasing relative weed density, compared to both control treatments (Table 1). Weed relative density in PCWpr was significantly less compared to CONTROL (-21.45%) and CONTROLSTRIP (-38.7%) at Valtriano 2017, and significantly less compared to CONTROL (-26.79%) and CONTROLSTRIP (-36.7%) at Santa Luce 2017.



Table 1. *Comparison of relative weed densities in the three treatments at both locations*

| Location | Treatment | Weed relative density | | Standard error |
|---|---|---|---|---|
| Valtriano 2017 | CONTROL | 1.03 | b | 0.08 |
| | CONTROLSTRIP | 1.32 | c | 0.12 |
| | PCWpr | 0.81 | a | 0.07 |
| Santa Luce 2017 | CONTROL | 0.96 | b | 0.04 |
| | CONTROLSTRIP | 1.11 | c | 0.06 |
| | PCWpr | 0.70 | a | 0.06 |
| F test | | *** | | |

Valtriano 2017




Santa Luce 2017

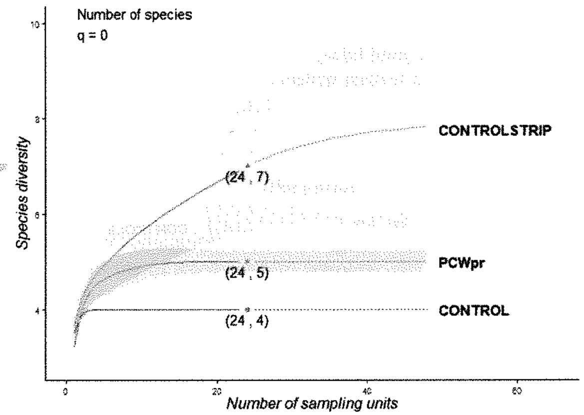
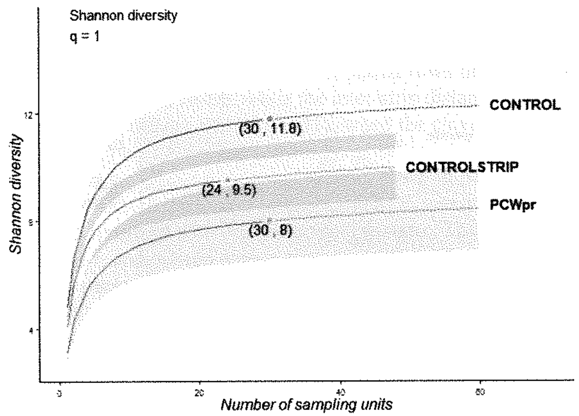



Fig. 1. Comparison of sample-size-based rarefaction (solid lines) and extrapolation (dashed lines) curves with 95% confidence interval, obtained by a bootstrap method based on 200 replications, for species richness at Valtriano 2017 and Santa Luce 2017.

Weed species richness, Shannon diversity and Simpson diversity are reported in Figs 1, 2 and 3. The differences between the two locations were extremely high, as Valtriano resulted in much higher diversity than Santa Luce. At Valtriano 2017 the temporary intercropping technique (PCWpr) resulted in slightly less weed species richness, lower Shannon index and lower Simpson index when compared to CONTROLSTRIP and CONTROL. At Santa Luce 2017 instead, CONTROL resulted in the lowest number of species detected, lowest Shannon and Simpson index. CONTROLSTRIP seemed to have higher species richness than the other two treatments, a similar Shannon and Simpson index to PCWpr. The extremely low number of weed species detected in Santa Luce 2017 did not allow for a clear-cut comparison among treatments.

Valtriano 2017




Santa Luce 2017

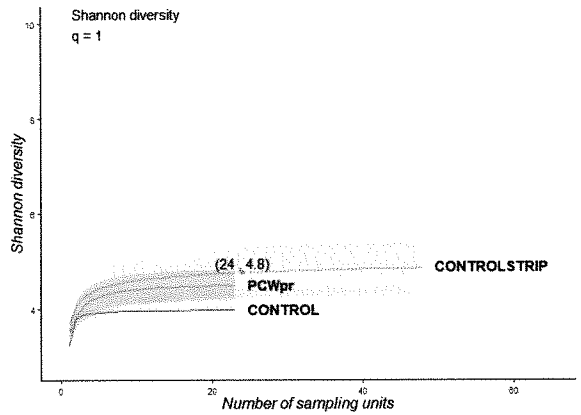
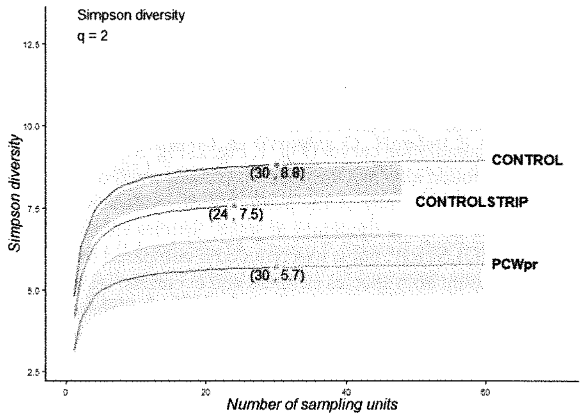



Fig. 2. Comparison of sample-size-based rarefaction (solid lines) and extrapolation (dashed lines) curves with 95% confidence interval, obtained by a bootstrap method based on 200 replications, for Shannon diversity at Valtriano 2017 and Santa Luce 2017.



Valtriano 2017




Santa Luce 2017

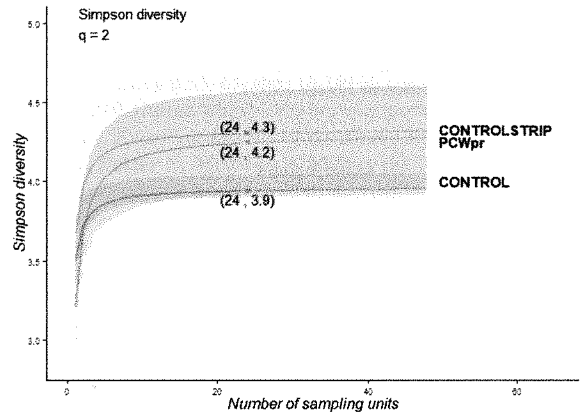



Fig. 3. Comparison of sample-size-based rarefaction (solid lines) and extrapolation (dashed lines) curves with 95% confidence interval, obtained by a bootstrap method based on 200 replications, for Simpson diversity at Valtriano 2017 and Santa Luce 2017.

## Discussion

The presence of the clover companion crop in PCWpr, during the early stages, was overall efficient at limiting the relative density of weeds, regardless of the growing site. This is in accordance with what was found by Amossé *et al.* (2013) for relay cropping and with Costanzo & Bàrberi (2016) and Hiltbrunner *et al.* (2007), who found the same reduction in weed density for a wheat-clover living mulch system. This could be the result of a smothering effect on weed germination, as well as an increased mortality of weed seedlings, due to competition for resources, e.g. light (Bàrberi, 2002; Kruidhof, 2008) relatively little attention has so far been paid to research on weed management in organic agriculture, an issue that is often approached from a reductionist perspective. This paper aims to outline why and how this problem should instead be tackled from a system perspective. Compared with conventional agriculture, in organic agriculture the effects of cultural practices (e.g.

fertilization and direct weed control, mostly linked to the legume biomass production (Amossé *et al.*, 2013).

The different patterns observed at the two locations did not allow us to draw general conclusions on the effect of intercropping on weed species diversity. Yet, between the two farm trials, Santa Luce 2017 resulted to be the less reliable one, showing an extremely low number of weed species, ranging from 4 in CONTROL to 7 in CONTROLSTRIP. This lack of variability has certainly undermined the creation of accumulation curves (Fig. 1, Fig. 2, Fig. 3), and thus a solid analysis of weed diversity at that site. As found also by Döring *et al.* (2012), weed diversity is more likely to be influenced by the history and geography of any particular site. Valtriano 2017, on the contrary, offered a clearer picture of the diversity dynamics at stake. Species richness in PCWpr was not reduced compared to CONTROLSTRIP, but it was reduced if compared to CONTROL. Shannon diversity, which takes into account both species richness and evenness, was considerably lower in PCWpr than in both control treatments, indicating a less uniform weed community in the presence of the companion clover crop. Simpson diversity was also considerably lower in PCWpr compared to both CONTROLSTRIP and CONTROL, suggesting a smoothing effect also on the most abundant weed species. Our results on species richness and diversity are in contrast with those of Poggio (2005), who found no difference in terms of species richness, diversity and evenness in a pea-barley intercropping system, and with Barilli *et al.* (2017), who found more varied weed communities in a lucerne-wheat intercropping system. A less even weed community in the intercropping system PCWpr could be the result of a selective competitive effect exerted by the clover crop towards certain weed species, leading, in the long-run, to a specialized weed community where perennial weed species may be favoured (Liebman & Dyck, 1993).

## Conclusions

This study showed the potential of wheat-clover intercropping in terms of weed smothering ability in the early stages of crops co-existence. Weed density was diminished at both sites, and therefore the potential competitive effect towards the wheat crop. This paper also acknowledged the site-specific nature of weed community diversity, and revealed that in some cases weed diversity may be decreased by the presence of a legume companion plant, leading to a specialization in the weed community. Once technical obstacles are overcome, farmers may consider intercropping as one of the alternative measures for managing weeds in organic and low-input farming systems.

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