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How about biological control in market gardening agroforestry?

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Abstract

Agroforestry is now aknowledged as a relevant tool for agroecological transition. It can provide multiple services to soil, crop, biodiversity… Systems associating diversified vegetables and fruit trees in France are increasingly interesting farmers. Fruit trees can also provide multiple services, and productive one might not be the main one. In this study, we investigated if biological control on vegetable and fruits could be improved by associating both types of crops. We worked on 3 kinds of plots (vegetable/orchard/mixed) from 2019 to 2022 and assessed predation rates and diversity in these plots by using sentinel preys between april and july (4 to 5 sessions per year).

Although some years gave significative effect on agroforestry on predation rates, global analysis of data on all sessions from 2019 to 2022 could not provide any evidence that predation service was improved in mixed systems compared to simple ones. In addition, within market garden orchards, predation services on artificial caterpillars are more important in fruit trees than in vegetable crops. Conversely, predation services on sentinel butterfly eggs are more important in vegetable crops than in fruit trees.

Keywords: agroecology, agroforestry, market gardening, biological control

Introduction

Agricultural systems have to deeply evolve to adapt to current environmental challenges. However, pest control remains an important issue for some types of production, such as organic fruit growing. Orchards account for 1% of but are responsible for 21% of insecticide use in France (Aubertot et al., 2005). Furthermore, the perennial nature of fruit trees limits the number of levers that can be used to maintain orchard performance, in addition to the limited number of means of direct control available to organic farmers (Simon et al., 2009). In a context of reduced use of plant protection products, it is needed to develop other means of control.

Agroforestry research projects therefore enable us to reconsider the ecosystem services of the agroecosystem while maintaining the economic and environmental performance of vegetable and fruit sectors (Geiger et al. 2010). Agroforestry is now recognized as a powerful way to support the agroecological transition. It makes plots more complex, increasing natural resources and efficiency of beneficials in providing services to crops (Rusch et al., 2017, Kenis et al., 2019). The benefits of increasing the number of habitats in agroforestry is confirmed by Pumarino et al. (2015) who indicate a greater abundance of beneficials in agroforestry compared to the various non-agroforestry controls.

Providing favorable habitats through crop diversification is therefore essential to maintain wildlife on farmland, and in particular beneficial arthropods (Harterreinten-Souza, 2021). Imbert (2019) further confirms that predatory insects are more numerous in agroforestry systems compared to market gardening alone. The presence of trees thus seems to directly affect the natural regulation regulation of pests, an essential ecosystem service, by providing food resources for predators (Martin-Chave et al., 2019, Simon et al., 2009).

Thomson & Hoffman (2013) showed that some beneficials were more abundant when proximity to trees was greater. However, these effects cannot be generalized. They depend on the context of soil and climate conditions, crop and tree associations, tree planting and

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age, canopy management as well as canopy management and farming practices (Debarge, 2015; Jose, 2009).

In this study, research focused on market gardening systems, mixing linear fruit trees with diversified vegetable crops (Imbert et al., 2020; Warlop et al., 2017). These systems are usually designed for direct selling to customers, and based on the principle of complementarity of fruit and vegetables in time and space (Léger et al., 2018; Paut, 2020; Warlop et al., 2017). The introduction of fruit trees allows a densification of crops on the plot (Imbert et al., 2019; Paut, 2020), a diversification of outlets (Debarge, 2015; Imbert et al., 2020; Léger et al., 2018; Paut, 2020), the creation of a micro-climate (Lauri et al., 2016; Martin-Chave, 2018) and increased regulation of pests, whether through bottom-up or top-down, such as predation) (Bopp et al., 2019; Lauri et al., 2016).

However, few projects study this type of agricultural model, and the results of natural regulation remain unclear (Imbert et al., 2020).

We formulated two hypotheses concerning these cultivated systems:

- The combination of fruit trees and market gardening provides better predation service than when these crops are grown independently;
- In market-garden orchards, there are differences in the predation services provided for both crop types.

This report presents a synthesis of four years of research.

Material and Methods

The specific aim of this study carried out is to compare the predation service on two types of potential prey (lure caterpillars and insect eggs) in 4 types of "systems": orchards (T), vegetable crops (V), fruit trees in market-gardening systems (AT) and vegetables in market-gardening systems (AV).

Different plots were identified in the area of Avignon, France, all in organic farming.

Every year from 2019 to 2022, 4 to 5 sessions were organized, between april and july. Predation cards (with Ephestia eggs) and plasticine caterpillars were exposed respectively 2 and 7 days per session. Sentinel preys were placed in at least 5 locations per type of « systems » and plot, and several prey were placed per location.

After exposition, predation rate was measured on cards and plasticin caterpillars. In addition, we distinguished the predators leaving traces on caterpillars (arthropods, birds, mammals or unidentified ones). Several indicators are calculated for predation : (i) Intensity and frequency of predation on sentinel eggs, and ; (ii) diversity, frequency and richness of predation on plasticine caterpillars.

The statistical analysis of the differences between types of system was carried out separately for each indicator using linear mixed models taking into account the year and the farm. The analyses were carried out using R v 4.2.2.

Results

For plasticine caterpillars, the linear mixed models (lmm) over the 4 years (Table 1) show that : (i) Predation frequency did not differ between the 4 types of system ; (ii) Predation intensity by birds is higher in AT than in V and AV ; (iii) Predation intensity by arthropods is higher in AT than in AV ; and (iv) Predation richness is also higher une AT than in AV.

For sentinel eggs, overall analysis by lmm (Table 1) shows that :
(i) Predation frequency is lower in T than in AV ;
(ii) Predation intensity is lower in T and AT than in AV ;

Table 1: Summary of multi-year statistical models for the predation service indicators monitored in the 4 types of system.

Sentinel preys	Predation indicators	T	AT	V	AV	AIC	R squared of fixed effects
Plasticine cat-terpilar	Frequency	Non significant				2722	0,01
	Intensity by birds	ab	a	b	b	191	0,31
	Intensity by arthropods	ab	a	ab	b	6887	0,03
	Richness	ab	a	ab	b	917	0,02
Sentinel eggs	Frequency	b	ab	ab	a	2047	0,02
	Intensity	b	b	ab	a	2592	0,03

Analysis by year of egg predation intensity shows variable results (Table 2) :

- In 2020 : predation in AV is higher than in V ;
- In 2021 : predation in AV is lower than in AT ;
- In 2022 : predation in T is lower than in the three other types of system.

Table 2: Results of annual statistical models on egg predation intensity in the different systems.

	Years	T	AT	V	AV	AIC	R squared of fixed effects
Predation intensity of sentinel eggs	2019	Non significant				632,2	0,12
	2020	ab	a	**b**	**a**	544,6	0,45
	2021	ab	**b**	ab	**a**	654,7	0,4
	2022	**b**	**a**	a	a	673,7	0,2

Discussion

Pluriannual statistical analysis show that market garden orchards do not provide higher predation service than untreated monocultures in our study (no significant differences were found between : T and AT, V and AV). Analyses done by year for predation intensity of sentinel eggs show some evidence of a benefit of agroforestry (AV > V in 2020, AT > T in 2022), than overall analysis. Additional analyses are necessary because the results may vary from one year or session to another. Furthermore, this partial conclusion should be hampered with a methodological consideration : orchards and vegetables plots considered as control systems in our study are also very extensive, untreated and diversified systems, therefore also very much favourable to natural predation.

Concerning our hypothesis on differences in predation in market garden, our results show that predation services on plasticine caterpillars are more important in fruit trees than in vegetable crops. Conversely, predation services on sentinel butterfly eggs are more important in vegetable crops than in fruit trees. As highlighted by the high R-squared (0,31) of the statistical model on predation intensity of caterpillars by birds, it seems that birds play an important role in the predation of fruit trees, perhaps underestimated in orchards but underlined here by the association with an annual crop.

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