Organic World Congress 2020
FRANCE
SEPTEMBER 21ST TO 27TH, 2020 IN RENNES
AT THE COUVENT DES JACOBINS • RENNES MÉTROPOLE CONFERENCE CENTRE
www.owc.ifoam.bio/2020

OWC 2020 Paper Submission - Science Forum

Topic 4 - Innovation in Organic farming: "Thinking out of the Box"

OWC2020-SCI-315

DIVERSITY OF WHEAT CROP MANAGEMENT FROM CONVENTIONAL TO ORGANIC FARMING: SOCIO-ECONOMIC AND ECOLOGICAL ASSESSMENT

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Abstract: Biological control is considered a promising way to reduce pesticide use in cropping systems. In this study we aimed to assess biological control and natural enemy communities in a diversity of organic and conventional wheat fields. We also aimed to evaluate economic and labor aspects of cropping systems studied. Twenty pairs of organic and conventional fields were studied in Brittany, France in 2016. Data on carabid abundance and species richness, as well as pest predation rates were collected in fields; crop management and machinery used were also surveyed. We identified 2 organic crop management types and 3 conventional types. Results were not equal for all types of each category. One type of organic crop management, associated with less work for farmers and more economic profit, was beneficial to carabid beetles. Predation rate was lower only in one type of conventional crop management compared with other management types. This study underlines the need to account for the diversity of crop management strategies to assess socio-economic and ecological aspects in organic and conventional farming systems.

Introduction

Enhancing biological control of crop pests by their natural enemies is considered a promising strategy to increase the sustainability of agricultural systems. Studies assessing the impacts of farming practices on natural enemies and pest regulation processes often compare organic and conventional crops. Overall, they show that natural enemies and pest control levels are enhanced in fields or farms under organic farming compared to conventional ones (Bengtsson et al., 2005). However, such comparisons do not allow to take into account the diversity of cropping systems and management strategies implemented by farmers in both organic and conventional production systems (David et al 2005; Puech et al. 2014). Moreover such studies do not assess socio-economic aspects of cropping systems. The aim of our research was to assess the diversity of natural enemies and levels of biological control in a diversity of organic and conventional wheat fields, considering farmers' labor and economic aspects related to wheat management applied to those fields.

Material and methods: The study was located in the Zone Atelier Armorique (Long Term Socio-Ecological Research site), in Brittany, in northwestern France. This area is characterized by a high density of hedgerows and mixed crop-livestock farming. Main crops are grassland (40 %), maize (30 %) and wheat (20 %). Ecological surveys were conducted in 2016 in 20 pairs of organic and conventional winter cereal fields. Carabid beetle communities were sampled using pitfall traps from April to July. In each field, three pitfall traps were randomly placed. Traps were open continuously and collected every two weeks, for a total of five sampling periods. In parallel, biological control levels were assessed in the 20 pairs of cereal fields by the mean of sentinel prey experiments. Pest predation levels were measured using sentinel preys - pea aphids (*Acyrthosiphon pisum*) and seeds of field pansy (*Viola arvensis*) - exposed during three sessions in each field. For each session and each field, predation measurements were performed at four sampling points, distributed along two parallel transects 10 m apart, at 15 m and 30 m from the field edge. At each sampling point, one card with 5 aphids was exposed during 24h at the top of cereal plants, and one card with 10 seeds was exposed during 5 days at the bottom of the same plants. The number of predated and exposed prey items were counted to estimate predation rates of aphids and seeds.

We surveyed farmers, except one who refused, to characterize crop management of sampled fields. Practices surveyed were: soil tillage (plowing and other tillage), mechanical weeding, nitrogen fertilization (Unit of Nitrogen, UN in kg of N.ha $^{-1}$), pesticide applications for which we calculated the Treatment Frequency Index (TFI) that is the ratio of pesticide standard concentration to pesticide concentration actually sprayed. Based on these data we made a typology by combining a FAMD (Factor Analysis of Mixed Data) and a HAC (Hierarchical Ascendant Clustering).

Lastly we calculated two indicators to characterize both socio-economic dimensions of each type of crop management. These indicators are:

- Margin (in €.ha $^{-1}$) which is the difference between the gross product (GP) and operating and machinery costs (OC and MC). GP was calculated based on yield estimated by farmers in their fields and with local selling price of wheat; OC were calculated with a French database of crop inputs prices; MC were calculated based on the survey of actual machinery used by farmers and on French references (APCA, 2015).
- Work Duration (WD) which is the in field work duration (h.ha $^{-1}$) based on French references (APCA, 2015) and the actual machinery used by farmers.

Results: We identified five types of crop management, two under organic farming (types 1 and 2) and three under conventional farming (types 3, 4 and 5) (Table 1). Nitrogen fertilization and use of tillage were the two practices which differentiated the two organic farming types: in type 1 farmers did not till their land, while in type 2, they did not apply nitrogen fertilization. Concerning conventional fields, all practices contributed to differentiate the three management types. Type 4 was the least intensive (lowest tillage frequency, pesticide use and nitrogen fertilization) but plowing was systematically done. On the contrary type 5 was the most intensive (tillage, mechanical weeding and pesticide use) but plowing was never implemented. Type 3 was intermediary except for nitrogen fertilization which was on average the highest among all types (190,5 kg of N.ha^{-1}).

Table 1: Average value and standard deviation of each crop management practice, yield and socio-economic indicators for each type of crop management (TFI, UN, WD : see text above).

	Type 1	Type 2	Type 3	Type 4	Type 5
No. of fields	11	8	4	9	7
Organic farming	Yes	Yes	No	No	No
Plowing frequency (no.)	0,9 ± 0,3	1,0 ± 0,0	0,5 ± 0,5	1,0 ± 0,0	0,0 ± 0,0
Tillage frequency (no.)	0,0 ± 0,0	1,3 ± 0,4	0,5 ± 0,5	0,3 ± 0,0	1,1 ± 0,0
Mechanical weeding frequency (no.)	0,7 ± 0,7	0,5 ± 0,7	0,0 ± 0,0	0,1 ± 0,5	0,4 ± 0,3
TFI	0,0 ± 0,0	0,0 ± 0,0	4,5 ± 1,2	4,0 ± 1,6	5,1 ± 1,8
UN (kgN.ha^{-1})	31,2 ± 36,5	0,0 ± 0,0	190,5 ± 16,3	139,6 ± 34,8	161,1 ± 21,7
Yield (t.ha^{-1})	3,8 ± 0,7	3,3 ± 1,3	7,1 ± 0,1	6,9 ± 1,5	7,5 ± 0,9
Margin (€.ha^{-1})	943 ± 183	826 ± 422	572 ± 20	632 ± 163	732 ± 99
WD (h.ha^{-1})	2,5 ± 0,6	3,0 ± 0,5	3,1 ± 0,6	3,3 ± 0,5	3,0 ± 1,0

Average yields of organic wheat fields (3.3 to 3.8 t.ha^{-1}) were about half of those of conventional ones (6.9 to 7.5 t.ha^{-1}) and there was a variability of about 0.5 t.ha^{-1} among both categories. Conversely, margins were higher for organic wheat fields, the highest one being 943 €.ha^{-1} (type 1) and the lowest one 572 €.ha^{-1} (type 3). Work duration in type 1 was about half an hour less than in the four other types, and the maximum was 3,3 h.ha^{-1} for type four.

The ecological results (figure 1) showed that carabid diversity (total abundances and species richness) was overall higher in organic than in conventional crops. The analyses testing the effects of crop management types further showed that the higher diversity of carabid beetles in organic crops was mainly related to one management type (type 1). Regarding predation levels, we did not find any difference in predation levels between organic and conventional fields. However, aphid predation rates differed according to crop management types, and were significantly lower in type 3 fields.

Discussion: Our study shows that organic cropping systems are overall beneficial for the diversity and abundance of carabid beetles in cereal fields, in concordance with existing studies (Bengtsson et al. 2005). However, our results further suggest that the positive effect of organic farming on carabid communities is related to a specific type of cropping system, characterized by reduced soil disturbance. On the contrary, other organic cropping systems harbored similar levels of natural enemies compared with conventional ones. Our study shows that ignoring this diversity might lead to erroneous conclusions regarding the impacts of organic farming on biodiversity. This could explain the contradictory results observed in meta-analyses (Hole et al. 2005). Regarding biological control levels, pest predation rates were similar in organic and conventional fields, while aphid predation rates were reduced in conventional cropping systems with higher levels of N fertilization. These results suggest that the predation of sentinel preys was not only performed by carabid beetles. Regarding crop management, our results shows that yields in organic wheat fields are lower but margins are higher than in conventional fields, which is in line with other studies (Batary et al 2018). Higher margins are explained by higher selling price and lower operating and machinery costs. While work duration is often mentioned to be an obstacle to the transition toward agro-ecological cropping systems (Delecourt et al, 2019) our results show on the contrary that work duration is similar among all types and even slightly lower in type 1.

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Disclosure of Interest: None Declared

Keywords: agroecology, biological control, carabid, wheat, labor