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Diversified cropping systems for promoting the beneficial insects - ground beetles (*Coleoptera: Carabidae*)

L. Talgre*, V. Eremeev, E. Mäeorg and A. Luik

Estonian University of Life Sciences, Institute of Institute of Agricultural and Environmental Sciences, Kreutzwaldi 5, EE51006 Tartu, Estonia
*Correspondence: liina.talgre@emu.ee

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Abstract. In agro-ecosystems ground beetles - carabids (*Coleoptera: Carabidae*) are important as generalist predators of invertebrate pests and weed seeds and as prey for larger animals. This way they contribute to biodiversity and influence the most important ecological processes. Impacts of crop management practices on the carabids are not well described. Carabids were studied in winter wheat which is one crop in the rotation experiment (barley undersown with clover-clover-winter wheat-pea-potato). Carabids were collected with pitfall trap during one week at the end of June 2022. In laboratory, their species was identified. Trapping of carabids during the spiking phase of winter wheat has shown significant differences in carabids activity-density and diversity depending on five different cropping systems. In two conventional systems where pesticides were used the number of carabids was two times smaller in comparison with three organic systems. Activity-density and diversity of carabids was significantly higher in all organic systems and especially in Org II system where winter cover crops and composted manure where used for rotation diversification. The Shannon–Wiener index values, which takes into account the number of species and their relative abundance were 1.24–1.53 in conventional systems, but higher in diversified organic systems (1.60–1.78). Only in organic systems Org I and Org II there were very rare species present, like *Acupalpus meridianus* (Linnaeus) and *Microlestes minutulus* (Goeze). In diversified organic systems the higher activity-density and abundance of carabids could be explained by the diverse plant community as possible source for better food and microclimatic conditions.

Key words: organic cropping, winter cover crops, conventional cropping, pesticides, weed.

INTRODUCTION

Ground beetles - carabids are species rich and abundant in arable habitats all over the world. Because of their predatory polyphagous nutrition, they are potentially important natural pest-controlling agents. For sustainable agricultural systems, self-regulation of predatory arthropods is considered to be crucial in preventing insect pest outbreaks. At the same time many of carabids as seed predators have potential for weed control (Bàrberi et al., 2010). The species assemblage of carabids present in any particular crop is determined by multiple factors. Crop type affects the carabid assemblage indirectly through cultivation practices and microclimatic changes (Holland & Luff, 2000).

Besides arthropods and weed seeds carabids are also slug predators, but long-term repeated pesticides treatments affect the number and diversity of carabids in agricultural habitats (van Toor, 2006). Moreover, overall carabid activity-density and species richness were higher in the low input 4-year crop rotation compared with the conventionally managed 2-year crop rotation (O'Rourke et al., 2008). The activity-density and species richness of carabids increased in cover crop based reduced tillage systems (Rivers et al., 2017). But Bourassa et al. (2008) have found that crop type had a stronger effect than sustainable treatment on the species richness and abundance of carabids. Still, they observed lower activity-density in potato plots which were sprayed with insecticides. It has been found that carabids as generalist predators had a strong positive response to plant diversity, that is, their abundance increased as the plant diversity increased. Positive effects of plant diversity on generalist predators confirm that, at a local scale, plant diversification of agroecosystems is a credible and promising option for increasing the effect of pest control (Dassou & Tixier, 2016). Weeds as part of biodiversity of a agroecosystem facilitate the diversity of carabid beetles. Intermediate diversity of carabid beetles species (3–8) exhibited the highest weed seed predation by invertebrates (Schumacher et al., 2020).

The aim of present study was to explain the activity-density and diversity of carabids depending on the cropping systems and diversity weed species in winter wheat during the spiking phase.

MATERIALS AND METHODS

Carabids were studied in winter wheat, which is a crop in the long-term rotation experiment (barley undersown with clover–clover-winter wheat-pea-potato). All crops are cultivated each year in two conventional and three organic systems. The experiment is set up in a systematic block design with four replicates of each treatment and a plot size of 60 m^2. The organic and conventional plots were separated with an 18 m wide section of grass-clover to prevent the spread of synthetic plant protection products and mineral fertilizers. In both conventional systems, winter wheat plots were treated with pesticides: seed treatment before drilling was done by Lamardor 400 FS (propiconazole 250 g L^{-1} + tebuconazole 150 g L^{-1}) (0.2 L ha^{-1}), weed control (middle of May) with Secator OD (amidosulfuron 100 g L^{-1} + iodosulfuron-methyl-sodium 25 g L^{-1} + mefenpyrodiethyl 250 g L^{-1}) (150 ml ha^{-1}) and fungicide Zantara (biksafen 50 g L^{-1} + tebukonazole 166 g L^{-1}) (1.2 L ha^{-1}) was used against plant diseases (end of May). In Conv 0 no mineral fertilizers were used. In Conv II system in winter wheat plots mineral nitrogen fertilizer was applied (150 kg ha^{-1}) and phosphorus and potassium mineral fertilizers were added to the soil at the rate of 25 and 95 kg ha^{-1}, respectively. All organic system crops were cultivated without any pesticides and Org 0 system also without fertilizers. In Org I and Org II systems winter cover crops were used as green manures, after winter wheat, pea and potato in rotation. Winter cover crops were used: the mixture of turnip rape, winter rye and phacelia after the winter wheat, mixture of winter turnip rape and phacelia after the pea, and mixture of winter rye and phacelia after the potato. Cover crops were ploughed into the soil before the drilling of the main crop in spring. Clover as precrop for winter wheat was ploughed into the soil at the beginning of September. Winter wheat was drilled in middle of September. Before drilling, in Org II system winter wheat plots fully composted cattle manure (10 t ha^{-1}) was applied.

Carabids were collected in winter wheat plots at the spiking phase (BBCH 51-52) with pitfall traps during the last week (from 22 to 28) of June 2022. This period was dry and warm with average temperature of 21 °C. On each of the 20 winter wheat plots a trap was set in the middle of the plot. Pitfall traps were with 8.5 cm diameter and 10 cm deep and ¾ filled with saturated salt (NaCl) solution. From all the traps the material collected was stored in 70% ethanol. In laboratory the material was assorted and carabid species were identified under microscope according to identification keys (Haberman, 1968; Lompe, 2002). While carabids are also dependent on the plant diversity the study of the composition of weed species was carried out at the same time. Weeds were collected from four squares of 0.25 m^2 in each plot. All weeds were collected, counted by species and the total biomass was weighed.

The statistical analysis of collected data was performed with the software Statistica 13 (Quest Software Inc., Aliso Viejo, Ca, USA). The significance of differences between the data on cropping systems tested with the Tukey HSD (honest significant difference) *post hoc* test. For carabids and weeds the Shannon-Wiener Diversity Index (H'), which takes into account the number of species and their relative abundance, was calculated using the following equation:

$$H' = -\sum P_i(\ln P_i)$$

where P_i is the proportion of each species in the sample.

RESULTS AND DISCUSSION

In winter wheat plots 15 different carabid species were found but the number of species was different in systems. In organic systems 12 species, but in conventional systems only 7 species were found (Table 1). Such finding supports the results of a previous study by Döring and Kromp (2003), who found 34% more species on the organic than on the conventional fields. In all cropping systems the most numerous species were *Harpalus rufipes* (Degeer), *Harpalus affinis* (Schrank) and *Bembidion properans* (Stephens) but these were more abundant in organic systems. These species are common in cereal fields (Kinnunen at al., 2001; Guseva & Koval, 2021).

Table 1. Presence (x) or absence (-) of ground beetle species in different cropping systems in winter wheat

Carabid species	Conv 0	Conv II	Org 0	Org I	Org II
Acupalpus meridianus	-	-	-	x	x
Amara fulva	-	-	-	x	x
Anchomenus dorsalis	-	-	-	x	x
Bembidion lampros (Herbst)	-	x	x	x	x
Bembidion properans (Stephens)	-	x	x	x	x
Bembidion quadrimaculatum (Linnaeus)	x	-	x	x	x
Harpalus affinis	x	x	x	x	x
Harpalus rufipes	x	x	x	x	x
Microlestes minutulus	-	-	-	x	x
Nebria brevicollis (Fabricius)	x	x	x	x	x
Poecilus cupreus (Linnaeus)	x	x	x	x	x
Pretostichus melanarius	-	-	-	-	x

Notes: Org 0 – without cover crops (CC), Org I – with CC, Org II – with CC and composted cattle manure Conv I – with pesticides, without fertilizers and Conv II – with mineral fertilizers and pesticides.

The rare species of *Acupalpus meridianus, Anchomenus dorsalis* (Pontoppidan), *Amara fulva* (Müller), *Microlestes minutulus* and *Pretostichus melanarius* (Illiger) appeared only in organic systems.

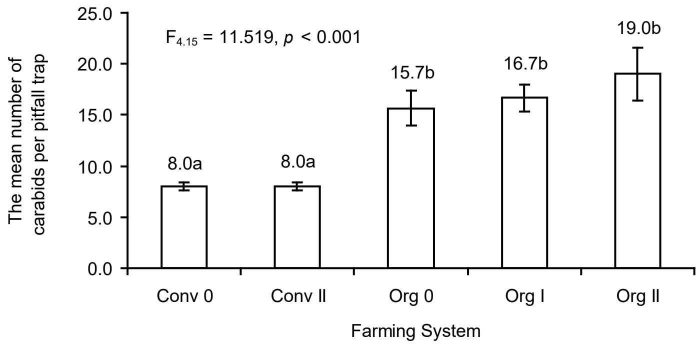

Figure 1. The mean activity-density of carabids per pitfall trap, depending on the cropping system. Org 0 – without cover crops (CC), Org I – with CC, Org II – with CC and composted cattle manure Conv I – with pesticides, without fertilizers and Conv II – with mineral fertilizers and pesticides. Means followed by a different letters indicate significant influence of crops (Tukey HSD post-hoc test, $p < 0.05$). Error bars denote the standard error of the means, $n = 4$.

The mean number of carabids per trap was significantly higher in all organic systems than in conventional ones (Fig. 1). In Org I and Org II systems the more abundant carabids was also more diverse (Fig. 2). The highest activity-density and diversity was observed in Org II system, where the crop rotation had been diversified with winter cover crop and composted manure (Figs 1, 2). The research of Adikhari and Menalled (2020) confirmed that the use of cover crops increased the populations of ground beetle not only in organic farming, but also in chemical-based conventional systems. Therefore, conventional producers should also use more cover crops in their crop rotation. Shannon–Wiener index is significantly higher in Org I system than in Conv 0. In organic systems less chemical disturbances occur and that is favoring the ground-dwelling insects (Kromp, 1999). In conventional systems chemical weed control decreases the density and diversity of weeds. It is possible that *Harpalus rufipes and Harpalus affinis* as first of all seed predators could not have had enough food. Holland & Luff (2000) confirmed that *Harpalus* sp has mixed diet, at the beginning of vegetation period when they use animal food, as later on they prefer seeds. Gallant et al. (2017) established that the activity-density of *Harpalus rufipes* was positively correlated with the mean seed predation.

Weed biodiversity facilitates the diversity of carabid beetle species (Schumacher et al., 2020). Weeds offer shelter, food and change in the microclimate. Our results also confirm that the occurrence of carabids was influenced by plant diversity. Significantly more diverse weed species' composition was seen in all organic systems (Fig. 3). The dominant weed species in the organic systems were *Matricaria inodora* L., *Viola arvensis* Murr., *Taraxacum officinale* and *Capsella bursa pastoris* L. Medicus. In the conventional systems *Elytrigia repens* was the dominant species. Also, the density and biomass of weeds were higher in organic systems, compared to conventional systems. In agroecosystems weeds provide also oviposition and mating sites. Therefore, the decline in the number of weed species affects also the higher trophic levels. Therefore, the conservation of diversity of weed species is also contributing to the conservation of higher order taxa (invertebrates and vertebrates) in the food web (Bàrberi et al., 2010).

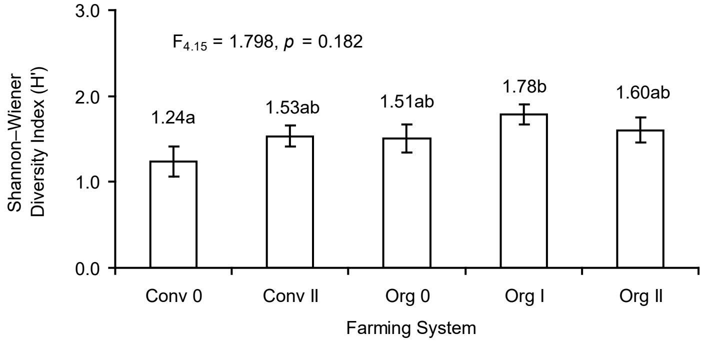

Figure 2. The Shannon-Wiener diversity index of carabids, depending on the cropping system (b). Org 0 – without cover crops (CC), Org I – with CC, Org II – with CC and composted cattle manure Conv I – with pesticides, without fertilizers and Conv II – with mineral fertilizers and pesticides. Indexes followed by a different letters indicate significant influence of crops (Tukey HSD post-hoc test, $p < 0.05$). Error bars denote the standard error of the means, $n = 4$.

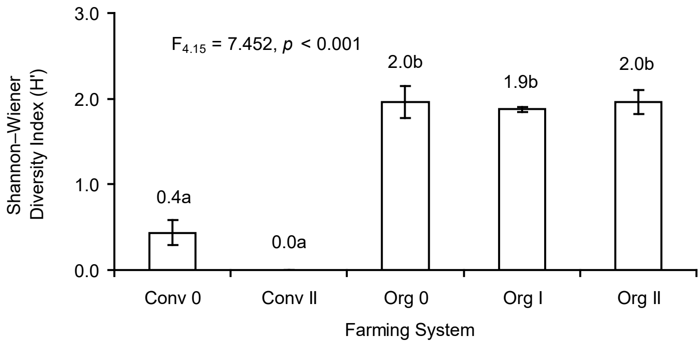

Figure 3. The Shannon-Wiener diversity index of weeds, depending on the cropping system. Org 0 – without cover crops (CC), Org I – with CC, Org II – with CC and composted cattle manure Conv I – with pesticides, without fertilizers and Conv II – with mineral fertilizers and pesticides. Indexes followed by a different letters indicate significant influence of crops (Tukey HSD post-hoc test, $p < 0.05$). Error bars denote the standard error of the means, $n = 4$.

CONCLUSIONS

Species richness, diversity, and community structure is significantly influenced by the farming systems. In organic cropping systems, where higher diversity of plant species occurs through the presence of weeds, also the activity-density and diversity of carabids are increased. Therefore the weedier cereal fields should also be tolerated in conventional management. The cultivation of winter cover crops in crop rotations improves the populations of ground beetles and therefore it is important to include the cover crops into the chemical-based conventional farming systems.

In this article the activity-density and diversity of carabids is analyzed in one of the crops in rotation. Further studies should include all rotational crops for better understanding and estimation of the role of carabids in agroecosystems.

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