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Authors: Rondon, Silvia I., Pantoja, Alberto, Hagerty, Aaron, and Horneck, Donald A.

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GROUND BEETLE (COLEOPTERA: CARABIDAE) POPULATIONS IN COMMERCIAL ORGANIC AND CONVENTIONAL POTATO PRODUCTION

SILVIA I. RONDON[1,*], ALBERTO PANTOJA[2,3], AARON HAGERTY[4,5] AND DONALD A. HORNECK[1]
[1]Oregon State University, Hermiston Agricultural Research and Extension Center, 2121 S. First Street, Hermiston, OR 97838, USA

[2]USDA, Agricultural Research Service, Subarctic Agricultural Research Unit, Fairbanks, AK, 99709, USA

[3]Current address: United Nations, Food and Agriculture Organization, Regional Office for Latin America and the Caribbean,Vitacura, Santiago, Chile. Avenida Dag Hammarskjöld 3241, Vitacura Santiago, Chile

[4]USDA, Agricultural Research Service, Subarctic Agricultural Research Unit, Fairbanks, Alaska

[5]Current address: Monsanto Arizona Cotton Research Center, 749 West Ash Ave, Casa Grande, AZ 85193, USA

*Corresponding author; E-mail: silvia.rondon@oregonstate.edu

ABSTRACT

In 2 consecutive years, ground beetles (Coleoptera: Carabidae) were sampled in commercial organic and conventional potato fields, using pit fall traps. Four conventional and 3 organic potato fields were surveyed to determine ground beetle taxa composition. In a related study, potato fields were assigned to 1 of 4 transitional systems to include: organic, no spray (usually referred to as no control and/or only OMRI certified control), IPM-conventional (directed control, after sampling) and conventional (broad spectrum pesticides) systems. Seven taxa of ground beetles were identified: *Anisodactylus kerbyi* Lindroth 1953, *Amara* sp., *Bembidion* sp., *Calosoma cancellatum* Eschscholtz 1833, *Calathus ruficollis* Casey 1920, *Calathus ingratus* Dejean 1828, and *Pterostichus adstrictus* Eschscholtz 1823. With the exception of *C. cancellatum*, which was not identified from organic fields in the first yr of this study, all taxa were collected in both organic and conventional potato fields both yr. Based on total number of specimens collected, *Bembidion* sp., *P. adstrictus* and *Amara* sp. represented 42.8% of the total specimens collected. The smallest number of ground beetles was collected from no spray and IPM-conventional systems. This study provides basic valuable information regarding beetles populations for growers making transition from conventional to organic potato production.

Key Words: biological control, conventional agriculture, generalist, ground beetles, organic agriculture, sustainable systems

RESUMEN

En dos años consecutivos, la composición de taxa de carabidos (Coleoptera: Carabidae) fue estudiada en campos comerciales de papa orgánica y convencional. Cuatro campos comerciales convencionales de papa y tres campos comerciales orgánicos, fueron monitoreados usando trampas de caída. Trampas fueron usadas desde la siembra (mediados de abril) hasta antes de la quema del follaje (mediados de agosto). También, para determinar como los sistemas transicionales afectan las poblaciones de carabidos, cuatro sistemas fueron evaluados: orgánico, sistema orgánico de transición (donde solo se permiten aplicaciones de pesticidas aprobados por el OMRI), IPM-convencional (solo se permiten aplicaciones de pesticidas después del monitoreo), y convencional (se permite el uso de pesticidas de amplio espectro). Siete especie de carabidos fueron identificados: *Anisodactylus kerbyi* Lindroth 1953, *Amara* sp., *Bembidion* sp., *Calosoma cancellatum* Eschscholtz 1833, *Calathus ruficollis* Casey 1920, *Calathus ingratus* Dejean 1828, y *Pterostrichus adstrictus* Eschscholtz 1823. Todas éstas taxas fueron encontradas en campos orgánicos y convencionales, con la excepción de *C. cancellatum* que no fue encontrada en campos orgánicos en el primer año de este estudio. *Bembidion* sp., *P. adstrictus* y *Amara* sp. fueron las taxas más abudantes (42.8% del número total de taxa colectadas). Sistemas orgánico de transición y IPM-convencionales presentaron el número más bajo de carabidos colectados. Este trabajo provee información básica importante para agricultores que intentan convertir su producción convencional a orgánica o visceversa.

Palabras Clave: control biológico, agricultura convencional, generalistas, carábidos, orgánico, sistemas sostenibles

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Generalist ground-dwelling predaceous arthropods are common inhabitants in agroecosystems; however, they are susceptible to changes in abiotic factors (e.g., temperature, humidity), vegetative community, prey availability, and agronomic practices such as fertilization (mainly nitrogen) and pesticide use (Witmer et al. 2003). Ground beetles (Carabidae) are a biologically diverse and ecologically important element of the ground-dwelling community. The vast majority of ground beetles are active predators (Harrison & Regnier 2003) feeding on mollusks, beetles, aphids, Hemiptera, Lepidoptera, and thrips, among others (Lovei & Sunderland 1996; Sunderland 2002; Prasad & Snyder 2004); they may also be omnivorous or partially herbivous (Laub & Luna 1992; Clark et al. 1993; Kromp 1999).

Increasing plant diversity within agroecosystems is believed to increase predator abundance and diversity (Root 1973). Moreover, habitat manipulation can affect densities of natural enemies (Barbosa 1998; Landis et al. 2000); still at present, the connection between abundance of beneficials and pest suppression is unclear (Bommarco & Banks 2003) and in some cases, controversial (Clark et al. 2006). According to Lundgren et al. (2006), the ground beetle community can be directly or indirectly impacted by farm management practices. Ground beetle composition responds to soil amendments and soil management (Purvis & Curry 1984; Reichert & Bishop 1990). No-till fields can have higher density of predators as compared to conventional tilled fields (House & All 1981; House & Alzugaray 1989; Whitmer et al. 2003; Clark et al. 2006; Shearin et al. 2007). Döring & Kromp (2003) suggested that ground beetles are less affected under organic farming systems rather than conventional, likely because some taxa are less or more susceptible to insecticides (Brust et al. 1985; Holland & Luff 2000). Koss et al. (2005) conducted an on farm study in Washington State where they compared predator and pest communities in potato fields treated with broad spectrum, selective or organic insecticides finding minor differences. Despite all this body of knowledge, few studies have been conducted specifically to determine the influence of transitional organic systems on ground-dwelling predators (Lundgren et al. 2006). In the United States, growers face a 3-yr transition from conventional to organic production that may have an effect on the biological community composition in transitional areas (Lundgren et al. 2006). In traditional intensive conventional agriculture systems as the one in the lower Columbia Basin of eastern Oregon, there are challenges that ground-dwelling communities may face such as limited food sources (since pests are being controlled), irrigation (eastern Oregon receives 203.2 mm of water per year), crop rotation (3 yr rotation) and other cropping practices. Growers with transitional and newly certified organic fields need better information on the impact of their practices on communities of beneficial arthropods. Therefore, the objectives of this research were to study ground beetle taxa composition and relative abundance in conventional, transitional, and organic potato farming systems in eastern Oregon.

Materials and Methods

Ground Beetle Survey in Organic and Conventional Potato Areas

In 2007 and 2008, ground beetles were surveyed in first yr commercial organic (n = 3) and conventional potato fields (n = 4) in the Boardman and Hermiston area located east of the Cascade Mountains in Oregon (Fig. 1). Insects were collected with pitfall traps; pitfall traps are widely used to collect soil arthropods in both agricultural and natural systems (Southwood 1978; Adis 1979; Weeks et al. 1997; Hansen & New 2005; O'Rourke et al. 2008). Ten pitfall traps per field were placed in a linear transect; traps were 15.2 m apart. Traps were placed in the rows to prevent flooding from irrigation. Typically potatoes are hilled, creating deep furrows between rows, and thus



Fig. 1. Map of eastern Oregon. The lower Columbia basin is one of the richest irrigated agriculture areas in the world. Circle shows the area where field plots were located (N 45.8411° W 119.2917°; N 45.8356° W 119.6992°).

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traps consisted of double 12 oz cups (Solo Cup, Highland Park, Illinois). First a cup with holes for drainage was buried at soil level. A second cup filled about ¼ full of a water and 10% soap solution was placed inside the first cup. A piece of wood was used as a partial lid to provide "shelter" and to reduce the likelihood of flooding. Each field was 50.6 ha in size under pivot irrigation with irrigation equivalent to 762 mm per season. Fields within each group followed similar pest management practices. Organic fields were treated with azadirachtin [neem extract at 7 oz/acre (512 mL/ha)] and *Bacillus thuringensis* subspecies *tenebrionsis* at 800 L of Bt per hectare, targeting aphids complex and Colorado potato beetle (*Leptinotarsa decemlineata* Say), respectively. Conventional fields were treated with selective pesticides for noctuid larvae (several taxa) and beet leafhopper (*Circulifer tenellus* Baker). Insecticides used were pyrethroids insecticides, imidacloprid and spinosad. Both yr, all these pests were present during the time of the experiment.

Traps were serviced weekly; samples were brought to the Oregon State University Hermiston Agricultural Research and Extension Center (OSU-HAREC) irrigated agricultural entomology laboratory in Hermiston for sorting, pinning, and preliminary identification. Insects were subsequently shipped to the USDA, ARS Entomology laboratory in Fairbanks, Alaska for identification confirmation. Ground beetles were identified primarily by A. Hagerty, using Lindroth (1969), Bousquet & Larochelle (1993), and Ball & Bousquet (2001) identification keys. Afterwards, identifications were confirmed by George E. Ball (University of Alberta, Edmonton, Alberta, Canada), Robert Davidson (Carnegie Museum of Natural History, Pittsburg, Pennsylvania) and Christopher J. Marshall (Oregon State Arthropod Collection, Corvallis, Oregon). Voucher specimens were kept in OSAC, OR (http://osac.science.oregonstate.edu/). Subsequent identifications were completed at the OSU-HAREC entomology laboratory by comparison with identified specimens.

Traps were monitored from planting (mid-Apr) until right before vine-killing (mid-Aug). Sampling was difficult before Apr or after Aug, because the fields followed normal farming practices (i.e. tillage, weed control, potato vine-killing before harvest).

Small Scale Transition Plots

Potato fields under a transition program from conventional to organic farming at the OSU-HAREC (N 45° 50' 26" W 119° 17' 17") in Hermiston Oregon were sampled in 2008. The transition to organic production was initiated in 2004 on a site that had been under conventional crop production the previous seasons. In our study, treatments were: 1) organic, 2) semi-organic (only OMRI or Organic Materials Review Institute certified sprays), 3) IPM-conventional (following IPM program including scouting and selective use of pesticides) and 4) conventional (broad spectrum pesticides). All seeds were certified. Potatoes were planted in May of 2008 and seed was provided by Three Mile Canyon Farms (RDO, Boardman, Oregon). Only OMRI approved materials for organic production were used in organic and semi organic treatments. Semi organic treatment used OMRI materials for pest control plus commercial fertilizer for plant nutrition (http://www.ams.usda.gov/AMSv1.0/nop). All 4 treatments have been cropped the same since their establishment in 2004. Crop rotation was berseem clover (*Trifolium alexandrinum* L.) in summer of 2004 followed by mustard (*Brassica juncea* (L.) Czern.) in the fall of 2004. Thirty three tons of compost per acre (67.4 t/ha) was applied to all treatments except conventional. Forage peas were planted in fall of 2005 but they did not germinate because of the late planting date. Green peas were planted in the spring of 2006; compost was then applied at 20 tons per acre (44.9 t/ha). Sudan grass was planted in summer of 2006. Winter wheat was planted in fall of 2006. Blood meal and chicken manure were used to fertilize the organic treatment and conventional fertilizers were used for the semi organic, IPM-conventional and conventional treatments. Standard potato practices were carried out in the conventional treatment with pesticide sprays occurring on a weekly basis (mainly for diseases like early blight). The IPM-conventional received 50% of the treatments that the conventional plots received. The semi organic received 75% of the treatments that the conventional plots received. The organic and semi organic received no pest control. Sixteen experimental plots (0.86 × 1.27 m each) were established and the 4 management intensity treatments were randomly assigned to the plots in a randomized complete block design with 4 replications. Blocks were separated by alleyways 3.47 m wide (4 potato rows). Plots within a block were separated by 6.1 m. The alleyways received no fertilizer or pest control (organic or conventional) but were always planted (Table 1). These plots were established by the 4th author for nitrogen best management practices studies for potato production. Small plots are standard for this type of evaluations (Hutchinson & Mylavarapu 2003).

Evaluation of Transition Practices in Ground Beetle Populations

Pitfall traps were set to determine the possible effect of farming transition on the diversity of ground beetles. Hence, 2 pitfall-traps per block per treatment (organic, semi organic, IPM-conventional and conventional) were placed 0.25 m apart. The set up procedure was similar than

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TABLE 1. TRANSITIONAL PLOTS IN HERMISTON, OREGON. SIXTEEN EXPERIMENTAL PLOTS (0.86 × 1.27 M EACH) WERE ESTABLISHED AND THE FOUR MANAGEMENT INTENSITY TREATMENTS WERE RANDOMLY ASSIGNED TO THE PLOTS IN A RANDOMIZED COMPLETE BLOCK DESIGN WITH 4 REPLICATIONS. THESE PLOTS WERE ESTABLISHED FOR NITROGEN BEST MANAGEMENT PRACTICES STUDIES FOR POTATO PRODUCTION.

Treatments or Farm practices	Year				
	2004	2005	2006	2007	2008
Organic	Berseem clover in the summer + 33 tons of compost + blood mean and chicken manure + mustard in the fall	Forage peas + blood mean and chicken manure	Green peas in the spring + 20 tons/a of compost + blood mean and chicken man manure + Sudan grass in the summer + Winter wheat in the fall	Peas + blood mean and chicken manure	potatoes
Semi-organic	Berseem clover in the summer + 33 tons/a of compost + mustard in the fall	Forage peas + conventional fertilizer (75% less than the conventional treatment)	Green peas in the spring + 20 tons/a of compost + conventional fertilizer (75% less than the conventional treatment) + Sudan grass in the summer + Winter wheat in the fall	Peas + conventional fertilizer (75% less than the conventional treatment)	potatoes
IPM-conventional	Berseem clover in the summer + 33 tons/a of compost + mustard in the fall	Forage peas + conventional fertilizer (50% less than the conventional treatment)	Green peas in the spring + Sudan grass in the summer + conventional fertilizer (50% less than the conventional treatment) + Winter wheat in the fall	Wheat + conventional fertilizer (50% less than the conventional treatment)	potatoes
Conventional	Berseem clover in the summer + mustard in the fall	Peas + conventional fertilizer	+ Sudan grass in the summer + conventional fertilizer + Winter wheat in the fall	Winter wheat + conventional fertilizer	potatoes

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the one described above under "Ground beetle survey". Traps were checked weekly and samples were sorted in the Hermiston Irrigated Agricultural Entomology Program Laboratory.

Data Analysis

The field survey and transitional system experiment was analyzed as repeated measures ANOVA since each trap was sampled multiple times during the season. ANOVA results are presented in footnotes to the tables (SAS 2007). The data were transformed by √ (capture + 0.5) before analysis to even the mathematical function of each point in the data set. Significant differences (5% level of probability) in the mean number of adults per trap between yr, taxa, and systems were determined for taxa for which at least 50 specimens were collected during the 2 yr sampling period (O'Rourke et al. 2008). The Simpson's diversity index was used to quantify the ground beetle biodiversity. This index takes into account the number of insects present as well as abundance of each species.

Results and Discussion

Table 2 lists all specimens collected during the study. Seven taxa of ground beetles from 6 genera were identified: *Anisodactylus kerbyi* Lindroth, *Amara* sp., *Bembidion* sp., *Calosoma cancellatum* Eschscholtz, *Calathus ruficollis* Casey, *Calathus ingratus* Dejean, and *Pterostichus adstrictus* Eschscholtz. With the exception of *C. cancellatum*, which was not collected in 2007, all taxa were recovered both yr. However, the relative density of specimens varied between yr with 86% of the carabids specimens recovered during 2007 as compared to 2008 (14%). This is a substantial reduction in the relative density possibly due a combination of weather conditions and management practices. Both factors are not manageable factors in applied field studies. *Bembidion* sp., *P. adstrictus, A. kerbyii,* and *Amara* sp. were the most abundant taxa (Table 2), representing 90% of the total carabid collected.

There were no significant differences in *Bembidion* densities in organic versus conventional systems, but there were significant differences in individual species such as *P. adstrictus* and *Amara* populations. *Amara* spp. was more abundant in conventional areas, while *P. adstrictus* was more abundant in organic areas (Table 3). The reasons for the differences in relative population densities cannot be explained with current biological knowledge of these taxa in Oregon. Possibly, the differences observed are influenced by taxa sensitivity to management practices. Considering that *Amara* populations were higher than *P. adstrictus* early in the season (Fig. 2) we speculate that further studies should consider possible competition between taxa. The seasonal population dynamics for the 3 most abundant taxa varied. One taxon, *Bembidion* sp. displayed high densities early in the season (May 1), but decline sharply to reach the lowest population density observed by these 3 taxa (Figure 2C). All taxa were collected the first week traps were deployed, suggesting that adult carabid activity in Oregon starts before May. Contrary to *Bembidion* sp., *Amara* sp. densities were the lowest recorded early in the season with a sharp increase in densities, reaching a peak of 0.45 insects per trap per 15 days period (Fig. 2A). *Pterostichus adstrictus* maximum densities (0.4 insects per trap per 15 days) were recorded on Jul 2 (Fig. 2B). All taxa were active toward the end of the potato season when traps were removed suggesting that further studies should consider earlier and latter collecting times; however sampling outside the planting season in commercial fields poses difficulties due to standard cultural practices.

Table 2. Total number of ground beetles collected in two commercial fields in eastern Oregon, 2007-2008.

	2007		2008	
Taxa	Number	%	Number	%
Anisodactylus kerbyi Lindroth	62	10	38	38
Amara spp.	135	22	2	2
Bembidion spp.	231	38	26	26
Calosoma cancellatum Eschscholtz	0	0	3	3
Calathus ruficollis Casey	3	< 1	4	4
Calathus ingrates Dejean	29	5	6	6
Pterostichus adstrictus Eschscholtz	150	25	20	20
Total Carabids	610	100	99	100

ANOVA (F = 3.50; df = 6, 14; P value = 0.0635); OD Simpson's D = 0.248, SID = 0.752; SRI = 4.032. The simpson's diversity index is a measure of diversity. In ecological terms, it is often used to quantify the biodiversity of a habitat taking into account the number of species present, as well as the abundance of each species.

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TABLE 3. MEAN +/- SE NUMBER OF CARABIDS COLLECTED IN THE 2007-2008 SEASONS IN CONVENTIONAL AND ORGANIC FIELDS IN EASTERN OREGON.

	Carabids		
	Amara sp.	*Pterostichus adstrictus*	*Bembidion* sp.
Site	Mean +/- SE	Mean +/- SE	Mean +/- SE
Organic	0.2 +/- 0.01 a	0.5 +/ 0.07 b	0.5 +/ 0.12 a
Conventional	0.5 +/ 0.07 b	0.09 +/ 0.03 a	0.4 +/ 0.06 a

Means followed by the same letter within columns are not significantly different (Fisher's LSD, $\alpha = 0.05$); Site ($F = 17.865$, df = 4, $P < 0.001$); *Amara* ($F = 41.726$, $P < 0.001$); *Pterostichus adstrictus* ($F = 26.795$, $P < 0.001$); *Bembidion* ($F = 0.842$, $P = 0.359$).

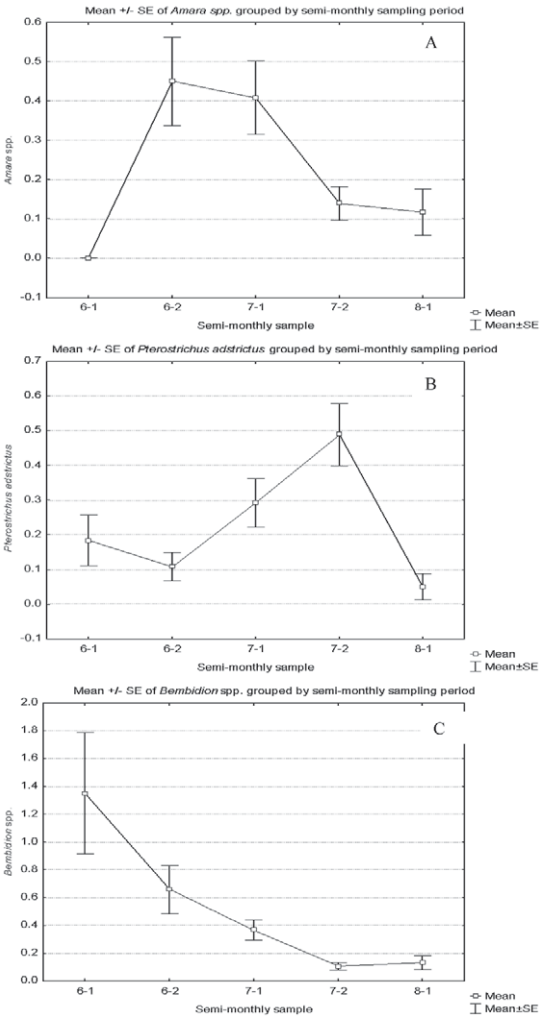


Fig. 2. Mean number of *Amara* sp (A), *Pterostichus adstrictus* (B), and *Bembidion* sp. (C) (+ SEM) in eastern Oregon, 2007.

Previous studies comparing ground beetles in organic and conventional cropping systems reported greater abundance under organic conditions (Clark et al. 2006; Dritschild & Wanner 1980), an observation not supported by our data (Table 3). In our study, ground beetles densities were greater in conventional than in organic systems. Since organic systems do not use synthetic inputs and use cover crops, in theory, organic settings should have been more favorable for ground beetle establishment and development. Dritschilo & Wanner (1980) reported that organic farms had twice the number of ground beetles found on conventional farms, but had the same level of diversity. In eastern Oregon, the high input potato system was suspected to have an effect on ground beetle population, but this study demonstrates that may not be case (Table 4). Probably the additional disturbance under the organic and no-spray treatments affected insect establishment more than conventional settings. To our knowledge, this is the first long-term report on taxa composition and population dynamics of ground beetles from organic and transition plots in Oregon potato fields. Information on ground beetles' taxa composition, distribution, population dynamics, dispersal, and biology is needed to understand their role as predators and seed consumers in potato fields and organic systems. This study provides some of the information necessary to guide future research such as taxa composition, seasonality, and a framework for sampling. Additional research is needed to study the ecology of the dominant taxa and their relationships with cultural practices.

TABLE 4. MEAN +/- SE AND MEAN SEPARATION OF CARABIDS IN EASTERN OREGON.

	Ground beetles
Site	Mean +/- SE
Organic	0.6 +/- 0.1 ab
Semi organic	0.2 +/- 0.1 a
IPM-conventional	0.3 +/- 0.1 a
Conventional	0.7 +/- 0.2 b

Means followed by the same letter within columns are not significantly different (Fisher's LSD, $\alpha = 0.05$); Site ($F = 2.656$, df = 3, $P = 0.049$); total carabids ($F = 2.656$, $P = 0.049$).

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