Brazilian Journal of Biology®

ISSN 1519-6984 (Print)
ISSN 1678-4375 (Online)

Original Article

Survey of ground beetles inhabiting agricultural crops in south-east Kazakhstan

Levantamento de besouros terrestres que habitam plantações agrícolas no sudeste do Cazaquistão

S. A. Jasim[a], G. Yasin[b*], C. Cartono[c], A. Sevbitov[d], R. A. Shichiyakh[e], Y. Al-Husseini[f], Y. F. Mustafa[g], A. T. Jalil[h,i,j] and A. Heri Iswanto[k]

[a]Al-Maarif University College, Medical Laboratory Techniques Department, Al-Anbar-Ramadi, Iraq
[b]Bahauddin Zakariya University, Multan, Pakistan
[c]Universitas Pasundan, Bandung, Jawa Barat, Indonesia
[d]I.M. Sechenov First Moscow State Medical University (Sechenov University), Department of Propaedeutics of Dental Diseases, Moscow, Russia
[e]Kuban State Agrarian University named after I.T. Trubilin, Krasnodar, Russia
[f]Al-Ayen University, College of Health and Medical Technololgy, Department of Anesthesia, Thi-Qar, Iraq
[g]University of Mosul, College of Pharmacy, Department of Pharmaceutical Chemistry, Mosul, Iraq
[h]Yanka Kupala State University of Grodno, Faculty of Biology and Ecology, Grodno, Belarus
[i]The Islamic University, College of Technical Engineering, Najaf, Iraq
[j]Kut University College, Department of Dentistry, Kut, Wasit, Iraq
[k]University of Pembangunan Nasional Veteran Jakarta, Faculty of Health Science, Public Health Department, Jakarta, Indonesia

Abstract

Ground beetles (Carabid beetles) may be found in virtually all of the world's habitats. They are one of the three most diverse families of extant beetles, with 34,275 species documented, and they serve as vital ecological markers in all environments. Edaphic living beetles catch and eat a wide variety of arthropods that live in the soil. In the case of weeds, most of the ground beetles eat their seeds and help regulate their populations. The findings of a field study in agrocenoses in South-East Kazakhstan from 2019 to 2020 are presented in this article. Twenty-seven ground beetle species from 9 genera were discovered as a consequence of the study. 670 soil traps yielded a total of 1012 beetles. Polytopic mesophilic beetles provide the foundation of the agrocenoses fauna. Hygrophils, mesophiles, and eurybionts are among the beetles found in irrigated areas, as are mixed and herbivorous species. The Carabidae family of beetles is the most numerous in fields and steppe settings. As a result, mixed-diet beetles can be found depending on the habitat and air temperature. The species of beetles in all fields in the investigation area are in accordance with the insects' complex. During the growth season, the diet of beetles shifts: predatory beetles take precedence initially, followed by mixed-diet beetles.

Keywords: phytophages, zoophytophages, zoophages, agrocenosis, Carabidae.

Resumo

Os besouros terrestres (besouros carabídeos) podem ser encontrados em praticamente todos os hábitats do mundo. Eles são uma das três famílias mais diversas de besouros existentes, com 34.275 espécies documentadas, e servem como marcadores ecológicos vitais em todos os ambientes. Os besouros vivos edáficos capturam e comem uma grande variedade de artrópodes que vivem no solo. No caso de ervas daninhas, os besouros terrestres, em sua maioria, comem sementes delas e ajudam a regular suas populações. Os resultados do estudo de campo em agrocenoses no sudeste do Cazaquistão de 2019 a 2020 são apresentados neste artigo. Foram descobertas 27 espécies de besouros terrestres de 9 gêneros como consequência do estudo. As 670 armadilhas de solo renderam um total de 1.012 besouros. Besouros mesófilos politópicos fornecem a base para a fauna de agrocenoses. Higrófilos, mesófilos e euribiontes estão entre os besouros encontrados em áreas irrigadas, assim como espécies mistas e herbívoras. Em campos e estepes, a família Carabidae de besouros é a mais numerosa. Como resultado, dependendo do hábitat e da temperatura do ar, podem ser encontrados besouros de dieta mista. As espécies de besouros em todos os campos da área de investigação estão de acordo com o complexo dos insetos. Durante a estação de crescimento, a dieta dos besouros muda: os besouros predadores têm precedência, seguidos dos besouros de dieta mista.

Palavras-chave: fitófagos, zoofitófagos, zoófagos, agrocenose, Carabidae.

*e-mail: yasingmn_bzu@yahoo.com
Received: January 16, 2022 – Accepted: February 8, 2022

1. Introduction

With over 400,000 species, Coleoptera (consisting of the beetles) is the most diverse group of insects. The variety of species in the order Coleoptera is amazing. Some species have very bright and metallic green, blue, red, and yellow colors, and some are charcoal black. Many species of Coleoptera feed on plant components, but many also feed on the carcasses of living organisms or themselves and even their excrement (Adhikari and Menalled, 2018). In beetles, the front wings have become a strong frame or cover that is used to protect the delicate membrane wings used in flight as well as their bodies. Adult beetles usually hunt on the surface of the earth, but they will periodically ascend into the leaves looking for food (Gobbi et al., 2018; Jung et al., 2019). These beetles' burrowing larvae seek for and eat pests in the soil, in addition to being useful predators. With over 40,000 species worldwide, carabid beetles are an exceptionally varied group of insects. Adult ground beetles can be as little as 2mm and as large as 35mm. Numerous ground beetle varieties have a diverse diet, consuming both insects and plant seeds (Kulkarni et al., 2016). In arable areas, field ground beetles (carabids) are diverse and prolific, although they are harmed by extensive agricultural agriculture (Nikbakhtzadeh and Tirgari, 2008; Adhikari and Menalled, 2018; Koivula et al., 2019; Putchkov et al., 2019; Bennewicz and Barczak, 2020; Lira et al., 2020). Depending on the type of investigation, fenced pitfall traps or pitfall trapping is advised for samples (Császár et al., 2018; Gobbi et al., 2018; Jung et al., 2019; Horn, 2020; Knapp et al., 2020). The majority of carabids' alleged beneficial pest control operations are still based on laboratory feeding records (Pizzolotto et al., 2018; Baulechner et al., 2019; Naccarato et al., 2020). Carabids have been shown to lower grain and sugar beet aphid populations in the field, mostly by preying on aphids that have fallen off the plant during their early colonization phase (Gailis et al., 2017; Wang, 2017; Kosewska et al., 2020; Hassan, 2021). Predation on Dipteran eggs, such as those of the cabbage root fly, has been exaggerated in previous work (El-Danasoury et al., 2017; El-Danasoury and Iglesias-Piñeiro, 2018). Carabid foraging on some coleopteran pest larvae is indicated by scattered evidence (Deroulers et al., 2020; Gareau et al., 2020; Halimov, 2020; Oliveira-Hofman et al., 2020; Cividanes, 2021). Some evidence for pest lepidopteran control has been discovered in North America (Floate and Hervet, 2017; Knodel and Shrestha, 2018). Slugs in greenhouses can be efficiently controlled by larger carabids, such as Abax parallelepipedus (Renkema et al., 2014). Certain Harpalus and Amara species may have some biological weed management potential due to their spermophagous eating habits (Ward, 2009; Ward et al., 2011; Kulkarni et al., 2015). Carabids are also becoming valuable in landscape ecological research (Gallé et al., 2019; Aguilera et al., 2020). Their unique environmental needs, along with their preference for walking over flying, allow them to disseminate widely enough to occupy new regions while being manageable in scale.

Ground beetles are widely distributed in the soil both in terms of number and species composition. 25,000 species are known in the world's fauna (Hong et al., 2017; Guseva, 2018). The special ecological adaptability of the species of the genus is the reason for the widespread distribution of these beetles. The vast majority of beetles are omnivorous predators, which determines their practical importance (Kulkarni et al., 2016). Beetles are an important partner in the field of agrocenosis, and they can reduce the number of pests and stop the growth of pests. Crop pests include insects and other animals that eat or damage plants. Pests can be controlled using pesticides or by introducing other species (biological control). To date, the world has accumulated a lot of information about the habitat of beetles in agrocenoses (Bukejs and Balalaikins, 2008; Bukejs, 2009; Guseva and Koval, 2021). There are also herbivores in this genus, which cause a lot of damage to agriculture, including relatives of Harpalus, Poecilus, Zabrus (Kalushkov et al., 2009; Teofilova, 2018). Prior to our research, beetles in special agrocenoses were not studied. The study aims to determine the species composition of beetles in the agrocenosis to study their life cycle, seasonal activity, and nutrient relationship.

2. Materials and Methods

During the collection of materials, common methods were used to catch insects in entomology: beetles were caught by hand from the hiding place and on the soil surface, by entomological filtering, and also collected at night from an artificial light source. Pitfall traps were also used to catch beetles (Gobbi et al., 2018; Baulechner et al., 2019; Naccarato et al., 2020).

Ground beetle (carabid) assemblages can be surveyed using a variety of methods. Litter washing, handpicking, window traps, malaise traps, sweep netting, sticky traps, and pitfall traps are just a few examples (Nasir et al., 2019). Because ground beetles can be collected quickly and cheaply using these pitfall traps, they are the most widely used field method. Pitfall trapping, on the other hand, has a number of drawbacks. Pitfall trap catches are contingent on the species' activity, which varies by species and season. As a result, pitfall catches reflect both the species' real activity and abundance. Pitfall traps capture more large-sized individuals than other methods, such as litter washing, while species not found in pitfall catches are often yielded in hand collecting (Gobbi et al., 2018; Jung et al., 2019; Knapp et al., 2020). Pitfall traps are simple to adapt to the study's specific requirements. The best collecting method is determined by the survey's environmental condition and goal, including the vegetation types in which the collection takes place (Gardarin and Valantin-Morison, 2021).

0.5 L plastic glass, 1/3 of which is filled with 4% formalin. Ten traps were installed at a distance of 10 meters from the studied field area, and soil traps were installed from late May to mid-October. We collected beetles from the trap every 7-10 days (Figure 1). As a result of the study, microscopy identified the collected materials in the laboratory.

Figure 1. Pitfall trap and the ground beetles trapped inside.

3. Results and Discussion

The following is an annotated list of species found as a result of the study. As a result of the study, 1012 beetles out of 670 traps were registered, which are 27 species belonging to 9 relatives (Figure 2). Among them are the most common species: Calathus (Neocalathus) ambiguus ambiguus Paykull, 1790, Amara aenea DeGeer, 1774, Poecilus versicolor Sturm, 1824, Poecilus sericeus sericeus Fischer von Waldheim, 1824, Poecilus punctulatus Schaller, 1783, Harpalus (Psedoophonus) rufipes DeGeer, 1774, and Harpalus smaragdinus, Harpalus (Psedoophonus) griseus Panzer, 1796 (Neculiseanu and Matalin, 2000; Sivčev et al., 2014; Teofilova, 2018).

According to Figure 2, the predominant species of beetles in the agrocenoses of South-East Kazakhstan are Poecilus (4 species, 15%), Amara (6 species, 23%), and Harpalus (10 species, 38%), of the remaining six relatives, only 1-2 species were known. Following some characteristics of the most common beetle species are mentioned (Kotze and O'Hara, 2003; Niemelä and Kotze, 2009):

Harpalus smaragdinus (Duftschmied, 1812): It feeds mainly on plants, harms cereals, gnaws at the stage of grain ripening. Mixed feed. It also feeds on eggs, larvae, and pupae of small or medium-sized insects that are less mobile.

Harpalus affinis Schrank, 1781: Lives in fields and meadows. Geochortobiont. Transpalaarctic species. It is found everywhere in the Palearctic, except in the mountains. Beetles are found from June to August. Mixed feed. It feeds mainly on plants. The usual type everywhere.

Harpalus anxius Duftschmid, 1812: Stenothermic, relatively heat-loving species (above 25°C). Mixed. It is found in fields and meadows.

Harpalus brevicornis Germar, 1824: A typical Kazakh steppe species, found in fields and Meadows. Mixed feed.

Harpalus distinguendus distinguendus Duftschmid, 1812: Polytope mesophilus. Geochortobiont. The usual type everywhere. It is found in fields and Meadows. The eurytherm species lives actively (at lower and upper temperatures).

Harpalus froelichii Sturm, 1818: Geochortobiont. It is found in fields and Meadows.

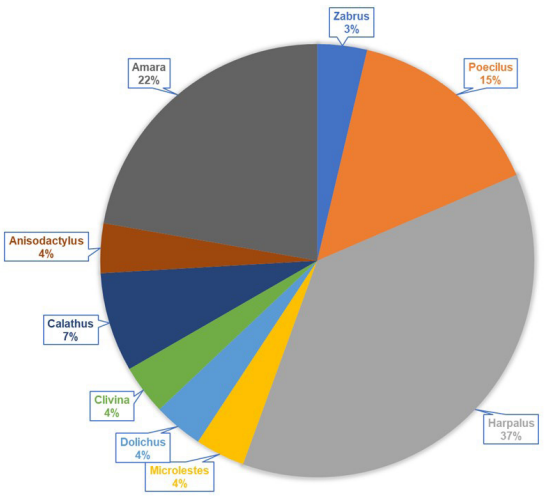

Figure 2. Species composition of ground beetles in agrocenoses of South-East Kazakhstan.

Harpalus (s. str.) serripes serripes Quensel, 1806: Geochortobiont. It is found in fields and Meadows.

Harpalus smaragdinus Duftschmid, 1812: Geochortobiont. Mixed feed. It is found in fields and Meadows.

Harpalus (Psedoophonus) griseus Panzer, 1796: Geochortobiont. Mixed feed. It is found in fields and Meadows.

Harpalus (Psedoophonus) rufipes DeGeer, 1774: A polyvariant species found in open biotopes, fields. Geochortobiont. Mixed feed. Active from the end of May to the end of August. The breeding season lasts from the second half of July to mid-August. Mass reproduction takes place in July.

Poecilus (s. str.) punctulatus Schaller, 1783: Geochortobiont. A predator. It is found in fields and Meadows.

Poecilus (s. str.) sericeus sericeus Fischer von Waldheim, 1824: It naturally regulates the numbers of many insects, land snails and other invertebrates, including dangerous pests. Stenothermic species, relatively cold-loving (17-23°C) species.

Poecilus versicolor (Sturm, 1824): It is one of the dominant species in agricultural landscapes. It is also found in all landscapes, mainly in fields and adjacent regions. The larvae were found both in the fields and in adjacent areas. Representatives of this species tend to soils with light mechanical composition. According to the famous Swedish carabidologist Carl Lindrot, this species is more xerophilous than P. supreus. It feeds on mixed food, various cultivated plants and causes damage. In the spring, in dry weather, to restore the water balance in the body, it chews the succulent shoots of plants. Eurybiont.

Poecilus cupreus (Linnaeus, 1758): The common life span of this species is similar to that of the species Poecilus versicolor, often found together. The difference lies in the indistinctness of the shoulder girdle on the upper wing. Poecilus cupreus is a common species that prevail in various agrocenoses located quite far from each other. It is an omnivorous predator with a wide range of nutritional connections. It is the most important entomophage of the Colorado potato beetle, Leptinotarsa decemlineata (Say), and the most common species in the agricultural landscape of South-East Kazakhstan. In agrocenoses, the number of these ground beetles is higher in the middle part than in the periphery of the field, as it is very favorable for their nutrition and reproduction.

Zabrus tenebrioides Goeze, 1777 = Zabrus gibbus Fabr: The common ground beetle. During the day, it hides under a rock; at night, it feeds on grains (wheat, rye, barley). Because they are prone to moisture, they are abundant during irrigation. Beetles often come out at the end of June; their larvae overwinter and become pupae in the soil at the end of May. Beetles settle in the field when the grain is ripe and feed on soft grain at night. After harvesting, the beetles hide in dry places at a temperature of 28-34°C. This will depend on the moisture content of the soil. From the second half of August to September-October, the female lays eggs in the soil to a depth of 5-15 cm. The female lays 120-270 eggs if she is well fed with winter grain and 30 eggs if she is not fed. Embryonic development lasts 9-12 days if the daily temperature is 23-25°C and 20-25 days if it is 12-14°C. The larvae come to the surface of the soil at night and feed on the leaves of grain crops. During the day, it pulls parts of the leaves into the holes. Larvae cause damage to winter sowing. When the temperature drops to 0-5°C, the larvae stop feeding and overwinter in the soil to a depth of 30-40 cm.

4. Conclusion

Although carabid beetles (ground beetles) use many ecological tactics, to represent the majority of species, generalizations may be established. As a result of field research in the agrocenoses of South-East Kazakhstan in 2019-2020, 27 species belonging to 9 relatives of the ground beetles (Order Coleoptera: Family Carabidae) were identified. Out of 670 pitfall traps, 1012 pieces of ground beetles were taken into account. Among them, the dominant species are: Calathus (Neocalathus) ambiguus ambiguus Paykull, 1790, Amara aenea DeGeer, 1774, Poecilus versicolor Sturm, 1824, Poecilus sericeus sericeus Fischer von Waldheim, 1824, Poecilus punctulatus Schaller, 1783, Harpalus (Psedoophonus) rufipes DeGeer, 1774, and Harpalus smaragdinus, Harpalus (Psedoophonus) griseus Panzer, 1796. The basis of the fauna of agrocenoses are polytopic mesophilic beetles. In irrigated fields, there is a high number of ground beetles and they consist of hygrophiles, mesophiles, epibionts, and in these places most of the beetles are zoophages. There is a mixed type of food among the groups of predators (zoophages) and herbivores (phytophages). These are the most frequent ground beetle species in fields and steppe landscapes. As a result, mixed-feed species might be found among ground beetles depending on the habitat and air temperature. The beetles' nutritional structure changes during the growing season: at first, predatory beetles predominate, and finally mixed-feed beetles predominate.

References

ADHIKARI, S. and MENALLED, F.D., 2018. Impacts of dryland farm management systems on weeds and ground beetles (Carabidae) in the Northern Great Plains. *Sustainability*, vol. 10, no. 7, pp. 2146. http://dx.doi.org/10.3390/su10072146.

AGUILERA, G., ROSLIN, T., MILLER, K., TAMBURINI, G., BIRKHOFER, K., CABALLERO-LOPEZ, B., LINDSTRÖM, S.A.-M., ÖCKINGER, E., RUNDLÖF, M., RUSCH, A., SMITH, H.G. and BOMMARCO, R., 2020. Crop diversity benefits carabid and pollinator communities in landscapes with semi-natural habitats. *Journal of Applied Ecology*, vol. 57, no. 11, pp. 2170-2179. http://dx.doi.org/10.1111/1365-2664.13712.

BAULECHNER, D., DIEKÖTTER, T., WOLTERS, V. and JAUKER, F., 2019. Converting arable land into flowering fields changes functional and phylogenetic community structure in ground beetles. *Biological Conservation*, vol. 231, pp. 51-58. http://dx.doi.org/10.1016/j.biocon.2019.01.005.

BENNEWICZ, J. and BARCZAK, T., 2020. Ground beetles (Carabidae) of field margin habitats. *Biologia*, vol. 75, no. 10, pp. 1631-1641. http://dx.doi.org/10.2478/s11756-020-00424-y.

BUKEJS, A. and BALALAIKINS, M., 2008. Ground beetles (Coleoptera: Carabidae) of wheat agrocenosis in Latvia. *Acta Zoologica Lituanica*, vol. 18, no. 2, pp. 134-138. http://dx.doi.org/10.2478/v10043-008-0019-7.

BUKEJS, A., 2009. Complex of carabid beetles (Coleoptera: Carabidae) of potato field agrocenosis in eastern Latvia. *Acta Zoologica Lituanica*, vol. 19, no. 3, pp. 216-222. http://dx.doi.org/10.2478/v10043-009-0026-3.

CIVIDANES, F.J., 2021. Carabid beetles (Coleoptera: Carabidae) and biological control of agricultural pests in Latin America. *Annals of the Entomological Society of America*, vol. 114, no. 2, pp. 175-191. http://dx.doi.org/10.1093/aesa/saaa051.

CSÁSZÁR, P., TORMA, A., GALLÉ-SZPISJAK, N., TÖLGYESI, C. and GALLÉ, R., 2018. Efficiency of pitfall traps with funnels and/or roofs in capturing ground-dwelling arthropods. *European Journal of Entomology*, vol. 115, pp. 15-24. http://dx.doi.org/10.14411/eje.2018.003.

DEROULERS, P., GAUFFRE, B., EMERIAU, S., HARISMENDY, A. and BRETAGNOLLE, V., 2020. Towards a standardized experimental protocol to investigate interactions between weed seeds and ground beetles (Carabidae, Coleoptera). *Arthropod-Plant Interactions*, vol. 14, no. 1, pp. 127-138. http://dx.doi.org/10.1007/s11829-019-09721-z.

EL-DANASOURY, H. and IGLESIAS-PIÑEIRO, J., 2018. Predation by polyphagous carabid beetles on eggs of a pest slug: potential implications of climate change. *Journal of Applied Entomology*, vol. 142, no. 3, pp. 340-348. http://dx.doi.org/10.1111/jen.12474.

EL-DANASOURY, H., CERECEDO, C., CÓRDOBA, M. and IGLESIAS-PIÑEIRO, J., 2017. Predation by the carabid beetle Harpalus rufipes on the pest slug Deroceras reticulatum in the laboratory. *Annals of Applied Biology*, vol. 170, no. 2, pp. 251-262. http://dx.doi.org/10.1111/aab.12337.

FLOATE, K.D. and HERVET, V.A., 2017. Noctuid (Lepidoptera: Noctuidae) pests of canola in North America. In: G.V.P. REDDY, ed. *Integrated management of insect pests on canola and other brassica oilseed crops*. Boston: CABI, pp. 96-113. http://dx.doi.org/10.1079/9781780648200.0096.

GAILIS, J., TURKA, I. and AUSMANE, M., 2017. The most frequent ground beetles (Coleoptera, Carabidae) are differently affected by main soil treatment and crop rotation in winter wheat fields. *Acta Biologica Universitatis Daugavpiliensis*, vol. 17, no. 1, pp. 29-52.

GALLÉ, R., HAPPE, A.-K., BAILLOD, A.B., TSCHARNTKE, T. and BATÁRY, P., 2019. Landscape configuration, organic management, and within-field position drive functional diversity of spiders and carabids. *Journal of Applied Ecology*, vol. 56, no. 1, pp. 63-72. http://dx.doi.org/10.1111/1365-2664.13257.

GARDARIN, A. and VALANTIN-MORISON, M., 2021. Which Pitfall Traps and Sampling Effort to Choose to Evaluate Cropping System Effects on Spider and Carabid Assemblages? *Environmental Entomology*, vol. 50, no. 1, pp. 256-266. http://dx.doi.org/10.1093/ee/nvaa145. PMid:33219662.

GAREAU, T.P., VOORTMAN, C. and BARBERCHECK, M., 2020. Carabid beetles (Coleoptera: Carabidae) differentially respond to soil management practices in feed and forage systems in transition to organic management. *Renewable Agriculture and Food Systems*, vol. 35, no. 6, pp. 608-625. http://dx.doi.org/10.1017/S1742170519000255.

GOBBI, M., BARRAGÁN, Á., BRAMBILLA, M., MORENO, E., PRUNA, W. and MORET, P., 2018. Hand searching versus pitfall trapping: how to assess biodiversity of ground beetles (Coleoptera: Carabidae) in high altitude equatorial Andes? *Journal of Insect Conservation*, vol. 22, no. 3, pp. 533-543. http://dx.doi.org/10.1007/s10841-018-0082-8.

GUSEVA, O.G. and KOVAL, A.G., 2021. Distribution of ground beetles of the genus Bembidion (Coleoptera, Carabidae) in the agricultural landscape in Northwestern Russia. *Acta Biologica Sibirica*, vol. 7, pp. 227-236. http://dx.doi.org/10.3897/abs.7.e70229.

GUSEVA, O.G., 2018. Distribution of ground beetles of the genus Poecilus Bonelli, 1810 (Coleoptera, Carabidae) in the agrolandscape in Northwestern Russia. *Acta Biologica Sibirica*, vol. 4, no. 3, pp. 102-107. http://dx.doi.org/10.14258/abs.v4i3.4414.

HALIMOV, F., 2020. Seasonal dynamics of dominant species of soil predators (Coleoptera: Carabidae, Staphylinidae) in agrolandscapes and their potential gluttony. *Travaux du Muséum National d'Histoire Naturelle "Grigore Antipa"*, vol. 63, pp. 175.

HASSAN, H.M., 2021. Role of the rove beetle, *Paederus memnonius* (Erichson) (Coleoptera: Staphylinidae) in controlling certain sugar beet pests for the first time in Egypt. *Journal of Plant Protection and Pathology*, vol. 12, no. 2, pp. 117-120. http://dx.doi.org/10.21608/jppp.2021.154392.

HONG, E., KIM, Y., JEONG, J.-C., KANG, S.-H., JUNG, J.-K. and SUK, S.-W., 2017. Community structure and distribution of ground beetles (Coleoptera: Carabidae) in Sobaeksan National Park, Korea. *Journal of Ecology and Environment*, vol. 41, no. 1, pp. 1-7. http://dx.doi.org/10.1186/s41610-017-0036-1.

HORN, S., 2020. Barrier pitfall traps increase captures of ground beetles (Coleoptera: Carabidae) on exposed riverine sediments. *European Journal of Entomology*, vol. 117, pp. 76-82. http://dx.doi.org/10.14411/eje.2020.008.

JUNG, J.-K., JEONG, J.-C. and LEE, J.-H., 2019. Effects of pitfall trap size and sampling duration on collection of ground beetles (Coleoptera: Carabidae) in temperate forests. *Entomological Research*, vol. 49, no. 5, pp. 229-236. http://dx.doi.org/10.1111/1748-5967.12358.

KALUSHKOV, P., GUEORGUIEV, B., SPITZER, L. and NEDVED, O., 2009. Biodiversity of ground beetles (Coleoptera: Carabidae) in genetically modified (Bt) and conventional (non-Bt) potato fields in Bulgaria. *Biotechnology, Biotechnological Equipment*, vol. 23, no. 3, pp. 1346-1350. http://dx.doi.org/10.1080/13102818.2009.10817667.

KNAPP, M., KNAPPOVÁ, J., JAKUBEC, P., VONIČKA, P. and MORAVEC, P., 2020. Incomplete species lists produced by pitfall trapping: how many carabid species and which functional traits are missing? *Biological Conservation*, vol. 245, pp. 108545. http://dx.doi.org/10.1016/j.biocon.2020.108545.

KNODEL, J.J. and SHRESTHA, G., 2018. Pulse crops: pest management of wireworms and cutworms in the Northern Great Plains of United States and Canada. *Annals of the Entomological Society of America*, vol. 111, no. 4, pp. 195-204. http://dx.doi.org/10.1093/aesa/say018.

KOIVULA, M.J., VENN, S., HAKOLA, P. and NIEMELÄ, J., 2019. Responses of boreal ground beetles (Coleoptera, Carabidae) to different logging regimes ten years post harvest. *Forest Ecology and Management*, vol. 436, pp. 27-38. http://dx.doi.org/10.1016/j.foreco.2018.12.047.

KOSEWSKA, A., NIJAK, K., NIETUPSKI, M., KĘDZIOR, R. and LUDWICZAK, E., 2020. Effect of plant protection on assemblages of ground beetles (Coleoptera, Carabidae) in sugar beet crops in four-year rotation. *Acta Zoologica Academiae Scientiarum Hungaricae*, vol. 66, suppl., pp. 49-68. http://dx.doi.org/10.17109/AZH.66.Suppl.49.2020.

KOTZE, D.J. and O'HARA, R.B., 2003. Species decline: but why? Explanations of carabid beetle (Coleoptera, Carabidae) declines in Europe. *Oecologia*, vol. 135, no. 1, pp. 138-148. http://dx.doi.org/10.1007/s00442-002-1174-3. PMid:12647113.

KULKARNI, S.S., DOSDALL, L.M. and WILLENBORG, C.J., 2015. The role of ground beetles (Coleoptera: Carabidae) in weed seed consumption: a review. *Weed Science*, vol. 63, no. 2, pp. 355-376. http://dx.doi.org/10.1614/WS-D-14-00067.1.

KULKARNI, S.S., DOSDALL, L.M., SPENCE, J.R. and WILLENBORG, C.J., 2016. Brassicaceous weed seed predation by ground beetles (Coleoptera: carabidae). *Weed Science*, vol. 64, no. 2, pp. 294-302. http://dx.doi.org/10.1614/WS-D-15-00069.1.

LIRA, L.A., BARROS-CORDEIRO, K.B., FIGUEIREDO, B., GALVÃO, M.F. and FRIZZAS, M.R., 2020. The carrion beetle *Oxelytrum discicolle* (Coleoptera: Silphidae) and the estimative of the minimum post-mortem interval in a forensic case in Brasília, Brazil. *Revista Brasileira de Entomologia*, vol. 64, no. 1, e201992. http://dx.doi.org/10.1590/1806-9665-rbent-2019-92.

NACCARATO, A., TASSONE, A., CAVALIERE, F., ELLIANI, R., PIRRONE, N., SPROVIERI, F., TAGARELLI, A. and GIGLIO, A., 2020. Agrochemical treatments as a source of heavy metals and rare earth elements in agricultural soils and bioaccumulation in ground beetles. *The Science of the Total Environment*, vol. 749, pp. 141438. http://dx.doi.org/10.1016/j.scitotenv.2020.141438. PMid:32827832.

NASIR, S., NASIR, I., HAFEEZ, F. and YOUSAF, I., 2019. Comparison of attractive and intercept traps for sampling rove beetles

(Coleoptera: staphylinidae). *Journal of Entomological Research Society*, vol. 21, no. 3, pp. 257-269.

NECULISEANU, Z.Z. and MATALIN, A.V., 2000. *A catalogue of the Ground-beetles of the Republic of Moldova:(Insecta, Coleoptera, Carabidae).* Sofia: Pensoft Publishers.

NIEMELÄ, J. and KOTZE, D.J., 2009. Carabid beetle assemblages along urban to rural gradients: A review. *Landscape and Urban Planning*, vol. 92, no. 2, pp. 65-71. http://dx.doi.org/10.1016/j.landurbplan.2009.05.016.

NIKBAKHTZADEH, M.R. and TIRGARI, S., 2008. Medically important beetles (insecta: coleoptera) of Iran. *The Journal of Venomous Animals and Toxins Including Tropical Diseases*, vol. 14, no. 4, pp. 597-618. http://dx.doi.org/10.1590/S1678-91992008000400004.

OLIVEIRA-HOFMAN, C., VICTOR, V.S., MEINKE, L.J. and PETERSON, J.A., 2020. Molecular gut-content analysis of adult ground beetles (Coleoptera: Carabidae) provides no evidence of predation of western corn rootworm (Coleoptera: Chrysomelidae) in a Nebraska corn agroecosystem. *Journal of Entomological Science*, vol. 55, no. 4, pp. 448-461. http://dx.doi.org/10.18474/0749-8004-55.4.448.

PIZZOLOTTO, R., MAZZEI, A., BONACCI, T., SCALERCIO, S., IANNOTTA, N. and BRANDMAYR, P., 2018. Ground beetles in Mediterranean olive agroecosystems: their significance and functional role as bioindicators (Coleoptera, Carabidae). *PLoS One*, vol. 13, no. 3, pp. e0194551. http://dx.doi.org/10.1371/journal.pone.0194551. PMid:29558493.

PUTCHKOV, A.V., BRYGADYRENKO, V.V. and MARKINA, T.Y., 2019. Ground beetles of the tribe Carabini (Coleoptera, Carabidae) in the main megapolises of Ukraine. *Vestnik Zoologii*, vol. 53, no. 1, pp. 3-12. http://dx.doi.org/10.2478/vzoo-2019-0001.

RENKEMA, J.M., CUTLER, G.C., BLANCHARD, D. and HAMMERMEISTER, A., 2014. Using ground beetles (Coleoptera: Carabidae) to control slugs (Gastropoda: Pulmonata) in salad greens in the laboratory and greenhouse. *Canadian Entomologist*, vol. 146, no. 5, pp. 567-578. http://dx.doi.org/10.4039/tce.2014.8.

SIVČEV, L.I., BÜCHS, W.G., PRESCHER, S., GRAORA, D.D.J., ĆURČIĆ, S.B., SIVČEV, I.L., SCHMIDT, L., TOMIĆ, V.T., DUDIĆ, B.D. and ČULJAK, T.G., 2014. Contribution to the knowledge of the ground beetle fauna from Serbia (Coleoptera: carabidae). *Acta Entomologica Serbica*, vol. 19, no. 1-2, pp. 13-23.

TEOFILOVA, T.M., 2018. Ground beetles (Coleoptera: Carabidae) in grasslands: model for assessment of the species diversity and ecosystem condition in Bulgaria. *North-Western Journal of Zoology*, vol. 14, no. 1, pp. 1-12.

WANG, Y., 2017. *Abundance of aphids and arthropod natural enemies in diversified wheat cropping systems in the Netherlands.* Wageningen: Wageningen University.

WARD, M.J., 2009. *Ecological weed management: the role of ground beetles in weed seed predation.* Pennsylvania: The Pennsylvania State University, 150 p. Master Thesis in Science.

WARD, M.J., RYAN, M.R., CURRAN, W.S., BARBERCHECK, M.E. and MORTENSEN, D.A., 2011. Cover crops and disturbance influence activity-density of weed seed predators Amara aenea and Harpalus pensylvanicus (Coleoptera: carabidae). *Weed Science*, vol. 59, no. 1, pp. 76-81. http://dx.doi.org/10.1614/WS-D-10-00065.1.