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Overwintering of Coccinellids (Coleoptera: Coccinellidae) in the Center of Iran

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ABSTRACT

Overwintering adult coccinellids were collected underneath the bark of tree trunks of apricot, pomegranate, almond and mulberry in the Mehriz region of Yazd province, Iran, in 2009 to 2012 at elevations 1420-1520 meters. We identified and illustrated the following six species: *Adalia bipunctata* (Linnaeus, 1758): 61 individuals, *Exochomus quadripustulatus* (Linnaeus, 1758): 7 individuals, *Exochomus undulatus* Weise, 1878: 26 individuals, *Hippodamia variegata* (Goeze, 1777): 1 individual, *Oenopia conglobata* (Linnaeus, 1758): 95 individuals, *Scymnus subvillosus* (Goeze, 1777): 3 individuals. Coccinellids occasionally overwintered in multispecies groups. Pomegranate was host of most overwintering coccinellids.

Key words: Coccinellidae, aggregation, diapause, overwintering, distribution, Iran.

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INTRODUCTION

Hibernacula of coccinellid beetles in temperate climate may be scattered in agricultural areas, along forest margins, gardens, dry vegetation and even on the walls of buildings. Certain hypsotactic species fly to prominent hilltops, often several kilometers away from where they reproduced. At these sites, diapausing adults stay from mid-summer (July-August) until the following spring (April-May), sheltering in various structures and largely refraining from feeding (Hagen, 1962; Hodek, 1996). Thus, they spend a considerable time in (aestivo-) hibernation and have physiological and behavioural adaptations that minimize mortality during this period. Overwintering at high elevations may be adaptive but sometimes turns into ecological trap (Güven, Gölluoğlu, & Ceryngier, 2015).

Hibernating adults may aggregate in clumps, which usually consist of a few but sometimes tens of thousands of individuals. Ecological theory predicts that clumping may decrease the risk of predation and/or parasitism (Sillen-Tullberg and Leimar, 1988; Turchin and Kareiva, 1989; Mooring & Hartl, 1992). However, the high population density may also facilitate the spread of disease (Bellows & Hassell, 1999). Aggregation was studied in three species that differ in their overwintering habits, *Coccinella septempunctata* L., *Hippodamia undecimnotata* (Schneider) and *Hippodamia variegata* (Goeze) by Honek, Martinkova, & Pekar (2007). The hibernation behaviour of *C. septempunctata* is plastic (Hodek, 1960). Adults of this species move between habitats (Ricci, Pontil & Pires, 2005) before flying to hibernacula (Honek, 1990; Nedved, Ceryngier, Hodkova, & Hodek, 2001). Many individuals of *C. septempunctata* and other species hibernate at lowland sites with warm microclimates (southern slopes, woodland margins and roadsides), where they overwinter under dead leaves or other dry vegetation, singly or in small groups (Honek, 1989). Adults of *C. septempunctata* and *H. variegata* that fly to hilltop hibernacula overwinter in grass tussocks or under stones, singly or in groups that may consist of several tens of individuals (Honek, 1989; Ceryngier, 2000; Güven et al, 2015). Adults of *H. undecimnotata* and *Tytthaspis sedecimpunctata* form large aggregations (thousands or more individuals) in crevices on hill tops (Hodek 1960, Nedvěd, 2006). According to Novak & Grenarova (1967), much higher resistance to low temperature as well as to low moisture was found in *A. bipunctata*, which hibernates in bark crevices, than in *C. septempunctata*, *Coccinella quinquepunctata* and *Exochomus quadripustulatus*, which hibernate in litter. Individuals exposed to cool and dry climatic conditions develop stronger cold hardiness (Nedvěd, 1993; 1995). However, coccinellids can move between exposed sites on bark to shelters even during winter, causing apparent changes of their abundance (Holecová et al, 2018). The abundance of overwintering adults greatly varies among years (Honek & Martinkova, 2005).

Location and timing of hibernation affect the survival of coccinellids and their presence on specific plants early in the next season where they are needed for suppression of pests. The present study was undertaken as part of an inventory of overwintering natural enemies in agricultural Mehriz region, Iran.

MATERIAL AND METHODS

Three locations in Mehriz region of Yazd province, Iran, were sampled: Mehriz (Baghdad Abad 31°34´25˝N, 54°26´13˝E, 1502 m, and Stehrij nearby), Khormiz (31°32´30˝N, 54°26´15˝E, 1520 m) and Saryazd (31°36´23˝N, 54°55´07˝E, 1420 m) (Fig. 1). Sampling in each station was done on ten old trees of apricot, pomegranate, almond, and mulberry, which were selected randomly, repeatedly from September 2009 to March 2010 and from December 2011 to March 2012. Minimum temperatures in January in the region were 6.4°C. The height where the individuals were sampled was measured using Measuring tape (2010-2012). Adult specimens were collected from under the bark of selected trees, using a screwdriver to pry the bark loose. All collected specimens were killed in a cyanide killing jar and pinned. each specimen was tagged with the information about the host plant, locality, and date of collection. Genitalia of both sexes were dissected by softening the specimens in hot water, removing the abdomen, placing it in a dilute solution of potassium hydroxide until the fat and muscle were dissolved, then rinsing the abdomen and genitalia in clean water, aimed to prepare microscopic slides for more examination. Morphological identification was done based on Nedved (2015).

Fig. 1. Sampling localities of the coccinellids in the Yazd province (Iran).

RESULTS

Six species of coccinellids were collected overwintering in early 2010 (Table 1): *Adalia bipunctata* (Linnaeus, 1758): 27 individuals, *Exochomus quadripustulatus* (Linnaeus, 1758): 5 individuals, *Exochomus undulatus* (Weise, 1878):2 individuals, *Hippodamia variegata* (Goeze, 1777): 1 individual, *Oenopia conglobata* (Linnaeus, 1758): 42 individuals, *Scymnus subvillosus* (Goeze, 1777): 1 individual. Dorsal colour pattern was highly variable in *A. bipunctata*, with two morphs and four aberrations

found in this survey (Fig. 2). No coccinellids were found from September to December 2009 and in March 2010. The highest number of species and individuals were obtained from pomegranate.

In 2011-2012, the same species, except *H. variegata*, and in similar numbers were sampled (Table 1), here provided with the mean height of sampling: *A. bipunctata*: 34 individuals, 1.2 m; *E. quadripustulatus*: 2 individuals, 1.7 m; *E. undulatus*: 17 individuals, 1.6 m; *O. conglobata*: 53 individuals, 1.0 m; *Scymnus subvillosus* (Goeze, 1777): 3 individuals, 1.5 m. Coccinellids were mostly found individually. The exception was a group of 12 *O. conglobata* with 9 *A. bipunctata* and two *E. undulatus* on mulberry.

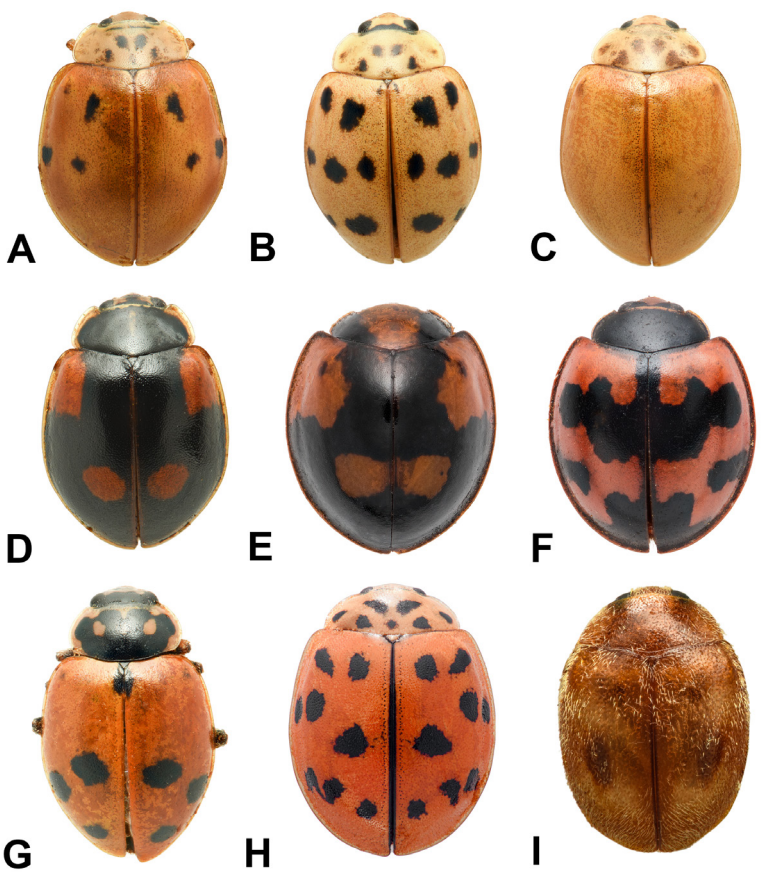

Fig. 2. Coccinellid species collected from the Yazd province during overwintering, dorsal view. A, B, C, D. Diverse colour morphs of *Adalia bipunctata* (Linnaeus, 1758); E. *Exochomus quadripustulatus* (Linnaeus, 1758); F. *Exochomus undulatus* Weise, 1878; G. *Hippodamia variegata* (Goeze, 1777); H. *Oenopia conglobata* (Linnaeus, 1758); I. *Scymnus subvillosus (*Goeze, 1777).

Table 1. Sampling locations and dates of ladybird species collected in the Yazd province along with host plant information during 2010–2012.

Location	Date	Host plant	Tree height (m)	Number
***Adalia bipunctata* (Linnaeus, 1758)**				
Khormiz	06.01.2010	Mulberry	1	1
Saryazd	26.01.2010	Pomegranate	1.64	3
Stehrij	19.02.2010	Almond	2.60	1
Khormiz	22.12.2011	Almond	3.00	1
Khormiz	02.01.2012	Pomegranate	1.00	1
Saryazd	25.01.2012	Pomegranate	1.68	2
Baghdad Abad	04.02.2012	Pomegranate	1.52	2
Stehrij	09.02.2012	Pomegranate	1.22	1
Baghdad Abad	11.02.2012	Mulberry	0.89	9
Stehrij	12.02.2012	Pomegranate	1.60	1
Stehrij	13.02.2012	Pomegranate	1.37	2
Baghdad Abad	15.02.2012	Pomegranate	1.09	2
Baghdad Abad	18.02.2012	Pomegranate	0.58	1
Baghdad Abad	23.02.2012	Pomegranate	0.48	1
Stehrij	26.02.2012	Pomegranate	1.66	1
Baghdad Abad	26.02.2012	Pomegranate	1.56	1
Baghdad Abad	29.02.2012	Pomegranate	1.38	1
Baghdad Abad	03.03.2012	Pomegranate	0.93	6
Baghdad Abad	03.03.2012	Pomegranate	1.56	2
***Exochomus quadripustulatus* (Linnaeus, 1758)**				
Saryazd	28.01.2010	Pomegranate	1.46	3
Stehrij	10.02.2010	Pomegranate	1.32	2
Saryazd	25.01.2012	Pomegranate	1.68	2
***Exochomus undulatus* (Weise, 1878)**				
Khormiz	29.01.2010	Apricot	1	1
Saryazd	02.02.2010	Almond	2.50	1
Khormiz	23.12.2011	Pomegranate	2.00	1
Khormiz	29.12.2011	Pomegranate	3.00	1
Khormiz	11.01.2012	Pomegranate	2.00	1
Khormiz	14.01.2012	Pomegranate	2.00	1
Khormiz	16.01.2012	Apricot	2.00	1
Khormiz	21.01.2012	Pomegranate	2.50	1
Saryazd	23.01.2012	Pomegranate	2.00	1
Saryazd	28.01.2012	Pomegranate	1.46	1
Saryazd	31.01.2012	Pomegranate	1.22	1
Saryazd	03.02.2012	Pomegranate	1.16	1
Saryazd	05.02.2012	Pomegranate	0.46	1
Baghdad Abad	11.02.2012	Mulberry	0.89	2
Baghdad Abad	14.02.2012	Pomegranate	1.65	1
Baghdad Abad	03.03.2012	Pomegranate	0.93	2
Baghdad Abad	03.03.2012	Pomegranate	1.56	1

Table 1. Continued.

Location	Date	Host plant	Tree height (m)	Number
***Hippodamia variegata* (Goeze, 1777)**				
Stehrij	08.02.2010	Pomegranate	1.24	1
***Oenopia conglobata* (Linnaeus, 1758)**				
Khormiz	13.01.2010	Apricot	1	3
Saryazd	28.01.2010	Almond	2.50	2
Mehriz	08.02.2010	Pomegranate	1.20	2
Khormiz	26.12.2011	Pomegranate	2.50	1
Khormiz	18.01.2012	Apricot	1.00	1
Baghdad Abad	04.02.2012	Pomegranate	1.52	1
Stehrij	07.02.2012	Pomegranate	1.65	1
Baghdad Abad	07.02.2012	Pomegranate	1.54	4
Baghdad Abad	11.02.2012	Mulberry	0.89	12
Baghdad Abad	14.02.2012	Pomegranate	1.65	1
Baghdad Abad	14.02.2012	Apricot	0.69	1
Baghdad Abad	15.02.2012	Pomegranate	0.89	1
Baghdad Abad	18.02.2012	Pomegranate	0.58	2
Baghdad Abad	18.02.2012	Pomegranate	1.56	1
Baghdad Abad	20.02.2012	Pomegranate	1.19	3
Baghdad Abad	20.02.2012	Pomegranate	1.33	1
Baghdad Abad	23.02.2012	Mulberry	0.48	1
Baghdad Abad	23.02.2012	Pomegranate	1.26	1
Baghdad Abad	26.02.2012	Pomegranate	1.56	4
Baghdad Abad	26.02.2012	Pomegranate	1.08	2
Baghdad Abad	29.02.2012	Pomegranate	1.38	2
Baghdad Abad	29.02.2012	Pomegranate	0.61	2
Stehrij	29.02.2012	Pomegranate	1.09	1
Baghdad Abad	03.03.2012	Pomegranate	0.48	1
Stehrij	03.03.2012	Apricot	0.52	2
Baghdad Abad	05.03.2012	Pomegranate	0.89	1
Stehrij	05.03.2012	Pomegranate	0.38	1
Baghdad Abad	07.03.2012	Pomegranate	0.49	2
Stehrij	07.03.2012	Pomegranate	0.41	1
Baghdad Abad	09.03.2012	Pomegranate	0.89	1
Stehrij	09.03.2012	Pomegranate	0.33	1
***Scymnus subvillosus* (Goeze, 1777)**				
Khormiz	13.01.2010	Pomegranate	1.30	1
Khormiz	05.01.2012	Pomegranate	1.00	1
Khormiz	08.01.2012	Pomegranate	2.00	1

DISCUSSION

Most coccinellid species in temperate region overwinter as adults, although *Scymnus abietis* (Paykull, 1798) also as larvae (Nedvěd & Honěk, 2012) and *S. impexus* Mulsant, 1850 as eggs (Delucchi, 1954). Different microhabitats are used for hibernation by the Coccinellidae (Hodek, 1960; 1973). They choose sites which offer shelter from cold and moisture. We observed six species of coccinellids typical for fruit trees overwintering directly in the orchards under the bark of tree species that were probably also host plants for these species during the breeding period. Only *H. variegata*, common in most of Iran, but found in a single individual in our study, prefers herbs such as alfalfa and overwintering sites among dry herbs. Anyway, various insects can fly long distances to find large trees with space under the bark for overwintering (Spitzer et al, 2010).

Pomegranate was far the richest tree for overwintering coccinellids, either measured as number of species, number of aggregations or individuals. *Adalia bipunctata* and *O. conglobata* were common in other soft fruit and stone fruit orchards in Iran, forming Müllerian mimicry ring by having similar elytral colour pattern (Nedvěd, Biranvand, Shakarami, & Şenal, 2020; Nedvěd, 2021).

Forming overwintering aggregations is common for many species, especially Hippodamia undecimnotata may establish very conspicuous overwintering clumps consisting of several thousands of individuals. *H. variegata* overwinters in a variety of lowland and hilltop hibernacula, singly or in small groups, frequently together with other coccinellid species (Hodek, 1960) but not under tree bark. A single larger aggregation found in the present study consisted of three species: *O. conglobata*, *A. bipunctata* and *E. undulatus*.

More *E. undulatus* were found under the bark in January, while the other two common species, *A. bipunctata* and *O. conglobata* were regularly sampled also in February and March. This finding seems to confirm the early spring activity of Exochomus species, documented in *E. quadripustulatus* in Central Europe. This species was observed to look for food and mates already in late February (Nedvěd, 1995). Contrary to our present study using samples under bark, coccinellids sampled on branches of pine *Pinus sylvestris* in Slovakia were common in November but almost absent in February (Holecová et al, 2018).

We confirmed presence of several predatory ladybird species in orchards in winter where they can become valuable natural enemies of pests during the vegetation season (Heidari Latibari, Zare Khormizi, Sahamian, Dehghan Dehnavi & Moravvej, 2018). Human activities greatly affect the efficiency of natural enemies. Conservation and protection of natural enemies, as a form of biological control, including their overwintering habitats can improve biological control efforts.

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REFERENCES

Bellows, T.S. & Hassell, M.P. (1999). Theories and mechanisms of natural population regulation. In T.S. Bellows & T.V. Fisher (Eds.). *Handbook of biological control* (pp. 17-44). Academic Press, San Diego.

Ceryngier, P. (2000). Overwintering of *Coccinella septempunctata* (Coleoptera: Coccinellidae) at different altitudes in the Karkonosze Mts, SW Poland. *European Journal of Entomology*, 97, 323-328.

Delucchi, V. (1954). *Pullus impexus* (Muls.) (Coleoptera, Coccinellidae), a predator of *Adelges piceae* (Ratz.) (Hemiptera, Adelgidae), with notes on its parasites. *Bulletin of Entomological Research*, 45(2), 243-278.

Güven, O., Göllüoğlu, H., Ceryngier, P. (2015). Aestivo-hibernation of *Coccinella septempunctata* (Coleoptera: Coccinellidae) in a mountainous area in southern Turkey: Is dormancy at high altitudes adaptive? *European Journal of Entomology*, 112, 41-48.

Hagen, K.S. (1962). Biology and ecology of predaceous Coccinellidae. *Annual Review of Entomology*, 7, 289-326.

Heidari Latibari, M., Zare Khormizi, M., Sahamian, E., Dehghan Dehnavi, L., & Moravvej, G. H. (2018). Faunistic survey of Aphidoidea (Hemiptera) and associated predatory ladybirds in orchards, Yazd Province, Iran. *EPPO Bulletin*, 48(1), 160-163.

Hodek, I. (1960). Hibernation-bionomics in Coccinellidae. *Čas. čs. Spol. Entomol.*, 57, 1-20.

Hodek, I. (1973). *Biology of Coccinellidae*. Academy of Science Prague, Dr W. Junk, Publishers, The Hague and Academia, Czechoslovak, Prague.

Hodek, I. (1996). Dormancy. In I. Hodek & A. Honek (Eds.). *Ecology of Coccinellidae* (pp. 239-318), Kluwer Academic Publishers, Dordrecht.

Holecová, M., Zach, P., Hollá, K., Šebestová, M., Klesniaková, M., Šestáková, A., Honěk, A., Nedvěd, O., Parák, M., Martinková, Z., Holec, J., Viglášová, S., Brown, P.M.J., Roy, H.E., & Kulfan, J. (2018). Overwintering of ladybirds (Coleoptera: Coccinellidae) on Scots pine in Central Europe. *European Journal of Entomology*, 115, 658-667.

Honek, A. & Martinkova, Z. (2005). Long term changes in abundance of *Coccinella septempunctata* (Coleoptera: Coccinellidae) in the Czech Republic. *European Journal of Entomology*, 10, 443-448.

Honek, A, Martinkova, Z., & Pekar, S. (2007). Aggregation characteristics of three species of Coccinellidae (Coleoptera) at hibernation sites. *European Journal of Entomology*, 104 (1), 51-56.

Honek, A. (1989). Overwintering and annual changes of abundance of *Coccinella septempunctata* in Czechoslovakia (Coleoptera, Coccinellidae). *Acta Entomologica Bohemoslovaca*, 86, 179-192.

Honek, A. (1990). Seasonal changes in flight activity of Coccinella septempunctata L. (Coleoptera, Coccinellidae). *Acta Entomologica Bohemoslovaca*, 87, 336-341.

Mooring, M.S & Hartl, B.L. (1992). Animal grouping for protection from parasites - selfish herd and encounter-dilution effects. *Behaviour,* 123, 173-193.

Nedvěd, O. & Honěk, A. (2012). Life History and Development. In Hodek, I., van Emde,n H., & Honěk, A. (Eds). *Ecology and behaviour of the ladybird beetles (Coccinellidae)* (pp. 54-109). Wiley-Blackwell.

Nedvěd, O. (2015). Brouci čeledi slunéčkovití (Coccinellidae) střední Evropy = Ladybird beetles (Coccinellidae) of Central Europe. Ladybird beetles (Coccinellidae) of Central Europe. Prague: Academia

Nedvěd, O. (1993). Comparison of cold hardiness in two ladybird beetles (Coleoptera: Coccinellidae) with contrasting hibernation behaviour. *European Journal of Entomology*, 90, 465-470.

Nedvěd, O. (1995). Cold reacclimation in postdormant *Exochomus quadripustulatus* (Coleoptera: Coccinellidae). *Cryo-Letters*, 16, 47-50.

Nedvěd, O. (2006). Ephemeral overwintering aggregations of ladybirds in South Bohemia. *Silva Gabreta,* 12(3), 151-155.

Nedvěd O. (2021). Bidirectional Müllerian Mimicry between *Adalia bipunctata* (Linnaeus) and O*enopia conglobata* (Linnaeus) (Coleoptera: Coccinellidae). *Outreach Science*, 120, 42-45.

Nedvěd, O., Biranvand, A., Shakarami, J., & Şenal, D. (2020). Potential Müllerian mimicry between A*dalia bipunctata* (L.) and *Oenopia conglobata* (L.) (Coleoptera: Coccinellidae) in Iran. *The Coleopterists Bulletin*, 74, 161-167.

Nedved, O., Ceryngier, P., Hodkova, M., & Hodek, I. 2001. Flight potential and oxygen uptake during early dormancy in *Coccinella septempunctata*. *Entomologia Experimentalis et Applicata*, 99, 371-380.

Novak, B. & Grenarova, A. (1967). Coccinelliden and der grenze des feld- und Waldbiotops Hibernationsversuchemit den Imagines fuhrender Arten. In: *Konferenz uber die schadlinge der Hackfruchte III* (pp. 49-59), Praha.

Ricci, C., Pontil, L., & Pires, A. (2005). Migratory flight and pre diapause feeding of Coccinella septempunctata (Coleoptera) adults in agricultural and mountain ecosystems of Central Italy. *European Journal of Entomology*, 102, 531-538.

Sillen-Tullberg, B., & Leimar**,** O. (1988). The evolution of gregariousness in distasteful insects as a Défense against predators. *The American Naturalist*, 132, 723-734.

Spitzer, L., Konvička, O., Tropek, R., Roháčová, M., Tuf, I.H., & Nedvěd, O. (2010). Overwintering communities of arthropods on white fir (*Abies alba*) in the Moravian Wallachia region (West Carpathians, Czech Republic). *Časopis Slezského Zemského Muzea*, 59, 217-232.

Turchin, P. & Kareiva, P. (1989). Aggregation in *Aphis varians*: An effective strategy for reducing predation risk. *Ecology*, 70, 1008-1016.