Linzer biol. Beitr.	41/1	639-672	30.8.2009

An annotated catalogue of Orthoptera (Insecta) and their natural enemies from Iranian rice fields and surrounding grasslands

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A b s t r a c t : The fauna of Iranian Orthoptera is very diverse in almost agroecosystems, especially rice fields. In a total of 74 species from 36 genera, and 8 families including, Acrididae, Catantopidae, Gryllidae, Gryllotalpidae, Pamphagidae, Pyrgomorphidae, Tetrigidae, and Tettigoniidae were collected from rice fields of Iran. In addition to the Orthoptera fauna, their predators (including Asilidae, Bombyliidae, Carabidae, Meloidae, Sphecidae, Staphylinidae and Tenebrionidae) and parasitoids (Scelionidae and Sarcophagidae) are studied and discussed in this paper. Totally 75 predators and 9 parasitoids were identified as the natural enemies of Iranian Orthoptera.

K e y w o r d s : Orthoptera, Predator, Parasitoid, Fauna, Rice field, Iran.

Introduction

The Orthoptera are a group of large and easily recognized insects which includes the Grasshoppers, Locusts, Groundhoppers, Crickets, Katydids, Mole-crickets and Camel-crickets as well as some lesser groups. These insects can be found in various habitats, as well as the more familiar species found in grasslands and forests (PEVELING et al. 1999). Grasshopper eggs are normally deposited in clusters, called egg-pods, placed just below the surface of the soil. The egg-pod is covered by a fairly durable coating of soil particles mixed with a glutinous substance excreted by the female as she lays her eggs in the soil. The female thrusts her abdomen into the soil to a depth of an inch or two and starts laying her eggs. When the cavity formed by her abdomen is filled with eggs, she commonly blocks the hole above the eggs with a glandular secretion (HEWITT 1979). The egg-pod may contain from 2 to more than 100 eggs, depending on the species of grasshopper. The eggs are quite tough and very resistant to cold. They are able to survive the most severe winters if the ground is not disturbed. Also, there is usually enough moisture in the surrounding soil to keep the eggs from drying out even in drought conditions. After the eggs have been deposited in a suitable spot, the female grasshopper provides no maternal or defensive care and merely abandons them. The eggs of some species hatch in a few weeks and thus escape destruction by many natural enemies (RENTZ 1991). Most of the grasshoppers lay their eggs in summer and fall and they remain in the ground during the winter in a state of suspended development called diapause, and they do not hatch until the following spring. These eggs are unprotected and exposed to their enemies for some 9 months of the year. In spite of the fact that grasshopper eggs are available to natural enemies for such long periods, there are surprisingly few insect enemies of the egg stage.

It must be noted that locating grasshopper egg-pods in the soil is usually a lengthy and difficult task. Because finding pods in soil and vegetation is so unpredictable, it is easy to miss egg-pods, and especially the larval stages of predators (KALTENBACH 1965; FLOOK & ROWELL 1998).

The fauna of Iranian Orthoptera was studied rather well (MODARRES AWAL 1997; MIRZAYANS 1998). But the fauna of these insects in Iranian rice fields was not studied so far; the alone work is KHAJEHZADEH & GHAZAVI (2000) which included the below 12 species. *Aiolopus thalassinus*, *Aiolopus savagyni*, *Locusta migratoria*, *Thisocetrinus pterostichus*, *Thisocetrus littoralis*, *Tropidopola longicornis*, *Truxalis robusta*, *Acrida oxycephala*, *Ochrilidia gracilis* of Acrididae, *Tettigonia viridissma* and *Nephoptera fibialis* of Tettigoniidae, and *Paratettix obliteratus* of Tetrigidae.

Grasshoppers, like all other animals, are subject to a large number of parasitoids, predators, and pathogens, including fungi, protozoa, and viruses (Henry et al. 1985, PRIOR & GREATHEAD 1989, STREETT & MCGUIRE 1990). Parasitoids, predators, and pathogens can be used as "classical" biological control agents. Classical biological control is defined as "the importation and release of an organism outside its natural range for the purpose of controlling a pest species" (HOWARTH 1991; LOCKWOOD 1993a). Another approach, "augmentative" biological control, uses native or exotic organisms that are released periodically to enhance mortality in a targeted pest population. Insect pathogens generally fall in this category because many can be massmultiplied and applied as biological pesticides (CARRUTHERS & ONSAGER 1993). In despite of studying the Iranian Orthoptera rather well, the fauna of their natural enemies was not perfectly studied so far. All the resources about the parasitoids and predators of Iranian grasshoppers are AYATOLLAHI (1971) about Bombyliidae (Diptera), MODARRES AWAL (1997, p. 252) about Sarcophagidae (Diptera), EBRAHIMI (2000) about Sphecidae (Hymenoptera), OSTOVAN & SABOORI (1999), KARIMI IRAVANLOU & KAMALI (2000) and KARIMI IRAVANLOU & SABOORI (2000) about parasitic mites (Acari), KHAJEHZADEH (2004) and GHAHARI et al. (2008) about different natural enemies. The mentioned resources will be discussed briefly in the discussion of this paper.

In this paper we introduce several natural enemies (predators and parasitoids) of grasshoppers which were collected from rice fields of Iran. Additionally the importance of biological control of grasshoppers is discussed briefly. There are several reasons why it is necessary to correctly identify species. (1) Species vary in their biotic potential and in their capacity for causing damage. (2) Depending on their food habits, species may be either pests or beneficials. (3) Certain species of pest grasshoppers are highly migratory and often pose a serious threat to distant crops. (4) Species vary in their seasonal cycle (period of hatching, development, and reproduction), which in turn affects the timing of control treatments. (5) Because current chemical and biological methods of controlling grasshoppers are more sophisticated, their effective use requires greater knowledge of the pests' life histories and habits. (6) As environmental impacts of control are more finely evaluated, recognition of pest species of grasshoppers has become essential in the selection of management strategies.

Materials and Methods

The materials were collected mainly by sweeping net with 17" in diameter. Both the flying and perched Orthoptera were collected from the rice seedlings, and around hedges and grasses. Of course, sometimes the perched Orthoptera were grabbed, and even grabbing the perched Orthoptera was easier to catch than those already in flight. After collecting the materials, they were killed by the cyanide, wings were spread, pinned and labeled (locality, date of collection). Then the materials were determined by different resources (CHOPARD 1943; JOHNSTON 1956; BEI-BIENKO & MISHCHENKO 1964; RAGGE 1965; DIRSH 1965; UVAROV 1966, 1977; HARZ & KALTENBACH 1969-1976; KNUTSON et al. 1983; MARSHALL & HAES 1988). Also many of the collected specimens were separately put in the voucher envelopes and sent to the specialists for identification. In addition to the adult Orthoptera specimens, several nymphs were collected too. Identification of grasshopper nymphs presents greater difficulties because of the absence of several reliable taxonomic characters of the adult stage. In nymphs, the wings are lacking and the genitalia are undeveloped and generalized. Sets of characters, however, are useful in identifying nymphs of the three large subfamilies of western grasshoppers. The chief characters diagnostic of slantfaced nymphs (Gomphocerinae) consist of the degree of facial slope, general color pattern, shape of the antennae and foveolae, and the extent of curving of the lateral carinae of the pronotum. Chief characters diagnostic of bandwinged nymphs (Oedipodinae) are: (1) height of the median carina of the pronotum and number of sulci; (2) position and length of the lateral carinae; (3) color patterns of the hindlegs; (4) variations in dark bands on the head and pronotum; and (5) shape of the foveolae. Chief characters diagnostic of spurthroated nymphs (Melanoplinae) are color patterns of the hind femur, color patterns of the gena and pronotum,and markings of the compound eyes. The characters of the compound eyes, namely, color, stripes, and number and size of spots, are evident in fresh specimens, but they disappear in specimens that have been held for any length of time, even frozen ones. In treatment of the individual species later on, the particular diagnostic characters of each are described and explained (BEI-BIENKO et al. 1964; UVAROV 1966; HARZ & KALTENBACH 1969-1976; DIRSH 1975). However, the specimens were sent to Dr. Hasan Sevgili (Harran Universitesi Fen-Edebiyat Fakultesi Biyoloji Bolumu, Osmanbey Kampusu, Sanliurfa, Turkey) by the first author and many other specimens were sent to Dr. Luck Willemse and Prof. F.M.H. Willemse (National Herbarium of Netherlands, Leiden) by the 2nd author for exact identification or confirmation. The predators of Orthoptera were collected by the sweeping net, aspirator and light traps. For collecting the parasitoids, the egg-pods of grasshoppers were collected and reared in good condition (27±2 °C, 75±5 %RH, 14±10 L: D). Also many of parasitoids were collected same as the method of predators as above. The predators and parasitoids were separated after collecting and sent to the related authorized specialists. Additionally, many available data and determined specimens in the collections of different universities were used for this paper.

Species list

In a total of 74 species of Orthoptera of 8 families including, Acrididae, Catantopidae, Gryllidae, Gryllotalpidae, Pamphagidae, Pyrgomorphidae, Tetrigidae, and Tettigoniidae were collected from Iranian rice fields and around grasslands. In addition to the orthopterans' fauna, diverse fauna of predators and parasitoids of Orthoptera were collected from rice fields of Iran. Totally 84 insect species (75 predators and 9 parasitoids) were identified as the natural enemies for Orthopteran of Iranian rice fields. In this paper, firstly we present the list of the orthopterans' fauna, then the importance of biological control of Orthoptera and its comparison with other control methods will be discussed briefly. The lists of all the predators and parasitoids of Orthoptera which were collected from Iranian rice fields and around grasslands are given finally.

Family Acrididae MACLEAY 1821

Genus *Acrida* LINNAEUS 1758

Acrida oxycephala (PALLAS 1771)

Material: East Azarbayjan province: Arasbaran, 3♀♀, July 2004. Mazandaran province: Amol, 1♀, 2 nymphs, August 2006.

Acrida turita LINNAEUS 1758)

Material: Chaharmahal-Bakhtiari province: Shahrekord, 1♀, September 2004. Mazandaran province: Babol, 1♂, 1 nymph, June 2006.

Genus *Acrotylus* FIEBER 1853

Acrotylus insubricus (SCOPOLI 1786)

Material: Mazandaran province: Fereydonkenar, 1♀, August 2004. Guilan province: Rasht, 1♂, 1♀, June 2005. East Azarbayjan province: Arasbaran, 3♂♂, 5♀♀, August 2005. Mazandaran province: Noor, Babol, Amol, 2♂♂, 3♀♀, July 2006. Zanjan province: Zanjan, 1♀, 1 nymph, September 2006.

Acrotylus longipes (CHARPENTIER 1845)

Material: Mazandaran province: Nooshahr, 1♀, July 2006.

Genus *Aiolopus* FIEBER 1853

Aiolopus thalassinus (FABRICIUS 1781)

Material: Mazandaran province: Babolsar, 1♀, June 2004. Chaharmahal-Bakhtiari province: Shahrekord, 1♂, September 2004. Zanjan province: Zanjan, 1♂, 2♀♀, August 2005.

Genus *A n a c r i d i u m* UVAROV 1923

Anacridium aegyptium (LINNAEUS 1764)

M a t e r i a l : Golestan province: Kordkoy, 1♂, August 2005. East Azarbayjan province: Arasbaran, 1♂, 1♀, September 2005. Mazandaran province: Ghaemshahr, 1♂, September 2006.

Genus *C h o r t h i p p u s* FIEBER 1852

Chorthippus albomarginatus (DE GEER 1773)

M a t e r i a l : Isfahan province: Lenjan, 2♀♀, September 2004. Guilan province: Amlash, Roodsar, 2♀♀, June 2005. Mazandaran province: Mahmood-Abad, 1♀, August 2006.

Chorthippus bicolor (CHARPENTIER 1825)

M a t e r i a l : Isfahan province: Zarrinshahr, 1♀, September 2003. Guilan province: Rasht, 1♂, September 2005.

Chorthippus brunneus (THUNBERG 1815)

M a t e r i a l : Mazandaran province: Fereydonkenar, 1♀, August 2004.

Chorthippus dorsatus (ZETTERSTEDT 1821)

M a t e r i a l : Mazandaran province: Savadkooh, 1♀, 2 nymphs, August 2006. Guilan province: Fooman, 1♀, October 2006. Chaharmahal-Bakhtiari province: Shahrekord, 1♂, 2♀♀, July 2007.

Chorthippus macrocerus (FISCHER DE WALDHEIM 1846)

M a t e r i a l : Guilan province: Bandar-Anzali, 2♂♂, 1♀, September 2005. Mazandaran province: Amol, 1♀, 1 nymph, August 2006. East Azarbayjan province: Arasbaran, 1♀, September 2006.

Chorthippus mollis mollis (CHARPENTIER 1825)

M a t e r i a l : Golesatn province: Kordkoy, 1♂, June 2005. Mazandaran province: Savadkooh, 1♂, 1♀, August 2006.

Genus *D o c i o s t a u r u s* FIEBER 1853 (= *Notostaurus* BEI-BIENKO 1933)

Dociostaurus albicornis (EVERSMANN 1848)

M a t e r i a l : Isfahan province: Lenjan, 1♀, August 2002. East Azarbayjan province: Arasbaran, 3♀♀, August 2004.

Dociostaurus (s. str.) *brevicollis* (EVERSMANN 1848)

M a t e r i a l : Zanjan province: Zanjan, 3♀♀, September 2004.

Dociostaurus (*Stauronotulus*) *hauensteini* (BOLIVAR 1893)

M a t e r i a l : Chaharmahal-Bakhtiari province: Shahrekord, 1♀, September 2004. Golestan province: Gorgan, 1♀, August 2005.

Dociostaurus (s.str) *maroccanus* (THUNBERG 1815)

M a t e r i a l : Golestan province: Gorgan, 2♀♀, August 2005.

Dociostaurus tartarus SHCHELKANOVTSEV 1921

M a t e r i a l : Mazandaran province: Neka, 1♀, September 2002. East Azarbayjan province: Arasbaran, 2♀♀, September 2006.

Genus *H e l i o p t e y i x* UVAROV 1914

Heliopterix humeralis (KUTHY 1907)

M a t e r i a l : Guilan province: Fooman, 1♀, June 2005. Isfahan province: Najaf-Abad, 3♀♀, September 2005.

Genus *H e t e r a c r i s* WALKER 1870

Heteracris littoralis (RAMBUR 1838)

M a t e r i a l : East Azarbayjan province: Arasbaran, 4♂♂, 1♀, September 2004. Guilan province: Fooman, 1♂, June 2005. Isfahan province: Lenjan, 1♂, September 2005. Guilan province: Rasht, 1♀, June 2005. Mazandaran province: Savadkooh, 1♀, August 2006. Mazandaran province: Mahmood-Abad, 1 nymph, August 2006. Mazandaran province: Sari, 1♂, April 2006. Mazandaran province: Ghaemshahr, 1♀, September 2006.

Genus *L o c u s t a* LINNAEUS 1758

Locusta migratoria (LINNAEUS 1758)

M a t e r i a l : Zanjan province: Zanjan, 2♀♀, July 2005. Mazandaran province: Savadkooh, 1♀, 1 nymph, August 2006.

Genus *M i o s c i r t u s* SAUSSURE 1888

Mioscirtus wagneri (KITTARY 1859)

M a t e r i a l : Guilan province: Rasht, 1♂, June 2005.

Genus *O e d a l e u s* FIEBER 1853

Oedaleus decorus (GERMAR 1817)

M a t e r i a l : Isfahan province: Isfahan, 1♂, July 2003. Guilan province: Rasht, 1♂, September 2005.

Oedaleus senegalensis (KRAUSS 1877)

M a t e r i a l : Mazandaran province: Savadkooh, 1♀, August 2004. Isfahan province: Isfahan, Najaf-Abad, 2♂♂, 1♀, July 2006.

Genus *O e d i p o d a* LATREILLE 1829

Oedipoda aurea UVAROV 1923

M a t e r i a l : Isfahan province: Isfahan, 1♂, 1♀, August 2001. Zanjan province: Zanjan, 1♂, September 2004. Guilan province: Lahijan, 1♂, September 2005.

Oedipoda coerulescens (LINNAEUS 1758)

M a t e r i a l : Mazandaran province: Fereydonkenar, 1♀, 2 nymphs, August 2004. Guilan province: Fooman, Rasht, Amlash, 4♀♀, 3 nymphs, June 2005.

Oedipoda germanica meridionalis RAMME 1913

M a t e r i a l : Golestan province: Gorgan, 1♂, June 2005.

Oedipoda miniata (PALLAS 1771)

M a t e r i a l : Golestan province: Kordkoy, 1♂, 1♀, August 2005.

Oedipoda schochi SAUSSURE 1884

M a t e r i a l : Guilan province: Fooman, 1♀, June 2005. Isfahan province: Lenjan, 1♀, 1 nymph, September 2005. Mazandaran province: Savadkooh, 1♂, 2♀♀, August 2006.

Genus *P y r g o d e r a* FISCHER VON WALDHEIM 1846

Pyrgodera armata FISCHER VON WALDHEIM 1846

M a t e r i a l : Mazandaran province: Sari, 2♂♂, April 2004. Chaharmahal-Bakhtiari province: Shahrekord, 1♂, 1♀, September 2004. East Azarbayjan province: Arasbaran, 2♂♂, 1♀, June 2006.

Genus *R a m b u r i e l l a* BOLIVAR 1906

Ramburiella turcomona (FISCHER VON WALDHEIM 1846)

M a t e r i a l : Isfahan province: Isfahan, 2♂♂, 1♀, September 2004. Mazandaran province: Babol, 1♂, June 2006.

Genus *S p h i n g o d e r u s* BEI-BIENKO 1950

Sphingoderus carinatus (SAUSSURE 1888)

M a t e r i a l : Golestan province: Gorgan, Kordkoy, 4♀♀, September 2005.

Genus *S p h i n g o n o t u s* FIEBER 1852

Sphingonotus nebulosus persa SAUSSURE 1884

M a t e r i a l : Guilan province: Roodsar, 1♀, June 2005. East Azarbayjan province: Arasbaran, 1♂, 1♀, September 2005.

Sphingonotus coerulans caspicus MISHCHENKO 1936

M a t e r i a l : Zanjan province: Zanjan, 2♀♀, July 2005. Mazandaran province: Behshahr, 1♀, October 2006.

Sphingonotus pilosus SAUSSURE 1884

M a t e r i a l : Golestan province: Kordkoy, 1♀, August 2005.

Sphingonotus rubescens rubescens (WALKER 1870)

M a t e r i a l : Guilan province: Someh-Sara, 1♂, 1♀, July 2005.

Sphingonotus satrapes SAUSSURE 1884

M a t e r i a l : East Azarbayjan province: Arasbaran, 1♀, August 2005. Golestan province: Gorgan, 1♂, September 2005.

Genus *S t e n o b o t h r u s* FISCHER 1853

Stenobothrus werneri ADELUNG 1907

M a t e r i a l : Mazandaran province: Mahmood-Abad, 1♀, August 2006.

Genus *T r o p i d o p o l a* STÅL 1873

Tropidopola turanica caspica UVAROV 1933

M a t e r i a l : Mazandaran province: Chalus, 1♀, 1 nymph, July 2004. Mazandaran province: Fereydonkenar, 1♂, 2 nymphs, August 2005. Guilan province: Rasht, 2♀♀, April 2006. East Azarbayjan province: Arasbaran, 1♂, September 2006.

Family Catantopidae BRUNNER VON WATTENWYL 1893

Genus *Calliptamus* SERVILLE 1831

Calliptamus barbarus (COSTA 1836)

Material: East Azarbayjan province: Arasbaran, 1♂, 1♀, September 2004. Golestan province: Gorgan, 1♂, August 2005. Zanjan province: Zanjan, 1♂, 1♀, September 2004. Mazandaran province: Nooshahr, 1♀, July 2006. Mazandaran province: Sari, 1♂, April 2006. Mazandaran province: Babol, 1♂, June 2006.

Calliptamus italicus (LINNAEUS 1758)

Material: Mazandaran province: Joibar, 1♂, 1 nymph, September 2006. Golestan province: Astaneh-Ashrafie, 1♀, June 2005.

Calliptamus siculus BURMEISTER 1838

Material: East Azarbayjan province: Arasbaran, 1♂, August 2004. Guilan province: Rasht, 1♂, 2 nymphs, September 2005.

Calliptamus turanicus TARBINSKY 1930

Material: Chaharmahal-Bakhtiari province: Shahrekord, 3♀♀, September 2004. Guilan province: Amlash, 1♀, 1 nymph, July 2005. Mazandaran province: Ghaemshahr, 1♀, September 2006.

Genus *Eyprepocnemis* FIEBER 1853

Eyprepocnemis plorans (CHARPENTIER 1825)

Material: Isfahan province: Isfahan, 2♂♂, 1♀, June 2000. East Azarbayjan province: Arasbaran, 2♀♀, September 2003. Guilan province: Talesh, 2♀♀, September 2005.

Family Gryllidae LAICHARDING 1781

Genus *Gryllus* LINNAEUS 1758

Gryllus bimaculatus DE GEER 1773

Material: Guilan province: Talesh, 1♀, July 2005.

Genus *Melanogryllus* CHOPARD 1961

Melanogryllus desertus (PALLAS 1771)

Material: Guilan province: Roodsar, 1♂, 1 nymph, June 2005. Guilan province: Rasht, Amlash, Astaneh-Ashrafieh, 2♂♂, 3♀♀, 2 nymphs, July 2005. Mazandaran province: Savadkooh, 1♂, August 2006. East Azarbayjan province: Arasbaran, 2♀♀, June 2006. Mazandaran province: Nooshahr, 1♂, July 2006.

Genus *M e t i o c h e* STÅL 1877

Metioche vittaticolis (STÅL 1861)

M a t e r i a l : Mazandaran province: Amol, Ghaemshahr, Kiakola, Babol, 1♂, 4♀♀, July 2003. East Azarbayjan province: Arasbaran, 2♀♀, August 2004.

Genus *S t e n o n e m o b i u s* GOROCHOV 1981

Stenonemobius cf. *gracilis* (JAKOVLEV 1871)

M a t e r i a l : Isfahan province: Zarrin Shahr, 1♂, September 2005.

Genus *T a r t a r o g r y l l u s* TARBINSKY 1940

Tartarogryllus tartarus tartarus (SAUSSURE 1874)

M a t e r i a l : Isfahan province: Lenjan, 1♀, September 2004. Chaharmahal-Bakhtiari province: Shahrekord, 1♀, Septembr 2004. Guilan province: Rasht, 2♀♀, 1 nymph, July 2005.

Tartarogryllus tartarus obscurus (UVAROV 1921)

M a t e r i a l : Zanjan province: Zanjan, 1♂, 1♀, September 2000. East Azarbayjan province: Arasbaran, 1♀, August 2005.

Tartarogryllus tartarus obscurior (UVAROV 1934)

M a t e r i a l : Mazandaran province: Savadkooh, 1♀, August 2006.

Family G r y l l o t a l p i d a e FIEBER 1852

Genus *G r y l l o t a l p a* LATREILLE 1804

Gryllotalpa gryllotalpa (LINNAEUS 1758)

M a t e r i a l : Khuzestan province: Ahwaz, 3♂♂, 2♀♀, May 1999. Mazandaran province: Babol, 1♂, 1 nymph, June 2000. Zanjan province: Zanjan, 3♂♂, September 2000. Guilan province: Fooman, Talesh, 2♂♂, 1 nymph, June 2005. East Azarbayjan province: Arasbaran, 4♂♂, 3♀♀, 2 nymphs, August 2005. Mazandaran province: Chalus, Ransar, Nooshahr, 6♀♀, June 2006. Mazandaran province: Behshahr, Ghaemshahr, Sari, Savadkooh, Babol, Joibar, 7♂♂, 9♀♀, 8 nymphs, September 2006.

Gryllotalpa unispina SAUSSURE 1874

M a t e r i a l : Zanjan province: Zanjan, 1♀, August 2005. East Azarbayjan province: Arasbaran, 1♂, 1♀, September 2005. Mazandaran province: Fereydonkenar, Babol, 1♂, 2 nymphs, June 2006.

Family P a m p h a g i d a e BURMEISTER 1840

Genus *E r e m o p e z a* SAUSSURE 1888

Eremopeza cinerascens (STÅL 1875)

M a t e r i a l : Khuzestan province: Ahwaz, 1♀, October 2003. East Azarbayjan province: Arasbaran, 1♂, 3♀♀, August 2004. Mazandaran province: Neka, 1♂, 2nymphs, September 2005.

Eremopeza saussurei (UVAROV 1918)

M a t e r i a l : Isfahan province: Isfahan, 1♂, 1♀, August 2002. Mazandaran province: Ghaemshahr, Sari, Joibar, 4♀♀, April 2006.

Family P y r g o m o r p h i d a e BRUNNER VON WATTENWYL 1874

Genus *P y r g o m o r p h a* SERVILLE 1838

Pyrgomorpha conica (OLIVIER 1791)

M a t e r i a l : Mazandaran province: Fereydonkenar, 1♂, August 2004. Chaharmahal-Bakhtiari province: Shahrekord, 1♂, 2♀♀, Septembr 2004. Mazandaran province: Savadkooh, 1♀, 2 nymphs, August 2006. Mazandaran province: Neka, 2♂♂, September 2005. Mazandaran province: Babol, 1♀, June 2006.

Pyrgomorpha conica deserti BEI-BIENKO 1951

M a t e r i a l : East Azarbayjan province: Arasbaran, 1♀, July 2004. Mazadnaran province: Ghaemshahr, 1♀, June 2005.

Family T e t r i g i d a e SERVILLE 1838

Genus *P a r a t e t t i x* BOLIVAR 1887

Paratettix uvarovi SEMENOV 1915

M a t e r i a l : East Azarbayjan province: Arasbaran, 2♂♂, July 2004. Mazandaran province: Sari, 2♂♂, July 2006. Guilan province: Rasht, 1♂, August 2003.

Family T e t t i g o n i i d a e KRAUS 1902

Genus *C o n o c e p h a l u s* THUNBERG 1815

Conocephalus longipennis (HAAN 1842)

M a t e r i a l : East Azarbayjan province: Arasbaran, 1♂, 1♀, July 2004.

Genus *D e c t i c u s* SERVILLE 1831

Decticus albifrons (FABRICIUS 1775)

M a t e r i a l : Chaharmahal-Bakhtiari province: Shahrekord, 1♀, September 2004. Guilan province: Talesh, 1♀, July 2005.

Decticus annaelisae RAMME 1929

M a t e r i a l : Mazandaran province: Fereydonkenar, 1♂, 1 nymph, August 2004.

Genus *I s o p h y a* BRUNNER VON WATTENWYL 1878

Isophya caspica caspica RAMME 1929

M a t e r i a l : Mazandaran province: Ghaemshahr, 1♀, September 2006.

Isophya caspica stshelkanovtzevi MIRAM 1938

M a t e r i a l : Qazvin province: Qazvin, 2♀♀, August 2002. East Azarbayjan province: Arasbaran, 1♀, June 2005.

Genus *M i x o d u s a* STOLYAROV 1994

Mixodusa bocquilloni (UVAROV 1917)

M a t e r i a l : Guilan province: Talesh, 1♀, 2 nymphs, July 2005.

Mixodusa siazovi (UVAROV 1929)

M a t e r i a l : Mazandaran province: Behshahr, 1♂, August 2003. East Azarbayjan province: Arasbaran, 2♀♀, July 2005.

Genus *P l a t y c l e i s* FIEBER 1853

Platycleis affinis FIEBER 1853

M a t e r i a l : Mazandaran province: Fereydonkenar, 1♀, August 2004. Khuzestan province: Ahwaz, 1♂, 1♀, October 2004. Guilan province: Roodsar, 1♂, June 2005. Guilan province: Chaboksar, 1♀, July 2005. Mazandaran province: Nooshahr, 1♀, July 2006. Mazandaran province: Amol, 1♀, August 2006.

Platycleis capitata UVAROV 1917

M a t e r i a l : Mazandaran province: Neka, 1♀, September 2005. Guilan province: Talesh, 1♂, 1 nymph, July 2005.

Platycleis escalerai iranica ZEUNER 1930

M a t e r i a l : Golestan province: Kordkoy, 1♂, August 2005. Mazandaran province: Ghaemshahr, 1♀, 2 nymphs, September 2006.

Platycleis fatima UVAROV 1912

M a t e r i a l : Guilan province: Amlash, 1♀, July 2005.

Platycleis intermedia (SERVILLE 1838)

M a t e r i a l : Guilan province: Roodsar, 1♂, June 2005. Mazandaran province: Behshahr, 1♂, October 2006.

Genus *T e t t i g o n i a* LINNAEUS 1758

Tettigonia caudata (CHARPENTIER 1845)

M a t e r i a l : Mazandaran province: Joibar, 1♂, September 2006. Mazandaran province: Noor, 1♀, 3 nymphs, July 2006. Mazandaran province: Babol, 1♂, June 2006.

Tettigonia viridissima (LINNAEUS 1758)

M a t e r i a l : Khuzestan province: Ahwaz, 1♂, 1♀, October 2004. Guilan province: Fooman, 1♂, 1 nymph, June 2005.

Tettigonia ussuriana UVAROV 1939

M a t e r i a l : Guilan province: Amlash, 1♂, July 2005. Mazandaran province: Sari, 1♀, 1 nymph, April 2006.

Tettigonia sp.

M a t e r i a l : Golestan province: Kordkoy, 1♀, June 2005.

Genus *U v a r o v i s t i a* MARAN 1953

Uvarovistia satunini (UVAROV 1934)

M a t e r i a l : Guilan province: Chaboksar, 1♂, July 2005. Mazandaran province: Babol, 2♂♂, June 2006. Mazandaran province: Ghaemshahr, 1♀, September 2006. Mazandaran province: Behshahr, 1♂, 1 nymph, October 2006.

Discussion

The grasshoppers occasionally can be the important pests in many agroecosystems. Grasshopper infestations or assemblages consist of the individuals of several species that live together in the same habitat sharing or competing for available food and space. Members of the dominant species outnumber members of other species and may make up more than 50 percent of the assemblage. Occasionally two or three species may become codominants. No evidence has been found for any essential relationship among species that brings them together. The habitat affords the minimum requirements for all the permanent species and ample measure for the abundant. These pests have several natural enemies which decrease their population density and therefore their damages (PRESTON-MAFHAM 1991; GANGWERE et al. 1997). The following remarks are intended to provide a brief overview of the life cycle and habits of the various insects that attack grasshoppers in Iran. Individually, these natural enemies may not seem significant, but collectively they determine how many grasshopper eggs will hatch and reach the nymphal stage and why the population density of grasshoppers in Iranian rice fields are pressured by diverse biotic factors and dos not reach to economic level.

Grasshopper control programs potentially can have a large impact on the rangeland ecosystem. Of particular concern are the effects of large-scale control programs on natural enemies of grasshoppers, pollinators of seed crops and endangered plant species, endangered species of vertebrates, and general biodiversity of grasslands. Therefore, it is important that land managers recognize the damage done to these beneficial insects when pesticides are sprayed during grasshopper control campaigns. Currently, when rangeland grasshoppers are treated with pesticides, the chemical of choice is usually malathion because it is effective and inexpensive and relatively nontoxic to mammals and birds. However, malathion is not selective, killing virtually all of the exposed insects, including the beneficial ones (THOMAS et al. 1995; LOMER et al. 1999).

Results of several researchers indicate that grasshoppers are attacked by a wide variety of predators and parasitoids and that grasshopper mortality can be quite high, at least on a local level. For example, birds can reduce grasshopper densities by 30 to 50 percent. PARKER & WAKELAND (1957) estimated that an average of 19 percent of grasshopper egg pods were destroyed by predators but that at the local level, mortality may be as high as 100 percent. Parasitism rates of grasshoppers can also be quite high at the local level (exceeding 50 percent), although they do not usually exceed 10 percent (LAVIGNE & PFADT 1966; REES 1973). As discussed by CAPINERA (1987), the collective effects of all the different mortality factors may add up to an overall large effect on grasshoppers. It seems clear that we should not underestimate the effects of grasshopper natural enemies and that we should work to preserve these organisms.

There is some evidence that grasshopper populations are regulated by natural enemies particularly birds) under certain conditions. In effect, natural enemies may be responsible for keeping grasshopper populations at low levels. Once the natural enemies are removed (for example, by nonselective insecticides), then grasshopper populations can no longer be regulated and outbreaks can occur. Once grasshoppers reach high densities, natural enemies are no longer able to suppress their populations. Unfortunately, few studies have examined the role of natural enemy reductions, caused by nonselective insecticides, on subsequent grasshopper outbreaks (DYSART 1991, 1993, 1994).

In a review of grasshopper population dynamics over several years, LOCKWOOD et al. (1988) found that the duration and stability of grasshopper outbreaks were greater in northern Wyoming, compared with southern Montana, and suggested that the more intensive grasshopper control programs in Wyoming may have contributed to this. In a study of the effects of an insecticidal spray (malathion) and bait (carbaryl on bran) on grasshopper and non-target arthropod populations, QUINN et al. (1989, 1991, 1993) found that populations of most dominant grasshopper species, four species of ground beetles, and numbers of other non-targets rebounded to or above pretreatment levels a year after treatment. An exception was *Ageneotettix deorum*. Densities of this species remained low a year after treatment. These results indicate that some non-target arthropods and grasshopper species are very resilient. Clearly, until more is known about the effects of natural enemies on grasshopper population dynamics and the effects of grasshopper control programs on resiliency of natural enemies, scientists and land managers should act to preserve these communities.

The place of biological control in locust integrated pest management (IPM), requires an assessment of the extent to which existing control operations can be considered IPM. There are many different definitions of IPM, but KOGAN (1998) gives a useful working definition which is quite widely accepted: "IPM is a decision support system for the selection and use of pest control tactics, singly or harmoniously coordinated into a management strategy, based on cost-benefit analyses that take into account the interest of, and impact on, producers, society and the environment". According to this definition, it is not absolutely necessary to consider more than one control technology, but the control technology should be in harmony with social, economic and environmental factors. Current locust control technology relies heavily on chemical pesticides, applied in response to intensive and accurate surveys. This preventative control approach can be seen as a first step towards IPM. So although there is little excess or wastage of pesticides, there are concerns about the effect of repeated and combined abuses to the environment. So one strong driving force for changing current practices is the concern for the environment. An important aspect of this is the issue of disposal of surplus pesticide stocks. Any well-run locust campaign will have at least some pesticide in reserve, and what to do with this at the end of the campaign is a problem. FAO is working with Crop Life International, the pesticide industry federation, to come up with solutions to this problem (LOCKWOOD 1993b; LOCKWOOD 2000).

The second force driving research on biological control is the practical consideration of wishing to combine all available technologies and make use of synergies, rather than relying on a single 'silver bullet' solution - an approach which has repeatedly led to control failures in the past. There is an increasing realization that integrated schemes which take full account of natural forces and make good use of existing natural enemies, are more successful in the long run than those relying on a single technological solution which ignores ecological interactions (PIMENTEL 1963; MCEVOY 1996).

A range of potential IPM technologies has been explored during the 1990s, including botanical pesticides, pheromones and biological control. Although many interesting research results have been obtained which will be useful in understanding locust biology and developing locust IPM (see KRALL et al. 1997 for a review), only biological control has fulfilled early expectations.

Biological control provides pest control solutions with unique properties. As well as being environmentally inoffensive, biological control agents are capable of self-propagation. Classical biological control provides the ideal solution, as the control agent becomes established and permanently reduces pest pressure. In situations where such a permanent solution does not work, inoculation and inundation biological control solutions are also environmentally benign, although not necessarily so cost-effective (Commonwealth Institute of Biological CONTROL 1981; THOMAS et al. 1995).

Biological control of locusts is by no means a new concept. In South Africa, the Bacteriological Institute developed and sold tubes of 'locust fungus' in 1898 (Plant Protection NEWS 1992). Extensive research on *Metarhizium* was conducted in Argentina in the 1930s (MARCHIONATTO 1934). Studies on the natural enemies of locusts and grasshoppers are also extensive (GREATHEAD 1963; SHAH et al. 1998; LOMER et al. 2001).

One of the main challenges of biological research is to understand the evolutionary assembly and maintenance of complex, multitrophic food webs (Singer and Stireman 2005; KITCHING 2006). The classic escape-and-radiate (EAR) hypothesis (EHRLICH & Raven 1964) envisions the current remarkable diversity of plants and herbivorous insects (STRONG et al. 1984; NOVOTNY et al. 2006) as a result of a cyclic coevolutionary process: a plant lineage that acquires a new defensive trait (e.g., a toxic chemical) becomes free to proliferate and rapidly divides into multiple descendant lineages (FARRELL et al. 1991). Over time, the defenses of the new clade are overcome by some insect species, which now enter a vacant adaptive zone and diversify to exploit the species of the hitherto herbivore-free plant group (EHRLICH & RAVEN 1964; FARRELL 1998). A new cycle of diversification starts whenever a novel defense evolves in one of the plant lineages. Although the EAR hypothesis was originally formulated in terms of plants and herbivores, it has recently been suggested that a concurrent EAR process operates between plant-feeding insects and their associated parasitoids (Vamosi 2005). Parasitic insects typically inflict heavy mortality on herbivore populations (Price et al. 1980), and the specialized host use of both insect herbivores and parasitoids leads to the intriguing possibility that these hyperdiverse interaction networks are created "from within", that is, by diversifying effects that are transmitted or even amplified through many trophic levels. "Bottom-up" speciation cascades could result if diversification of plants spurs speciation of herbivores (FARRELL 1998; JANZ et al. 2006) that, in turn, leads to increased resource diversity for associated parasitoids (ABRAHAMSON et al. 2003; STIREMAN et al. 2006). "Top-down" diversifying forces could be equally important if parasitoids use plants as cues for finding their host insects; in such cases, an evolutionary shift to a novel host plant could provide "enemy-free space" for the herbivores. Release from enemies could accelerate diversification in the herbivore lineage that, in turn, would create more possibilities for parasitoid speciation (LILL et al. 2002; MURPHY 2004).

The insects that feed on grasshopper eggs can be divided into two groups, predators and parasitoids, based upon the insects' method of feeding. We discuss on these natural enemies which have effective role in control of Orthoptera in Iranian rice fields as following.

I. Predators of Orthoptera

Egg predators attack the egg-pod as a whole, feeding externally on the grasshopper eggs. Predators are capable of moving from one egg or egg-pod to another as they complete their development. Most insect predators of grasshopper eggs are generalists. They pose a threat to grasshopper egg populations, but in an undirected way. Some of these predators are no more than scavengers. They locate egg-pods somewhat at random, taking advantage of targets of opportunity. In addition to the egg predators, the big wasps including Sphecidae are the powerful predators of adult Orthoptera and capture them in flight. The predators of Orthoptera which are discussed in this paper are divided into three orders including, Diptera (Asilidae, Bombyliidae), Coleoptera (Meloidae, Carabidae, Tenebrionidae, Staphylinidae) and Hymenoptera (Sphecidae). In this research, totally 75 insect species were collected as the predators of Orthoptera in Iranian rice fields. Of course, the predation of many species must be tested carefully in laboratory condition.

Family Asilidae (Diptera)

Members of the Asilidae are known as robber flies. These raptors of the insect world are strong fliers noted for their voracious appetites and predatory behavior toward flying insects (REES & ONSAGER 1985). Totally 17 asilid species were identified from the rice fields of Iran as the predators of different taxa of Orthoptera.

Anisopogon asiaticus OLDROYD 1963

Material: Mazandaran province: Ramsar, 1♀, September 2005.

Apoclea micracantha LOEW 1856

Material: Mazandaran province: Amol, 1♂, September 2005.

Choerades gilva (LINNAEUS 1758)

Material: Guilan province: Somaesara, 2♂♂, August 2002.

Dasypogon octonotatus LOEW 1869

Material: Mazandaran province: Ghaemshahr, 1♀, April 2005.

Erax barbatus SCOPOLI 1763

Material: Mazandaran province: Ramsar, 4♀♀, July 2003.

Eutolmus rufibarbis (MEIGEN 1820)

Material: Zanjan province: Zanjan, 1♀, July 2002.

Habropogon spissipes HERMANN 1909

Material: East Azarbayjan province: Arasbaran, 1♂, 1♀, September 2003.

Machimus annulipes (BRULLÉ 1832)

Material: Guilan province: Astaneh, 2♀♀, August 2004.

***Machimus thoracius* (LOEW 1849)**

M a t e r i a l : Mazandaran province: Amol, 2♂♂, July 2006.

***Promachus canus* (WIEDEMANN 1818)**

M a t e r i a l : Guilan province: Amlash, 1♀, September 2005.

***Promachus leoninus* LOEW 1848**

M a t e r i a l : Isfahan province: Isfahan, 1♀, September 2002.

***Saropogon leucocephalus* (Meigen 1820)**

M a t e r i a l : Guilan province: Amlash, 1♀, August 2002.

***Stenopogon roederii* BEZZI 1895**

M a t e r i a l : Mazandaran province: Behshahr, 1♂, 1♀, July 2001.

***Stenopogon rufipilus ruficauda* ENGEL 1929**

M a t e r i a l : East Azarbayjan province: Arasbaran, 1♂, July 2005.

***Stichopogon scaliger conjungens* BEZZI 1895**

M a t e r i a l : Guilan province: Rasht, 1♀, April 2005.

***Tolmerus atricapillus* (FALLÉN 1814)**

M a t e r i a l : Isfahan province: Isfahan, 1♂, August 2000.

***Tolmerus tesselatus* (LOEW 1849)**

M a t e r i a l : Khuzestan province: Ahwaz, 2♂, April 2001.

Family B o m b y l i i d a e (Diptera)

The larvae of certain bombyliid flies are also important predators of grasshopper eggs. As many as 13 genera have the habit of consuming acridid (grasshopper) eggs. The adults are called bee flies because certain species have furry bodies resembling a bumble bee. Also they hover in midair and dart swiftly from place to place, moving like bees. When the flies are at rest, the wings are held away from the body (BOWDEN 1980). Eggs are deposited in soil cracks and crevices in the vicinity of ovipositing grasshoppers. After a brief incubation period, the eggs hatch and the larvae wander through the soil in a random search for food. Encounters with grasshopper egg-pods appear to be more or less accidental (HULL 1973). A bee-fly larva can completely consume the contents of a pod, but at times only a few eggs are eaten in each of several pods. In this way, many egg-pods can be damaged, allowing the entry of other scavengers. The bee-fly larval stage can last for several years. The number of egg-pods destroyed per individual often exceeds three (REES 1973). When the bee-fly larva is fully developed, it leaves the egg-pod and pupates near the surface of the soil.

The fauna of Iranian bombyliids as the egg predators of grasshoppers were not studied perfectly so far. Until now only 7 species were reported by AYATOLLAHI (1971). In this research, totally 13 species of Bombyliidae were identified from Iranian rice fields and surrounding grasslands; but the predation behavior of the below bombyliid flies were not observed on Orthoptera by the authors. Therefore, although all these species were collected from rice fields or surrounding grasslands but many of these species may not be the predators of egg masses of Orthoptera. However, conducting many researches on this interesting subject can be useful for biological control science.

***Anastoechus angustifrons* PARAMONOV 1930**

M a t e r i a l : Golestan province: Gonbad, 1♀, 1♂, September 2001.

***Apolysis dolichorostris* PARAMONOV 1947**

M a t e r i a l : Mazandaran province: Neka, 2♀♀, August 2000.

***Apolysis fumipennis* LOEW 1844**

M a t e r i a l : Guilan province: Rasht, 2♂♂, June 2001.

***Apolysis pusilla* PARAMONOV 1929**

M a t e r i a l : Guilan province: Fooman, 1♀, June 2001.

***Conophorus asiaticus* PARAMONOV 1929**

M a t e r i a l : Isfahan province: Lenjan, 1♀, 1♂, July 1999.

***Conophorus bivittatus* LOEW 1862**

M a t e r i a l : Khuzestan province: Ahwaz, 1♀, May 1999.

***Karakumia nigra* PARAMONOV 1927**

M a t e r i a l : Golestan province: Kordkoy, 1♀, 1♂, August 2000.

***Legnotomyia cineracea* AUSTEN 1937**

M a t e r i a l : Khuzestan province: Ahwaz, 1♀, May 2001.

***Legnotomyia persica* PARAMONOV 1933**

M a t e r i a l : Isfahan province: Zarrin-Shahr, 2♂♂, July 1999.

Legnotomyia trichorhoea **LOEW 1855**

M a t e r i a l : Guilan province: Talesh, 1♀, 1♂, June 1999.

Oligodranes flavus **PARAMONOV 1929**

M a t e r i a l : Mazandaran province: Behshahr, 1♀, August 2000.

Parageron punctipennis **LOEW 1846**

M a t e r i a l : Mazandaran province: Neka, 1♀, 1♂, July 1998.

Usia versicolor **FABRICIUS 1787**

M a t e r i a l : Zanjan province: Zanjan, 1♀, 2♂♂, September 2000.

Family M e l o i d a e (Coleoptera)

The larvae of blister beetles (meloids) are an important group of predators of grasshopper eggs. Although the larvae of this group of beetles are predaceous, the adults feed exclusively on vegetation, and certain species can become numerous enough on crops such as alfalfa to require treatment with pesticides. In this family, the beneficial aspect of the larva frequently is offset by the destructive habit of the adult. REES (1973) lists 26 species of meloids whose larvae are known to attack grasshopper eggs in North America. In early summer, the female blister beetle lays a group of 100-200 eggs in an earthen chamber. When the young larva hatches from the egg, it is quite mobile and begins to search through the soil for a grasshopper egg-pod. Once a pod is located, the meloid larva transforms into a fat white grub and usually eats all of the eggs within the egg-pod. In fact, if the larva still has not completed its development, it will seek out another egg-pod on which to feed. Some species require 2 years to complete their life cycle. In this research totally 5 species of the genus *Mylabris* were collected as the egg predators of grasshoppers.

Mylabris **(*Eumylabris*)** ***calida*** **(PALLAS 1781)**

M a t e r i a l : Mazandaran province: Sari, 1♀, June 2001.

Mylabris 10-punctata **PETAGNA 1787**

M a t e r i a l : Isfahan province: Lenjan, 1♂, July 1999.

Mylabris **(*Eumylabris*)** ***decempunctata*** **FABRICIUS 1781**

M a t e r i a l : Khuzestan province: Ahwaz, 2♀♀, May 2001.

Mylabris **(*Hycleus*)** ***fusca*** **(OLIVIER 1811)**

M a t e r i a l : Mazandaran province: Ramsar, 1♂, June 2001.

***Mylabris tenebrosa* LAPORTE DE CASTELNAU 1840**

M a t e r i a l : Guilan province: Rasht, 1♀, 1♂, June 2001.

Family C a r a b i d a e (Coleoptera)

Both the adult and larval stages of this family are predaceous on other insects, but members of the family are known as generalists in their choice of hosts. The adults are commonly called ground beetles. The larvae of carabid beetles are predaceous on grasshopper eggs, and in some local situations, they seem to be of importance (GREATHEAD 1963). In this study, totally 4 carabid species were collected as the egg predators of grasshoppers.

***Cicindela deserticola* FALDERMANN 1836**

M a t e r i a l : Isfahan province: Lenjan, 1♀, July 2000.

***Cicindela* (*Myriochile*) *melancholica* FABRICIUS 1798**

M a t e r i a l : Zanjan province: Zanjan, 2♂♂, September 2000.

***Cicindela monticola* MÉNÉTRIÈS 1832**

M a t e r i a l : Guilan province: Rasht, 2♀♀, 1♂, June 2001.

***Cicindela* (*Cicindela*) *rhodoterena* TSCHITSCHITSCHERINE 1903**

M a t e r i a l : Mazandaran province: Amol, 1♀, September 2005; Kiakola, 2♀, April 2006.

Family T e n e b r i o n i d a e (Coleoptera)

Tenebrionidae, or darkling beetles, are one of the most numerous and diverse families of beetles, with more than 15,000 known species. Darkling beetles can be found in desert or semidesert regions all over the world. They burrow under stones, bark and leaf litter. Some species even move through sand, "swimming" with their legs (PENRITH & ENDRÖDY-YOUNGA 1994). In this research, in a total of 14 tenebrionid species were collected and identified from different Iranian rice fields and surrounding grasslands.

***Bioramix afghanistana* (GRIDELLI 1954)**

M a t e r i a l : Mazandaran province: Amol, 1♀, April 1999.

***Bioramix freudei* (KASZAB 1970)**

M a t e r i a l : Mazandaran province: Ramsar, 1♂, May 1999.

***Cyphogenia gibba* (FISCHER 1831)**

M a t e r i a l : Golestan province: Gorgan, 2♀♀, 1♂, May 2000.

***Dailognatha crenata* REICHE & SAULCY 1857**

M a t e r i a l : Guilan province: Astara, 1♀, October 1999.

***Dendarus tenellus* (MULSANT & REY 1854)**

M a t e r i a l : Mazandaran province: Savadkooh, 2♀♀, March 2000.

***Bioramix lindbergi* (KASZAB 1973)**

M a t e r i a l : Guilan province: Lahijan, 2♀♀, 1♂, April 1999.

***Diesia sefirana* REITTER 1894**

M a t e r i a l : Khuzestan province: Ahwaz, 2♀♀, October 1998.

***Dissonomus substriatus* REITTER 1898**

M a t e r i a l : Khuzestan province: Ahwaz, 1♀, 2♂♂, May 2001.

***Mesomorphus villiger* (BLANCHARD 1853)**

M a t e r i a l : Mazandaran province: Kiasar, 1♀, December 2001.

***Oodescelis oblonga* (BALLION 1878)**

M a t e r i a l : Mazandaran province: Kiakola, 1♀, August 2000.

***Pisterotarsa gigantea* (FISCHER VON WALDHEIM 1821)**

M a t e r i a l : Khuzestan province: Ahwaz, 2♀♀, 1♂, October 1998.

***Psammocryptus minutus* (TAUSCHENBERG 1812)**

M a t e r i a l : Mazandaran province: Joibar, 1♂, March 2001.

***Rizalus piceus* (OLIVIER 1811)**

M a t e r i a l : Mazandaran province: Nooshahr, 1♀, 2♂♂, August 2000.

***Sphenaria acuta* SEMENOW 1894**

M a t e r i a l : Guilan province: Fooman, 1♂, April 1999.

Family S t a p h y l i n i d a e (Coleoptera)

The Staphylinoidea is one of the largest superfamilies of the order Coleoptera, comprising more than 40,000 species from all zoogeographical regions of the world except for the Antarctic. Of the members of the superfamily, the Staphylinidae Latreille contain about 30,000 species belonging to about 20 subfamilies, and many of subfamilies are characterized by credible autapomorphies (SMETANA 1995). Rove beetles are known from every type of habitat that beetles occur in and their diets include just about everything except the living tissues of higher plants (NAOMI 1985). Most rove beetles are predators of insects and other kinds of invertebrates, living in forest leaf litter and similar kinds of decaying plant matter. They are also commonly found under stones, and around freshwater margins. Several types are known to live on ocean shores that are submerged at high tide, several species have adapted to live as inquilines in ant and termite colonies, and some are "parasites" of mammals that actually benefit their hosts by eating fleas and other parasites. Few species, notably those of the genus *Aleochara*, are parasitoids of other insects, particularly of certain fly pupae. Although rove beetles' appetites for other insects would seem to make them obvious candidates for biological control of pests, and empirically they are believed to be important controls in the wild, experiments with using them have not been notably successful. Greater success is seen with those species (genus *Aleochara*) that are parasitoids (LÖBL 1997). In a total of 7 rove beetles were collected from Iranian rice fields and around grasslands as the egg predators of Orthoptera.

***Acrotona pseudopygmaea* (SCHEERPELTZ 1963)**

Material: Mazandaran province: Savadkooh, 1♀, March 2000.

***Creophilus maxilosus* (LINNAEUS 1758)**

Material: Isfahan province: Lenjan, 1♀, 1♂, July 1999.

***Deliphrosoma linbergi* (SCHEERPELZ 1958)**

Material: Khuzestan province: Ahwaz, 2♂♂, May 2001.

***Philonthus dimidiatipennis* ERICHSON 1840**

Material: Mazandaran province: Kiakola, 1♀, August 2000.

***Quedius ochripennis* MENETRIES 1832**

Material: Zanjan province: Zanjan, 2♀♀, 1♂, September 2000.

***Stenus mongolicus* EPPELSHEIM 1889**

Material: Guilan province: Lahijan, 2♀♀, April 1999.

***Sunius picinus* (BERNHAUER 1902)**

Material: Isfahan province: Zarrin-Shahr, 1♀, 1♂, July 1999.

Family Sphecidae (Hymenoptera)

In this paper 14 sphecid species of 7 genera were collected as the predators of grasshoppers. EBRAHIMI (2000) reported three sphecids species including, *Tachysphex pompiliformis* (PANZER), *T. unicolor* (PANZER) and *T. brulli* (SMITH) as the predators of grasshoppers.

***Larra anathema* (ROSSI 1790)**

M a t e r i a l : Mazandaran province: Savadkooh, 2♀♀, March 1998. Predator of Gryllotalpidae.

***Larra bicolor* FABRICIUS 1804**

M a t e r i a l : Khuzestan province: Ahwaz, 1♀, 2♂♂, May 2001. Predator of Acrididae.

***Liris niger* (FABRICIUS 1775)**

M a t e r i a l : Guilan province: Astara, 2♀♀, 2♂♂, October 1999. Predator of Gryllidae.

***Palmodes occitanicus* (LEPELETIER & SERVILLE 1828)**

M a t e r i a l : Isfahan province: Lenjan, 1♀, 2♂♂, July 1999. Predator of Tettigonidae.

***Prionyx* (*Prionyx*) *crudelis* (SMITH 1793)**

M a t e r i a l : Khuzestan province: Ahwaz, 2♂♂, May 1999. Predator of Acrididae.

***Prionyx* (*Prionyx*) *viduatus* (CHRIST 1791)**

M a t e r i a l : Chaharmahal-Bakhtiari province: Shahrekord, 3♀♀, 1♂, July 2002. Predator of Tettigonidae.

***Prionyx* (*Prionyx*) *viduatus mocsaryi* (KOHL 1898)**

M a t e r i a l : Zanjan province: Zanjan, 2♀♀, 2♂♂, September 2000. Predator of *Oedipoda aurea* and *Aiolopus thalassinus*.

***Sphex dorsalis* LEPELETIER 1845**

M a t e r i a l : Isfahan province: Lenjan, 2♀♀, July 2000. Predator of *Notostaurus albicornis*.

***Sphex flavipennis* FABRICIUS 1793**

M a t e r i a l : Guilan province: Rasht, 2♀♀, June 2001. Predator of *Stenonemobius* cf. *gracilis*.

***Sphex funerarius* GUSSAKOVSKIJ 1934**

M a t e r i a l : Isfahan province: Isfahan, 1♀, 2♂♂, July 1999. Predator of *Eremopeza saussurei*.

***Tachytes europaeus* KOHL 1884**

M a t e r i a l : Isfahan province: Zarrin-Shahr, 2♂♂, July 1999. Predator of Acrididae.

***Tachytes obsoletus* (ROSSI 1792)**

M a t e r i a l : Mazandaran province: Amol, 2♀♀, September 1998. Predator of Acrididae.

***Tachysphex pompiliformis* (PANZER 1805)**

M a t e r i a l : Mazandaran province: Behshahr, 2♀♀, 1♂, March 1999. Predator of Tettigonidae.

***Tachysphex fulvitarsis* (COSTA 1867)**

M a t e r i a l : Zanjan province: Zanjan, 1♀, 2♂♂, September 2000. Predator of *Oedipoda aurea*.

***Tachysphex pompiliformis* (PANZER 1805)**

M a t e r i a l : Chaharmahal-Bakhtiari province: Shahrekord, 2♂♂, August 2000. Predator of Acrididae.

II. Parasitoids of Orthoptera

Parasitoids feed internally and complete their development within a single egg. In general, parasitoids of the eggs of insects usually are tiny hymenopterous wasps that come from one of several different families. However, the eggs of grasshoppers are attacked by wasps of the family Scelionidae only. In addition to the Scelionidae, the members of family Sarcophagidae (Diptera) are the main parasites of grasshoppers in Iran. In a total of 9 insect species of the families Scelionidae and Sarcophagidae were collected as the parasitoids of Orthoptera and are listed in this paper.

Family S c e l i o n i d a e (Hymenoptera)

Members of this group are the only true parasitoids of grasshopper eggs. The North American species of Scelionidae that develop as parasites in the eggs of grasshoppers belong to two genera: the genus *Scelio*, which contains about 19 species, and the genus *Synoditella*, represented by 2 species (MUESEBECK 1972). *Scelio* species occur throughout the world wherever grasshoppers are found. Only a single wasp develops within a grasshopper egg. *Scelio* adults live only a very short time, usually no more than 3 weeks under the best conditions. The sex ratio varies among species, but there are usually more females than males by a considerable margin (LAKIN 1994; BAKER et al. 1996).

The factors involved in host selection are not entirely clear, but it seems certain that the adult female is attracted by some chemical in the egg-pod froth. After locating a suitable egg-pod, the female wasp chews a passageway through the froth until she encounters the grasshopper eggs. Then the wasp backs out, reenters the passageway tail first, and, using her long ovipositor, lays eggs in as many host eggs as she can reach. After the *Scelio* larva hatches, it feeds internally on the contents of the host egg (DANGERFIELD et al. 2001).

When mature, the larva pupates within the host egg shell, and the adult wasp emerges during the summer months. In the Northern Plains, *Scelio* species are thought to have only one generation per year (DYSART 1995).

In this research only 4 scelionid species were collected as the egg parasite of grasshoppers. Surely there are many other species of this family which needs to more samplings in different regions of Iran.

***Scelio flavibarbis* (MARSHALL 1874)**

M a t e r i a l : Khuzestan province: Ahwaz, 3♀♀, 1♂, October 2003.

Comment: KHAJEHZADEH and GHAZAVI (2000) reported that this parasitoid infests 27 % of the egg capsules resulting in destruction of some 4-16 % of eggs of *Locusta migratoria*.

***Scelio nitens* BRUES 1906**

Material: Isfahan province: Lenjan, 2♀♀, 1♂, July 2000. Egg parasitoid of *Locusta migratoria*.

***Scelio remaudierei* FERRIÈRE 1952**

Material: Golestan province: Kordkoy, 1♀, 1♂, September 2001. Egg parasitoid of *Locusta migratoria*.

***Scelio zolotarevskyi* FERRIÈRE 1930**

Material: Mazandaran province: Behshahr, 2♀♀, June 2002. Egg parasitoid of *Locusta migratoria*.

Family Sarcophagidae (Diptera)

Most sarcophagids or flesh flies are scavengers as larvae, but some are parasitoids of insects. This family is distributed almost worldwide with more than 2,000 described species, most of which occur in tropical to warm temperate areas (SHEWELL 1987). There are about 21 to 23 species that are parasites of grasshoppers in North America. Sarcophagidae are without exception ovoviviparous, meaning that their eggs hatch within the uterus and the female deposits a live larva on the host (SHEWELL 1987). Sarcophagid larvae complete three instars (growth stages) in 6 to 9 days within the host before reaching maturity. The mature larva exits through a hole in the grasshopper body wall and pupates in the soil. One to three generations are possible, depending on the species, number of suitable hosts available, and environmental conditions. These flies target last-stage nymphs and adults and are generally considered the most effective group of grasshopper parasites (REES 1973). In this study five species of Sarcophagidae were identified as the larval parasites of grasshoppers as following. Additionaly of this study, seven species of Sarcophagidae were listed in the check-list of MODARRES AWAL (1997, p. 252) as the parasitoids of Orthoptera.

***Blaesoxipha litoralis* VILLENEUVE 1908**

Material: Guilan province: Lahijan, 1♀, 2♂♂, April 1999.

***Blaesoxipha filipjevi* ROHDENDORF 1928**

Material: Isfahan province: Lenjan, 1♂, July 2000.

***Blaesoxipha lineate lapidosa* ZETTERSTEDT 1845**

Material: Mazandaran province: Kiasar, 1♀, 1♂, October 2001.

***Blaesoxipha monticola pygmaea* ZETTERSTEDT 1844**

Material: Zanjan province: Zanjan, 2♂♂, September 2000.

***Parasarcophaga jakobsoni* ROHDENDORF 1937**

M a t e r i a l : Mazandaran province: Joibar, 1♂, September 2002.

In this paper a diverse fauna of several predators and parasitoids were collected as the natural enemies of Iranian grasshoppers. In addition to this paper, many natural enemies including, *Blaesoxipha* spp. (Dip.: Sarcophagidae), *Stenopogon* spp. (Dip.: Asilidae), *Mylabris* spp. (Col.: Meloidae), *Sphex* spp. (Hym.: Sphecidae), *Mantis* sp. (Mantodea), *Cataglyphis* spp. (Formicidae), *Scelio flavibarbis* (Hym.: Scelionidae), *Podapolipus grissi* and *Leptus* sp. (Acari) and *Agriope* spp. (Aranei) were recorded by KHAJEHZADEH (2004). Also, four parasitic mites including, *Leptus fathipeuri* HAITLINGER & SABOORI, *L. zhangi* SABOORI & ATAMEHR, *L. esmailii* SABOORI & OSTOVAN and *Keramotrombium talebii* were reported by KARIMI IRAVANLOU & SABOORI (2000) and KARIMI IRAVANLOU & KAMALI (2000) as the parasites of Acrididae. Therefore, the populations of Orthoptera in Iranian rice fields are pressured severely by diverse natural enemies and the grasshoppers generally are not the key pests of rice fields.

Conclusion

Many articles in the literature describe the habits and life history of grasshopper parasitoids and predators, but few good ecological studies describe the impact of these natural enemies on grasshopper populations. REES (1973) speculated that grasshopper egg predators probably have more effect on grasshopper populations than do predators of nymphs and adults. Based on a 10-year study in North Dakota and Montana, PARKER (1952) estimated that predators destroyed 20 percent of the eggs laid by grasshoppers. Parker and WAKELAND (1957) cite results from the studies made at 16 sites in 7 states. Average annual destruction of egg-pods by predators was about 18 percent (9 percent by blister beetles, 6 percent by bee flies, and 3 percent by ground beetles). PRIOR and GREATHEAD (1989) estimated that, in Africa, scelionid egg parasites (*Scelio* spp.) were the predominant cause of egg mortality in solitary locust populations. However, scelionids were rather ineffective mortality factors in the egg beds of gregarious species, such as the desert locust. In Australia, parasitism by *Scelio* species at certain sites has been found in up to 90 percent of the egg-pods. In the study areas of DYSART (1995) in Montana and North Dakota, *Scelio* parasitism never reached such high levels. He found that a complex of four species of *Scelio* parasitized about 11 percent of the egg-pods.

Classical Introduction Approach. According to a review article by PRIOR & GREATHEAD (1989), the classical biological control of a pest grasshopper using an insect parasitoid or predator as the beneficial agent has been attempted on nine occasions: there were two cases using bombyliids or bee flies, three cases using sarcophagid flies, two cases using meloid beetles, and two cases using scelionid wasps. Only two of these nine attempts resulted in the establishment of the introduced beneficial, a meloid beetle in Corsica and a scelionid wasp in Hawaii. However, the only project that has been claimed as a success was the introduction of a *Scelio* sp. from Malaysia, released against the rice grasshopper in Hawaii.

As suggested by GREATHEAD (1992) and by SIDDIQUI et al. (1986), the possibilities for classical work certainly have not been exhausted, particularly with any scelionid egg parasites having an acceptable degree of host specificity. A controversy surrounding the request by Richard J. Dysart for permission to release a species of *Scelio* from Australia against pest grasshoppers in the United States seemed to pivot around the issue of host specificity. In spite of the constraints involved in the classical biological control approach, there are even more problems to consider in the augmentative approach.

Augmentative Approach. Using insect parasitoid or predators as substitutes for chemical insecticides is not considered feasible for the control of grasshoppers. In his recent review of biological control options for tropical locusts and grasshoppers, GREATHEAD (1992) expressed the same sentiments. In order for this approach to be workable, the natural enemy to be used must have a number of attributes:

- An acceptable level of host specificity, assuring some degree of safety to nontarget organisms,
- The ability to be easily reared in a laboratory situation and be produced in large quantities, and
- Costs of production and delivery to the target areas low enough so that the cost of using the biocontrol organism is competitive with the cost of using chemicals.

Concerns about host specificity would eliminate several groups of natural enemies, for example, the meloid and carabid beetles, whose larvae wander through the soil in search of a wide range of hosts. Similarly, certain beneficial groups can be eliminated from consideration because they are not amenable to handling in captivity, for example, the egg predators (Bombyliidae, Meloidae) and the nemestrinid parasites (GREATHEAD 1992).

Although certain scelionid egg parasites can be reared easily in the laboratory, the rearing process is dependent on a constant supply of grasshopper eggs of a certain age. Considering the immense areas that would require release of parasites, plus the logistics of rearing and delivery, it is certain that the costs of using *Scelio* sp. parasites in an augmentative approach would be unacceptable.

The availability of novel methods such as microbial control open a window of opportunity for the development of environmentally sound options for grasshopper and locust control, and for the integration of all stakeholders such as farmers, plant protection agencies and international organizations.

A future IPM strategy will include three different approaches. One component will consist of the release of exotic natural enemies such as *Scelio* spp. or *Nosema* spp. for long-term impact. This approach still needs a careful environmental risk assessment. The second component will be the preventative application of Green Muscle™, a product developed by the LUBILOSA program, which is based on the entomopathogenic fungus *M. anisopliae*. The third component is a reduced application of conventional insecticides in situations which are unsuitable for alternatives. Potential negative side effects of releases of exotic natural enemies need to be studied very carefully for their potential risk to indigenous nontarget species or natural enemies.

An IPM approach based on biological control needs GIS-based decision-making tools to determine zones of different ecological vulnerability, natural enemy distribution, grasshopper population dynamics, crop damage and *Metarhizium* efficacy under different climatic conditions.

The successful implementation of such an IPM approach will require training at all levels. A good understanding of biological control is necessary to convince plant protection officers and farmers that quick kill is only necessary when using curative control strategies. Participatory trials with plant protection officers and farmers will help to establish full confidence in these types of control strategies.

Coevolutionary studies on parasitoids and their prey commonly focus on physiological defenses and counterdefenses (PENNACCHIO & STRAND 2006), but our results clearly show that ecological traits constitute a central part of the defensive arsenal of herbivorous insects. Prior to a niche shift, an evolving prey lineage must exhibit a polymorphism in resource use, which can be followed by quick fixation of one of the alternative states whenever different resources are associated with different enemy attack patterns. Furthermore, our finding that several parasitoid lineages have responded to gall-type divergence by adaptive speciation provides strong support for suggestions (NYMAN et al. 2007) that coevolutionary arms races have played an important role in the generation of the unusual diversity of herbivorous insects and parasitoids. Nevertheless, our data also indicate that in its classic form the EAR hypothesis is too simplistic to explain reciprocal diversification effects in complex food webs, in which escapes from enemies will tend to be too brief to lead to the predicted speciation bursts. Instead, the observed patterns of parasitism and diversification are consistent with a scenario of stepwise antagonistic coevolution: colonization of new ecological niches by prey lineages is being continuously driven by temporary relief from parasitism, after which an evolutionary response by some of the associated enemies returns mortalities to normal levels. A close integration of ecological and evolutionary research is clearly needed if the origins of such networks are to be fully understood.

Acknowledgments

The authors are indebted to Dr. Hasan Sevgili (Harran Universitesi Fen-Edebiyat Fakultesi Biyoloji Bolumu, Osmanbey Kampusu, Sanliurfa, Turkey), Dr. Luck Willemse and Prof. F.M.H. Willemse (National Herbarium of Netherlands, Leiden) for identification the Orthoptera specimens. We also thank to Dr. Battal Ciplak (Akdeniz Universitesi, Fen-Edebiyat Fakultesi, Biyoloji Bolumu, Antalya, Turkey) and Prof. Rüstem Hayat (Department of Plant Protection, Faculty of Agriculture, Atatürk University, 25240 Erzurum, Turkey) for editing the manuscript. The research was supported by Shahre Rey Islamic Azad University, Mazandaran Rice Research Institute, Ghaemshahr Islamic Azad University, and Fars Science & Research Branch.

Zusammenfassung

Die iranische Orthopterenfauna ist in den meisten agrarisch genutzen Ökosystemen artenreich, insbesondere in Reisfeldern. Dort wurden 74 Arten aus 36 Gattungen und den 8 Familien Acrididae, Catantopidae, Gryllidae, Gryllotalpidae, Pamphagidae, Pyrgomorphidae, Tetrigidae und Tettigoniidae nachgewiesen. Neben den Orthoptern wurden in vorliegender Arbeit auch deren Prädatoren (75 Arten) (Asilidae, Bombyliidae, Carabidae, Meloidae, Sphecidae, Staphylinidae und Tenebrionidae) sowie die Parasitoiden Scelionidae und Sarcophagidae (9 Arten) behandelt.

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