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Entomo-Fauna Associated with Bajra Crop as Observed in an Agro-ecosystem in Rajasthan, India

Sima and Meera Srivastava
Laboratory of Entomology,
Post-Graduate Department of Zoology,
Govt. Dungar College, Bikaner, (RJ)

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ABSTRACT: Pearl millet (*Pennisetum glaucum*) is the most widely grown type of millet. It is locally known as *bajra*, and is primarily consumed in the states of Haryana, Gujarat, Madhya Pradesh and Rajasthan. In Rajasthan it forms the staple diet of the local people. Ecologically, insects play many different roles as pests, predators and parasites, pollinators, decomposers and scavengers and so forth. The present study was undertaken to survey the insect fauna in an agro-ecosystem situated in the Indian desert in Jhujhunu district situated in western Rajasthan on *bajra* crop. The insect visitors were surveyed and collected every week from October 2008 to April 2009. Sweep net was used for insect collection. In all, ninety insect species were found to be associated with the crop. Of these, 14 were coleopterans, 28 were lepidopterans, 12 were hemipterans, 16 were hymenopterans, 6 were dipterans, 2 were dictyopterans, 8 were orthopterans, 3 were odonates and one was a neuropteran.

Key words: Pearl millet, insects, Rajasthan desert

INTRODUCTION

Pearl millet (*Pennisetum glaucum*) is the most widely grown type of millet. Grown in African and the Indian subcontinent since prehistoric times, it is generally accepted that pearl millet originated in Africa and was subsequently introduced into India. Pearl millet is well adapted to growing areas characterized by drought, low soil fertility, and high temperature. It performs well in soils with high salinity or low pH. Because of its tolerance to difficult growing conditions, it can be grown in areas where other cereal crops would not survive. Today pearl millet is grown on over 260,000 km² worldwide. It accounts for approximately 50% of the total world production of millets. India is the largest producer of pearl millet. It is locally known as *bajra*, and is primarily consumed in the states of Haryana, Gujarat, Madhya Pradesh and Rajasthan. In Rajasthan it forms the staple diet of the local people.

Millet is one of the oldest foods known to humans and possibly the first cereal grain to be used for domestic purposes. In India flat thin cakes called *roti* are often made from millet flour and used as the basis for meals. Millet is highly nutritious, non-glutinous and like buckwheat and quinoa, is not an acid forming food so is soothing and easy to digest. In fact, it is considered to be one of the least allergenic and most digestible grains available and it is a warming grain so will help to heat the body in cold or rainy seasons and climates. The seeds are also rich in phytochemicals, including Phytic acid, which is believed to lower cholesterol, and Phytate, which is associated with reduced cancer risk. Ecologically, insects play many different roles as pests, predators and parasites, pollinators, decomposers and scavengers and so forth. The present study was undertaken to survey the insect fauna in an agro-ecosystem situated in the Indian desert in Jhujhunu district situated in western Rajasthan on *bajra* crop.

MATERIAL AND METHODS

The study area

The state of Rajasthan is the largest state of Indian republic located between 23º3' to 20'13 N latitude and 69º30' to 78º17'C longitudes. The study area in the form of an agricultural field is located at 28°08′N, 75°24′ E and 28.13°N 75.4°E having an average elevation of 323 m (1059 feet) in the district of Jhunjhunu. The agro-ecosystem in the form of crop fields studied lies about 5km away from the city of Jhunjhunu, covering an area of 1000 x 500 m.

Methodology

The study concentrated on insect visitors of pearl millet (*Pennisetum glaucum*), a plant of economic importance and belonging to plant family Poaceae. The insect visitors were surveyed and collected every week from October 2008 to April 2009. For the study, the field area was divided into five stations. Sweep net was used for insect collection.

The insects collected by the above method were transferred to killing bottles, killed and preserved. The fauna were sorted out and help from the Section of Entomology, Department of Agriculture, Bikaner and Desert regional Station of the Zoological Survey of India, Jodhpur was also taken for identification and for confirmation. Besides, the reference collection in the Department of Zoology, Dungar College was also consulted.

RESULTS AND DISCUSSION

In all, ninety insect species were found to be associated with the crop. Of these, 14 were coleopterans, 28 were lepidopterans, 12 were hemipterans, 16 were hymenopterans, 6 were dipterans, 2 were dictyopterans, 8 were orthopterans, 3 were odonates and one was a neuropteran as presented in Table 1.

Table 1. Entomo fauna documented on millet crop cultivated during April to October in the agro-ecosystem studied.

Sr. No.	Insect species
	Order: Coleoptera
	Family: Scarabaeidae
1.	*Anomela bengalensis*
2.	*Onthophagus catta*
3.	*Onthophagus bonasus*
4.	*Adoretus* sp.
5.	*Ochodius* sp.
6.	*Peltonotus nasutus* Arrow
7.	*Apogonia ferruginea*
	Family: Coccinellidae
8.	*Coccinella septempunctata*
	Family: Curculionidae
9.	*Myllocerus* sp.
10.	*Hypolixus truncatulus* Fab.
	Family: Cicindelidae
11.	*Cicindella* sp.
	Family: Elateridae
12.	*Melanotis* sp.
	Family: Cerambycidae
13.	*Plocaederus sp.*
	Family : Meloidae
14.	*Cylindrothorax pictus* Fab.
	Order: Lepidoptera
	Family: Pieridae
15.	*Catopsila pomona* Cramer
16.	*Colotis vestalis* Butler
17.	*Colias fieldii* Menetries
18.	*Eurema hecabe*
19.	*Anaphaeis aurota*
	Family: Lycaenidae
20.	*Lampides boeticus* Linn.
21.	*Euchrysops cnejus*
	Family:Danaidae
22.	*Danaus chrysippus*
	Family:Papilionidae
23.	*Papilio demoleus* Linn
	Family: Noctuidae
24.	*Earias insulana* Boisduival
25.	*Mythimna seprata* Walker
26.	*Agrotis ipsilon* Hufnagel
27.	*Chrysodeixis chalcites* Esper
28.	*Thysanolusia orichalcae* Fab.
29.	*Heliothis peltigera* Schiff
30.	*Pericallia ricini* Fab.
	Family: Crambidae
31.	*Leucinodes orbonalis* Guenee
32.	*Hymenia fasciles* Cramer
33.	*Cnaphalocrocis medinalis*
34.	*Cryptographis indica* Saunders
	Family*:* Pyralidae
35.	*Sphenarches caffer* Zell
36.	*Scirpophoga nivella*
37.	*Etiella zinckenella* Treitschke
	Family: Arctidae
38.	*Utethesia pulchella* Linn.
39.	*Creatonotos gangis* Linn.
	Family: Sphingidae
40.	*Acherontia styx*
	Family : Geometridae
41.	*Tephrina* sp.
42.	Unidentified sp. a
	Order: Hemiptera
	Family: Pentatomidae
43.	*Nezara viridula*
44.	*Bagrada hilaris*
45.	*Aspongopus janus*
46.	*Andrallus spinidens*
47.	*Alcaeus* sp.
48.	*Piezodorus* sp.
49.	*Oncocephalus* sp.
	Family: Pyrrhocoridae
50.	*Dysdercus cingulatus* Fab.

51.	*Dysdercus koneigii*
	Family: Lygaeidae
52.	*Aphanus* sp.
	Family : Coreidae
53.	*Clavigrella* sp.
	Family: Fulgoroidae
54.	*Pyrilla perpusilla* Walker
	Order: Hymenoptera
	Family: Apidae
55.	*Xylocopa fenestrata* Fab.
56.	*Xylocopa violacea*
57.	*Apis cerana* Fab.
58.	*Apis mellifera* Linn.
59.	*Apis dorsata* Fab.
60.	*Apis florea*
	Family: Vespidae
61.	*Polistes* sp.
62.	*Eumens farternus*
	Family: Formicidae
63.	*Dolichoderus affinis*
64.	*Formica* sp.
	Family: Sphecidae
65.	*Sceliphron brunneum*
	Family: Chrysomididae
66.	*Chrysis dugesi*
67.	*Delta* sp.
68.	Unidentified sp. A
69.	Unidentified sp. B
70.	Unidentified sp. C

	Order: Diptera
	Family: Muscidae
71.	*Musca nibulo*
72.	*Musca domestica*
	Family: Bombyliidae
73.	*Anthrax* sp.
	Family: Tabanidae
74.	*Tabanus* sp.
	Family: Culicidae
75.	*Culex quinquefasciatus* Say
	Family: Asilidae
76.	*Stichopogon* sp.
	Order: Dictyoptera
	Family: Mantidae
77.	*Deiphobe incisa* Werner
	Family: Blattidae
78.	*Periplaneta americana* Linn.
	Order: Orthoptera
	Family:Acrididae
79.	*Chrotogonus* sp.
80.	*Ochrilidia* sp.
81.	*Schistocerca gregaria*
82.	*Oxya chinensis*
	Family:Tettigoniidae
83.	*Euconocephalus* sp.
84.	Unidentified sp. A
	Family: Gryllidae
85.	*Acheta domestica*

Coleoptera

Anomela bengalensis, Onthophagus catta, O. bonasus, Adoretus sp., *Ochodius* sp., *Peltonotus nasutus, Apogonia ferruginea, Coccinella septempunctata, Myllocerus* sp., *Hypolixus truncatulus, Cicindella* sp., *Melanotus* sp., *Plocaederus sp.*and *Cylindrothorax pictus* were the coleopterans noted on pearl millet crop during the present study. Bionomics of white grub *Anomela lineatopennis* in western Himalaya has been studied by Mishra *et al.* (1998 b) who found the insects to cause damage to almost all the kharif crops grown under rain fed conditions. Coleopterans were noted on the heads of *Mikania* by Cerena (2004). *Adoretus* adults and larvae are polyphagous (Miller, 1991). *Anomela* sp. is wide spread and attack many different plants both as adults and larvae are found throughout Asia including India. *Cylindrothorax* has been reported to damage and feed on panicle of maize, millets, rices and legumes in India. The larvae of *Myllocerus* found in dry soil damage the fine roots of plants by biting, while the adults eat the leaf lamella.

The grey weevil *M. undecimpustulatus* is a serious polyphagous pest in the Indian union. It causes damage to cotton, sorghum, maize, soybean and other crops and has been found to be active from mid July to mid November by Singh & Singh (1997). Falerio *et al.,* (1986) observed *M. undecimpustulatus* as a stray insect during kharif while studying the pest complex in cowpea. A high incidence of this weevil was recorded on pearl-millet during kharif crop season by Singh & Singh (1977 b) who also stated that heavy rainfall followed by bright sunshine under high humidity (85±5%) and mean temperature (20±2^{o}C) favoured the build up of pest population in early stage of plant growth and it attained its peak by first week of August. Swaminathan & Verma (1991) have also reported it as a pest damaging pearl-millet and Jujube in Rajasthan. Two members belonging to family Meloidae viz. *Milabris rajasthanicus* and *Cylindrothorax pictus* were also collected from the desert region by Dhas (2007). These were rare species documented from the area. *Cylindrothorax*

pictus was reckoned during all the crop seasons while *Milabris rajasthanicus* was collected only in Kharif crop season. Earlier *M. rajasthanicus* has been reported by Saigal (2002) only in the month of July from this region. The other related species *M. phalerata*, *M. pustulata* and *M. balteta* have been reported in India by Nayar *et al.* (1998). *Cylindrothorax ruficollis* and its related species *C. tennicollis* have been found to occur on ears of paddy and other millets (Nayar *et al.* 1998) and David and Kumaraswami (1998). Saigal (2002) also reported *Silesis inficetus* from both sewage and tube well water irrigated field and *Melanotus* sp. from well water irrigated field from the region. Many elaterids or click beetles are serious pests in cold countries but no species has been found to cause appreciable damage to any crop in India (Pruthi, 1969). Neupane (1993) and Pandey *et al.* (1993) also reported *Holotrichia* and *Anomala* sp. as major pests. Parvez (2010) collected 18 coleopteran insect species from an agro-ecosystem near Bikaner, Rajasthan.

Lepidoptera

The lepidopterans reckoned from the study area included *Catopsila pomona, Colotis vestalis, Colias fieldii, Eurema hecabe, Anaphaeis aurota, Lampides boeticus, Euchrysops cnejus, Danaus chrysippus, Papilio demoleus, Earias insulana, Mythimna seprata, Agrotis ipsilon, Chrysodeixis chalcites, Thysanolusia orichalcea, Heliothis peltiger, Spodoptera exigua, Pericallia ricini, Leucinodes orbonalis, Hymenia fasciles, Cnaphalocrocis medinalis, Cryptographis indica, Sphenarches caffer, Scirpophoga nivella, Etiella zinckenella , Utethesia pulchella, Acherontia styx, Tephrina* sp. and an Unidentified sp.A. Hussain *et al.* (2011) associated increase in number of butterfly species with winter seasons and their abundance fluctuation to be positively correlated with richness, while, Roy *et al.* (2001) noted that high temperature negatively affects butterfly abundance. Earlier studies by Kunte (2000-01), Padhye *et al.* (2006), Tiple & Khurd (2009) also suggested temperature and precipitation to be two vital factors which influence butterfly richness and population.

Sen (1952), Chaudhary (1953) and Narayanan (1954 b) have all suggested *Agrotis ypsilon* to be destructive pest of many cultivated crops. Srivastava & Khan (1962) made studies on cutworms *Agrotis ypsilon* and *Agrotis flammatra* were recorded from entire north-eastern hill region of India throughout the year as polyphagous pest by Ayyar (1963). Lall (1964) and Kamal & Shoeb (1964) have also recorded cutworms as polyphagous pests. Singh & Sinha (1965) reported *Agrotis ypsilon* to be a notorious pest in all rabi crops in tal areas of Bihar, Uttar Pradesh and Madhya Pradesh. Birat (1968) has also reported *Agrotis ypsilon* as a destructive pest of many other cultivated crops. Pruthi (1969) also recorded cutworms *Agrotis ypsilon* and *Agrotis flammatra* from entire northern-eastern hill region of India throughout the year as polyphagous pests. Bindra & Singh (1970) reported *Agrotis ypsilon* to be a notorious pest of all Rabi crops. Thimmaiah *et al.* (1972) reported *Agrotis ypsilon* to be a destructive pest causing damage to many crops.. *Agrotis* sp. has been reported to feed on gram, tobacco, peas, wheat, lentil, mustard, linseed, maize, sugarcane, cucurbits, vegetable seedlings and several weeds (Atwal & Dhaliwal, 1999).

A. ypsilon has been reported to be a destructive pest in India and abroad by Lefroy (1904), Singh (1949), Sen (1952), Narayanan (1954 b), Kamal & Soeb (1964), Birat (1968), Thimmaiah *et al.* (1972). It has been found to attack all Rabi crops in Bihar, U. P. and M. P. by Singh & Sinha (1965) and Bindra & Singh. (1970). Cut worms *A. ypsilon* and *A. flammatra* were recorded from entire North-eastern hill region of India throughout the year as a polyphagous pest by Ayyar (1963), Lall (1964), Pruthi (1969), Sachan and Gangwar (1980). *A. ypsilon*, *A. flammatra* and *A. spinifera* were recorded at Bikaner in IGNP area of Rajasthan (Progress Report-ARSSW 1998, 1999, 2001). All the three species of *Agrotis* were also reported by Roonwal (1982) from the arid region of Rajasthan and are in conformation with the present findings. *Agrotis* was noted as the pollinator of *Dipterocarpus obtusifolius* by Ghazoul (1997). This noctuid moth is the primary pollination vector at night and accounted for 60% of pollen transfer.

Yadava *et al.* (1974) and Yadava & Sachan (1975 a) observed diamond back moth *Plutella xylostella* to be a serious pest in warm climate areas of Rajasthan, Uttar Pradesh, Bihar, Madhya Pradesh and many southern states of the country. In studies conducted at Punjab by Singh & Singh (1975), the tomato fruit borer *Heliothis armigera* was recorded on maize during rainy season. Kushwaha (1977) reported *Amsacta lineola*, *Agrotis spinifera*, *Laphygma exigua*, *Heliothis armigera* and *Chilo partellus* as serious pests of cereals. The pod borer *Heliothis armigera* has been reported as serious pest of gram throughout India by Rawat *et al.* (1979). It is a polyphagous pest and prefers gram, red gram, pea, cotton, tobacco and sorghum. The African armyworm *Spodoptera exempta* has been reported to be a serious pest of cereals and grasslands in many parts of Africa South of Sahara. The gram pod borer *H. armigera* is an important polyphagous pest which causes considerable damage to the crops like gram, tur, peas, sorghum, maize, sun flower, cotton, soybean etc. as reported by Kadu *et al.* (1987).

Anita and John (2003) reported that *H. armigera* (Hubner) attacks more than 181 plant species. In studies conducted at Punjab by Singh and Singh (1975) the pest was seen from March to May and also during July to August. *H. armigera* has also been reported to be a serious pest of cereals by Kushwaha (1977). Vyas (1996) reported three species of *Heliothis* viz., *H. armigera*, *H. peltigera* and *H. assulta* from the desert region of India. Three species viz., *H. armigera*, *H. assulta* and *H. peltigera* were monitored at Bikaner and were found to be dominant forms in the months from August to October (Progress Report-ARSSW, 1998, 1999, 2000, 2001). Roonwal (1982) has also reported American bollworm from Thar Desert of Rajasthan. The tobacco caterpillar *S. litura* is found throughout the tropical and sub-tropical parts of the world and is wide spread in India. Besides attacking tobacco it feeds on castor, groundnut, tomato, sunflower, cabbage and various other cruciferous crops (Atwal & Dhaliwal, 1999). The indigo caterpillar *S. exigua* is a polyphagous pest attacking indigo, gram, linseed, lentil, cabbage, maize, cotton etc. and is geographically distributed in Europe, South Africa, America and the Orient. In India it is known as Lucerne caterpillar and besides attacking lucerne it also infests chillies, onion, brinjal, coriander, radish, cowpea etc. (Nayar *et al.* 1998). *S. exigua* and *S. litura* have been reported to be dominant forms at Bikaner during November (Progress Report ARSSW, 1998). During the present study also this species was reckoned more during November month. Another related species *S. exempta*, the African army worm, is a serious pest of cereals and grasslands in many parts of Africa and has been found to show a density dependent polypherism with a low density solitaria phase that was rarely seen and a high density gregaria phase that occurred in conspicuous out breaks (Tucker, 1994).

The spotted bollworm *Earias insulana* and *E. vitella* (family Noctuidae) were collected from the agroecosystem as rare species. These insects are widely distributed in North Africa, Pakistan and India causing serious damages to cotton (Atwal & Dhaliwal, 1999). *Plusia orichalcea* occurs in all parts of India and is most common during winter and spring. Singh *et al.* (1979) observed semi-looper during vegetative stage under the agro-climatic conditions prevailing around Delhi. The seasonal incidence of insect pest of cole crops at Shillong were studied by Sachan & Gangwar (1990). They reported *P. orichalcea* to be a minor pest because of its negligible number recorded only during June to August. Degri & Chaudhary (1998) also reported *Plusia* species to be a minor pest of cowpea in Nigeria. *Utethesia pulchella* was noted in large numbers during April by Bhardwaj (2009). This is in conformation with the studies done by Dhas (2007) who also found the insect to be active throughout the year being highest during April. Similar findings have also been furnished by the Agricultural department in their Progress Report (ARSSW, 1998, 2001). Martin (1993) observed *Utethesia* to also occasionally visit flowers. Katiyar (1982) suggested the population of this insect was profoundly influenced by different agro-climatic conditions. He further suggested that warm but not excessively hot weather, cloudiness and frequent light rains were conducive for rapid multiplication of this insect, which was true during the present study also. According to Atwal & Dhaliwal (1999) *U. pulchella* is the most important pest of sunhemp in Tamil Nadu and hence termed as sunhemp hairy caterpillar. This insect is distributed in India, SriLanka, Africa, Europe, Philippines, New Guinea, Malay, Archipelago and Australia (Nayar *et al.*, 1998). It has also been reported by Vyas (1996) and Roonwal (1982) IGNP region of North West Rajasthan. *U. pulchella* has also been monitored at Bikaner and found active throughout the year being present in high numbers during April from the IGNP area of Rajasthan (Progress Report-ARSSW, 1998, 2001). *Acherontia styx*, the till hawk moth a rare form was collected from agroecosystem by Dhas (2007). This insect which has been described as a pest of sesamum is common in India and is also distributed in Indonesia, SriLanka, Philippines and Myanmar. Besides, sesamum, it has been found to damage potato, brinjal, lab-lab and ornamental plants (Pradhan, 1998; Atwal and Dhaliwal, 1999). *A. styx* has also been reported in the arid regions of Rajasthan by Roonwal (1982).

Danaus chrysippus is a very common butterfly found in India, the larvae of which feed on the leaves of *Calotropis gigantea*, *Eruca sativa* etc. (Nayar *et al.*, 1998). Atwal & Dhaliwal (1999) have reported the butterfly from September to December, their population becoming high during the months of October and November. *D. chrysippus* has also been reported earlier by Donahue (1962) and Roonwal (1982) from the Thar Desert of Rajasthan. *Hymenia recurvalis* was one of the forms documented and its population was found to increase May onwards and remained quite high up to December by Bhardwaj (2009). A similar trend was also noted by Dhas (2007) in the same region. Sharma and Joshi (2009) identified 41 lepidoterans from Dholbaha dam in Punjab while Sharma (2011) observed 38 lepidopteran insects to be associated with vegetables in Aravalli Ranges of Rajasthan.

Hemiptera

Nezara viridula, Bagrada hilaris, Aspongopus janus, Andrallus spinidens, Alcaeus sp., *Piezodorus* sp., *Oncocephalus* sp., *Dysdercus cingulatus, D. koneigii, Aphanus* sp., *Clavigrella* sp. and *Pyrilla perpusilla* belonging to order Hemiptera were collected from the agriculture field studied. *B. hilaris* is a serious pest of cruciferous crops and has also been observed feeding on other crops like rice and sugarcane, and is widely distributed. It has been found to be active from March to December and it passes the winter months of January and February in the adult stage (Atwal & Dhaliwal, 1999). *persicae, Dysdercus cingulatus, Bagrada hilaris, Lapricus varicornis* and *Nezara graminea* were reported earlier by Dhas (2007). *D. cingulatus* has been found to be active throughout the year, passing winter in the adult stage (Atwal & Dhaliwal, 1999). *D. cingulatus*, the red cotton bug, and its allied species *D. koenigii* and *D. olivaceus* are widely distributed in India and are known to feed on cotton, maize, pearl-millet, wheat, *Abelmoschus esculentus, Hibiscus, Solanum verbacifolium* (Atwal & Dhaliwal, 1999; Nayar *et al.* 1998). *D. cingulatus* has also been reported from IGNP region of Rajasthan and found to attack leaves and cotton bolls (Progress Report-ARSSW, 1999). Ghosh *et al.* (1996) also reported another related species *D. koenigii* from the arid region of Rajasthan. Another related species *N. viridula* has been found to infest millet crops in India (Nayar *et al.*, 1998), and has been cited to be an important pest by Atwal & Dhaliwal (1999). Ghosh *et al.* (1996) also reported *N. graminea* from the arid region of Rajasthan. Kumar & Ahmad (2003) reported *N. viridula* as a pest causing damage to foliage of *Paulownia fortunei*. *Nezara viridula* has been reported to be one of the most abundant species infesting sorghum panicle (Krugar *et al.*, 2008). The adults and nymphs cause damage by sucking the sap from the leaves and ear heads.

Falerio *et al.* (1986) and Sardana (1986) found *B. hilaris* to attack cowpea in India. Singh *et al.* (1979) and Narayanan (1954 a) have reported another related species *B. cruciferarum* as a serious pest to remain active throughout the year especially infesting various cruciferous crops during winter. During spring it has been found to feed on mature pods or remain under the heap of harvested rape mustard and radish by Narayanan (1954 a), Batra (1958), Atwal (1959) and Bhai (1959). Sandhu (1975) observed the seasonal movement of the painted bug from cruciferous plants to graminaceous plants and its occurrence as a serious pest of maize, sorghum and pearl-millet during spring in Punjab. Swami *et al.* (1998) observed the incidence of *B. cruciferarum* to commence from third week of December and reach its peak during third week of January, thereafter to decrease gradually. Srivastava *et al.* (1972) reported the incidence of bug from January to March while Saigal (2002) reported it throughout the year. Narayanan (1954 a) found *Bagrada cruciferarum* Kirk. to be a major pest of cruciferous crops not only in India but also in Burma, Sri Lanka, Pakistan, Arabia, Iraq, Kenya, Ethiopia and Southern Rhodesia. Whitefly *Neomeskellia bergii* was found to attack pearl-millet at Diajar village near Jodhpur by Verma (1980). Two species of membracids viz., *Tricentrus bicolor* and *Leptocentrus obliguis*, a pyrrhocorid bug *Dysdercus cingulatus* and several pentatomid species were found to attack lucerne in southern Rajasthan by Kushwaha (1977). In Punjab severe outbreaks of white backed plant hopper were found to have occurred at several locations by Dhaliwal & Singh (1983). *Bagrada hliaris* and *Nezara viridula* were the two pentatomid bugs documented from the region by Bhardwaj (2009). *B. hilaris* was the rarest form observed only in the months of December and March. According to Atwal & Dhaliwal (1999) also this species is active from March to December. Thapa (2006) also reported *N. viridula* to visit the flowers of rape seed and Rovira *et al.* (2003) suggested stink bug as pollinator of *Seseli ferrenyi* which corroborate the present findings.

Dysdercus cingulatus have been reported to damage okra, cotton and other plants of the same family (Kranz, 1977; Swain, 1971 and Frohlich, 1970). The population of *D. cingulatus* was found to be more during June -July, while, that of *D. koenigii* was seen in the month of April by Bhardwaj (2009).Hemipterans are less suited for pollination as suggested by Kearns (2001). Hemipterans were noted on the heads of *Mikania* by Cerana (2004). In all, six hemipteran species viz. *Lipaphis erysimi, Myzus*

Hymenoptera

The hymenopterans documented were *Xylocopa fenestrata, X. violacea, Apis cerana, Apis mellifera, Apis dorsata, Apis florea, Polistes* sp., *Eumens farternus, Dolichoderus affinis, Formica* sp., *Sceliphron brunneum, Chrysis dugesi, Delta* sp., Unidentified sp. A, Unidentified sp. B and Unidentified sp. C. According to Roubik (1989) hymenopterans are responsible for 67–93% of the floral visits. Total pollination activities, over 80% are performed by insects, and bees contribute nearly 80% of the total insect pollination and therefore, they are considered the best pollinators. Hymenopterans were noted on the heads of *Mikania* by Cerena (2004). Heithaus (1974) observed a positive relationship between bee and floral abundance. Change in major weather factors such as temperature and RH might be responsible for the difference in visitation rate of honeybee was suggested by Selva Kumar *et al.* (1996). Bee foraging activity is highly influenced by prevailing weather factors have also been reported by Szabo (1980), Sihag & Abrol (1986), Abrol (1987).

Milk weed has been found to be pollinated by *Polistes* as reported by Kephart (1983), Ivey *et al.* (2003) and Robert *et al.* (1994). Hannan (2007) found wasps mostly during April and May. According to Martin (1993) *Polistes sp.* are very common floral visitors of *Acacia* with little pollen movement. Wasp as a floret visitor of Asteraceae was documented by Tooker & Hanes (2001). Patt (2000) found that umbels such as coriander, dill, fennel, caraway are very attractive beneficial insects like wasp. *Scolia* sp. as flower visitors of *Sesamum* and *S. ruficeps* as potential pollinators of teak flowers were suggested by Ivey *et al.* (2006) respectively. Yamazaki & Kato (2003) also reported scolid wasp as a good pollinator of some plants in the grassland ecosystem. Thapa (2006) reported *Sphex sp.* as pollinator of various crops. Kephart (1983), Robert *et al.* (1994) and Ivey *et al.* (2003) reported *Sphex sp.* as pollinators of milkweed. Tybirk (1992) also observed *Coelioxys* as the pollinators of African *Acacias* which supports the present findings. Two ants belonging to family Formicidae viz., *Camponotus compressus* and *Dorylus orientalis* were collected earlier by Bhardwaj (2009). The black ant *C. compressus* has been reported to cause harm by distributing plant lice to various growing plants like ragi, cotton etc. (Ayyar 1984). These ants are also suggested to be dangerous enemies of the bee, attacking weak colonies and carrying away the honey, pollen and brood. *Dorylus*, commonly known as driver or migratory ant, is carnivorous. The dorylines are reported to completely clean the ground, vegetation and trees, holes, caves, nests and even houses and therefore scaring animals and even human beings to take flight (Linsenmaier, 1972). *Dorylus* sp. has also been reported to cause damage to canes and brinjal (Ayyar, 1984). Vir *et al.* (2002) reported 13 species of hymenopterans from leguminous trees of Thar Desert. Ichneumon wasps are parasites and mostly the hosts are lepidopterans. Many can also be seen feeding on flowers in the sunshine particularly umbelliferae. Vespid wasps are basically carnivorous and feed on a wide range of insects and other invertebrates, but also seek nectar, honey and bite holes in ripe fruit to suck the sugary sap. Their role in agriculture is complex. They kill many crop pests and occasionally assist in pollination. Sphecid wasps is a group which prey upon lepidopteran caterpillars, hemipterans, orthopterans and some have been recorded on thrips, may flies, spring tails, cockroaches, bees and even other wasps. All these findings support the present observations where a number of hymenopterans were collected from different crops.

Diptera

Musca nibulo, M. domestica, Anthrax sp., *Tabanus* sp., *Culex quinquefasciatus and Stichopogon* sp. were the dipterans noted in the farmland during nthe present study. Small flies may be instrumental in the forest for shrubs with numerous, small inconspicuous, often dioecious flowers was suggested by Larson *et al.* (2001). According to Herrera (1988) flies exhibit marked diurnal activity patterns of flower visitation. Representatives of at least 25 Diptera families have bee reported visiting flowers in the Oriental Region (Corlett, 2004). Flower flies are not only important as pollinator in agro-ecosystem, but they also serve as bio-control agents as their zoophagus larvae eat aphids, scales and other homopteran pests. *Musca* sp. and *Calliphora* sp. pollinate umbelliferous plants (USDA, 2007). *C. quinquefasciatus* is a domestic mosquito common in India found to breed in rain barrels, ground pools, ditches, pits, and drains, tanks, in standing water near houses and in sewers with high organic pollution. The adults take shelter in cow sheds, dark corners and also under fallen leaves. This species of mosquito has also been reported earlier by Kumar & Kumar (1996) as well as Saigal (2002) from Bikaner region of the Thar Desert. *Musca domestica* of family Muscidae was also collected from the study area. Houseflies are cosmopolitan in distribution and are found in abundance in hot and humid conditions. Presence of manure in agricultural fields is a preferred site for houseflies. Amongst dipterans *Culex pipiens* (Culicidae), *Musca domestica* and *M. nebulo* (Muscidae), *Eristalis sp* (Syrphidae), *Dacus cucurbita* (Tephritidae), *Tabanus sp.* (Tabanidae) and *Sarcophaga bravicornis* (Sarcophagidae) were documented by Bhardwaj (2009). Maner *et al.* (1999) observed milkweed flowers to attract *C. pipiens* and Anderson & Joenson (1986) who found *C. pipiens* to feed on nectar of *Tanacetum vulgare*. According to Jhumur *et al.* (2006) *C. pipiens* are effectively attracted by appropriate floral scent of flowers. The male members of Culicidae are floral visitors which feed on nectar and other plant juices. *Musca sp.* has been observed by various workers visiting flowers and acting as pollinators these include reports of Sung *et al.* (2006) and Singh (1983) who suggested *M. domestica* as a potential pollinator of mango flowers. According to Borror (1992) the males of family Tabanidae feed chiefly on pollen and nectar and are often found on flowers. *Tabanus* as pollinators of mustard, sponge gourd and brinjal has also been reported by Thapa (2006). Tangmitcharoen *et al.* (2006) also suggested *Tabanus* as potential pollinators of teak flowers while according to Ivey *et al.* (2003) although *Tabanus* was found to visit milk weed flowers but it did not carry pollen. Dipterans as visitors to the flowers of chervil were reported by Knuth (1908) and Sievers (1948). Robertson (1928) also recorded dipterans on the flowers of Asteraceae, Apiacae, Fabaceae, Lamiaceae and Asclepiadaceae.

Dipterans as pollinators of plants belonging to Asteraceae were noted by Noronha & Gottsberger (1980); Arroyo *et al.* (1982); Sazima & Machado (1983) and Abbot& Irwin (1988). Khemba & Mutinga (1982) suggested dipteran species as pollinator of sunflower especially when the number of bee visitors is too low to provide sufficient pollination. Dipteran as pollinator of an umbelliferous plant, carrot was reported by Ahmed & Aslam (2002), as pollinators of *T. erecta* have been noticed by Gange & Smith (2005), as floral visitors of mango were reported by Sung *et al.* (2006) and on the heads of *Mikania* were noted by Cerena (2004).

Dictyoptera

Only two dictyopterans were observed viz., *Deiphobe incise* and *Periplaneta americana*. Dhas (2007) has also earlier reported *Mantis sp.* from the region as a rare form. Not much literature is available on dictyopterans in agro-ecosystems.

Orthoptera

Chrotogonus sp., *Ochrilidia* sp., *Schistocerca gregaria, Oxya chinensis, Euconocephalus* sp., *Acheta domestica, Gryllus assimilis* and Unidentified sp. A were the orthopterans collected from the study area. The desert locust *Schistocerca gregaria* has been reported to be the most destructive species from Indian desert by Rao (1960). *Schistocerca gregaria* as a destructive species has also been reported by Roonwal (1961a). Economically important *Hieroglyphus nigrorepletus* and *Schistocerca gregaria* as destructive species from the Indian desert have been reported by Roonwal (1978 a) and Roonwal (1978 b) repectively. Venkatesh (1977) reported desert locust as most destructive species. Only 3 members belonging to this order viz., *Chrotogonous* sp. and *Acridia* sp. belonging to Acrididae, *Gryllus domesticus* belonging to Gryllidae were collected by Dhas (2007). Jayappa *et al.* (2003) reported that the field cricket *Gryllus* sp., occurred only at seedling stage of soybean during both kharif and summer. The authors also reported the surface grasshopper, *Chrotogonus* sp. to damage soybean crop from seedling to pod maturing stage and upto pod setting stage in kharif and summer respectively. According to Atwal & Dhaliwal (1999) the surface grasshopper *C. trechypterus* is widely distributed in the Orient and Africa and in India it is common in the North where as *C. oxypterus* in the Southern regions. Besides cotton and wheat these polyphagous pests feed on a number of other cultivated crops such as sugarcane, barley, fodder etc. Comparative attack of *C. trechypterus* at seedling stage in different cotton varieties has also been made by Singh *et al.,* (1990) in Punjab. The principal ecological factors that influence the diversity of grass hoppers are the rain fall pattern, atmospheric temperature, relative humidity, vegetation, soil type, protection from external enemies as suggested by Bhargava (1996). According to the author, vegetation and soil types are perhaps more directly important than the others and most of the grass hoppers are restricted to open vegetation of grass lands but some are found on tree plantations. *C. trechypterus* and *A. exaltata* have also been reported from arid region of Rajasthan by Parihar (1996). The desert locust *Schistocerca gregaria*, the most destructive species from the Indian desert, has been reported by Roonwal (1945 a, 1961 a, 1971, 1978 b), Rao (1960) and Venkatesh (1977). The two species of house cricket prevalent in India are *G. domesticus* and *G. sigillatus* and are active throughout the year, abundant during monsoon. In field these crickets occasionally damage crops by chewing roots, underground stems of various plants and the fruits touching ground (Atwal & Dhaliwal, 1999). Saxena (2002) observed two cricket species namely *Acheta domestica* and *Gryllodes melanocephalus* from Ajmer (Rajasthan). He recorded an out break in cricket population on a rainy day (temperature 23-35^{o}C; RH 65-80%). *Chrotogonus* sp. and *Ochrilidia* sp., both belonging to family Acrididae were also reported by Bhardwaj (2009). Commonly known as short horned grasshoppers, these are plant feeders and are very destructive to vegetation. Crickets generally are detritivorous and omnivorous and some are herbivorous and can be pests of some importance. *Acheta domesticus* is cosmopolitan and present throughout the warmer parts of the world. *Chrotogonus* sp. is polyphagous surface grasshopper found in the desert area of Asia and damage cotton, sorghum and millets. Locusts prefer diet of Gramineae family, grasses and crops but eat all plants during dry seasons. During monsoon the millets are sown in the sandy loam soil of the agricultural fields around Jodhpur and on investigation the cricket *Acheta domesticus* was found to nibble the young seedling and cause considerable damage by Bhargava (1996).

Odonata

Bradinopyga geminata, Rhodischnura nursei and unidentified sp. A were the three odonates reckoned during the study period. Only one member of order odonata, *Lestes* sp. (Lestidae), a rare form was observed during Kharif crop season by Dhas (2007). Odonates were also reported earlier by Saigal (2002) from tube-well irrigated field around Bikaner. *Pantala flavescens* and *Agriocnemis femina* were the two odonates belonging to families Libellulidae and Coenagrionidae respectively observed by Bhardwaj (2009). The number of both the species was found to be high in the month of October by the author. Sarrag *et al.* (1993) have also recorded odonates but as visitors of sunflowers.

Neuroptera

Order Neuroptera was represented by only *Chrysopa carnea*. The present reports get support from the earlier studies of Dhas (2007) who also noted *Chrysopa* sp. from the desert region, although Ghosh (1977) has reported 13 species of Neuroptera from the Indian desert of western Rajasthan. The commonly known green lacewing fly is a predaceous insect and preys upon aphids, jassids, psyllids, coccids, thrips, mites etc. In India *C. scelestes* is reported to be very common species (Pruthi, 1969). Other related species found in India are *C. cymbele* and *C. madestes* and are found to prey upon leaf hopper and in Punjab and *C. madestes* is a predator of lac insect (Nayar, 1998). *Chrysopa sp*. was a rare species documented from December to May, maximum in the month of April by Bhardwaj (2009). According to Ivey *et al*. (2003) although *Chrysopa sp.* visited the flowers of milkweed but they were not found to carry pollen.

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