Bio-ecology of the acridid genus *Oxya* in selected agro-ecosystems of Southern Rajasthan

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Thesis
Submitted to the
Maharana Pratap University of Agriculture and Technology, Udaipur
in partial fulfillment of the requirement
for the degree of

Doctor of Philosophy in Agriculture
(Entomology)

By
Abhishek Pareek

2012

Maharana Pratap University of Agriculture and Technology, Udaipur

Rajasthan College of Agriculture, Udaipur

CERTIFICATE-I

Dated: 21 / 11 /2011

This is to certify that **Mr. Abhishek Pareek** has successfully completed the Preliminary Examination held on 06.06.2009 as required under the regulation for the degree of **Doctor of Philosophy** in Agriculture.

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Dated: 21 /11 /2011

This is to certify that the thesis entitled **"Bio-ecology of the acridid genus *Oxya* in selected agro-ecosystems of Southern Rajasthan"** submitted for the degree of **Doctor of Philosophy in Agriculture** in the subject of **Entomology**, embodies bonafide research work carried out by **Mr. Abhishek Pareek** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of this thesis was also approved by the advisory committee on 03.10.2011.

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Dated: 08 /02 /2012

This is to certify that the thesis entitled **"Bio-ecology of the acridid genus *Oxya* in selected agro-ecosystems of Southern Rajasthan"** submitted by **Mr. Abhishek Pareek** to the Maharana Pratap University of Agriculture and Technology, Udaipur in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Agriculture** in the subject of **Entomology** after recommendation by the external examiner was defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination on his thesis has been found satisfactory; we therefore, recommend that the thesis be approved.

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This is to certify that **Mr. Abhishek Pareek** of the **Department of Entomology**, Rajasthan College of Agriculture, Udaipur has made all corrections/ modifications in the thesis entitled **"Bio-ecology of the acridid genus *Oxya* in selected agro-ecosystems of Southern Rajasthan"** which were suggested by the external examiner and the advisory committee in the oral examination held on 08.02.2012. The final copies of the thesis duly bound and corrected were submitted on ---------------- are enclosed herewith for approval.

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ABSTRACT

Title: "Bio-ecology of the acridid genus *Oxya* in selected agro-ecosystems of Southern Rajasthan"

Abhishek Pareek **Dr. U. S. Sharma**
Research Scholar* **Major Advisor****

Investigations on the bio-ecology of the acridid genus *Oxya* in selected agro-ecosystems of Southern Rajasthan were carried out in the Department of Entomology, Rajasthan College of Agriculture, MPUAT, Udaipur, with the following objectives (i) Survey of the acridid fauna in the agro-ecosystems of Southern Rajasthan; (ii) Estimation of the qualitative and quantitative abundance of acridid genus *Oxya* in paddy; (iii) Studies on the biology, taxonomy and food preference of the dominant *Oxya* species; (iv) Evaluation of the management strategies for *Oxya* spp. in paddy nurseries.

Surveys conducted in the five crop ecosystems of Banswara, Chittorgarh, Dungarpur, Pratapgarh and Udaipur districts of Southern Rajasthan during 2008-09 and 2009-10, resulted in the collection of 10 acridid species from paddy, maize, sugarcane and sorghum crop ecosystems; while, 7 acridids from soybean crop ecosystem. Among the surveyed crop ecosystems, the acridid species diversity was maximum in sorghum and sugarcane ecosystem with the Shanon Weiner Diversity Index being 2.219 and 2.199 for sorghum; followed by 2.205 and 2.207 for sugarcane during 2008-09 and 2009-10, respectively. Soybean ecosystem was least diverse with diversity index of 1.827 and 1.767 during 2008-09 and 2009-10, respectively. The acridid monthly mean and relative density values varied considerably among these crop ecosystems. The population of acridids and their biological activity was observed to be maximum from July to October months.

In paddy, the numerical abundance of *Oxya* spp. was significantly higher during July in both the years; however, their occurrence differed significantly district-wise only during 2008-09. During the present study, six species of the genus *Oxya viz.*, *Oxya fuscovittata* (Marschall) *Oxya intricata* (Stål), *Oxya rufostriata* Willemse, *Oxya nitidula* (Walker), *Oxya ebneri* Willemse and *Oxya hyla hyla* Serville could be recognized.

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Studies on the biology of rice small grasshopper evinced that the mean development period from egg to adult was 70.15 days and the adult females lived a little longer (40.70 days) than the males (37.50 days). A single female could lay about 2 egg pods with an average of 23 eggs per pod that had a hatchability of 67.46 per cent. The mean duration of different nymphal stages from I through V was 51.85 days where the duration of nymphal stage I was the shortest (7.20 $\pm$ 0.23), while that of the nymphal stage V was the longest (13.10 $\pm$ 0.30). Growth and development of *Oxya fuscovittata* (Marschall) was best on *Oryza sativa* L. ranking first followed by *Cyperus rotundus* L. ranking second; resultantly, the developmental period on *O. sativa*, manifested by hopper duration, was the lowest; the survival was 100 per cent; consequently, the growth index was the highest during both years. The food utilization indices, efficiency of conversion of ingested food (ECI), approximate digestibility (AD) and efficiency of conversion of digested food into body substances (ECD) were the highest when the grasshopper (*O. fuscovittata*) was fed on *O. sativa*.

In an effort to evaluate the management strategies for *Oxya* spp. in paddy nurseries, Fipronil (0.02%) was observed the best treatment when applied on unweeded paths around the paddy nurseries.

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1. INTRODUCTION

Variations in the distribution and activity of insects within an ecosystem are important factors to be taken into account before the development of an economic and effective programme of insect pest management. Insect pests continually adjust to changing man-made or natural ecological situations; as a result several species have attained pest status. Grasshoppers are annotated in the list of destructive crop pests. The family Acrididae alone has more than 100 species that are pests of agricultural crops and pastures. Further, peculiarities of life economy in grasshoppers, their discrimination of micro climatic conditions and habitational orientation on cultivated or wild flora in wake of their divergent biologies and sequent transformation in colour patterns harmonizing with varied seasonal surroundings in view of long span of life depict evolutionary superiority of this fauna amongst the agricultural insect pests. It is generally established that the occurrence of acridid species primarily depends on the presence of host plant species (Kemp *et al*., 1990a; 1990b).

Records of grasshopper fauna representing 17 genera in Rajasthan desert zones in the thirties and the need for intensive studies on this group, which comprise a wide spectrum pest complex, was emphasized by Ramchandra Rao (1960). Kushwaha (1968) conducted a survey of insect pests of pastures that included 35 species of Acridids. Kushwaha and Bhardwaj (1977) dealt with field identification features, seasonal incidence and details of life cycle of a few species at Udaipur. Since Acridids are wholly herbivorous and occur in abundance, they are most injurious to agriculture. It may be pointed out that more attention has to be paid towards studies on Acridids in Rajasthan as it has been speculated that some species are closely associated with the breeding of desert locust and thus develop an instinct for gregarious phase. Ramchandra Rao (1960), in his eminent monograph, *The Desert Locust in India*, emphasized the need for greater interest in studies on Orthopteran fauna, particularly the Acridids, and has reported the common genera from the desert zone.

Among the pests of paddy (an important crop in southern Rajasthan), the small rice grasshopper that belongs to the genus *Oxya* is abundant in paddy fields, especially causing damage to the seedlings in nursery. Considerable work has been done on the acridid, *Hieroglyphus* spp., but similar work on *Oxya* spp. is required. The precise reason as to why species of this genus have dominated is yet to be ascertained. Species of the genus *Oxya* are widely known to be pests of rice, sugarcane and other crops, in Pakistan, throughout the oriental region, China, S. E. Russia, the Australian region, and the genus had been introduced to Hawaii in the last century. The insects are well adapted to the marshy conditions in which they live as the hind tibia and tarsus are expanded and 'oar-like', enabling the insect to swim (Uvarov, 1928); the female is able to oviposit in soil in drier conditions and, in flooded fields to cement egg masses between grass stems, in leaf axils or on stones, an inch or two above the water level. The genus *Oxya* was last revised by the C. Willemse (1925) and he recognized thirty species. Uvarov (1926) published a few minor corrections to Willemse's revision. He synonymized three of the species that Willemse recognized, added three more species which Willemse omitted (as he was unable to make type- examinations) and altered some points of nomenclature. Since then, further two species and three subspecies have been added; of the two former, two have sunk into synonymy, and of the latter, one has been given full specific status and another synonymized. Thus, the genus was thought to contain forty species and one subspecies. Later, Hollis (1971) suggested that the genus contained eighteen species, two of which were described as new and further three were each divided into two subspecies.

To provide field identification keys, studies on the seasonal incidence, behaviour, nature of damage and morphological peculiarities become necessary. Keeping these facts in view the present study was undertaken with the following objectives:

1. To conduct a survey of the acridid fauna in the agro-ecosystems of Southern Rajasthan.
2. To estimate the qualitative and quantitative abundance of the acridid genus *Oxya* in paddy.
3. To study the biology, taxonomy and food preference of the dominant *Oxya* species.
4. To evaluate the management strategies for *Oxya* spp. in paddy nurseries.

2. REVIEW OF LITERATURE

2.1 Survey and diversity of acridid fauna in agro-ecosystems:

Grasshoppers are important components of agriculture fields, grasslands, and forest under-storey; and their global pest status has been reviewed in detail (Jago, 1998). Among the different acridids, the genus *Oxya* has been reported to cause considerable damage to paddy at the seedling stage (Dean, 1976; Irshad *et al.*, 1977; Singh and Sinha, 1978; Garg and Tandon, 1983; Thakur, 1984); besides it also infests maize, sugarcane, sorghum and fodder crops.

Apart from *Hieroglyphus banian* (F.) and *Hieroglyphus nigrorepletus* Bolivar, which may cause serious damage to paddy, millet and sugarcane, grasshoppers appear to be relatively unimportant pests in Orissa. *Chrotogonus trachypterus* (Blanch.) is a minor pest of sorghum, maize, groundnut, cotton and tobacco; *Aularches miliaris* (L.) of sorghum and maize; *Atractomorpha crenulata* (F.) of maize and tobacco; and *Poecilocerus pictus* (F.) and *Orthacris* sp. of sorghum (Sengupta and Behura, 1957). Records of grasshopper fauna representing 17 genera in Rajasthan desert zones in the thirties and the need for intensive studies on this group, which comprise a wide spectrum pest complex, were emphasized by Ramchandra Rao (1960). Kushwaha and Bhardwaj (1977) studied 35 species of forage and pasture grasshoppers of Rajasthan. A highly dense population of the pyrgomorphid, *C. trachypterus*, up to 46 per unit area was noticed in the *Kelwara* area and more or less similar incidence was noticed in the other localities as well.

The species richness, density and diversity of grasshoppers (Orthoptera: Acrididae) in a habitat of the mixed grass prairie comprised the gomphocerines (10 species) representing about 80 per cent of the total density, melanoplines (9 species) 15 per cent and locustines (5 species) 5 per cent. Grass feeders (gomphocerines and most locustines) made up 85 per cent of the total density. The dominant species was *Ageneotettix deorum* (Scud.), which contributed 52 per cent of the grasshopper density in

1981 and 37 per cent in 1982. The grasshopper population was at outbreak density in both years (60 and 36/m^2, respectively). The pasture was never treated with insecticide or herbicide. The Shannon-Wiener index of about 2.00 indicated high grasshopper diversity (Pfadt, 1984).

Shah *et al*. (1991) studied the seasonal fluctuations in population densities of major acridid species on range grasses and observed that populations of *H. nigrorepletus* started appearing in the second half of June and remained active until early November with a peak in the first half of August. *Oedaleus abruptus* (Thun.) appeared at the beginning of August and disappeared in mid-November, with a peak population build-up from mid-August to mid-September. *Catantops pinguis* Stål. (*Diabolocatantops pinguis*) appeared in early September and remained active until mid-November with a peak population density from mid-September to late October. While studying the population dynamics of three grasshopper species in a forest floor environment, Mishra and Dwivedi (1997) recorded *Aulacobothrus* sp. throughout the year, *Oxya hyla hyla* Serv. only during the rainy season and *Spathosternum prasiniferum* (Wlk.) with its two generations during the rainy and summer seasons.

Eight species of grasshoppers were reportedly injurious to the range grasses in Jhansi: *H. nigrorepletus, A. crenulata*, *O. abruptus*, *C. pinguis*. (*D. pinguis*), *Acrida exaltata* (Wlk.), *Thisoicetrus pulcher* Bol. (*T. pulchra*), *Cyrtacanthacris tatarica* (L.) and *C. trachypterus*. *C. trachypterus* was the first to appear (May), while *C. pinguis* was the last (September). The most abundant grasshoppers were *H. nigrorepletus, O. abruptus* and *C. pinguis* (Shah, 2001).

Mayya *et al*. (2005) recorded a total of 28 species of short horned grasshoppers (Acrididae) belonging to four subfamilies from Dakshina Kannada district, Karnataka. *A. exaltata, Dociostaurus* sp. and *Stauroderus bicolour* (Charp.) were relatively abundant among grasshoppers of subfamily Acridinae; among the species from sub family Oedipodinae, *Morphacris fasciata* (Thun.), *Dittopternis venusta* (Wlk.), *O. abruptus* and *Acrotylus humbertianus* (Sauss.) were abundant; similarly, among the different species of subfamily Catantopinae, *S. prasiniferum* and *Catantops pinguis innotabilis* (Wlk.) were most abundant. *Chrotogonus oxypterus* (Blanch.) and *A. crenulata* were abundant species from the subfamily Pyrgomorphinae. It was found that Acridinae were abundant during January and February; Oedipodinae during February and March, while Catantopinae and Pyrgomorphinae were present in large numbers during December and January.

Rathore (2009) collected a total of 27 acridids species from five selected districts (Udaipur, Dungarpur, Banswara, Bhilwara, and Sirohi) of South Western Rajasthan and classified under 10 sub families *viz.*, Acridinae, Catantopinae, Coptacridinae, Cyrtacanthacrinae, Eyprepocnemidinae, Gomphocerinae, Hemiacridinae, Oedopodinae, Oxyinae, and Truxalinae belonging to 25 genera. The adult species diversity was the maximum at Banswara and Dungarpur with the Shanon Weiner Diversity Index being the maximum 3.11 and 3.06 for Banswara during 2006-07 and 2007-08, respectively; followed by 3.08 and 3.11 for Dungarpur during 2006-07 and 2007-08, respectively. Paulraj *et al.* (2009) collected a total of 33 species of grasshoppers from different host plants and habitats and classified under four families *viz.*, Acrididae, Pyrgomorphidae, Tetrigidae and Tettigoniidae. Family Acrididae was the most dominant with 21 species grouped under fifteen genera of seven subfamilies, accounting 63.6 per cent of the total collected species. The second largest family was Tettigoniidae with five genera and three subfamilies, which contributed 18.2 per cent (6 species) of the total collected species, while Pyrgomorphidae ranked third with 15.2 per cent of the total species collected (5 species) with four genera and only one subfamily. Tetrigidae was represented by only one species.

Mukhtar *et al.* (2010) collected fourteen species and five sub species of the family Acrididae under six subfamilies (Acridinae, Cyrtacanthacrinae, Eyprepocnemidinae, Gomphocerinae, Truxalinae and Oedopodinae) belonging to twelve genera from Quetta division Balochistan. Among the recorded species, *Aiolopus thalassinus thalassinus* F. was the most abundant on all plant categories contributed to 20.3 per cent of the overall catches. In another study, Tamkeen *et al.* (2011) collected 25 grasshopper species belonging to two families, Acrididae and Pyrgomorphidae from three districts of Mirpur division of Azad Jammu and Kashmir, Pakistan. Eighteen species were found in each Mirpur and Bhimber districts, while 14 species were found in Kotti district. Species diversity was highest (2.46) in Mirpur followed by Bhimber (2.19) and Kotti (1.98), while grasshopper abundance was higher in Bhimber followed by Mirpur and Kotti. On the basis of number of specimens collected, *Oxya hyla hyla* Serv. was most abundant in Bhimber; while, *Spathosternum prasiniferum prasiniferum* (Wlk.) was most abundant in both Mirpur and Kotti districts. In relation to species distribution 9 species were distributed broadly, 7 intermediately and 9 narrowly in the study area.

Paddy-ecosystem:

Irshad *et al.* (1977) described the food-plants and biology of six species of grasshopper that infested rice and they were *Oxya hyla hyla* Serv. (*multidentata* Willemse), *O. velox* (F.), *H. banian, Shirakiacris shirakii* (Bol.), *Eyprepocnemis plorans* (Charp.) and *Atractomorpha acutipennis* (Guérin-Méneville). Singh and Sinha (1978) observed *H. banian*, *H. nigrorepletus* and *Oxya* sp. as dominant acridid pests in paddy besides other insect-pests. Of the ten species of Orthoptera observed to cause damage to paddy seedlings in the nursery, the most abundant were *H. banian*, *Oxya fuscovittata* (Marshall) and *A. crenulata*. The moderately abundant species were *A. exaltata*, *Chrotogonus* sp., *Trigonidium cicindeloides* Ramb., and *Euconocephalus* sp. The less abundant species were *Catantops pinguis innotabilis* (Wlk.), *Teleogryllus occipitalis* (Serv.) and *Gryllotalpa* sp. (Garg and Tandon, 1983). Bhardwaj *et al.* (1986) recorded *A. crenulata* and *Oxya velox* (F.) as the most common species on summer paddy in Raipur, Madhya Pradesh. Chitra *et al.* (2000) surveyed rice ecosystem at Coimbatore and recorded fifty species of Orthoptera (8 long horned grasshoppers, 28 short horned grasshoppers, 3 crickets, 1 tree cricket and 10 pygmy grasshoppers). Those collected from rice fields were found feeding on rice foliage and grains and a few of the Orthopterans *viz., Anaxipha longipennis* (Serv.), *Metioche vittaticollis* (Stål), *Metioche bicolour* (Stål) (Trigonidiidae) collected mainly from bunds were observed to be predators of rice insect pests. The four species of grasshoppers infesting paddy were *H. banian, Oxya nitidula* (Wlk.), *Chrotogonus trachypterus trachypterus* (Blanch.) and

Aiolopus tumulus (F.). The pyrgomorphid, *C. trachypterus trachypterus* was maximum (12.80 nymphs and 39.20 adults/ observation) during July - October when the mean temperature was 37.97º C. Nymphs of *A. tamulus* and *O. nitidula* were 37.60 and 57.00/ observation, whereas the adults were 39.00 and 70.00/ observation, respectively and were maximum during September – October when the mean temperature ranged from 34.02 - 37.90º C. *H. banian* was observed to be the maximum during August - October (4.6 nymphs and 15.2 adults/ observation) at a mean temperature range of 35.65 - 37.950º C (Lanjar *et al.*, 2002). Similarly, in an irrigated rice ecosystem in Madurai, Tamil Nadu, Kandibane *et al.* (2004) collected 21 species of grasshoppers belonging to three families, Acrididae (71.40 %), Tettigoniidae (23.80 %) and Pyrgomorphidae (4.70 %). Among the acridids, two species *viz.*, *O. nitidula* and *O. fuscovittata* were the most dominant taxa in rice ecosystem.

Other Crop-ecosystems:

Khaemba (1979) recorded *Acrotylus patruelis* (Herrich-Schäfer), *Chrotogonus hemipterous* Schaum, *Gastrimargus africanus* Saussure, *Morphacris fasciata* (Thunberg), *Ornithacris* sp. and *Zonocerus elegans* (Thunberg), as pests of sunflower before the flowering stage. Yadav and Yadav (1983) recorded *C. trachypterus* as a pest of cowpea (*Vigna sinensis*). Perwin *et al*. (1983) studied the seasonal incidence and relative abundance of about 80 species of grasshoppers, belonging to 47 genera, on vegetable crops in Karachi, Pakistan. *A. thalassinus* formed more than 40 per cent of the grasshoppers collected. The next in abundance were *A. exaltata*, *Aiolopus simulatrix simulatrix* (Wlk.), *C. trachypterus* and *Aiolopus strepens* (Latr.) on vegetables, maize and grasses.

The tettigoniid, *Neoconocephalus* sp., the pyrgomorphids, *C. trachypterus* and *A. crenulata* were recorded as pests of sunflower in North West Frontier Pakistan (Sattar *et al*., 1984). Reddy and Puttaswamy (1984) observed the acridid, *A. exaltata* and the pyrgomorphid, *A. acutipennis*, *C. trachypterus*; the gryllids, *Anaxipha rufonotata* Chopard, *Modicogryllus fascialis* (Wlk.) and *Plebeiogryllus guttiventris* (Wlk.) as important orthopteran pests of chilli (*Capsicum annum* L.) in the nursery. In an experiment on insect-pest colonization and succession in wheat, *Triticum aestivum* L., Hasan and Cervancia (1986) recorded the occurence of the tettigonids, *Phaneroptera furcifera* (Stål.) and *Euconocephalus varius* (Wlk.) (*E. nasutus*) and the acridids, *Oxya intricata* (Stål) (*O. hyla intricata*) and *Atractomorpha psittacina* (De Haan) during the third week after germination. Gyawali (1989) recorded *Acrida, Atractomorpha, Oxya* sp. and the tettigoniid, *Phaneroptera gracilis* on the upper canopy of blackgram (*Vigna mungo*) at the later stage of the plant growth.

Mulchandani *et al.* (1993) observed adults and nymphs of *A. thalassinus* damaging wheat and sorghum seedlings. Population of the pest reached a peak in October and started declining from November onwards. Thippaiah and Kumar (1999) surveyed the grasshopper fauna of soybean in Karnataka during *kharif* and summer seasons and reported *Chrotogonus* sp. and *Cyrtacanthacris tatarica* (L.) to be most numerous in both seasons. Six orthopteran pests *viz., Gryllus* sp., *Chrotogonus* sp., *Oxya* sp., *C. tatarica*, *A. crenulata* and *Pyrgomorpha bispinosa* (Walk.) were observed to infest soybean at different growth stages (Jayappa *et al*., 2003). The diversity of grasshoppers in rainfed cotton ecosystem included *C. oxypterus*, *C. trachypterus*, *A. crenulata*, *C. tatarica*, *Holochlora albida* (Brunner van Wattenwyl), *Eyprepocnemis alacris alacris* (Serv.) and *C. pinguis* (*D. pinguis*). Among these, *C. oxypterus*, *C. tatarica* and *A. crenulata* were the most abundant (Balakrishnan *et al*., 2004).

2.2 Quantification of acridid diversity and population abundance:

Literature on the quantification of the acridid fauna includes the earlier consideration of the sub-family Pyrgomorphinae under family Acrididae. Hence, much work on population diversity and abundance of grasshoppers includes both pyrgomorphids and acridids.

Ecologists have quantified Orthoptera (grasshoppers and crickets) density in a wide variety of conservation studies. Objective determination of Orthoptera population size is possible using mark-release recapture techniques but these are time-consuming and of little use for all but the smallest scale studies. Therefore, a wide range of sampling techniques has been devised to quantify population density and the most commonly used methods include sweep netting and quadrat counts. The most rapid and inexpensive sampling methods, such as quadrat and transect counts, involve 'flushing' grasshoppers from the sward. These techniques are fairly accurate in short, open swards (<50 cm sward height) where grasshopper densities are low (<2 adults per m^2). At higher population densities (>2 adults per m^2), methods which require the capture of grasshoppers such as box quadrats and sweep netting may be more appropriate. Sampling grasshopper populations in taller vegetation (>50 cm sward height) is more problematic as the efficiency of many techniques may be reduced by vegetation structure. Methods such as timed counts can be used at low densities (<2 adults per m^2) and night trapping might be most applicable where high numbers of grasshoppers are present (>2 adults per m^2). Sweep netting was used to determine extent of Orthoptera populations in 45.5% of papers reviewed and is by far the most commonly used method. Transects (17.0% of records), open quadrats (13.4% of records) and pitfall traps (9.8%) have all often been used to quantify Orthoptera abundance by various authors. The rarest methods used included box quadrats, night trapping, ring counts and timed counts (2–5% of records) (Gardiner *et al.*, 2005).

Sweep netting is the most frequently used method to sample the relative abundance (a subjective measure of population size) and species composition of grassland Orthoptera assemblages as it is possibly the least intensive and most rapid method in the field (Strubinskii, 1979). Sweep netting has formed the basis of fixed-effort sampling protocols used extensively in the US, Canada, South America and the former Soviet Union (Sergeev, 1986, 1992; Lockwood *et al.*, 1993; Olfert *et al.*, 1995; Cigliano *et al.*, 2000; Torrusio *et al.*, 2002). The method has also been used extensively in surveys of pest species (e.g. *Calliptamus italicus* L.) populations in agricultural land in the former Soviet Union (Strubinskii, 1979) and to a certain extent in semi-arid zone grasslands (Krokene, 1993; Peveling *et al.*, 1999). However, relative abundance implies frequency of occurrence (i.e. a combination of frequency and density; Young and Young, 1998) but, arguably, sweep netting does not provide an accurate assessment of either frequency or density as it samples a hypothetical volume above the grass layer. The most commonly used net size is 38 cm diameter (Bomar, 2001; Fuhlendorf *et al*., 2002; O' Neill *et al*., 2003), although other sizes such as 30 cm (Foord *et al.*, 2002; Karpakakunjaram *et al*., 2002), 40.6 cm (Quinn *et al*., 2000) and 49 cm (Dawes-Gromadzki, 2002) have been used. There is little data presented in the literature on fabric type or mesh size. The standard procedure for sweeping the vegetation is once back and forth in a 180_ arc in front of the observer (Evans *et al*., 1983; Quinn *et al.*, 2000; O' Neill *et al.*, 2003) and sweeps are often taken at fixed points on transects or grid formations (Foord *et al*., 2002). The number of sweeps required to estimate the density of grasshoppers at a site is normally high (>50; Fuhlendorf *et al*., 2002) although the number of sweeps can be varied according to estimates of the variability of previously sampled populations and/or the size of area sampled (Mukerji *et al*., 1981). Furthermore, it is also important to record the number of insects captured per man hour and estimate the area of survey (Strubinskii, 1979; Lockwood and Sergeev, 2000) to improve the fidelity of the estimate of total population. When sampling mixed species populations of Orthoptera, it is recommended that sweep net methods should include a pre-determined number of 'high-fast' and 'low-slow' sweeps to ensure all species (rapid vs. slow dispersal species) are sampled (Foster and Reuter, 1996). This would rely on the development of more complex sampling protocols and sequential or repeated sampling would have to be applied, increasing the labour intensity and reducing the rate of sampling. Sweep sampling is also affected by climatic conditions as the numbers of target insects collected in sweep samples can be low when the weather is cool and wet (Richards and Waloff, 1954). However, a trade-off between sampling efficiency and climatic conditions has to be considered. Marshall and Haes (1988) advised that recording Orthoptera was easiest in the morning (between 0930 and 1130 h) and in the late afternoon (1600 h onwards) as grasshoppers are less active and therefore less likely to escape capture by sweeping. However, is the sweeping of sites during these times likely to provide accurate estimates of Orthoptera populations at a site?

Recent work has emphasized that a species' habitat is made up of a number of discrete resources and that these resources may or may not be spatially separated (Quinet *et al.,* 2004; Dennis *et al.,* 2006; Dennis and Sparks, 2006).Gardiner (2006) noted that the dispersal distance of the grasshopper, *Chorthippus parallelus* Zetterstedt in a grazed pasture, was significantly reduced at high wind speeds (>2.5 m/s). Movements may also be highly directional on agricultural land (Gardiner and Hill, 2004) so it is possible that grasshoppers may congregate in areas of farmland where wind speeds are reduced such as the leeward side of hedge rows.

2.3.1 Bionomics of the acridid, *O. fuscovittata*:

Life-history traits of insects may be expected to vary with latitude and altitude as populations adapt to local environments. Three interrelated traits that are of fundamental importance to an organism's fitness and that often vary with length of growing season are developmental rate, growth rate, and adult size (Dingle *et al*., 1990; Ayres and Scriber, 1994; Nylin and Gotthard, 1998; Telser and Hassall 1999; Bentz *et al.*, 2001; Fischer and Fiedler, 2002; Berner *et al*., 2004; Gotthard, 2004). Many different selection pressures may influence the evolution of these traits, including season length, juvenile and adult mortality rates, and food quality and quantity (Abrams *et al*., 1996; Chippindale *et al*., 1996; Fielding, 2004; Stoks *et al*., 2005). Rapid development potentially increases fitness by reducing generation time and by reducing the risk of mortality before reproducing. Rapid development may be achieved by some combination of maturation at a smaller size (less growth) or more rapid weight gain (faster growth). Smaller individuals are generally assumed to be less fit. Size is often positively correlated with fecundity (Roff, 1992; Nylin and Gotthard, 1998) and competitive ability (Belovsky and Slade, 1995) in insects, although in some cases, smaller individuals may be less susceptible to predation (Belovsky *et al*., 1990; Branson 2005). The trade-off between size and development time can be circumvented by increasing growth rate. The generally assumed advantages of large size and rapid development lead to the expectation that growth rates in most organisms should be maximized (Arendt, 1997); however, empirical evidence suggests that growth rate is seldom at its potential maximum (Margraf *et al*., 2003; Tammaru *et al*., 2004). Possible costs associated with rapid growth in insects include diminished resistance to starvation or other stresses, greater sensitivity to food quality (Stockhoff, 1991; Gotthard *et al*., 1994), and increased predation risk (Gotthard, 2000; Danner and Joern, 2003; McPeek, 2004; Stoks *et al*., 2005).

Oxya chinensis Thunberg had one generation per year and is known to hibernate in the egg stage at the field borders or in uncultivated land, which later on hatched in early May. The nymphal stage lasted for 51-73 days and the average fecundity was 33 eggs/ female (Shen *et al.,* 1988). In rice fields of eastern Hebei, China, the locust, *O. chinensis* was found to lay eggs 3 cm deep in soil, in canal dikes with weeds (65%), on ridges of paddy fields (30%) and in the fields themselves (5%). Nymphs fed on rice plants on the 3rd-5th day after hatching, with feeding peaks at 07.00-09.00 h and 16.00-19.00 h. Adults began to copulate 15-30 days after emergence. Females laid 1-4 egg masses with 53 eggs on average (Sun *et al.,* 1991). Duration of nymphal development, mortality, fecundity and longevity of *Oxya fuscovittata* were affected by the food plant. Nitrogen content of foliage was positively correlated with female weight and fecundity (Dhang *et al.,* 1993).

2.3.2 Food preference by the acridid, *O. fuscovittata*

Dietary mixing in phytophagous insects has been the focus of various studies in the past decades (Bernays and Bright 1993; Bernays *et al.,* 1994, 1997; Miura and Ohsaki 2006; Mody *et al.,* 2007). In the majority of these studies, dietary mixing was found to positively affect the performance of generalist herbivores (Bernays and Bright 1993; Hägele and Rowell-Rahier 1999; Miura and Ohsaki 2004; Berner *et al.* 2005) although the underlying mechanisms are not totally clear. There are two older hypotheses for mixing behaviour in generalist herbivores. The nutrient complementation hypothesis assumes that single plant species rarely contain all the nutrients necessary for herbivore growth, and postulates that by broadening the diet, herbivores are more likely to obtain a full complement of essential nutrients (Pulliam, 1975; Rapport, 1980). A number of studies have found compensatory feeding in insect herbivores as predicted by this theory (Lee *et al.,* 2004; Berner *et al.,* 2005; Takeuchi *et al.,* 2005). The toxin dilution hypothesis states that by dietary mixing individual toxins produced by particular plant species are consumed at a lower dosage which therefore lessens their effect

(Freeland and Janzen 1974; Behmer *et al.,* 2002; Singer *et al.,* 2002; Marsh *et al.,* 2006). More recently, Raubenheimer and Simpson (1999) developed a geometric model of feeding for generalist insects that allows an exploration of how the intake of dietary protein, carbohydrate and salts affects herbivore development and based on this approach, a number of studies have shown that herbivores generally have to balance their intake of different nutrients for successful development (Behmer and Joern, 1993; Berner *et al.,* 2005; Lee *et al.,* 2002).

So far, a shortcoming in most studies on dietary mixing in generalist insect herbivores is that they have often been restricted to one particular developmental stage rather than observing the complete ontogeny of insects with respect to food plant use. It is conceivable that as generalist insects grow and thus change morphologically and physiologically, they might change their food plant species in order to meet their nutritional requirements. Werner and Gilliam (1984) proposed the concept of the ontogenetic niche to address such patterns of resource and habitat use that can change when an organism grows. “The ontogenetic niche offers a temporal perspective of variation in resource use that can direct investigation toward life stages in which specialization and the propensity for resource-associated adaptation is most likely” (Dopman *et al.,* 2002). Such ontogenetic niches have been reported for a variety of groups of organisms with respect to both resource and habitat use. For example, in amphibians, tadpoles are restricted to aquatic habitats while adults of many species are largely terrestrial.

Ontogenetic shifts may, however, also be more subtle. In paurometabolous insects such as grasshoppers, the different nymphal stages and the adult feed in the same habitat and on the same type of food *i.e.* herbaceous plants, but nevertheless there can be changes in host plant preferences. In an experiment by Sword and Dopman (1999), the generalist grasshopper *Schistocerca emarginata* showed a developmental shift in resource breadth, with narrow diet breadth as juveniles and true polyphagous feeding patterns as adults. This study gives an indication that a certain mix of plant species might meet the requirements of generalist herbivores only at a particular time during their development but may not be appropriate for all developmental stages. Host-plant switches during the development might not only happen as a result of the insect's morphology and physiology but also because of spatial and temporal changes of food plant quality (Hellmann, 2002; Scriber and Slansky, 1981). Furthermore, there may be sex-related differences in nutritional requirements. Females most often gain higher weight as adults and have thus an overall higher need for food. Whether the composition of food plants differs between the sexes throughout their development remains unclear. Information about shifts in foraging strategies of herbivorous insects related to their ontogeny and sex-dependent feeding preferences is necessary in order to detect adaptive feeding behaviour in heterogeneous environments.

Grasshoppers exhibit habitat selection on a variety of spatial and temporal scales (Samways and Sergeev, 1997). At the broadest scale, some migrate hundreds of kilometers over the course of one or more weeks in response to changes in habitat quality (Farrow, 1990). At a smaller scale, grasshoppers typically move several meters per day, responding to the distribution of food, mates, oviposition sites, and suitable microclimates (Joern, 1983a; Smith and Grodowitz, 1987; With, 1994). Other adaptive movements are likely to occur rapidly over spatial scales of several centimetres and intervals of several seconds. Constraints due to microclimatic heterogeneity may force grasshoppers to respond this rapidly if they are to approach or attain preferred body temperatures, and avoid stressful temperatures (Chappell and Whitman, 1990). Behavioural responses to temperature must be dynamic, because the location of favourable microhabitats varies during the day with environmental temperatures, the incident angle and intensity of solar radiation, wind speed, humidity and perhaps, with varying thermal requirements of the grasshoppers themselves. However, although microclimatic variation may constrain grasshoppers, patchy thermal environments also present them with numerous options for regulating body temperature (Bernays *et al.*, 1997).

Generalist herbivores, from mammals to insects and mollusks, commonly grow better when they have a mixed diet than when they are confined to single food item

(Bernays and Bright, 1993; Bernays *et al.,* 1994). Functional reasons for this have been discussed in terms of the beneficial effects both of obtaining complementary nutrients to achieve a balanced diet (Pennings *et al.,* 1993) and of diluting individual poisons from different plants (Freeland and Janzen, 1974). In terms of how the mixture is actually obtained, the picture is more complicated. For generalist herbivores, the question of plant palatability is not a simple case of a plant being either palatable or unpalatable; most plants fall between these two extremes. For plants that are very unpalatable the foraging decision should be simple; such plants will not be included in the diet, even if they are nutritionally ideal. At the other end of the spectrum, if plants are highly palatable, the herbivore should feed on them, and continue to do so if they are nutritionally suitable, relying on nutritional feedbacks to regulate the amounts eaten. However, if most potential food plants are of intermediate or low palatability, an interesting question arises: How do generalist herbivores incorporate such plants into the diet? (Bernays *et al.,* 1997)

Generalist grasshoppers are stimulated to feed on novel foods after feeding on a single food item for a period, even if the recently experienced food is of high quality. Different species show the phenomenon to different degrees and have different time frames for developing this preference for novelty. While it is unlikely to be the sole mechanism involved in dietary mixing, it may have particular importance for generalists in identifying and utilizing new available foods in the environment (Bernays *et al.,* 1997).

Chand and Muralirangan (1999) studied the dynamics of leaf feeding by the small rice grasshopper *Oxya nitidula* (Walker) under laboratory conditions on eighteen commonly grown rice cultivars. The plants were categorized into five growth stages, based on fifteen days interval, namely 31-45 days after sowing (DAS) (Stage I), 46-60 DAS (Stage II), 61-75 DAS (Stage III), 76-90 DAS (Stage IV), and 91-105 DAS (Stage V). Feeding tests involved the caging of ten adult females for 24 hours on each of the five growth stages of all eighteen cultivars and assessing the quantity of leaf consumed. *O. nitidula* showed preference to growth stages II and III in all cultivars.

The duration of post- embryonic development and food utilization indices such as consumption, growth rate, approximate digestibility, efficiency of conversion of ingested and digested food (ECI and ECD, respectively), were evaluated to assess adaptability by *O. nitidula* reared on four monocotyledonous host plants, viz. *Oryza sativa*, *Panicum maximum*, *Pennisetum glaucum* and *Zea mays*. The duration of post-embryonic development of both sexes of *O. nitidula* were least on *P. maximum* while the consumption index and growth rate were the highest, when fed on *P. maximum* in comparison to the other three host plants. The consumption index and growth rates of nymphs varied on the different hosts. The approximate digestibility ranged between 72 to 91 per cent in nymphs and adults on the various host plants with the mean value being maximal when fed on *P. maximum*. The efficiency of conversion of digested and ingested food into the body tissues varied, viz., ECD ranged between 3 to 9 per cent among the different host plants with the highest mean of 8 per cent on *P. maximum*. ECI ranged between 2 to 8 per cent with the highest mean of 6.8 per cent on *P. maximum*. The data suggests that *O. nitidula* is more adapted to *P. maximum* followed by *O. sativa*, *P. glaucum* and *Z. mays* (Priscilla *et al.*, 1999). In the laboratory experiment, Sultana and Wagan (2007) observed that feeding on *O. sativa* (29.85 days), *Z. mays* (30.48 days) and mixed diet (29.80 days) led to faster development of nymphs of *H. nigrorepletus* compared to those fed on *Saccharum officinarum* (41.85 days) and *Desmostachya bipinnata* (42.45 days). Adults laid greater number of egg pods (3.30 $\pm$ 1.82 and 3.30 $\pm$ 1.50) per female and production of eggs was also high (78.30 $\pm$ 46.19 and 78.30 $\pm$ 33.23) on *O. sativa* and mixed diet, respectively, compared to other host plants tested. They concluded that in *H. nigrorepletus*, *O. sativa* and mixed diet are highly favoured for optimum nymphal development, longevity and higher fertility.

Unsicker *et al.* (2008) observed that the meadow grasshopper, *Chorthippus parallelus* performed better in food plant mixtures than on single plant species and survival as well as fecundity were highest in the eight-food mixture and lowest in the food plant monocultures. The developmental stage significantly influenced feeding patterns of *C. parallelus* individuals and RFT (Relative Forage Total) of mixtures was always higher than what would have been expected from forage in monocultures alone. This increase in RFT was due to an increase in consumption of all plant species rather than in just a few favoured species such that the CE (Complementarity Effect) explained most of the change of consumption in mixtures compared to monocultures.

Among the food plants evaluated, growth and development of *H. nigrorepletus* was best on maize followed by sorghum; consequently, the development period on maize, manifested by hopper duration, was the lowest on these two food plants (21.5 to 22.0 days on maize; 22.75 to 23.5 days on sorghum); the survival ranged from 97.50 to 100 per cent; and the growth index was the highest during both years on maize (4.54 and 4.65), followed by that on sorghum (4.26 and 4.40). Plants of Graminae (Poaceae) were more preferred than dicots; however, mixed food indicated a moderate preference. The food utilization indices, efficiency of conversion of ingested food (ECI) and the approximate digestibility (AD) were the highest when the grasshopper (*H. nigrorepletus*) was fed on maize, though the efficiency of conversion of digested food into body substances was the maximum for sorghum and *Cynodon dactylon* (Rathore and Swaminathan, 2010).

2.4 Management of *Acridids* with special reference to *Oxya* spp.:

The Anti-Locust Research Centre, established in 1945, developed the use of chemical pesticides against locusts, selecting dieldrin as the most effective and economical control agent because of its long persistence (Bennet and Symmons, 1972). Use of dieldrin allowed the treatment of barrier strips; migrating hopper bands would cross these strips and accumulate a lethal dose. The Anti-Locust Research Center also pioneered the aerial application of low doses of dieldrin as a fine droplet cloud to control desert locust swarms (Sayer, 1959), one of the most efficient applications of chemical pesticides known (Mathews, 1992). An increasing awareness of the negative environmental impact of organochlorine pesticides has led to restriction of their use to certain limited public health applications. Organophosphate, carbamate and pyrethroid pesticides replaced dieldrin for locust and grasshopper control, but these could not be tested against African locusts because populations of those insects were in recession. The substitute organophosphate pesticides, such as fenitrothion and malathion, had shorter environmental persistence and were often repeatedly applied as blanket treatments over large areas. Ironically, such treatments may have caused greater environmental damage than the organochlorine treatments they were designed to replace (Rowley and Bennet, 1993). Most modern control operations rely on safer organophosphates such as fenitrothion, carbamates such as bendiocarb, pyrethroids such as deltamethrin and lambda-cyhalothrin, fipronil, and insect growth regulators such as dimilin and triflumeron (Food and Agriculture Organization, 1998).

Research into new technologies and tactics in locust control gained momentum in the early nineties (Krall *et al.,* 1997). Apart from innovations in ultra-low-volume (ULV) spraying techniques (e.g., improved atomizers and track guidance systems), the research followed 2 main tracks. The first concerns reestablishment of the barrier treatment technique against hopper bands. In the past, this widely practiced technique relied on the use of persistent insecticides such as dieldrin (Wilps, 2004). It was abandoned following the ban on organochlorines in the late eighties. The second concerns development of locust-specific biological control agents based on entomopathogenic fungi (Lomer *et al.,* 1997; Milner, 1997). Both research tracks lead to the development and commercialization of locust insecticides suitable for barrier treatment or biological control, respectively. However, adoption of barrier treatment and bio control differs greatly among locust-affected countries.

Onsager (1978) applied carbaryl at 0.56 kg (1.12 kg) toxicant/ha for the control of mixed population of grasshoppers (*Melanoplus sanguinipes* (F.), *M. Infantalis* Scud., *Aulocara elliotti* (Thos.), *Amphitornus coloradus* (Thos.), *M. packardii* Scud. and *Ageneotettix deorum* Scud.). The treatment caused 89-96 per cent mortality within 7 days and ultimately 94-98 per cent. In laboratory experiment, Singh *et al.* (1982) reported monocrotophos 0.03 per cent and 0.1 per cent carbaryl (85-S) as most effective treatments giving 100 per cent mortality of *H. banian* after 24 hours. Mukerji and Ewen (1984) reported that spraying of carbaryl at 700 g/ha reduced the grasshopper population by 90 per cent within 12 hours. According to Reuter *et al.* (1993), a reduced rate of carbaryl spray gave 95 per cent or more reduction of rangeland grasshopper within seven days of treatment. They also stated that this rate was statistically equal to that given by standard carbaryl rate.

Among the chemical control strategies, Fipronil showed promise for acridid control at all the stages and by all application methods (Rachadi, 1995). Similarly, application of carbaryl at 1.2 kg/ha effectively reduced grasshopper numbers; having little impact on birds (Fair *et al.,* 1995). Balanca *et al.* (1997) used very low doses of fipronil (0.6- 2 g) and reported 0.6 g a.i./ha treatment effective against grasshopper outbreak with 47 per cent mortality obtained in two days and 91 per cent in ten days. Under caged and field experiments fipronil was found to be a powerful contact and stomach poison against different grasshoppers at very low doses of 4 and 8 g a.i./ha (Liu *et al.,* 1999). While working on the effects of reduced agent area insecticide treatments for rangeland grasshopper control on bird densities, Norelius and Lockwood (1999) observed malathion, carbaryl and fipronil reducing grasshopper population by 73- 99 per cent. As a result of experiments, Sokolov *et al.,* (2000) proposed fipronil for grasshopper control in Russia. Wang *et al.,* (2007) recommended fipronil and triazophos as desirable insecticides for the Chinese grasshopper (*Oxya chinensis* Thunberg) control in rice field.

Radcliffe *et al.* (1991) tested neem kernel extract against *Kraussaria angulifera* (Krauss) in Niger. Neem appeared to be more effective against nymphs than adults. In feeding choice experiments with nymphs, neem sprayed seedlings sustained less feeding injury than non sprayed seedlings for 144 hours post treatment. Olaifa *et al.* (1991) observed spraying of freshly prepared neem extracts to be more effective, when they used aqueous extracts of neem kernels and leaves at concentration of 5- 20 per cent on cowpea to protect the crop from attack by variegated grasshopper, *Zonocerus variegates* (L.). Passerini and Hill (1993) applied aqueous extract of neem formulations at 0.5 to 1.0 per cent concentration against sahelian grasshopper, *K. angulifera* on millet (*Pennisetum glaucum*) and observed reduced feeding by the grasshoppers. The residual activity was at least seven days. Schmutterer *et al.* (1993) reported neem oil as a very strong feeding deterrent for *Schistocerca gregaria* (Forskal), *Nomadocris septumfasciata* (Serville) and

Z. variegates. However, *Locusta migratoria migratorioides* R. & F. was repelled from the food treated with neem oil to a much lesser extent. They concluded that neem oil and products (aqueous seed kernel extract, neem seed powder) can be used for controlling some important locust and grasshopper pests in the fields with a good success rate.

Olaifa and Adenga (1988) evaluated the efficiency of three neem products against the acridid, *Z. variegates* on cassava and observed neem oil and neem kernel water extract superior to that of insecticides. They recommended emulsifiable concentrate of neem oil at 0.5- 2.0 per cent to be applied every eight days; an emulsifiable concentrate of neem oil at 3- 4 per cent to be applied every 10 days; neem water kernel extract at 7-10 per cent to be applied every 12 days; or neem leaf water extract at 50 per cent to be applied every 6 days. While working on antifeedent effect of aqueous extract of neem (*Azadirachta indica* A. Juss) leaves on *Oxya velox* F., Joshi and Lockwood (2000) concluded that the water based extractions of neem may provide substantial protection of treated foliage from damage by grasshoppers. Shah and Pandey (2001) tested the efficacy of four commercial neem formulations against the grasshopper complex [*Acrida exaltata* (Walker), *C. trachypteruhs, L. migratoria, Poekilocerus pictus* (Fabricius), *Schistocerca cancellata* (Serville) and *S. gregaria*] and recorded significantly lower leaf damage and higher green forage yield over untreated control. Among these formulations, Achook recorded the lowest leaf damage (3.12%) and the highest green foliage yield (8.76 t/ha).

Johnson and Goettel (1993) applied *Beauveria bassiana* at the rate of 2.0 x 10^{13} spores/ha in 10 kg bait/ha to reduce field population of grasshoppers and observed mycosis in the 70 per cent treated populations collected after 2 days, declining to 41% by 13 days and 5% by 19 days after application. Treated populations declined 60 per cent and 33 per cent by 9 and 15 days after application, respectively. The results of the experiment on effects of the control of grasshoppers in Xinjiang rangeland by using *Nosema locustae* bran bait with a different formulation showed that the susceptibility of *Dociostaurus kraussi* (Ingenizkji) (*D. Crassiusculus*) was 86.3%, but that of *C. italicus* and *Gomphocerus sibiricus* (L.) was only 34 and 17.7%, respectively. After the addition of 4 ml of 50% malathion to 100 g *N. Locustae* treated bran, the population density of *C.*

italicus was reduced by 76.7%, a much greater effect than that of using *N. locustae* alone (Wang *et al.*, 1994). Under field cage experiments, using 4th- and 5th-instar nymphs of *Hieroglyphus daganensis* Krauss, Caudwell and Gatehouse (1996) recorded significant mortality in hoppers with both fresh and weathered maize-starch contact bait formulations of *M. flavoviride*, relative to untreated controls. Foster *et al.*, (1999) treated the field plots with either single applications of 2% carbaryl bran bait at 1.68, 3.36, or 5.04 kg/ha; double applications of carbaryl bran bait at 1.68 kg/ha for each application; triple applications of the bait at 1.68 kg/ha. The insecticidal bait treatments caused significant reductions (57-100%) in densities of *Aulocara elliotti* Thomas, *Melanoplus sanguinipes* (F.), *Camnula pellucida* Scudder and *Ageneotettix deorum* (Scudder), but had no significant effect on *Aeropedellus clavatus* (Thomas) and *Melanoplus bivittatus* (Say). However, final mortality of total grasshoppers after 7 days was not affected by high dosages or multiple applications of the insecticidal baits, indicating that multiple and high dosages of insecticidal baits had no real advantage over single applications at 1.68 kg/ha.

3. MATERIALS AND METHODS

3.1 Survey and diversity of acridid fauna in agro-ecosystems:

Surveys to assess the relative incidence of the acridids were conducted in Banswara, Chittorgarh, Dungarpur, Pratapgarh and Udaipur districts of Southern Rajasthan.

District Banswara, the southern-most part of Rajasthan, represents a rugged terrain undulated by short ridges to the west. It is situated between 23°11" to 23° 56" latitude and 73° 21" to 74° 23" longitude. The eastern part is occupied by flat-topped hills of the Deccan trap and has the southern end of the Aravali Hills. The district has rich flora and fauna; teak and bamboo forests abound and the fauna includes a large variety of wild animals. The crops grown in Banswara are wheat, maize, paddy, soybean, gram, sugarcane, blackgram, barley, sorghum, groundnut, fenugreek and greengram. The atmospheric temperature ranges from 10 to 46° C and the annual precipitation is 92.24 cm.

Chittorgarh district is located in the southern part of the state of Rajasthan. It is surrounded by Kota in the east, Banswara in the south-west, Udaipur and Rajsamand in the west and Bhilwara and Bundi in the north. It is situated between 23° 32" to 25° 13" latitude and 74° 12" to 75° 49" longitude. The atmospheric temperature ranges from 7 to 45° C and the annual precipitation is 85.21 cm. Maize, groundnut, sorghum, cotton, sugarcane, soybean, greengram, sesamum, wheat and barley crops are grown here.

The district Dungarpur is located in the southern part of Rajasthan. It is situated between 23° 20" to 24° 1" and 73° 21" to 73° 23". The district is surrounded by Udaipur in the north and Banswara in the east, respectively; it is surrounded by the borders of the neighboring state of Gujarat towards the south and west. The atmospheric temperature ranges from 10 to 45° C and the annual precipitation varies from 47.70 to 82.00 cm. The crops grown are wheat, maize, paddy, soybean, gram, sugarcane, blackgram, barley, sorghum, groundnut, fenugreek and greengram.

Pratapgarh, is a newly constituted district of Rajasthan . It was carved out from the erstwhile Chittorgarh, Udaipur and Banswara districts and is situated between 23° 40" to 24° 50" latitude and 74° 10" to 74° 94" longitude. The atmospheric temperature ranges from 7 to 47° C and the annual precipitation is 87.50 cm. The major crops include maize, sorghum, soybean, paddy, groundnut, wheat, sugarcane, mustard, gram, sesamum, blackgram, Arhar and Azwain.

Udaipur district is situated in the southern tip of Rajasthan adjoining the state of Gujarat and is oval in shape with a very narrow strip stretching towards the north. It is situated between 23° 46" to 25° 5" latitude and 73° 90" to 74° 35" longitude and is bounded in the north by Rajsamand and Pali districts, in the south by Dungarpur and Banswara, in the east by Bhilwara and Chittorgarh, and on the west by Pali and Sirohi districts of Rajasthan and Sabarkantha district of Gujarat. The atmospheric temperature ranges from 3 to 46° C and the annual precipitation is 63.45 cm. The crops include maize, soybean, greengram, sugarcane, blackgram, barley, sorghum, groundnut, fenugreek, wheat and gram.

For conducting a survey for acridid fauna five common crop-ecosystems (agro-ecosystems) *viz.,* paddy, maize, sugarcane, sorghum and soybean were selected in these districts during 2008-09 and 2009-10.

(a) <u>Estimation of adults</u>:

To study the diversity of acridids, sampling was done by net sweeping; covering a linear distance of 10 m. replicated four times taking different locations. The sampling was done in the forenoon from 8 to 10 a.m. and in the afternoon from 4 to 6 p.m.

(i) Collections:

The fauna of short-horned grasshoppers were collected during the survey employing the sweep netting technique. The collected grasshoppers were killed in a cyanide killing jar and mounted singly with an insect pin. Grasshoppers were pinned through the posterior part of the pronotum slightly to the right side from the mid-line. Each specimen was labeled by giving information about locality, date of collection and collector's name.

(ii) Identification:

Identification of the acridids was done with the help of ICAR Network Project on Insect Biosystematics at Department of Entomology, Rajasthan College of Agriculture, MPUAT, Udaipur. Pertinent literature listed under References was consulted and comparisons were made with the identified (from British Museum, London) Reference Collection in the Department. The most useful key to the genera was that by Dirsch (1965) and Kirby (1914). Specific determinations were made by referring to recent revised papers on various genera. The species of genera that have not been revised were identified on the basis of descriptions provided by Kirby (1914).

(b) <u>Estimation of grasshopper density</u>:

The following mathematical/ statistical analyses were made towards estimating the species richness and diversity indices.

(i) Mean Density:

$$\text{Mean Density} = \frac{\sum Xi}{n} \qquad (i = 1, 2, 3 \ldots\ldots\ldots\ldots, n)$$

Where,

Xi = Number of grasshoppers in i^{th} months

n = Total number of observations

(ii) Relative Density (%) :

$$\text{Relative Density (\%)} = \frac{\textit{Number of individuals of one species}}{\textit{Number of individuals of all species}} \times 100$$

(iii) Diversity indices:

$$\text{Shannon's index } (H') = \sum_{i=1}^{S} (Pi \ 1n \ Pi) \qquad \text{(Shanon and Weaver, 1949)}$$

Where,

S	=	Total number of species
P	=	is the proportional abundance of the i^{th} species
1n	=	Natural logarithm of n (Log to the base *e*)

3.2 <u>Estimation of population abundance of *Oxya* in paddy</u>:

Sampling for grasshoppers was done in quadrats of 0.25 m^2. Adults/ nymphs were counted by sudden trapping, for which an iron-frame trap (0.5 m. x 0.5 m. x 1.0 m. size) covered with mosquito net was used. The quantitative population abundance was observed from ten spots (samples) in four different locations (replications), thus covering an area of 10 sq. mt.

3.3.1 Taxonomical studies of *Oxya* spp.:

(i) Identification:

Species identification of the genus *Oxya* was done with the help of standard references on the genus (Kirby, 1914; Willemse, 1925; Mishchenko, 1952) and the revisionary work done by Hollis (1971) and Usmani and Shafee (1985).

(ii) Illustrations:

The illustrations of various morphological characters of taxonomic importance (such that of head, frontal area, pronotum (dorsal & lateral), meso- and meta-sterna, external male and female genitalia, cerci, and valves of ovipositor) were prepared with the help of drawing tube attached to the Motorized Stereo-Zoom Microscope (Discovery model V-12 of Carl Zeiss, Germany) and photographs taken with the installed camera (Cannon Power Shot A620) on Stemi 2000 C Stereo Binoculars (Carl Zeiss). The photographs of adult specimens were taken using Sony DSC H-1 digital still camera.

Studies on life history and food preference were carried out with dominant *Oxya* sp. present in the paddy field. For this, adults of the genus *Oxya* collected during early months of the year 2008 were identified with the help of standard references mentioned above. It was noted that *Oxya fuscovittata* (Marschall) was dominant species which contributed to 56.65 per cent of the total population collected. Therefore, life history and food preference of *O. fuscovittata* were studied during the present investigation.

3.3.2 Life history studies of *Oxya fuscovittata* (Marschall):

Studies on the life history of *O. fuscovittata* were carried out under ambient conditions of temperature and humidity for two successive *kharif* seasons (July 2008 – Nov. 2008 and July 2009 – Nov. 2009).

(a) Maintenance of paddy plants as food for rearing:

Paddy was grown in pots (filled with pulverized and puddled soil) for regular availability of food to feed the grasshoppers. For this purpose, fifty pots (18” length with 12’’ diameter) were maintained in the Department of Entomology, RCA, Udaipur during both the years of study (2008-09 and 2009-10).

(b) Biology:

1. Oviposition: Adults of *O. fuscovittata* collected from the farmer’s fields were maintained in wooden frame wire gauge cages (50 cm x 50 cm x 60 cm) with a glass covered top. One pair of adults was kept in one cage and a total of 10 such cages were maintained. Fresh food comprising paddy leaves was provided regularly. The leaves were kept fresh by sprinkling distilled water. Food was provided twice every day. In order to facilitate climbing, moulting, basking *etc*., a dry twig with branches was also provided in the cage. Sterilized, sieved dry desert sand with 15 percent moisture was kept in every cage with a depth of 10 cm to facilitate oviposition as usually followed for *Hieroglyphus* and locust. The egg pods laid by the females were collected for further studies during 2008-09 and 2009-10.

2. Incubation of eggs: The egg pods laid by the females were kept in glass vials (100 ml.) separately (one in each vial) and replicated 10 times. The pods were covered with sand (medium) and kept at ambient temperature and relative humidity. Care was taken to keep the soil moist using distilled water. The duration and number of nymphs that hatched out were recorded.

3. Nymphal stages: Immediately after hatching, young nymphs were transferred into the rearing cages. Ten nymphs were confined to one cage and two such sets of rearing cages were maintained at ambient temperature and relative humidity. The date of each moulting was recorded carefully by observing the exuviae to ascertain the number of instars and duration of each nymphal period till it matured.

4. Pairing and oviposition: After attaining maturity, one pair each of male and female was transferred to rearing cage described earlier and five such cages were maintained providing the oviposition media. The date of first oviposition by female was noted. After initiation of oviposition, the plastic container with moist soil was replaced every day and number of egg pods laid by female, if any, was counted and the date of egg-laying was also recorded.

5. Eggs: The eggs were laid in an egg pod, the coat of which was hard. In order to study the number of eggs per pod, the freshly laid eggs within the pod were kept in distilled water over night in a Petri dish. Next day (after 24-26 hrs), the Petri dish along with egg pod was shaken gently to separate the soil particles glued. The eggs were collected and counted. Ten egg pods were examined in this way to know the number of eggs per pod.

(c) Morphometrics:

The adult grasshoppers were killed in cyanide poison bottle either pinned or preserved in 70 per cent alcohol for further studies. Twenty specimens of either sex were used for the study on morphometrics. Permanent mounts were also made wherever necessary. Linear measurements of various body parts of male and female grasshoppers were measured under Stemi 2000 C Stereo Binoculars (Carl Zeiss) using the Axio Vision LE 4.5 software. The terminology used by Albrecht (1955) was adopted for denoting different parts of the body of the grasshopper. The major linear measurements taken have been tabulated here under:

S. No.	Body Parameters	Defined as
1.	Length of the antenna (A)	The distance from the basal segment, the scape up to the terminal segment
2.	Length of the tegmina (T)	The distance from the base of the radius and media to the apex of the tegmina
3.	Width of the tegmina (t)	The distance between the two parallel lines touching the anterior and the posterior boundaries of the tegmina
4.	Length of the wing (W)	The distance from the base of the costa to the apex of the wing
5.	Width of the wing (w)	The distance between the two parallel lines touching the anterior and posterior boundaries of the wing when fully stretched
6.	Length of the body up to wing tip (BW)	The distance from the anterior end of head to the apex of the tegmina
7.	Length of the body up to genitalia (BG)	The distance from the anterior end of head to the apex of the genitalia
8.	Width of the body (b)	The widest part of the thorax near the first abdominal segment
9.	Length of the pronotum (P)	The distance from the anterior end to the posterior end of the pronotum, measured along the medial pronotal carina
10.	Width of the pronotum (p)	The distance between the tips of the lateral edges of the pronotum
11.	Length of the fore leg (FL)	The distance from the base of the trochanter to the tip of the claw
12.	Length of the middle leg (ML)	The distance from the base of the trochanter to the tip of the claw
13.	Length of the hind leg (HL)	The distance from the base of the trochanter to the tip of the claw
14.	Length of fore femur (FF)	The maximum length from base to the apex
15.	Length of middle femur (MF)	The maximum length from base to the apex

16.	Length of hind femur (HF)	The maximum length from base to the apex
17.	Width of the hind femur (hf)	The maximum width of femur from margin to margin
18.	Maximum head length (H)	The distance between the vertex to the posterior end of labrum
19.	Maximum head width (h)	The maximum width of head at the genal region
20.	Vertical diameter of eyes (VD)	The length of eyes in longitudinal direction
21.	Horizontal diameter of eyes (HD)	The length of eyes in horizontal direction

3.3.3 Effect of food plants on the growth and development of *O. fuscovittata:*

Field collected adults of the grasshopper, *Oxya fuscovittata* (Marschall), were reared during 2008 and 2009 in the laboratory on fresh and untreated paddy leaves as food and the live culture was maintained in aluminium frame wire-gauge cages kept on steel racks protected from ants. The adults were put into the wire-gauge cages (30 x 30 x 30 cm), wherein they were allowed to mate and lay eggs.

For food plant preference studies during each year, newly hatched-out hoppers were maintained on leaves of paddy until they moulted twice. Healthy III instar hoppers, starved for 6 hours were transferred into individual wooden wire-gauge cages (15 x 7.5 x 7.5 cm) having a furnished bottom with small dry twigs to facilitate moulting. Four replications of 10 hoppers each were maintained on fresh leaves from the 8 different food plants, selecting 5 from cultivated crops and 3 from uncultivated pasture grasses and weeds. Fresh food was provided twice daily.

The different food plants selected were:

1.	Paddy	*Oryza sativa* L.
2.	Maize	*Zea mays* L.
3.	Sugarcane	*Saccharum officinarum* L.
4.	Sorghum	*Sorghum bicolor* (L.) Moench.

5.	Soybean	*Glycine max* (L.) Merr.
6.	Purple nutsedge	*Cyperus rotundus* L.
7.	Yellow foxtail	*Setaria glauca* (L.) Beauv.
8.	Bermuda grass	*Cynodon dactylon* (L) Pers.

Observations were recorded for each subsequent hopper period (in days). The time required for adult development on each food plant was recorded and the survival of adults was recorded. To compare the relative growth of hoppers on different food plants the growth index was calculated using the following formula:

$$\text{Growth index} = \frac{\text{Percent hoppers attaining V instar}}{\text{Duration of hoppers (in days)}}$$

Food utilization indices were calculated on a dry weight basis for the newly formed V instar hoppers. The hoppers reared on paddy right from hatching, were starved overnight, and thereafter provided with the different food-plants until they develop into adults. Fresh, tender green parts of the different food plants were divided into two equal portions. One portion was weighed wet and fed to the newly formed and starved V instar hopper, while the other portion taken as aliquot. The aliquot food was weighed wet first, then dried at 80^{o} C in an oven and the dry weight was recorded. Left over food and faeces were removed every 24 hours and dried to a constant weight at 80^{o} C. At the end of the experiment the newly formed adults were starved to devoid their guts of residual faecal material. Faeces for the period of starvation were also collected every 24 hours. After starvation, the newly formed adults were killed and dried to a constant weight at 80^{o} C in an oven.

CALCULATION OF FOOD UTILIZATION INDICES:

Having recorded the dry weight of left over food and faeces, the quantity of ingested food was calculated by subtracting it from the weight of the food introduced. The approximate weight of digested food was calculated by subtracting the weight of faeces from the weight of the ingested food. From these values, on a dry weight basis, the utilization indices were computed (Waldbauer, 1968):

$$\text{Efficiency of conversion of ingested food [ECI]} = \frac{\text{Weight gained}}{\text{Weight of food ingested}} \times 100$$

$$\text{Approximate digestibility [AD]} = \frac{\text{Wt. of food ingested} - \text{Wt. of faeces}}{\text{Weight of food ingested}} \times 100$$

$$\text{Efficiency of conversion of digested food into body substances [ECD]} = \frac{\text{Weight gained}}{\text{Wt. of food ingested} - \text{Wt. of faeces}} \times 100$$

3.4 Evaluation of management strategies for *Oxya* spp.

For management of the small rice grasshopper (*Oxya* spp.) in paddy nurseries, a two year based study was conducted at Udaipur and Banswara locations. During the first year (2008-09), the bioefficacy/ antifeedent activity of certain botanicals and chemical pesticides was evaluated under caged conditions.

The treatments were as under:

1. *Azadirachta indica* A. Juss. leaves extract (5%)
2. *A. indica* seed kernels extract (5%)
3. *A. indica* oil (2%)
4. *Pongamia glabra* Vent. oil (2%)
5. Fipronil (0.02%)
6. Carbaryl (0.2%)
7. Control (Water spray)

Paddy was grown in pots (18” length with 12” diameter) maintained at Department of Entomology, Rajasthan College of Agriculture, Udaipur. All the seven treatments mentioned above were applied at seedling stage and replicated four times. The treated seedlings were provided as food to ten adults of laboratory reared *O. fuscovittata* in each replicate. Observations on mortality were recorded 1, 3, 5 and 7 days after treatment and expressed as percentage. As there was no mortality recorded in the control, hence computation of corrected mortality was not required.

In the subsequent year (2009-10), second trial was conducted in paddy nurseries at farmer's field in Banswara district. Paddy nurseries were taken for evaluation of the most effective chemical pesticide (Fipronil) and the botanical (*A. indica* oil) recorded during the previous year laboratory experimentation. Following treatments were taken with four replications:

1. Unweeded paths around the paddy nursery
2. Weeded paths around the paddy nursery
3. Unweeded paths treated with Fipronil (0.02 %)
4. Weeded paths treated with Fipronil (0.02 %)
5. Unweeded paths treated with *A. indica* oil (2 %)
6. Weeded paths treated with *A. indica* oil (2 %)

Observations:

Before applying the treatments, population of *Oxya* spp. (nymphs and adults) was counted on paths using the quadrat (1 m^2) count method. Later, five and fifteen days after application of the treatments, population of the grasshoppers (*Oxya* spp.) was recorded from the paddy nurseries using the similar quadrat sampling technique.

4. RESULTS

4.1 Survey and diversity of acridid fauna in agro-ecosystems:

Surveys were conducted in five districts of Southern Rajasthan *viz.*, Banswara, Chittorgarh, Dungarpur, Pratapgarh and Udaipur during 2008-09 and 2009-10 with a view to assess the relative incidence of the acridid fauna in the selected crop ecosystems (paddy, maize, sugarcane, sorghum and soybean).

The acridids were most abundant in paddy, maize, sugarcane and sorghum as the species richness was maximum (10) in these crop ecosystems; whereas, the soybean ecosystem was represented by the least number of species (7) from all the districts surveyed. However, an intermediate number of species (8) was collected from Chittorgarh district in maize, sugarcane and sorghum crop ecosystems.

The relative density of acridid population among the crop ecosystems surveyed (Tables 1 to 10) showed that different grasshopper species dominated these ecosystems. The acridid, *Oxya* spp. was most abundant in paddy ecosystem with maximum density (24.48 to 29.92 per cent) in four (Banswara, Dungarpur, Pratapgarh and Udaipur) of the five districts surveyed, where paddy happened to be a regular crop of the area. However, mean population of *Oxya* spp. was relatively more in Banswara district (13.50 and 12.17 per 40 m during 2008-09 and 2009-10, respectively). In the maize crop ecosystem, *Hieroglyphus nigrorepletus* Bolivar happened to be the most dominant grasshopper in all the five districts surveyed, and the mean population was relatively higher in Udaipur district (23.60 and 19.20 per 40 m during 2008-09 and 2009-10, respectively). Populations of *Spathosternum prasiniferum* Walker and *Trilophidia annulata* Stål were more abundant in sugarcane ecosystem with a range from 13.48 to 20.98 per cent and 14.44 to 20.29 per cent; however, at Udaipur, relative density of *H. nigrorepletus* was equally higher with 15.73 and 15.35 per cent during 2008-09 and 2009-10, respectively. In sorghum ecosystem, the densities of *H. nigrorepletus* and *S. prasiniferum* were more or less similar for all the districts during both the years. However, at Udaipur during

2008-09 and at Pratapgarh during 2009-10, the Phadaka grasshopper, *H. nigrorepletus* was relatively more abundant as compared to other acridid species with the mean relative density of 21.54 and 22.02 per cent, respectively. The grasshopper species *S. prasiniferum* and *T. annulata* showed a similar trend of population abundance in soybean ecosystem in all the districts surveyed and contributed to as high as 34.09 and 31.18 per cent.

A perusal of Tables (1-10) indicates that during both the years (2008-09 and 2009-10), the acridid species diversity as given by Shannon Weiner Diversity Index was the maximum for sorghum (2.219 and 2.199 during 2008-09 and 2009-10, respectively) and sugarcane (2.205 and 2.207 during 2008-09 and 2009-10, respectively) ecosystems in all the five districts surveyed, while the soybean ecosystem was least diverse (1.827 and 1.767 during 2008-09 and 2009-10, respectively).

4.1.1: Abundance of acridid species in select crop ecosystems:

The population abundance of dominant acridid species recorded from five select crop ecosystems (Paddy, Maize, Sugarcane, Sorghum, and Soybean) of Southern Rajasthan (Banswara, Chittorgarh, Dungarpur, Pratapgarh and Udaipur) has been detailed below:

1. Paddy ecosystem:

(a) *Acrida* spp.: During both the years of study (2008-09 and 2009-10), the mean population abundance of *Acrida* spp. did not differ significantly for months, districts and interactions between months and districts (Tables 11 & 12). However, the maximum mean population was noted in October (1.30 and 1.24 per 10 m during 2008-09 and 2009-10, respectively).

(b) *Oxya* spp.: From the data summarized in the Tables (11 & 12), it could be observed that the mean population of *Oxya* spp. varied significantly for months among the districts surveyed; however, their abundance was not significant for districts and interactions. The month-wise maximum population was recorded in September being 5.02 and 4.43 per 10 m during 2008-09 and 2009-10, respectively.

(c) *Catantops pinguis* Stål: The mean grasshopper population was significantly variable for months and districts during 2008-09 and 2009-10. However, the interactions between months and districts were non-significant during both the years (Tables 11 & 12). Among the districts compared, the maximum mean population was recorded from Udaipur (0.71 and 0.67 per 10 m) during both the years. The mean population recorded was maximum in November being 0.89 and 0.85 per 10 m during 2008-09 and 2009-10, respectively.

(d) *Hieroglyphus banian* (F.): The data presented in Tables 11 and 12 indicate that the mean population of *H. banian* was significantly different for months only in all the four districts compared. The month-wise mean population was maximum in August (3.95 and 3.70 per 10 m) during both the years (2008-09 and 2009-10) of study.

(e) *Hieroglyphus nigrorepletus* Bolivar: It is evident from the Tables 11 and 12 that the mean population of *H. nigrorepletus* differed significantly for months; however, it was non-significant for districts and interactions. The mean population recorded was maximum in September being 0.73 and 0.87 per 10 m during 2008-09 and 2009-10, respectively.

(f) *Phlaoeba infumata* Brunner: The population abundance of *P. infumata* (Tables 11 & 12) was statistically variable for the months; however, the population was statistically at par for districts and interactions. The maximum mean population was recorded in July (0.99 and 0.89 per 10 m) during 2008-09 and 2009-10, respectively.

(g) *Spathosternum prasiniferum* Walker: During both the years, the population of *S. prasiniferum* differed significantly for months. However, the mean population was non-significant for districts and interactions between months and districts. The maximum mean population was recorded in October (1.57 per 10 m) during 2008-09 and in November (1.46 per 10 m) during 2009-10 (Tables 11 & 12).

(h) *Trilophidia annulata* Stål: The mean population of *T. anuulata* among the districts had significant difference for months during 2008-09 and 2009-10; however, it was not significantly variable for districts and interactions during both the years. The mean population was maximum in July (1.66 per 10 m) during 2008-09 and in June (1.46 per 10 m) during 2009-10 (Tables 11 & 12).

(i) *Truxalis* spp.: The mean population of *Truxalis* spp. was observed to be significantly different for months during both the years of study (2008-09 and 2009-10); however, for districts surveyed and interactions, the population was statistically at par. The mean population was recorded to be maximum in October (1.19 per 10 m) during both the years of study (Tables 11 & 12).

(j) *Aiolopus thalassinus* Fabricius: The month-wise mean population of *A. thalassinus* varied significantly and the maximum population was recorded in August as 0.89 and 1.04 per 10 m during 2008-09 and 2009-10, respectively. However, the population was non-significant for districts and interactions (Tables 11 & 12).

2. Maize ecosystem:

(a) *Acrida* spp.: The mean population of *Acrida* spp. varied significantly for months during the year both the years (2008-09 and 2009-10) and the maximum population was recorded in October (1.52 and 1.40 per 10 m). However, the mean population did not differ significantly for districts surveyed and interactions between months and districts (Tables 13 & 14).

(b) *Oxya* spp.: The mean numerical abundance of *Oxya* spp. differed significantly for months and districts in the first year (2008-09) of study; however, in the subsequent year (2009-10), the mean acridid population was significantly variable for months only. In the year 2008-09, district-wise maximum population was recorded from Banswara (1.49 per 10 m). The month-wise maximum population was recorded in September (1.66 and 1.27 per 10 m) during both the years (Tables 13 & 14).

(c) *Catantops pinguis* Stål: The mean population of *C. pinguis* showed significant difference for months among the districts compared; however, for districts and interactions, the abundance was observed to be statistically at par. The month-wise maximum population was recorded in October (1.63 and 1.35 per 10 m) during 2008-09 and 2009-10, respectively (Tables 13 & 14).

(d) *Hieroglyphus nigrorepletus* Bolivar: The data summarized in the Tables 13 and 14 indicate that the mean abundance of *H. nigrorepletus* significantly varied for months and districts surveyed. District-wise, the maximum mean population was recorded from Udaipur (5.07 and 4.12 per 10 m during 2008-09 and 2009-10, respectively); while, month-wise maximum population was recorded in August (8.80 and 7.45 per 10 m) during both the years.

(e) *Phlaoeba infumata* Brunner: A significant difference in the mean population of *P. infumata* for months was noted; while the population had no significant variation for districts and interactions during both the years. During the year 2008-09, the mean abundance was maximum in August (1.19 per 10 m), while in the subsequent year (2009-10), it was maximum in July (1.22 per 10 m) (Tables 13 & 14).

(f) *Spathosternum prasiniferum* Walker: The mean population of *S. prasiniferum* differed statistically for months; but was at par for districts and interactions. The maximum mean acridid population was recorded in October (3.22 and 2.63 per 10 m during 2008-09 and 2009-10, respectively) (Tables 13 & 14).

(g) *Trilophidia annulata* Stål: The mean grasshopper population varied significantly for months and the population was recorded maximum in July (2.26 and 2.32 per 10 m) during 2008-09 and 2009-10, respectively. However, the population had no significant difference for districts and interactions (Tables 13 & 14).

(h) *Truxalis* spp.: The mean acridid population was significantly variable for months during both the years of study (2008-09 and 2009-10); however, it was statistically at par for districts and interactions. The maximum mean population was recorded in October (1.19 and 1.32 per 10 m during 2008-09 and 2009-10, respectively) (Tables 13 & 14).

(i) *Gastrimargus africanus* Sjost: It is clear from the Tables 13 and 14 that the month-wise mean population of *G. africanus* varied significantly among the districts surveyed; however, the population was statistically similar for districts and interactions. The maximum grasshopper population was recorded in October (0.89 and 0.85 per 10 m during 2008-09 and 2009-10, respectively).

(j) *Aiolopus thalassinus* Fabricius: A significant difference was recorded for month-wise mean population of *A. thalassinus* among the districts compared. The maximum mean population was recorded in July (1.24 and 1.35 per 10 m during 2008-09 and 2009-

10, respectively). However, the population was non-significant for districts and interactions (Tables 13 & 14).

3. Sugarcane ecosystem:

(a) *Acrida* spp.: The mean population of *Acrida* spp. varied statistically for months during both the years (2008-09 and 2009-10); however, for districts and the interactions it was non-significant. During 2008-09, the mean population was recorded maximum in October (1.40 per 10 m), while, during 2009-10, it was maximum (1.04 per 10 m) in November (Tables 15 & 16).

(b) *Oxya* spp.: The month-wise mean abundance of *Oxya* spp. differed significantly for months; however, the mean population was not significant for districts and interactions. The population was recorded maximum in September (0.94 and 0.89 per 10 m) during both the years (Tables 15 & 16).

(c) *Catantops pinguis* Stål: The mean population of *C. pinguis* was significantly variable for months and the maximum population was recorded in November (1.52 and 1.32 per 10 m) during 2008-09 and 2009-10, respectively. However, the population was statistically at par for districts and interactions (Tables 15 & 16).

(d) *Hieroglyphus nigrorepletus* Bolivar: The mean population of *H. nigrorepletus* differed significantly for months and districts during 2008-09 and 2009-10. The district-wise maximum mean population was recorded from Udaipur (1.38 per 10 m) during both the years of study. The month-wise mean population was maximum in August (2.85 and 2.60 per 10 m during 2008-09 and 2009-10, respectively) (Tables 15 & 16).

(e) *Phlaoeba infumata* Brunner: The data summarized in the Tables (15 & 16) shows that abundance of *P. infumata* was significantly variable for months; however it was statistically at par for districts surveyed and interactions during both the years of study. The maximum mean population was recorded in July (1.43 and 1.38 per 10 m during 2008-09 and 2009-10, respectively).

(f) *Spathosternum prasiniferum* Walker: The mean population had significant difference for months and districts during the year 2008-09, while in the subsequent year (2009-10), it varied only for months. During 2008-09, abundance of *S. prasiniferum* was recorded maximum from Chittorgarh (1.84 per 10 m). The month-wise mean population was maximum in November (2.16 per 10 m) during 2008-09 and in October (2.32 per 10 m) during 2009-10 (Tables 15 & 16).

(g) *Trilophidia annulata* Stål: The mean population of *T. anuulata* was significantly different for months; however, it was not so for districts and interactions compared. The maximum population was recorded in June (2.19 and 1.81 per 10 m) during 2008-09 and 2009-10, respectively (Tables 15 & 16).

(h) *Truxalis* spp.: During both the years, the mean population of *Truxalis* spp. varied significantly for months and was at par for districts and interactions. The population was maximum in October (1.01 per 10 m) during 2008-09 and in November (0.99 per 10 m) during 2009-10 (Tables 15 & 16).

(i) *Gastrimargus africanus* Sjost: A significant difference was noted in the mean population of *G. africanus* for months and the maximum population was recorded in October (0.60 and 0.56 per 10 m during 2008-09 and 2009-10, respectively. However, the population did not vary significantly for districts and interactions (Tables 15 & 16).

(j) *Aiolopus thalassinus* Fabricius: The mean grasshopper population was significantly variable for months, while statistically at par for districts and interactions. The maximum mean population was recorded in August (1.24 and 1.22 per 10 m) during 2008-09 and 2009-10 (Tables 15 & 16).

4. Sorghum ecosystem:

(a) *Acrida* spp.: The mean population varied significantly for months during the year 2008-09; whereas in the subsequent year (2009-10), it was statistically at par for months, districts and interactions. The abundance of *Acrida* spp. was maximum in September (1.46 per 10 m) during 2008-09 and in October (1.32 per 10 m) during 2009-10 (Tables 17 & 18).

(b) *Oxya* spp.: A significant difference in the mean population of *Oxya* spp. for the months was noted during both the years; while, the mean population did not differ statistically for districts and interactions. The population was maximum in September (0.92 and 1.06 per 10 m during 2008-09 and 2009-10, respectively) (Tables 17 & 18).

(c) *Catantops pinguis* Stål: The mean population did not differ significantly for months, districts and interactions during 2008-09, while in the subsequent year (2009-10), it varied only for months. The mean population recorded was maximum in October (1.43 and 1.35 per 10 m during 2008-09 and 2009-10, respectively) (Tables 17 & 18).

(d) *Hieroglyphus nigrorepletus* Bolivar: During 2008-09, the mean numerical abundance of *H. nigrorepletus* significantly varied for months. While, in the subsequent year (2009-10) it differed for months as well as districts compared and maximum population (2.09 per 10 m) was recorded from Pratapgarh. The month-wise maximum population was recorded in August (4.12 and 3.87 per 10 m during 2008-09 and 2009-10, respectively) (Tables 17 & 18).

(e) *Phlaoeba infumata* Brunner: The data summarized in the Tables 17 and 18 shows that the abundance of *P. infumata* was significantly variable for months; however it was statistically at par for districts and interactions. The mean population was maximum in July (1.19 and 0.89 per 10 m) during 2008-09 and 2009-10.

(f) *Spathosternum prasiniferum* Walker: The mean population was significantly different for months but was statistically at par for districts and interactions. The maximum population was recorded in October (2.26 and 2.49 per 10 m during 2008-09 and 2009-10, respectively) (Tables 17 & 18).

(g) *Trilophidia annulata* Stål: The mean population varied significantly for months; while, for districts and interactions the difference was non-significant. The maximum grasshopper population was recorded in October (2.29 and 2.42 per 10 m during 2008-09 and 2009-10, respectively) (Tables 17 & 18).

(h) *Truxalis* spp.: The mean population of *Truxalis* spp. differed significantly for months; however, for districts and interactions, it was non-significant. The mean population was maximum in September (1.22 per 10 m) during 2008-09 and in October (1.14 per 10 m) during 2009-10 (Tables 17 & 18).

(i) *Gastrimargus africanus* Sjost: During 2008-09, the abundance of *G. africanus* varied significantly for months; while, during 2009-10, variation in the mean population was non-significant for months, districts and interactions. The population was recorded maximum in August and September (0.62 per 10 m) during 2008-09 and in October (0.42 per 10 m) during 2009-10 (Tables 17 & 18).

(j) *Aiolopus thalassinus* Fabricius: During both the years, the mean population of *A. thalassinus* had significant variation only months; whereas, for districts and interactions, the difference was not significant. The maximum population was in August (1.27 per 10 m) during 2008-09 and in July (1.32 per 10 m) during 2009-10 (Tables 17 & 18).

5. Soybean ecosystem:

(a) *Acrida* spp.: In the year 2008-09, the mean population of *A. exaltata* did not differ significantly for months, districts and interactions; however, in the subsequent year (2009-10), it significantly differed for months. The month-wise mean population was maximum in October (0.89 and 0.87 per 10 m) during both the years (Tables 19 & 20).

(b) *Catantops pinguis* Stål: During both the years (2008-09 and 2009-10), the mean population did not vary significantly for months, districts and interactions. However, the population was maximum in October (0.71 per 10 m) during 2008-09 and in July (0.46 per 10 m) during 2009-10 (Tables 19 & 20).

(c) *Phlaoeba infumata* Brunner: The variation in mean population of *P. infumata* was statistically significant for months; however, it was at par for districts and interactions during both the years. The mean population was maximum in August (0.60 per 10 m) during 2008-09 and in July (0.58 per 10 m) during 2009-10 (Tables 19 & 20).

(d) *Spathosternum prasiniferum* Walker: During both the years (2008-09 and 2009-10) of study, the mean grasshopper population did not differ significantly for months, districts and the interactions; although, the population of *S. prasiniferum* was maximum in October (1.93 and 2.06 per 10 m during 2008-09 and 2009-10, respectively) (Tables 19 & 20).

(e) *Trilophidia annulata* Stål: The mean population of *T. annulata* had significant difference for months during 2008-09; however, the population was statistically at par for months, districts and interactions during 2009-10. The maximum population was recorded in July (2.06 and 1.66 per 10 m during 2008-09 and 2009-10, respectively) (Tables 19 & 20).

(f) *Truxalis* spp.: During 2008-09, the population abundance of *Truxalis* spp. showed significant variation for months; however, in the subsequent year (2009-10), the population did not vary significantly for months, districts and interactions. The mean population was maximum in October (0.58 and 0.33 per 10 m during 2008-09 and 2009-10, respectively) (Tables 19 & 20).

(g) *Aiolopus thalassinus* Fabricius: During both the years, the mean population of *A. thalassinus* had significant variation only for months; whereas, for districts and interactions, the difference was not significant. The maximum population was in July (1.19 and 0.92 per 10 m) during 2008-09 and 2009-10, respectively (Tables 19 & 20).

4.2 Quantitative abundance of *Oxya* spp. in paddy:

A survey of paddy fields clearly depicts that the small rice grasshopper, *Oxya* spp. was abundant in all four districts (Banswara, Dungarpur, Pratapgarh and Udaipur) where paddy is cultivated as a regular crop. Thus, a comparison among four districts was made for the monthly mean population during 2008-09 and 2009-10. From the data summarized in the Tables 21 and 22, it can be noted that the grasshopper population significantly varied for months and districts during 2008-09 and only for months during 2009-10. Interactions between months and districts were not significant during both the years of study. Location-wise maximum mean population was recorded from Banswara (1.11 and 0.99 per 0.25 m^2 during 2008-09 and 2009-10, respectively), while it was recorded minimum from Dungarpur (0.87 per 0.25 m^2) during 2008-09 and from Dungarpur and Pratapgarh (0.92 per 0.25 m^2) during 2009-10. The month-wise maximum mean population was recorded in July (1.63 and 1.40 per 0.25 m^2) and minimum in November (0.62 and 0.67 per 0.25 m^2) during both the years.

4.3.1 Taxonomical studies on the genus *Oxya*:

During the present investigation, morphological characters of the genus *Oxya* were studied with the help of standard references on the genus (Kirby, 1914; Willemse, 1925; Mishchenko, 1952) and the revisionary work done by Hollis (1971) and Usmani and Shafee (1985). In male, the differences in supra anal plate (presence or absence of basi lateral folds and general shape of plate) and cercus (acutely pointed to truncate apically) were considered for variation in individual species. In female, identification of the specimens up to species level was done by considering the number, size and placing of teeth (or spines) on the visible ventral margin of the female sub-genital plate, and the ovipositor valve with marginal longer or shorter spines. On the basis of above characters, six species of the genus *Oxya* i.e. *Oxya fuscovittata* (Marschall), *Oxya intricata* (Stål), *Oxya rufostriata* Willemse, *Oxya nitidula* (Walker), *Oxya ebneri* Willemse and *Oxya hyla hyla* Serville were identified during the study.

4.3.2 Biology of *Oxya fuscovittata* (Marschall) on paddy:

From the Table 23, detailing the biological parameters of *O. fuscovittata*, it was observed that the mean developmental period from egg to adult was 70.15 days. The adult females lived a little longer (40.70 ± 2.56 days) than the males (37.50 ± 2.29 days). A single female could lay about 2 egg pods with nearly 23 eggs per pod that had a hatchability of 67.46 per cent. The oviposition period of a female was about 18 days. The linear morphometric variations for the small rice grasshopper, *O. fuscovittata* have been depicted in Tables 24 and 25. The length of male body up to genitalia was 22.87 ± 0.33 mm, while that of the female was 29.77 ± 0.52 mm. The female was distinctly bigger than male.

During the present investigation it was clear that *O. fuscovittata* had only one generation during the year and it passed through five nymphal stages to become an adult. The mean duration of different nymphal stages from I through V was 51.85 days. The duration of nymphal stage I was the shortest (7.20 ± 0.23 days), while that of the nymphal stage V was the longest (13.10 ± 0.30 days).

4.3.3 Effect of food plants on the growth and development of *O. fuscovittata:*

The study on the effect of food plants on the growth and development of *O. fuscovittata* indicated a preference for *Oryza sativa* L. ranking first followed by *Cyperus rotundus* L. ranking second (Tables 26 and 27). The developmental period manifested by the hopper duration was the lowest (34.79 days); the survival was 100 per cent; and the growth index was the highest (2.87) during 2008-09 on paddy. Similarly, in the subsequent year too, *O. sativa* was the most preferred food and the corresponding figures were 35.05 days (hopper duration), 100 per cent (survival), and 2.85 (growth index). Results clearly show that plants of Graminae (Poaceae) were the more preferred food plants having secured ranks from I to VII and the developmental period ranged from 35.40 to 39.98 days. Soybean (*Glycine max*) that ranked VIII was least preferred by the grasshopper and the hoppers took 45.58 and 46.16 days to complete their development during 2008-09 and 2009-10, respectively.

The order of preference of different food plants in a descending order was as: *Oryza sativa* > *Cyperus rotundus* > *Zea mays* > *Saccharum officinarum* > *Sorghum bicolor* > *Setaria glauca* > *Cynodon dactylon* > *Glycine max*.

It becomes evident from Table 28 that when the grasshopper (*O. fuscovittata*) was fed on *O. sativa*, the food utilization indices were the highest. The values for efficiency of conversion of ingested food (ECI), approximate digestibility (AD) and the efficiency of conversion of digested food into body substances (ECD) were 35.05, 72.19 and 48.58 during 2008-09 and 36.36, 73.38 and 49.56 per cent during 2009-10, respectively. However, the approximate digestibility (70.71 and 72.18 per cent) was equally high, when the hoppers were reared on *C. rotundus* during 2008-09 and 2009-10, respectively. Among the different food plants, *S. glauca* and *C. dactylon* were statistically at par with respect to ECI, AD and ECD values during both the years. Similarly, *S. bicolor* and *S. officinarum* showed no significant difference for these values during 2008-09. The ECI, AD, ECD values were significantly the lowest, when hoppers were reared on *G. max*.

4.4 Evaluation of management for *Oxya* spp. in paddy nurseries:

Among the different treatments evaluated for their efficacy against *Oxya* spp. under caged condition, Fipronil (0.02%) was most effective causing 100 per cent mortality three days after application (Table 29) (Figure- 1). Further, among the botanical treatments, *Azadirachta indica* A. Juss. oil (2%) was comparatively effective that brought about 87 per cent mortality of *O. fuscovittata* seven days after application.

Both the treatments (Fipronil and *A. indica* oil) were included under second year (2009-10) experimental schedule. The results obtained during the experiment clearly indicate that five and fifteen days after application of Fipronil (0.02 %) on unweeded paths, population of *Oxya* spp. was significantly the lowest (1.25 and 1.75 per 1 m^2) in paddy nurseries. Though rest of the treatments also significantly reduced the population of the grasshoppers in paddy nurseries when compared to the control treatment (unweeded paths around paddy nurseries), all these treatments were significantly less effective in comparison to Fipronil (0.02 %) on unweeded paths (Table 30).

5. DISCUSSION

5.1 Survey and diversity of acridid fauna in agro-ecosystems:

Acridid faunal surveys conducted in the five districts *viz.*, Banswara, Chittorgarh, Dungarpur, Pratapgarh and Udaipur of Southern Rajasthan over a two-year period (2008-09 and 2009-10) resulted in the collection of 10 acridid genera from maize, sugarcane and sorghum crop ecosystems; 9 from paddy crop ecosystem; while, 7 from soybean ecosystem. However, an intermediate number of genera (8) was collected from Chittorgarh district in maize, sugarcane and sorghum crop ecosystems. The collected acridid genera (10) belonged to six sub-families (Acridinae, Catantopinae, Hemiacridinae, Oedopodinae, Oxyinae, and Truxalinae) identified as *Acrida* Linnaeus, *Aiolopus* Fieber, *Catantops* Schaum, *Gastrimargus* Saussure, *Hieroglyphus* Krauss, *Oxya* Serville, *Phlaoeba* Bolivar, *Spathosternum* Krauss, *Trilophidia* Stål, and *Truxalis* Fabricius.

Species diversity was maximum in sorghum and sugarcane ecosystems during both the years of study. Based on the Shanon Weiner Diversity Index, diversity was the maximum being 2.219 and 2.199 for sorghum during 2008-09 and 2009-10, respectively; followed by 2.205 and 2.207 for sugarcane during 2008-09 and 2009-10, respectively. However, the soybean ecosystem was least diverse with lesser species richness and lower abundance of acridids. Earlier, Pfadt (1984) reported that the Shanon-Wiener index value of about 2.0 indicated high grasshopper diversity in a habitat of mixed grass prairie.

In the present study, population abundance of different acridid species was recorded and it was observed that the acridid monthly mean population varied considerably among the crop ecosystems surveyed. Based on the relative density of acridid population, *Oxya* spp. dominated the paddy ecosystem in four (Banswara, Dungarpur, Pratapgarh and Udaipur) of the five districts surveyed, where paddy happened to be a regular crop of the area. However, mean population of *Oxya* spp. was relatively more in Banswara district. The members of subfamily Oxyinae have been reported as a pest of rice crop in Pakistan and worldwide (Sultana and Wagan, 2009; Sultana and Wagan, 2007), which is indicative of the fact that paddy is the preferred host; hence, its being reasonably abundant in paddy ecosystem as observed. The findings of Kandibane *et al.* (2004) are also comparable with our results, who recorded two acridid species *viz.*, *Oxya nitidula* (Walker) and *Oxya fuscovittata* (Marschall) as the most dominant acridid taxa in rice ecosystem. However, Lanjar *et al.* (2002) recorded four species of grasshoppers *viz.*, *H. banian, O. nitidula, Chrotogonus trachypterus trachypterus* (Blanchard) and *Aiolopus tumulus* (F.) infesting rice. In paddy nurseries, *H. banian* and *Oxya* spp. have also been reported to damage considerably by Irshad *et al.* (1977) and Garg and Tandon (1983).

In maize ecosystem, the dominant species was *Hieroglyphus nigrorepletus* Bolivar in all the five districts surveyed, and the mean population was relatively higher in Udaipur district. The species *Spathosternum prasiniferum* Walker and *Trilophidia annulata* Stål were relatively more abundant in sugarcane ecosystem, but their numerical abundance was a little more in the district Chittorgarh, when compared to other districts. The density of *H. nigrorepletus* and *S. prasiniferum* had an equal representation in sorghum ecosystem for all the districts during both the years. However, at Udaipur during 2008-09 and at Pratapgarh during 2009-10, *H. nigrorepletus* was relatively more abundant as compared to other acridid species. In soybean ecosystem, the grasshopper species *S. prasiniferum* and *T. annulata* showed a similar trend of population abundance in all the districts surveyed. Earlier reports indicate that *H. nigrorepletus* causes considerable damage to rice, maize, millets, sugarcane, wheat and fodder crops (Main, 1912; Kirby, 1914; Uvarov, 1922, 1932, 1977; Roonwal, 1945 and 1976; Ahmad, 1975-80; Bhatia *et al.*, 1965; Charan Singh, 1972, Mason, 1973 and Shioshodia, 2009). However, Karimullah and Ahmad (1992) recorded *Atractomorpha crenulata*, *Gastrimargus sulphureus* (*G. africanus sulphureus*) and *Calliptamus cephalotes* (*C. barbarus barbarus*) as minor pests of maize.

The monthly mean population of acridids among the crop ecosystems surveyed showed that different species responded in a different manner. The maximum biological activity of grasshopper species was noted from July to October months during both the years (2008-09 and 2009-10). The month-wise mean population of *Oxya* spp., *H. nigrorepletus* and *H. banian* was recorded maximum in August and September; the mean abundance of *Acrida* spp., *C. pinguis, , S. prasiniferum, Truxalis* spp. and *G. africanus* was maximum in October and November; while, the population of *P. infumata, T. annulata* and *A. thalassinus* was recorded maximum in July and August. The present findings clearly indicate that grasses inside and around the fields supported a large number of grasshopper species of which some of them could infest the main crop grown. Similar results were also obtained by Chitra *et al.* (2000) while surveying the different habitats as they recorded grasses to be the most common habitat for grasshoppers (54.5 per cent of the population).

5.2 Quantitative abundance of *Oxya* spp. in paddy:

During the present investigation, the monthly mean population of *Oxya* spp. varied significantly during both the years; however, during 2008-09, the mean population showed a significant difference for districts surveyed and the maximum population was recorded from Banswara; while, minimum from Dungarpur. This variation in the population density values of the districts compared can be attributed to the sowing of paddy crop in a regular manner in the study area. The density of *Oxya* spp. per unit area sampled (0.25 m^2) was maximum in the month of July during both the years of the study which might due to hatching of eggs (laid during the previous year) May onwards and shifting of the nymphs and adults of *Oxya* spp. into the paddy nurseries. Similar results were also observed by Shen *et al.* (1988), who recorded that *Oxya chinensis* had one generation per year and is known to hibernate in the egg stage at the field borders or in uncultivated land, which later on hatched in early May.

5.3.1 Taxonomical studies of *Oxya* spp.:

The grasshoppers of the genus *Oxya* (Orthoptera: Acridoidea) are distributed along Pakistan region, China, southeastern Russia, and Australia. The morphologically monotypic speices of *Oxya* are commonly found in fields of graminoid plants with relatively abundant water supply. They are agricultural pests damaging rice, sugarcane and other crops. This genus was established by J. G. Audinet-Serville in 1831 and had been revised several times. D. Hollis (1971) in his revisionary publication described the genus *Oxya* as an unnatural grouping of species, which was retained as a taxonomic unit for purely practical purposes, and recognized the difficulty to determine its phylogenetic relationships. He re-documented 18 species based on 8 morphological characters of the phallic complex.

During the present investigation, six species of the genus *Oxya* could be recognized i.e. *Oxya fuscovittata* (Marschall), *Oxya intricata* (Stål), *Oxya rufostriata* Willemse, *Oxya nitidula* (Walker), *Oxya ebneri* Willemse and *Oxya hyla hyla* Serville. In a revisionary work, Usmani and Shafee (1985) revised Indian species of the genus *Oxya* and described eight species and one new species, *Oxya gorakhpurensis*.

5.3.2 Biology of *Oxya fuscovittata* (Marschall) on paddy:

Based on the biological parameters of the small rice grasshopper, *O. fuscovittata*, the mean developmental period from egg to adult was recorded to be 70.15 days and the females lived a little longer than the males. A single female could lay about 2 egg pods with nearly 23 eggs per pod that had a hatchability of 67.46 per cent. The mean duration of different nymphal stages from I through V was 51.85 days. The duration of nymphal stage I was the shortest (7.20 $\pm$ 0.23 days), while that of the nymphal stage V was the longest (13.10 $\pm$ 0.30 days). During the present study, it was clear that *O. fuscovittata* has only one generation during the year and it passes through five nymphal stages to become an adult. This is possibly because paddy is cultivated only during *kharif* in Rajasthan; later on, temperatures fall and do not supports the survival requirement range for *Oxya*.

According to the available literature, little is known about the life history aspects of *Oxya* spp. under Indian conditions. However, Shen *et al*. (1988) described the bionomics of *Oxya chinensis* (Thunberg) in China. Results indicated that the grasshopper had one generation a year and passed through six mymphal stages to become an adult. The nymphal stages averaged 51- 73 days. Oviposition averaged 33 eggs/ female (with a range of 15 to 105 eggs/ female). From the present study and from the available literature it has become increasingly clear that considerable variation in the number of moults occur, which might be due to the effect of food and prevailing climatic conditions of the region.

5.3.3 Effect of food plants on the growth and development of *O. fuscovittata:*

It is a well established fact that food plants are known to affect the biology and behaviour of insects including rate of growth and development, survival, fecundity and fertility (Pickford, 1962; Banjerjeet and Haque, 1985; Aslam and Whitworth, 1988). Extensive studies on food selection by grasshoppers have been adequately reviewed by Uvarov (1977) and Chapman (1990). An overall majority of phytophagous insects restrict host plant use to closely related groups of plant species, sometimes even a single species (Berneys and Chapman, 1994). Phylogenetic differences exist among grasshoppers in relation to host plant preferences (Dadd, 1963; Joern, 1979). For example, members of the acridid subfamily Gomphocerinae tend to have a preference for grasses, Cyrtacanthacridinae prefer forbs, and Oedipodinae eat both grasses and forbs (Dadd, 1963; Joern and Lawlor, 1980; Otte, 1981). The Acridinae are typically considered to be grass-feeders (Chapman, 1964; Isley, 1944). Although the feeding ecology of polyphagous herbivores has been widely studied, little is known about the nutritional ecology of mixed feeding herbivores. Polyphagous herbivores feed on plants from a variety of plant families (Chapman, 1990), where most polyphagous species feed only on plants in dicotyledonous families and fewer feed only on monocotyledonous plants. In an even smaller subset of polyphagous species, both dicots (*i.e.*, forbs) and monocots (*i.e*., grasses) are consumed in a mixed feeding strategy, presenting these herbivores with interesting problems because they must overcome the physical and chemical challenges unique to each plant group (grass *vs* forb) (Jonas and Joern, 2008).

During the present investigation, the growth and development of *O. fuscovittata* was best on *Oryza sativa* L. ranking first followed by *Cyperus rotundus* L. ranking second; resultantly, the development period manifested by hopper duration was the lowest; the survival was 100 per cent; and the growth index was the highest during both years on *O. sativa*. During the study, the order of preference for different food plants was observed as follows in a descending order: *Oryza sativa* > *Cyperus rotundus* > *Zea mays* > *Saccharum officinarum* > *Sorghum bicolor* > *Setaria glauca* > *Cynodon dactylon* > *Glycine max*.

Aziz and Aziz (1985) recorded a descending order of preference for late instar hoppers and adults of *Oxya velox* as mixed diet of rice, *Cyanodon dactylon* and *Echinocloa colonum* > rice > wheat > *E. colonum* > *Hemarthira compressa* > *Setaria verticillata* > maize > pearl millet; while, *Trifolium alexandrium* was not fed upon at all.

In our study, plants of Graminae (Poaceae) were the more preferred food plants for *O. fuscovittata* securing a rank from I to VII. Soybean (ranked VIII) was least preferred as a food plant for the grasshopper during both the years of study. The food utilization indices, efficiency of conversion of ingested food (ECI), approximate digestibility (AD) and the efficiency of conversion of digested food into body substances (ECD) were the highest when the grasshopper (*O. fuscovittata*) was fed on *O. sativa*. Therefore, it could be inferred that the acridid, *O. fuscovittata* is typically a grass feeder, as is evinced by the first to seventh ranks occupied by plants of Poaceae and the eight rank occupied by the dicot, *G. max* (Fabaceae). It might also be deduced that the protein requirements for *O. fuscovittata* is relatively lower, which is more in the legumes than in the grasses.

Mixed feeding by insect herbivores is relatively uncommon (Mulkern *et al*., 1969; Joern, 1983b). Forbs usually make up the bulk of mixed feeder diets with grasses' contribution a variable but often minor component (Joern, 1983b; Bernays and Bright, 1993). As seen in most polyphagous species, which perform best on diets containing plants from multiple families (Rapport, 1980; Hägele and Rowel-Rahier, 1999), mixed feeding herbivores also experience their greatest performance when both forbs and grasses are consumed (Bailey and Mukherji, 1976; McFarlane and Thorsteinson, 1980; Randolph *et al*., 1995; Hägele and Rowel-Rahier, 1999; Randolph and Cameron, 2001; Miura and Ohsaki, 2006).

5.4 Evaluation of management for *Oxya* spp. in paddy nurseries:

During the present investigation, a two-year-trial was conducted to find out an appropriate strategy for the control of *Oxya* spp. in paddy nurseries. In the first year trial, Fipronil (0.02 %) and *Azadirachta indica* A. Juss. oil (2%) were observed effective treatments among the chemical pesticides and botanicals under caged conditions. From earlir records of experiments, similar results on efficacy of fipronil and neem oil against other grasshoppers and locusts (Balanca and de Visscher, 1997; Butler and Du Preez, 1994; Kriel *et al.*, 1994, Liu *et al.,* 1996; Lockwood *et al.,* 1996; Olaifa and Adenuga, 1988; Schmutterer *et al.*, 1993) confirm the present findings.

During second year trial, both these treatments were applied in the field on paths around the paddy nurseries harbor the early instar hoppers of *Oxya* spp., which later on transfer to the nurseries and causes considerable damage to the paddy seedlings. Aziz and Aziz (1985) also found that early instar hoppers of *Oxya velox* preferred grasses to cereals, while late instar hoppers preferred cereals to grasses. Results showed that application of Fipronil (0.02 %) on weeded and unweeded paths caused minimum shifting of *Oxya* spp. into the paddy nurseries even fifteen days after treatment. Further, treatment of weeds on paths with *A. indica* oil (2 %) was moderately effective with lower population of *Oxya* spp. in paddy nurseries. In the present study, removal of weeds from paths was also effective in reducing the population of grasshopper in nursery when compared to control (unweeded paths around paddy nursery). It could be deduced that timely weeding of paths from sowing of seeds in nursery until transplanting will protect the seedlings from grasshopper infestation to a greater extent.

SUMMARY

Investigations on the bio-ecology of the acridid genus *Oxya* in selected agro-ecosystems of Southern Rajasthan were carried out in the Department of Entomology, Rajasthan College of Agriculture, MPUAT, Udaipur with the following objectives: (i) Survey of the acridid fauna in the agro-ecosystems of Southern Rajasthan; (ii) Estimation of the qualitative and quantitative abundance of acridid genus *Oxya* in paddy; (iii) Studies on the biology, taxonomy and food preference of the dominant *Oxya* species; (iv) Evaluation of management strategies for *Oxya* spp. in paddy nurseries.

Surveys conducted in five crop ecosystems of Banswara, Chittorgarh, Dungarpur, Pratapgarh and Udaipur districts of Southern Rajasthan, over a two-year period (2008-09 and 2009-10) resulted in the collection of 10 acridid species from paddy, maize, sugarcane and sorghum; while, 7 acridids from soybean. The dominant acridid species in the different ecosystems were *Oxya* spp. in paddy; *Hieroglyphus nigrorepletus* Bolivar in maize; *Spathosternum prasiniferum* Walker and *Trilophidia annulata* Stål in sugarcane; *H. nigrorepletus* and *S. prasiniferum* in sorghum; *S. prasiniferum* and *T. annulata* in soybean. Among the surveyed crop ecosystems, species diversity was maximum in sorghum and sugarcane crops during both the years of study with the Shanon Weiner Diversity Index being 2.219 and 2.199 for sorghum during 2008-09 and 2009-10, respectively; followed by 2.205 and 2.207 for sugarcane during 2008-09 and 2009-10, respectively. Soybean ecosystem was least diverse with the index value of 1.827 and 1.767 during 2008-09 and 2009-10, respectively. The monthly mean and relative density values of acridid varied considerably among these ecosystems; their population and biological activity was observed maximum during July through October.

In paddy, the numerical abundance of *Oxya* spp. was significantly the highest in July during both the years; however, their occurrence differed significantly district-wise only during 2008-09.

During the present investigation, morphological characters *viz.,* differences in supra anal plate and cercus in male; number, size and placing of teeth on the visible

ventral margin of the sub-genital plate and ovipositor valve with marginal, longer or shorter spines in female were considered for variation in individual species of the genus *Oxya*. On the basis of above characters, six species *viz.*, *Oxya fuscovittata* (Marschall), *Oxya intricata* (Stål), *Oxya rufostriata* Willemse, *Oxya nitidula* (Walker), *Oxya ebneri* Willemse and *Oxya hyla hyla* Serville were identified under the study. Among the species recorded, *Oxya fuscovittata* (Marschall) was the dominant species.

Studies on the biology indicated that the mean developmental period from egg to adult was 70.15 days; the adult females lived a little longer (40.70 days) than the males (37.50 days). A single female could lay about 2 egg pods with an average of 23 eggs per pod that had a hatchability of 67.46 per cent. The oviposition period for females was about 18 days. The linear morphometric variations of *O. fuscovittata* (males and females) were also made and it was noted that females (29.77 ± 0.52 mm) were relatively larger than males (22.87 ± 0.33 mm) in their body length from tip of head to tip of genitalia. The mean duration of different nymphal stages from I through V instars was 51.85 days. The duration of nymphal stage I was the shortest (7.20 ± 0.23 days), while that of the nymphal stage V was the longest (13.10 ± 0.30 days).

Growth and development of *Oxya fuscovittata* (Marschall) was best on *Oryza sativa* L. ranking first followed by *Cyperus rotundus* L. ranking second; resultantly, the development period on *O. sativa*, manifested by hopper duration, was the lowest and survival was 100 per cent; consequently, the growth index was the highest (2.87 and 2.85) during both years (2008-09 and 2009-10). The plants of Graminae (Poaceae) were the more preferred food plants having secured ranks from I to VII and the developmental period ranged from 34.79 to 39.98 days. The food *Glycine max* (ranking VIII) a dicot plant was least preferred by the grasshopper and the hoppers took 46.16 days to complete their development.

The order of preference of different food plants was observed as follows in descending order: *Oryza sativa* > *Cyperus rotundus* > *Zea mays* > *Saccharum officinarum* > *Sorghum bicolor* > *Setaria glauca* > *Cynodon dactylon* > *Glycine max*.

The food utilization indices, efficiency of conversion of ingested food (ECI), approximate digestibility (AD) and efficiency of conversion of digested food into body substances (ECD) were the highest when the grasshopper (*O. fuscovittata*) was fed on *O. sativa*. Among the different food plants, *S. glauca* and *C. dactylon* were statistically at par with respect to ECI, AD and ECD values during both the years. Similarly, *S. bicolor* and *S. officinarum* showed no significant difference for these values during 2008-09. The ECI, AD, ECD values were significantly lower, when hoppers were raised on *G. max* during both the years of study.

In the cage experiment, Fipronil (0.02%) and *Azadirachta indica* A. Juss. oil (2%) were observed effective treatments with higher per cent mortality of *O. fuscovittata*. When these treatments were applied in the field, the application of Fipronil (0.02 %) on unweeded paths caused minimum shifting of *Oxya* spp. and the population of grasshopper was recorded significantly lowest (1.25 and 1.75 per 1 m^2) in paddy nurseries. However, rest of the treatments also significantly reduced the population of the grasshopper in paddy nurseries when compared to the control treatment (unweeded paths around paddy nurseries).

Table 1: Acridid species richness and diversity in different crops surveyed in Banswara district during 2008-09

S. No.	Grasshopper species	Paddy		Maize		Sugarcane		Sorghum		Soybean	
		Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)
1.	*Acrida* spp.	4.17	8.31	4.80	7.48	4.00	10.04	4.20	8.68	2.50	14.56
2.	*Oxya* spp.	13.50	26.91	6.60	10.28	1.50	3.77	2.80	5.79	NR	0.00
3.	*Catantops pinguis*	2.33	4.65	4.60	7.17	3.67	9.21	4.80	9.92	2.17	12.62
4.	*Hieroglyphus banian*	9.83	19.60	NR	0.00	NR	0.00	NR	0.00	NR	0.00
5.	*Hieroglyphus nigrorepletus*	1.83	3.65	19.80	30.84	5.67	14.23	9.00	18.60	NR	0.00
6.	*Phlaoeba infumata*	2.83	5.65	4.40	6.85	4.67	11.72	4.00	8.26	1.50	8.74
7.	*Spathosternum prasiniferum*	5.33	10.63	7.60	11.84	6.67	16.74	8.20	16.94	4.83	28.16
8.	*Trilophidia annulata*	4.83	9.63	7.00	10.90	6.17	15.48	7.00	14.46	4.17	24.27
9.	*Truxalis* spp.	3.67	7.31	3.80	5.92	3.17	7.95	3.80	7.85	0.67	3.88
10.	*Gastrimargus africanus*	NR	0.00	1.60	2.49	1.50	3.77	1.60	3.31	NR	0.00
11.	*Aiolopus thalassinus*	1.83	3.65	4.00	6.23	2.83	7.11	3.00	6.20	1.33	7.77
Total		50.17		64.20		39.83		48.40		17.17	
Species Richness		10		10		10		10		7	
Shanon index			2.081		2.089		2.203		2.190		1.827

*NR = Not Recorded

Table 2: Acridid species richness and diversity in different crops surveyed in Banswara district during 2009-10

S. No.	Grasshopper species	Paddy		Maize		Sugarcane		Sorghum		Soybean	
		Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)
1.	*Acrida* spp.	4.67	10.18	4.20	7.32	3.17	8.52	4.60	10.75	2.17	13.40
2.	*Oxya* spp.	12.17	26.55	5.20	9.06	1.00	2.69	2.20	5.14	NR	0.00
3.	*Catantops pinguis*	1.83	4.00	5.40	9.41	4.50	12.11	4.40	10.28	1.50	9.28
4.	*Hieroglyphus banian*	8.17	17.82	NR	0.00	NR	0.00	NR	0.00	NR	0.00
5.	*Hieroglyphus nigrorepletus*	1.33	2.91	18.40	32.06	5.00	13.45	7.60	17.76	NR	0.00
6.	*Phlaoeba infumata*	3.50	7.64	2.80	4.88	4.00	10.76	3.60	8.41	1.33	8.25
7.	*Spathosternum prasiniferum*	4.50	9.82	6.60	11.50	7.33	19.73	7.40	17.29	5.17	31.96
8.	*Trilophidia annulata*	4.33	9.45	5.60	9.76	6.50	17.49	6.40	14.95	3.67	22.68
9.	*Truxalis* spp.	3.00	6.55	4.00	6.97	2.67	7.17	3.00	7.01	0.67	4.12
10.	*Gastrimargus africanus*	NR	0.00	2.00	3.48	0.83	2.24	1.00	2.34	NR	0.00
11.	*Aiolopus thalassinus*	2.33	5.09	3.20	5.57	2.17	5.83	2.60	6.07	1.67	10.31
Total		45.83		57.40		37.17		42.80		16.17	
Species Richness		10		10		10		10		7	
Shanon index			2.096		2.082		2.138		2.173		1.767

*NR = Not Recorded

Table 3: Acridid species richness and diversity in different crops surveyed in Chittorgarh district during 2008-09

S.No.	Grasshopper species	Maize		Sugarcane		Sorghum		Soybean	
		Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)
1.	*Acrida* spp.	4.40	7.64	4.83	12.95	4.40	10.38	1.83	11.83
2.	*Oxya* spp.	NR	0.00	NR	0.00	NR	0.00	NR	0.00
3.	*Catantops pinguis*	4.60	7.99	3.83	10.27	4.40	10.38	0.50	3.23
4.	*Hieroglyphus banian*	NR	0.00	NR	0.00	NR	0.00	NR	0.00
5.	*Hieroglyphus nigrorepletus*	21.80	37.85	7.00	18.75	10.00	23.58	NR	0.00
6.	*Phlaoeba infumata*	4.00	6.94	3.83	10.27	3.60	8.49	0.67	4.30
7.	*Spathosternum prasiniferum*	9.00	15.63	7.83	20.98	8.00	18.87	4.33	27.96
8.	*Trilophidia annulata*	6.20	10.76	6.33	16.96	6.00	14.15	4.83	31.18
9.	*Truxalis* spp.	3.20	5.56	2.33	6.25	3.40	8.02	1.17	7.53
10.	*Gastrimargus africanus*	NR	0.00	NR	0.00	NR	0.00	NR	0.00
11.	*Aiolopus thalassinus*	4.40	7.64	1.33	3.57	2.60	6.13	2.17	13.98
Total		57.60		37.33		42.40		15.50	
Species Richness		8		8		8		7	
Shanon Index			1.838		1.995		1.985		1.738

*NR = Not Recorded

Table 4: Acridid species richness and diversity in different crops surveyed in Chittorgarh district during 2009-10

S.No.	Grasshopper Species	Maize		Sugarcane		Sorghum		Soybean	
		Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)
1.	*Acrida* spp.	4.20	8.08	3.83	11.11	4.00	9.80	1.50	10.34
2.	*Oxya* spp.	NR	0.00	NR	0.00	NR	0.00	NR	0.00
3.	*Catantops pinguis*	4.80	9.23	3.67	10.63	5.20	12.75	0.83	5.75
4.	*Hieroglyphus banian*	NR	0.00	NR	0.00	NR	0.00	NR	0.00
5.	*Hieroglyphus nigrorepletus*	18.40	35.38	5.67	16.43	8.80	21.57	NR	0.00
6.	*Phlaoeba infumata*	3.20	6.15	3.67	10.63	2.60	6.37	1.00	6.90
7.	*Spathosternum prasiniferum*	7.20	13.85	6.50	18.84	7.40	18.14	4.00	27.59
8.	*Trilophidia annulata*	7.40	14.23	7.00	20.29	6.60	16.18	4.33	29.89
9.	*Truxalis* spp.	3.00	5.77	2.00	5.80	3.20	7.84	1.00	6.90
10.	*Gastrimargus africanus*	NR	0.00	NR	0.00	NR	0.00	NR	0.00
11.	*Aiolopus thalassinus*	3.80	7.31	2.17	6.28	3.00	7.35	1.83	12.64
Total		52.00		34.50		40.80		14.50	
Species Richness		8		8		8		7	
Shanon Index			1.869		1.994		1.992		1.745

*NR = Not Recorded

Table 5: Acridid species richness and diversity in different crops surveyed in Dungarpur district during 2008-09

S. No.	Grasshopper species	Paddy		Maize		Sugarcane		Sorghum		Soybean	
		Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)
1.	*Acrida* spp.	3.83	9.06	4.40	8.21	3.67	10.73	4.40	9.69	1.33	9.09
2.	*Oxya* spp.	12.67	29.92	5.00	9.33	2.50	7.32	2.80	6.17	NR	0.00
3.	*Catantops pinguis*	1.17	2.76	4.40	8.21	4.33	12.68	4.80	10.57	1.00	6.82
4.	*Hieroglyphus banian*	7.17	16.93	NR	0.00	NR	0.00	NR	0.00	NR	0.00
5.	*Hieroglyphus nigrorepletus*	1.00	2.36	14.40	26.87	3.33	9.76	7.40	16.30	NR	0.00
6.	*Phlaoeba infumata*	3.17	7.48	3.20	5.97	4.50	13.17	3.40	7.49	0.33	2.27
7.	*Spathosternum prasiniferum*	4.33	10.24	7.60	14.18	5.17	15.12	7.60	16.74	5.00	34.09
8.	*Trilophidia annulata*	4.50	10.63	6.20	11.57	5.50	16.10	6.20	13.66	4.17	28.41
9.	*Truxalis* spp.	3.33	7.87	3.40	6.34	2.50	7.32	3.40	7.49	0.83	5.68
10.	*Gastrimargus africanus*	NR	0.00	2.00	3.73	0.67	1.95	1.80	3.96	NR	0.00
11.	*Aiolopus thalassinus*	1.17	2.76	3.00	5.60	2.00	5.85	3.60	7.93	2.00	13.64
Total		42.33		53.60		34.17		45.40		14.67	
Species Richness		10		10		10		10		7	
Shanon index			2.031		2.138		2.200		2.219		1.689

*NR = Not Recorded

Table 6: Acridid species richness and diversity in different crops surveyed in Dungarpur district during 2009-10

S. No.	Grasshopper species	Paddy		Maize		Sugarcane		Sorghum		Soybean	
		Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)
1.	*Acrida* spp.	4.33	11.11	5.40	10.47	3.33	10.70	3.80	9.36	1.67	12.35
2.	*Oxya* spp.	10.83	27.78	4.00	7.75	2.17	6.95	3.20	7.88	NR	0.00
3.	*Catantops pinguis*	1.67	4.27	4.20	8.14	3.50	11.23	3.60	8.87	0.83	6.17
4.	*Hieroglyphus banian*	6.67	17.09	NR	0.00	NR	0.00	NR	0.00	NR	0.00
5.	*Hieroglyphus nigrorepletus*	1.33	3.42	13.80	26.74	2.67	8.56	6.40	15.76	NR	0.00
6.	*Phlaoeba infumata*	2.33	5.98	3.60	6.98	3.67	11.76	2.60	6.40	1.17	8.64
7.	*Spathosternum prasiniferum*	3.67	9.40	7.20	13.95	5.83	18.72	6.60	16.26	4.33	32.10
8.	*Trilophidia annulata*	4.00	10.26	5.80	11.24	4.50	14.44	7.00	17.24	3.67	27.16
9.	*Truxalis* spp.	2.50	6.41	3.40	6.59	3.00	9.63	3.20	7.88	0.50	3.70
10.	*Gastrimargus africanus*	NR	0.00	1.00	1.94	1.00	3.21	1.20	2.96	NR	0.00
11.	*Aiolopus thalassinus*	1.67	4.27	3.20	6.20	1.50	4.81	3.00	7.39	1.33	9.88
Total		39.00		51.60		31.17		40.60		13.50	
Species Richness		10		10		10		10		7	
Shanon index			2.087		2.125		2.206		2.199		1.711

*NR = Not Recorded

Table 7: Acridid species richness and diversity in different crops surveyed in Pratapgarh district during 2008-09

S. No.	Grasshopper species	Paddy		Maize		Sugarcane		Sorghum		Soybean	
		Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)
1.	*Acrida* spp.	4.00	9.64	4.60	8.30	4.00	11.06	4.60	9.96	2.67	15.24
2.	*Oxya* spp.	10.33	24.90	2.60	4.69	NR	0.00	1.60	3.46	NR	0.00
3.	*Catantops pinguis*	2.50	6.02	3.60	6.50	4.33	11.98	5.40	11.69	1.50	8.57
4.	*Hieroglyphus banian*	7.50	18.07	NR	0.00	NR	0.00	NR	0.00	NR	0.00
5.	*Hieroglyphus nigrorepletus*	1.67	4.02	18.20	32.85	4.50	12.44	8.20	17.75	NR	0.00
6.	*Phlaoeba infumata*	2.50	6.02	3.60	6.50	3.83	10.60	3.40	7.36	1.17	6.67
7.	*Spathosternum prasiniferum*	4.00	9.64	7.60	13.72	7.17	19.82	7.40	16.02	4.50	25.71
8.	*Trilophidia annulata*	4.67	11.24	7.00	12.64	6.00	16.59	6.60	14.29	4.17	23.81
9.	*Truxalis* spp.	3.00	7.23	3.40	6.14	2.83	7.83	3.20	6.93	1.50	8.57
10.	*Gastrimargus africanus*	NR	0.00	1.60	2.89	1.00	2.77	1.60	3.46	NR	0.00
11.	*Aiolopus thalassinus*	1.33	3.21	3.20	5.78	2.50	6.91	4.20	9.09	2.00	11.43
Total		41.50		55.40		36.17		46.20		17.50	
Species Richness		10		10		9		10		7	
Shanon index			2.120		2.043		2.097		2.186		1.813

*NR = Not Recorded

Table 8: Acridid species richness and diversity in different crops surveyed in Pratapgarh district during 2009-10

S. No.	Grasshopper species	Paddy		Maize		Sugarcane		Sorghum		Soybean	
		Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)
1.	*Acrida* spp.	3.50	9.21	4.60	9.20	3.50	10.82	4.00	9.17	2.33	14.58
2.	*Oxya* spp.	9.67	25.44	2.00	4.00	NR	0.00	1.80	4.13	NR	0.00
3.	*Catantops pinguis*	1.50	3.95	3.80	7.60	3.83	11.86	4.60	10.55	1.33	8.33
4.	*Hieroglyphus banian*	7.17	18.86	NR	0.00	NR	0.00	NR	0.00	NR	0.00
5.	*Hieroglyphus nigrorepletus*	1.33	3.51	14.80	29.60	4.17	12.89	9.60	22.02	NR	0.00
6.	*Phlaoeba infumata*	2.00	5.26	3.80	7.60	3.83	11.86	2.40	5.50	0.67	4.17
7.	*Spathosternum prasiniferum*	4.50	11.84	7.60	15.20	6.33	19.59	6.40	14.68	5.00	31.25
8.	*Trilophidia annulata*	4.33	11.40	6.20	12.40	5.17	15.98	6.00	13.76	3.83	23.96
9.	*Truxalis* spp.	2.67	7.02	3.00	6.00	2.33	7.22	3.80	8.72	1.33	8.33
10.	*Gastrimargus africanus*	NR	0.00	1.60	3.20	0.83	2.58	1.20	2.75	NR	0.00
11.	*Aiolopus thalassinus*	1.33	3.51	2.60	5.20	2.33	7.22	3.80	8.72	1.50	9.38
Total		38.00		50.00		32.33		43.60		16.00	
Species Richness		10		10		9		10		7	
Shanon index			2.086		2.078		2.097		2.159		1.757

*NR = Not Recorded

Table 9: Acridid species richness and diversity in different crops surveyed in Udaipur district during 2008-09

S. No.	Grasshopper species	Paddy		Maize		Sugarcane		Sorghum		Soybean	
		Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)
1.	*Acrida* spp.	4.50	9.44	5.20	7.34	4.50	10.11	4.40	8.46	2.33	14.00
2.	*Oxya* spp.	11.67	24.48	5.40	7.63	3.00	6.74	3.80	7.31	NR	0.00
3.	*Catantops pinguis*	3.17	6.64	5.40	7.63	5.00	11.24	5.40	10.38	1.83	11.00
4.	*Hieroglyphus banian*	8.17	17.13	NR	0.00	NR	0.00	NR	0.00	NR	0.00
5.	*Hieroglyphus nigrorepletus*	2.17	4.55	23.60	33.33	7.00	15.73	11.20	21.54	NR	0.00
6.	*Phlaoeba infumata*	3.00	6.29	4.00	5.65	4.83	10.86	4.00	7.69	1.67	10.00
7.	*Spathosternum prasiniferum*	4.67	9.79	9.60	13.56	6.00	13.48	6.60	12.69	4.67	28.00
8.	*Trilophidia annulata*	5.50	11.54	8.60	12.15	7.17	16.10	8.00	15.38	4.17	25.00
9.	*Truxalis* spp.	2.83	5.94	3.60	5.08	3.50	7.87	3.80	7.31	0.50	3.00
10.	*Gastrimargus africanus*	NR	0.00	2.40	3.39	1.17	2.62	2.40	4.62	NR	0.00
11.	*Aiolopus thalassinus*	2.00	4.20	3.00	4.24	2.33	5.24	2.40	4.62	1.50	9.00
Total		47.67		70.80		44.50		52.00		16.67	
Species Richness		10		10		10		10		7	
Shanon index			2.141		2.040		2.205		2.188		1.799

*NR = Not Recorded

Table 10: Acridid species richness and diversity in different crops surveyed in Udaipur district during 2009-10

S. No.	Grasshopper species	Paddy		Maize		Sugarcane		Sorghum		Soybean	
		Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)	Mean	Relative Density(%)
1.	*Acrida* spp.	3.83	8.49	4.20	6.71	3.67	9.13	4.80	10.08	1.67	10.75
2.	*Oxya* spp.	12.33	27.31	4.60	7.35	2.33	5.81	2.60	5.46	NR	0.00
3.	*Catantops pinguis*	2.67	5.90	4.60	7.35	4.17	10.37	4.20	8.82	2.00	12.90
4.	*Hieroglyphus banian*	7.67	16.97	NR	0.00	NR	0.00	NR	0.00	NR	0.00
5.	*Hieroglyphus nigrorepletus*	2.33	5.17	19.20	30.67	6.17	15.35	9.40	19.75	NR	0.00
6.	*Phlaoeba infumata*	2.17	4.80	3.80	6.07	4.33	10.79	3.20	6.72	1.00	6.45
7.	*Spathosternum prasiniferum*	4.17	9.23	8.60	13.74	6.83	17.01	8.00	16.81	4.33	27.96
8.	*Trilophidia annulata*	5.17	11.44	8.00	12.78	5.83	14.52	6.60	13.87	4.50	29.03
9.	*Truxalis* spp.	3.17	7.01	3.60	5.75	3.33	8.30	3.80	7.98	0.83	5.38
10.	*Gastrimargus africanus*	NR	0.00	2.40	3.83	1.83	4.56	1.80	3.78	NR	0.00
11.	*Aiolopus thalassinus*	1.67	3.69	3.60	5.75	1.67	4.15	3.20	6.72	1.17	7.53
Total		45.17		62.60		40.17		47.60		15.50	
Species Richness		10		10		10		10		7	
Shanon index			2.106		2.080		2.207		2.187		1.748

*NR = Not Recorded

Table 11: Population abundance of acridid species in paddy ecosystem during 2008-09.

Acridids / **Months**	*Acrida* spp.	*Oxya* spp.	*Catantops pinguis*	*Hieroglyphus banian*	*Hieroglyphus nigrorepletus*	*Phlaoeba infumata*	*Spathosternum prasiniferum*	*Trilophidia annulata*	*Truxalis* spp.	*Aiolopus thalassinus*
June	1.06*	1.80	1.02	-	-	1.17	1.17	1.39	0.81	0.93
	(0.62)	(2.74)	(0.54)	-	-	(0.87)	(0.87)	(1.43)	(0.16)	(0.36)
July	1.17	2.04	0.89	1.53	0.77	1.22	1.09	1.47	0.93	1.05
	(0.87)	(3.66)	(0.29)	(1.84)	(0.09)	(0.99)	(0.69)	(1.66)	(0.36)	(0.60)
August	1.16	1.59	0.84	2.11	1.06	1.08	1.11	1.33	1.17	1.18
	(0.85)	(2.03)	(0.21)	(3.95)	(0.62)	(0.67)	(0.73)	(1.27)	(0.87)	(0.89)
September	1.23	2.35	0.97	1.91	1.11	1.03	1.27	1.16	1.10	0.80
	(1.01)	(5.02)	(0.44)	(3.15)	(0.73)	(0.56)	(1.11)	(0.85)	(0.71)	(0.14)
October	1.34	1.77	1.05	1.62	1.02	0.97	1.44	1.11	1.30	0.74
	(1.30)	(2.63)	(0.60)	(2.12)	(0.54)	(0.44)	(1.57)	(0.73)	(1.19)	(0.05)
November	1.22	1.35	1.18	1.09	0.81	0.87	1.39	1.20	1.26	-
	(0.99)	(1.32)	(0.89)	(0.69)	(0.16)	(0.26)	(1.43)	(0.94)	(1.09)	-
S. Em. ±	**0.076**	**0.083**	**0.068**	**0.078**	**0.061**	**0.078**	**0.073**	**0.066**	**0.070**	**0.061**
CD (P=0.05)	**NS**	**0.235**	**0.192**	**0.220**	**0.172**	**0.221**	**0.207**	**0.188**	**0.198**	**0.172**
Districts										

Banswara	1.20	1.92	1.00	1.60	0.93	1.09	1.31	1.28	1.14	0.93
	(0.94)	(3.19)	(0.50)	(2.06)	(0.36)	(0.69)	(1.22)	(1.14)	(0.80)	(0.36)
Dungarpur	1.17	1.83	0.85	1.43	0.83	1.07	1.22	1.23	1.12	0.84
	(0.87)	(2.85)	(0.22)	(1.54)	(0.19)	(0.64)	(0.99)	(1.01)	(0.75)	(0.21)
Pratapgarh	1.19	1.72	1.02	1.44	0.92	1.04	1.19	1.26	1.07	0.88
	(0.92)	(2.46)	(0.54)	(1.57)	(0.35)	(0.58)	(0.92)	(1.09)	(0.64)	(0.27)
Udaipur	1.24	1.79	1.10	1.51	0.97	1.04	1.26	1.34	1.05	0.96
	(1.04)	(2.70)	(0.71)	(1.78)	(0.44)	(0.58)	(1.09)	(1.30)	(0.60)	(0.42)
S. Em. ±	**0.062**	**0.068**	**0.055**	**0.064**	**0.050**	**0.064**	**0.060**	**0.054**	**0.057**	**0.061**
CD (P=0.05)	**NS**	**NS**	**0.157**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

* $\sqrt{x + 0.5}$ transformed values; Figures in parentheses are re-transformed values

Table 12: Population abundance of acridid species in paddy ecosystem during 2009-10.

Acridids / **Months**	*Acrida* spp.	*Oxya* spp.	*Catantops pinguis*	*Hieroglyphus banian*	*Hieroglyphus nigrorepletus*	*Phlaoeba infumata*	*Spathosternum prasiniferum*	*Trilophidia annulata*	*Truxalis* spp.	*Aiolopus Thalassinus*
June	1.10*	1.46	0.93	-	-	1.14	1.05	1.40	0.74	0.74
	(0.71)	(1.63)	(0.36)	-	-	(0.80)	(0.60)	(1.46)	(0.05)	(0.05)
July	1.05	1.77	0.84	1.34	0.77	1.18	1.11	1.34	0.96	1.08
	(0.60)	(2.63)	(0.21)	(1.30)	(0.09)	(0.89)	(0.73)	(1.30)	(0.42)	(0.67)
August	1.19	1.72	0.74	2.05	0.93	1.04	1.20	1.23	0.99	1.24
	(0.92)	(2.46)	(0.05)	(3.70)	(0.36)	(0.58)	(0.94)	(1.01)	(0.48)	(1.04)
September	1.21	2.22	0.93	1.84	1.17	0.97	1.25	1.28	1.15	0.99
	(0.96)	(4.43)	(0.36)	(2.89)	(0.87)	(0.44)	(1.06)	(1.14)	(0.82)	(0.48)
October	1.32	2.05	1.11	1.60	1.00	0.92	1.29	1.03	1.30	0.76
	(1.24)	(3.70)	(0.73)	(2.06)	(0.50)	(0.35)	(1.16)	(0.56)	(1.19)	(0.08)
November	1.30	1.41	1.16	1.17	0.84	0.84	1.40	1.15	1.19	-
	(1.19)	(1.49)	(0.85)	(0.87)	(0.21)	(0.21)	(1.46)	(0.82)	(0.92)	-
S. Em. ±	**0.073**	**0.075**	**0.063**	**0.077**	**0.059**	**0.072**	**0.056**	**0.067**	**0.065**	**0.061**
CD (P=0.05)	**NS**	**0.213**	**0.179**	**0.217**	**0.166**	**0.202**	**0.160**	**0.189**	**0.184**	**0.172**

Districts										
Banswara	1.25	1.82	0.96	1.53	0.88	1.14	1.24	1.22	1.07	0.98
	(1.06)	(2.81)	(0.42)	(1.84)	(0.27)	(0.80)	(1.04)	(0.99)	(0.64)	(0.46)
Dungarpur	1.22	1.73	0.91	1.38	0.87	0.99	1.17	1.19	1.02	0.91
	(0.99)	(2.49)	(0.33)	(1.40)	(0.26)	(0.48)	(0.87)	(0.92)	(0.54)	(0.33)
Pratapgarh	1.14	1.67	0.86	1.43	0.88	0.97	1.25	1.23	1.04	0.88
	(0.80)	(2.29)	(0.24)	(1.54)	(0.27)	(0.44)	(1.06)	(1.01)	(0.58)	(0.27)
Udaipur	1.17	1.86	1.08	1.47	0.99	0.97	1.21	1.31	1.09	0.91
	(0.87)	(2.96)	(0.67)	(1.66)	(0.48)	(0.44)	(0.96)	(1.22)	(0.69)	(0.33)
S. Em. ±	**0.059**	**0.061**	**0.051**	**0.063**	**0.048**	**0.058**	**0.046**	**0.054**	**0.053**	**0.049**
CD (P=0.05)	**NS**	**NS**	**0.146**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

* $\sqrt{x + 0.5}$ transformed values; Figures in parentheses are re-transformed values

Table 13: Population abundance of acridid species in maize ecosystem during 2008-09.

Acridids / Months	*Acrida* spp.	*Oxya* spp.	*Catantops pinguis*	*Hieroglyphus nigrorepletus*	*Phlaoeba infumata*	*Spathosternum prasiniferum*	*Trilophidia annulata*	*Truxalis* spp.	*Gastrimargus africanus*	*Aiolopus Thalassinus*
June	1.10*	0.92	1.23	-	1.15	1.31	1.52	0.98	-	1.13
	(0.71)	(0.35)	(1.01)	-	(0.82)	(1.22)	(1.81)	(0.46)	-	(0.78)
July	1.11	1.23	1.09	2.36	1.29	1.46	1.66	1.03	0.77	1.32
	(0.73)	(1.01)	(0.69)	(5.07)	(1.16)	(1.63)	(2.26)	(0.56)	(0.09)	(1.24)
August	1.22	1.36	1.18	3.05	1.30	1.49	1.39	1.02	0.93	1.29
	(0.99)	(1.35)	(0.89)	(8.80)	(1.19)	(1.72)	(1.43)	(0.54)	(0.36)	(1.16)
September	1.38	1.47	1.22	2.60	1.02	1.57	1.29	1.28	1.10	1.05
	(1.40)	(1.66)	(0.99)	(6.26)	(0.54)	(1.96)	(1.16)	(1.14)	(0.71)	(0.60)
October	1.42	1.18	1.46	2.10	1.06	1.93	1.45	1.30	1.18	0.75
	(1.52)	(0.89)	(1.63)	(3.91)	(0.62)	(3.22)	(1.60)	(1.19)	(0.89)	(0.06)
S. Em. ±	**0.071**	**0.103**	**0.071**	**0.059**	**0.067**	**0.073**	**0.074**	**0.067**	**0.067**	**0.086**
CD (P=0.05)	**0.201**	**0.291**	**0.199**	**0.168**	**0.189**	**0.206**	**0.208**	**0.189**	**0.190**	**0.242**
Districts										
Banswara	1.26	1.41	1.24	2.18	1.22	1.47	1.46	1.16	0.90	1.14
	(1.09)	(1.49)	(1.04)	(4.25)	(0.99)	(1.66)	(1.63)	(0.85)	(0.31)	(0.80)

Chittorgarh	1.22	-	1.22	2.28	1.18	1.62	1.38	1.07	-	1.19
	(0.99)	-	(0.99)	(4.70)	(0.89)	(2.12)	(1.40)	(0.64)	-	(0.92)
Dungarpur	1.21	1.24	1.23	1.90	1.09	1.50	1.40	1.12	0.94	1.04
	(0.96)	(1.04)	(1.01)	(3.11)	(0.69)	(1.75)	(1.46)	(0.75)	(0.38)	(0.58)
Pratapgarh	1.24	0.99	1.15	2.10	1.12	1.51	1.46	1.12	0.91	1.08
	(1.04)	(0.48)	(0.82)	(3.91)	(0.75)	(1.78)	(1.63)	(0.75)	(0.33)	(0.67)
Udaipur	1.31	1.30	1.34	2.36	1.20	1.67	1.59	1.14	1.01	1.05
	(1.22)	(1.19)	(1.30)	(5.07)	(0.94)	(2.29)	(2.03)	(0.80)	(0.52)	(0.69)
S. Em. ±	**0.071**	**0.092**	**0.071**	**0.059**	**0.067**	**0.073**	**0.073**	**0.067**	**0.060**	**0.086**
CD (P=0.05)	**NS**	**0.261**	**NS**	**0.168**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

* $\sqrt{x+0.5}$ transformed values; Figures in parentheses are re-transformed values

Table 14: Population abundance of acridid species in maize ecosystem during 2009-10.

Acridids / Months	*Acrida* spp.	*Oxya* spp.	*Catantops pinguis*	*Hieroglyphus nigrorepletus*	*Phlaoeba infumata*	*Spathosternum prasiniferum*	*Trilophidia annulata*	*Truxalis* spp.	*Gastrimargus africanus*	*Aiolopus Thalassinus*
June	1.07*	0.85	1.30	-	1.07	1.28	1.45	0.79	-	1.19
	(0.64)	(0.22)	(1.19)	-	(0.64)	(1.14)	(1.60)	(0.12)	-	(0.92)
July	1.17	1.11	1.07	2.20	1.31	1.45	1.68	1.05	0.76	1.36
	(0.87)	(0.73)	(0.64)	(4.34)	(1.22)	(1.60)	(2.32)	(0.60)	(0.08)	(1.35)
August	1.23	1.31	1.08	2.82	1.15	1.39	1.33	1.18	0.98	1.12
	(1.01)	(1.22)	(0.67)	(7.45)	(0.82)	(1.43)	(1.27)	(0.89)	(0.46)	(0.75)
September	1.34	1.33	1.33	2.46	1.05	1.58	1.25	1.21	0.95	1.01
	(1.30)	(1.27)	(1.27)	(5.55)	(0.60)	(2.00)	(1.06)	(0.96)	(0.40)	(0.52)
October	1.38	1.09	1.36	1.98	0.99	1.77	1.38	1.35	1.16	0.76
	(1.40)	(0.69)	(1.35)	(3.42)	(0.48)	(2.63)	(1.40)	(1.32)	(0.85)	(0.08)
S. Em. ±	**0.068**	**0.101**	**0.080**	**0.059**	**0.065**	**0.069**	**0.079**	**0.065**	**0.078**	**0.073**
CD (P=0.05)	**0.192**	**0.287**	**0.226**	**0.166**	**0.184**	**0.194**	**0.223**	**0.184**	**0.221**	**0.206**
Districts										
Banswara	1.20	1.27	1.31	2.11	1.04	1.43	1.35	1.18	0.93	1.10
	(0.94)	(1.11)	(1.22)	(3.95)	(0.58)	(1.54)	(1.32)	(0.89)	(0.36)	(0.71)

Chittorgarh	1.20	-	1.25	2.11	1.08	1.47	1.49	1.08	-	1.14
	(0.94)	-	(1.06)	(3.95)	(0.67)	(1.66)	(1.72)	(0.67)	-	(0.80)
Dungarpur	1.31	1.13	1.20	1.87	1.15	1.49	1.33	1.10	0.83	1.08
	(1.22)	(0.78)	(0.94)	(3.00)	(0.82)	(1.72)	(1.27)	(0.71)	(0.19)	(0.67)
Pratapgarh	1.26	0.94	1.15	1.93	1.16	1.51	1.37	1.07	0.90	1.01
	(1.09)	(0.38)	(0.82)	(3.22)	(0.85)	(1.78)	(1.38)	(0.64)	(0.31)	(0.52)
Udaipur	1.21	1.21	1.24	2.15	1.14	1.59	1.55	1.15	0.99	1.12
	(0.96)	(0.96)	(1.04)	(4.12)	(0.80)	(2.03)	(1.90)	(0.82)	(0.48)	(0.75)
S. Em. ±	**0.068**	**0.091**	**0.080**	**0.059**	**0.065**	**0.069**	**0.079**	**0.065**	**0.070**	**0.073**
CD (P=0.05)	**NS**	**NS**	**NS**	**0.166**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

* $\sqrt{x + 0.5}$ transformed values; Figures in parentheses are re-transformed values

Table 15: Population abundance of acridid species in sugarcane ecosystem during 2008-09.

Acridids / **Months**	*Acrida* spp.	*Oxya* spp.	*Catantops pinguis*	*Hieroglyphus nigrorepletus*	*Phlaoeba infumata*	*Spathosternum prasiniferum*	*Trilophidia annulata*	*Truxalis* spp.	*Gastrimargus africanus*	*Aiolopus thalassinus*
June	1.04*	0.83	1.12	-	1.31	1.29	1.64	0.86	-	0.80
	(0.58)	(0.19)	(0.75)	-	(1.22)	(1.16)	(2.19)	(0.24)	-	(0.14)

July	1.22	1.16	0.99	1.38	1.39	1.36	1.52	0.89	-	1.25
	(0.99)	(0.85)	(0.48)	(1.40)	(1.43)	(1.35)	(1.81)	(0.29)	-	(1.06)
August	1.14	0.93	1.15	1.83	1.28	1.37	1.45	1.17	0.74	1.32
	(0.80)	(0.36)	(0.82)	(2.85)	(1.14)	(1.38)	(1.60)	(0.87)	(0.05)	(1.24)
September	1.19	1.20	1.20	1.59	1.24	1.46	1.28	1.09	0.94	1.02
	(0.92)	(0.94)	(0.94)	(2.03)	(1.04)	(1.63)	(1.14)	(0.69)	(0.38)	(0.54)
October	1.38	0.96	1.33	1.24	1.01	1.50	1.30	1.23	1.05	0.75
	(1.40)	(0.42)	(1.27)	(1.04)	(0.52)	(1.75)	(1.19)	(1.01)	(0.60)	(0.06)
November	1.24	-	1.42	-	1.12	1.63	1.24	1.15	0.86	-
	(1.04)	-	(1.52)	-	(0.75)	(2.16)	(1.04)	(0.82)	(0.24)	-
S. Em. ±	**0.064**	**0.112**	**0.075**	**0.081**	**0.066**	**0.052**	**0.057**	**0.057**	**0.066**	**0.060**
CD (P=0.05)	**0.181**	**0.317**	**0.211**	**0.228**	**0.187**	**0.147**	**0.161**	**0.162**	**0.187**	**0.171**
Districts										
Banswara	1.19	0.88	1.14	1.27	1.29	1.44	1.40	1.08	0.89	1.03
	(0.92)	(0.27)	(0.80)	(1.11)	(1.16)	(1.57)	(1.46)	(0.67)	(0.29)	(0.56)
Chittorgarh	1.25	-	1.18	1.33	1.17	1.53	1.41	1.04	-	0.93
	(1.06)	-	(0.89)	(1.27)	(0.87)	(1.84)	(1.49)	(0.58)	-	(0.36)
Dungarpur	1.15	0.98	1.21	1.06	1.24	1.32	1.35	1.02	0.78	0.93

	(0.82)	(0.46)	(0.96)	(0.62)	(1.04)	(1.24)	(1.32)	(0.54)	(0.11)	(0.36)
Pratapgarh	1.18	-	1.19	1.18	1.16	1.49	1.39	1.06	0.82	1.01
	(0.89)	-	(0.92)	(0.89)	(0.85)	(1.72)	(1.43)	(0.62)	(0.17)	(0.52)
Udaipur	1.24	1.03	1.28	1.37	1.27	1.39	1.48	1.14	0.85	0.98
	(1.04)	(0.56)	(1.14)	(1.38)	(1.11)	(1.43)	(1.69)	(0.80)	(0.22)	(0.46)
S. Em. $\pm$	**0.058**	**0.079**	**0.068**	**0.074**	**0.060**	**0.047**	**0.052**	**0.052**	**0.054**	**0.055**
CD (P=0.05)	**NS**	**NS**	**NS**	**0.208**	**NS**	**0.134**	**NS**	**NS**	**NS**	**NS**

* $\sqrt{x + 0.5}$ transformed values; Figures in parentheses are re-transformed values

Table 16: Population abundance of acridid species in sugarcane ecosystem during 2009-10.

Acridids / **Months**	*Acrida* spp.	*Oxya* spp.	*Catantops pinguis*	*Hieroglyphus nigrorepletus*	*Phlaoeba infumata*	*Spathosternum prasiniferum*	*Trilophidia annulata*	*Truxalis* spp.	*Gastrimargus africanus*	*Aiolopus thalassinus*
June	0.93*	-	0.99	-	1.26	1.32	1.52	0.86	-	0.86
	(0.36)	-	(0.48)	-	(1.09)	(1.24)	(1.81)	(0.24)	-	(0.24)
July	1.15	-	1.09	1.18	1.37	1.28	1.47	0.86	-	1.09
	(0.82)	-	(0.69)	(0.89)	(1.38)	(1.14)	(1.66)	(0.24)	-	(0.69)
August	1.05	1.01	1.07	1.76	1.18	1.33	1.29	0.98	0.84	1.31
	(0.60)	(0.52)	(0.64)	(2.60)	(0.89)	(1.27)	(1.16)	(0.46)	(0.21)	(1.22)
September	1.21	1.18	1.23	1.51	1.20	1.45	1.20	1.14	0.91	0.91
	(0.96)	(0.89)	(1.01)	(1.78)	(0.94)	(1.60)	(0.94)	(0.80)	(0.33)	(0.33)
October	1.21	1.10	1.24	1.10	1.04	1.68	1.33	1.15	1.03	0.80
	(0.96)	(0.71)	(1.04)	(0.71)	(0.58)	(2.32)	(1.27)	(0.82)	(0.56)	(0.14)
November	1.24	0.75	1.35	0.90	0.98	1.57	1.37	1.22	0.87	-
	(1.04)	(0.06)	(1.32)	(0.31)	(0.46)	(1.96)	(1.38)	(0.99)	(0.26)	-
S. Em. ±	**0.063**	**0.094**	**0.081**	**0.092**	**0.062**	**0.052**	**0.063**	**0.060**	**0.058**	**0.054**
CD (P=0.05)	**0.178**	**0.265**	**0.229**	**0.260**	**0.176**	**0.146**	**0.177**	**0.169**	**0.164**	**0.152**
Districts										

Banswara	1.10	0.82	1.22	1.22	1.20	1.49	1.43	1.04	0.82	0.96
	(0.71)	(0.17)	(0.99)	(0.99)	(0.94)	(1.72)	(1.54)	(0.58)	(0.17)	(0.42)
Chittorgarh	1.17	-	1.14	1.25	1.10	1.43	1.46	0.95	-	0.97
	(0.87)	-	(0.80)	(1.06)	(0.71)	(1.54)	(1.63)	(0.40)	-	(0.44)
Dungarpur	1.07	0.94	1.09	0.99	1.17	1.38	1.25	1.07	0.83	0.89
	(0.64)	(0.38)	(0.69)	(0.48)	(0.87)	(1.40)	(1.06)	(0.64)	(0.19)	(0.29)
Pratapgarh	1.17	-	1.16	1.13	1.16	1.42	1.31	1.00	0.80	0.98
	(0.87)	-	(0.85)	(0.78)	(0.85)	(1.52)	(1.22)	(0.50)	(0.14)	(0.46)
Udaipur	1.15	0.98	1.20	1.37	1.23	1.47	1.36	1.12	0.93	0.92
	(0.82)	(0.46)	(0.94)	(1.38)	(1.01)	(1.66)	(1.35)	(0.75)	(0.36)	(0.35)
S. Em. ±	**0.057**	**0.066**	**0.074**	**0.084**	**0.057**	**0.047**	**0.057**	**0.054**	**0.047**	**0.049**
CD (P=0.05)	**NS**	**NS**	**NS**	**0.237**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

* $\sqrt{x+0.5}$ transformed values; Figures in parentheses are re-transformed values

Table 17: Population abundance of acridid species in sorghum ecosystem during 2008-09.

Acridids / Months	*Acrida* spp.	*Oxya* spp.	*Catantops pinguis*	*Hieroglyphus nigrorepletus*	*Phlaoeba infumata*	*Spathosternum prasiniferum*	*Trilophidia annulata*	*Truxalis* spp.	*Gastrimargus africanus*	*Aiolopus thalassinus*
June	1.07*	0.88	1.26	-	1.13	1.39	1.54	0.94	-	1.04
	(0.64)	(0.27)	(1.09)	-	(0.78)	(1.43)	(1.87)	(0.38)	-	(0.58)
July	1.25	1.02	1.14	1.69	1.30	1.47	1.67	1.05	0.80	1.23
	(1.06)	(0.54)	(0.80)	(2.36)	(1.19)	(1.66)	(2.29)	(0.60)	(0.14)	(1.01)
August	1.17	1.18	1.26	2.15	1.24	1.48	1.48	1.12	1.06	1.33
	(0.87)	(0.89)	(1.09)	(4.12)	(1.04)	(1.69)	(1.69)	(0.75)	(0.62)	(1.27)
September	1.40	1.19	1.33	1.89	1.12	1.61	1.21	1.31	1.06	1.06
	(1.46)	(0.92)	(1.27)	(3.07)	(0.75)	(2.09)	(0.96)	(1.22)	(0.62)	(0.62)
October	1.24	0.83	1.39	1.41	0.96	1.66	1.31	1.22	1.00	-
	(1.04)	(0.19)	(1.43)	(1.49)	(0.42)	(2.26)	(1.22)	(0.99)	(0.50)	-
S. Em. ±	**0.064**	**0.087**	**0.077**	**0.065**	**0.070**	**0.060**	**0.066**	**0.065**	**0.084**	**0.067**
CD (P=0.05)	**0.182**	**0.247**	**NS**	**0.183**	**0.198**	**0.171**	**0.186**	**0.182**	**0.239**	**0.190**
Districts										
Banswara	1.21	1.06	1.25	1.56	1.19	1.57	1.47	1.16	0.89	1.05
	(0.96)	(0.62)	(1.06)	(1.93)	(0.92)	(1.96)	(1.66)	(0.85)	(0.29)	(0.60)
Chittorgarh	1.22	-	1.20	1.62	1.14	1.56	1.38	1.11	-	1.01

	(0.99)	-	(0.94)	(2.12)	(0.80)	(1.93)	(1.40)	(0.73)	-	(0.52)
Dungarpur	1.23	0.96	1.24	1.44	1.11	1.51	1.38	1.11	0.92	1.11
	(1.01)	(0.42)	(1.04)	(1.57)	(0.73)	(1.78)	(1.40)	(0.73)	(0.35)	(0.73)
Pratapgarh	1.26	0.97	1.34	1.52	1.12	1.51	1.44	1.09	0.88	1.21
	(1.09)	(0.44)	(1.30)	(1.81)	(0.75)	(1.78)	(1.57)	(0.69)	(0.27)	(0.96)
Udaipur	1.23	1.10	1.34	1.71	1.18	1.44	1.54	1.17	0.99	1.00
	(1.01)	(0.71)	(1.30)	(2.42)	(0.89)	(1.57)	(1.87)	(0.87)	(0.48)	(0.50)
S. Em. ±	**0.064**	**0.078**	**0.077**	**0.065**	**0.070**	**0.060**	**0.066**	**0.065**	**0.075**	**0.067**
CD (P=0.05)	**NS**	**NS**	**NS**	**0.159**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

* $\sqrt{x + 0.5}$ transformed values; Figures in parentheses are re-transformed values

Table 18: Population abundance of acridid species in sorghum ecosystem during 2009-10.

Acridids / Months	*Acrida* spp.	*Oxya* spp.	*Catantops pinguis*	*Hieroglyphus nigrorepletus*	*Phlaoeba infumata*	*Spathosternum prasiniferum*	*Trilophidia annulata*	*Truxalis* spp.	*Gastrimargus africanus*	*Aiolopus Thalassinus*
June	1.12*	0.82	1.24	-	1.17	1.30	1.48	0.94	-	1.09
	(0.75)	(0.17)	(1.04)	-	(0.87)	(1.19)	(1.69)	(0.38)	-	(0.69)
July	1.17	1.09	1.04	1.48	1.18	1.34	1.71	1.15	0.86	1.35
	(0.87)	(0.69)	(0.58)	(1.69)	(0.89)	(1.30)	(2.42)	(0.82)	(0.24)	(1.32)
August	1.16	1.00	1.12	2.09	1.03	1.46	1.41	1.10	0.95	1.20
	(0.85)	(0.50)	(0.75)	(3.87)	(0.56)	(1.63)	(1.49)	(0.71)	(0.40)	(0.94)
September	1.28	1.25	1.31	1.79	1.01	1.56	1.26	1.13	0.86	0.99
	(1.14)	(1.06)	(1.22)	(2.70)	(0.52)	(1.93)	(1.09)	(0.78)	(0.24)	(0.48)
October	1.35	0.74	1.36	1.52	0.90	1.73	1.22	1.28	0.96	0.78
	(1.32)	(0.05)	(1.35)	(1.81)	(0.31)	(2.49)	(0.99)	(1.14)	(0.42)	(0.11)
S. Em. ±	**0.064**	**0.096**	**0.076**	**0.062**	**0.070**	**0.063**	**0.067**	**0.069**	**0.069**	**0.079**
CD (P=0.05)	**NS**	**0.272**	**0.213**	**0.174**	**0.198**	**0.179**	**0.190**	**0.194**	**NS**	**0.223**
Districts										
Banswara	1.25	0.96	1.22	1.46	1.13	1.50	1.41	1.07	0.84	0.99
	(1.06)	(0.42)	(0.99)	(1.63)	(0.78)	(1.75)	(1.49)	(0.64)	(0.21)	(0.48)
Chittorgarh	1.18	-	1.30	1.55	1.03	1.48	1.43	1.08	-	1.10
	(0.89)	-	(1.19)	(1.90)	(0.56)	(1.69)	(1.54)	(0.67)	-	(0.71)
Dungarpur	1.17	1.06	1.13	1.36	1.02	1.44	1.44	1.10	0.84	1.06
	(0.87)	(0.62)	(0.78)	(1.35)	(0.54)	(1.57)	(1.57)	(0.71)	(0.21)	(0.62)
Pratapgarh	1.20	0.90	1.23	1.61	1.01	1.41	1.36	1.17	0.86	1.14
	(0.94)	(0.31)	(1.01)	(2.09)	(0.52)	(1.49)	(1.35)	(0.87)	(0.24)	(0.80)
Udaipur	1.27	1.00	1.19	1.60	1.10	1.55	1.44	1.16	0.93	1.10
	(1.11)	(0.50)	(0.92)	(2.06)	(0.71)	(1.90)	(1.57)	(0.85)	(0.36)	(0.71)
S. Em. ±	**0.064**	**0.086**	**0.076**	**0.062**	**0.070**	**0.063**	**0.067**	**0.069**	**0.062**	**0.079**
CD (P=0.05)	**NS**	**NS**	**NS**	**0.174**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

* $\sqrt{x + 0.5}$ transformed values; Figures in parentheses are re-transformed values

Table 19: Population abundance of acridid species in soybean ecosystem during 2008-09.

Acridids / **Months**	*Acrida* spp.	*Catantops pinguis*	*Phlaoeba infumata*	*Spathosternum prasiniferum*	*Trilophidia annulata*	*Truxalis* spp.	*Aiolopus thalassinus*
July	1.00*	0.95	0.94	1.40	1.60	0.79	1.30
	(0.50)	(0.40)	(0.38)	(1.46)	(2.06)	(0.12)	(1.19)
August	1.10	0.98	1.05	1.43	1.47	0.91	1.12
	(0.71)	(0.46)	(0.60)	(1.54)	(1.66)	(0.33)	(0.75)
September	1.06	0.90	0.86	1.46	1.19	0.86	1.05
	(0.62)	(0.31)	(0.24)	(1.63)	(0.92)	(0.24)	(0.60)
October	1.18	1.10	0.88	1.56	1.37	1.04	0.83
	(0.89)	(0.71)	(0.27)	(1.93)	(1.38)	(0.58)	(0.19)
S. Em. ±	**0.073**	**0.075**	**0.061**	**0.073**	**0.077**	**0.061**	**0.069**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**0.219**	**0.172**	**0.194**
Districts							
Banswara	1.15	1.10	1.01	1.48	1.36	0.89	1.04
	(0.82)	(0.71)	(0.52)	(1.69)	(1.35)	(0.29)	(0.58)

Chittorgarh	1.04	0.87	0.87	1.38	1.47	0.93	1.11
	(0.58)	(0.26)	(0.26)	(1.40)	(1.66)	(0.36)	(0.73)
Dungarpur	0.92	0.89	0.84	1.43	1.45	0.84	1.12
	(0.35)	(0.29)	(0.21)	(1.54)	(1.60)	(0.21)	(0.75)
Pratapgarh	1.19	1.01	0.93	1.56	1.37	1.01	1.06
	(0.92)	(0.52)	(0.36)	(1.93)	(1.38)	(0.52)	(0.62)
Udaipur	1.13	1.03	1.02	1.48	1.39	0.83	1.04
	(0.78)	(0.56)	(0.54)	(1.69)	(1.43)	(0.19)	(0.58)
S. Em. $\pm$	**0.082**	**0.084**	**0.069**	**0.081**	**0.087**	**0.068**	**0.077**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

* $\sqrt{x + 0.5}$ transformed values; Figures in parentheses are re-transformed values

Table 20: Population abundance of acridid species in soybean ecosystem during 2009-10.

Acridids / **Months**	*Acrida* spp.	*Catantops pinguis*	*Phlaoeba infumata*	*Spathosternum prasiniferum*	*Trilophidia annulata*	*Truxalis* spp.	*Aiolopus thalassinus*
July	0.86*	0.98	1.04	1.41	1.47	0.81	1.19
	(0.24)	(0.46)	(0.58)	(1.49)	(1.66)	(0.16)	(0.92)
August	1.08	0.92	0.94	1.31	1.41	0.86	1.08
	(0.67)	(0.35)	(0.38)	(1.22)	(1.49)	(0.24)	(0.67)
September	1.10	0.92	0.79	1.47	1.27	0.88	0.99
	(0.71)	(0.35)	(0.12)	(1.66)	(1.11)	(0.27)	(0.48)
October	1.17	0.96	0.83	1.60	1.37	0.91	0.81
	(0.87)	(0.42)	(0.19)	(2.06)	(1.38)	(0.33)	(0.16)
S. Em. ±	**0.063**	**0.075**	**0.060**	**0.073**	**0.070**	**0.057**	**0.073**
CD (P=0.05)	**0.179**	**NS**	**0.171**	**NS**	**NS**	**NS**	**0.207**
Districts							
Banswara	1.11	0.97	0.96	1.53	1.33	0.84	1.05
	(0.73)	(0.44)	(0.42)	(1.84)	(1.27)	(0.21)	(0.60)
Chittorgarh	0.99	0.86	0.89	1.39	1.40	0.90	1.02
	(0.48)	(0.24)	(0.29)	(1.43)	(1.46)	(0.31)	(0.54)

Dungarpur	1.02	0.87	0.92	1.40	1.36	0.81	0.96
	(0.54)	(0.26)	(0.35)	(1.46)	(1.35)	(0.16)	(0.42)
Pratapgarh	1.13	0.96	0.84	1.49	1.35	0.92	1.09
	(0.78)	(0.42)	(0.21)	(1.72)	(1.32)	(0.35)	(0.69)
Udaipur	1.03	1.07	0.89	1.43	1.45	0.87	0.98
	(0.56)	(0.64)	(0.29)	(1.54)	(1.60)	(0.26)	(0.46)
S. Em. ±	**0.071**	**0.084**	**0.067**	**0.082**	**0.078**	**0.064**	**0.082**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

* $\sqrt{x + 0.5}$ transformed values; Figures in parentheses are re-transformed values

Table 23: Biology of *Oxya fuscovittata* (Marschall) on paddy

S.No.	Biological Parameters	Period (Days)		
		Minimum	Maximum	Mean ± S. Em.
1.	Adult Longevity: Male	24	46	37.50 ± 2.29
	Female	27	53	40.70 ± 2.56
2.	Pre oviposition period	3	8	05.60 ± 0.54
3.	Oviposition period	12	26	17.60 ± 1.44
4.	Number of egg pods/female	1	3	01.90 ± 0.28
5.	Number of eggs/pod (Hatching %)	15 (53)	33 (76)	22.40 ± 1.78 (67.46 ± 2.14)
6.	Incubation period	12	26	18.30 ± 1.31
7.	First Instar	6	9	07.20 ± 0.23
8.	Second Instar	7	10	08.65 ± 0.22
9.	Third Instar	9	14	10.85 ± 0.29
10.	Fourth Instar	10	14	12.05 ± 0.27
11.	Fifth Instar	11	15	13.10 ± 0.30

Table 21. Population abundance of *Oxya* spp. in paddy in different districts of Southern Rajasthan during 2008-09.

Districts	Months						Mean
	June	July	August	September	October	November	
Banswara	1.26*	1.53	1.25	1.25	1.24	1.07	1.27
	(1.09)	(1.84)	(1.06)	(1.06)	(1.04)	(0.64)	(1.11)
Dungarpur	1.18	1.41	1.13	1.15	1.11	1.05	1.17
	(0.89)	(1.49)	(0.78)	(0.82)	(0.73)	(0.60)	(0.87)
Pratapgarh	1.25	1.41	1.15	1.23	1.17	1.06	1.21
	(1.06)	(1.49)	(0.82)	(1.01)	(0.87)	(0.62)	(0.96)
Udaipur	1.30	1.51	1.15	1.22	1.13	1.07	1.23
	(1.19)	(1.78)	(0.82)	(0.99)	(0.78)	(0.64)	(1.01)
Mean	1.25	1.46	1.17	1.21	1.16	1.06	
	(1.06)	(1.63)	(0.87)	(0.96)	(0.85)	(0.62)	
S Em±: Months= 0.023 ; Districts= 0.018; Months X Districts=0.046							
CD (P=0.05): Months= 0.065; Districts= 0.053; Months X Districts= NS							

* $\sqrt{x + 0.5}$ transformed values; Figures in parentheses are re-transformed values

Table 22. Population abundance of *Oxya* spp. in paddy in different districts of Southern Rajasthan during 2009-10.

Districts	Months						Mean
	June	July	August	September	October	November	
Banswara	1.21*	1.46	1.14	1.22	1.16	1.16	1.22
	(0.96)	(1.63)	(0.80)	(0.99)	(0.85)	(0.85)	(0.99)
Dungarpur	1.18	1.36	1.11	1.23	1.21	1.07	1.19
	(0.89)	(1.35)	(0.73)	(1.01)	(0.96)	(0.64)	(0.92)
Pratapgarh	1.14	1.35	1.16	1.27	1.19	1.03	1.19
	(0.80)	(1.32)	(0.85)	(1.11)	(0.92)	(0.56)	(0.92)
Udaipur	1.15	1.36	1.19	1.31	1.16	1.07	1.20
	(0.82)	(1.35)	(0.92)	(1.22)	(0.85)	(0.64)	(0.94)
Mean	1.17	1.38	1.15	1.26	1.18	1.08	
	(0.87)	(1.40)	(0.82)	(1.09)	(0.89)	(0.67)	
S Em±: Months= 0.026 ; Districts= 0.021; Months X Districts= 0.053							
CD (P=0.05): Months= 0.075; Districts= NS; Months X Districts= NS							

* $\sqrt{x + 0.5}$ transformed values; Figures in parentheses are re-transformed values

Table 26: Effect of food plants on the development of *O. fuscovittata* (2008-09)

Food Plants	Average Hopper Duration (days)				Hopper Survival (%)	Growth Index	Rank
	III instar	IV instar	V instar	Total			
Oryza sativa L.	10.68	11.53	12.58	34.79	100.00	2.87	I
Zea mays L.	11.15	12.03	13.25	36.43	100.00	2.74	III
Sorghum bicolor (L.) Moench.	11.72	12.63	13.68	38.03	97.50	2.56	V
Saccharum officinarum L.	11.33	12.27	13.58	37.18	100.00	2.69	VI
Glycime max (L.) Merr.	14.05	15.18	16.35	45.58	77.50	1.70	VIII
Setaria glauca (L.) Beauv.	12.25	12.93	13.90	39.08	92.50	2.37	VI
Cyperus rotundus L.	10.87	11.73	12.80	35.40	100.00	2.82	II
Cynodon dactylon (L.) Pers.	12.35	13.13	14.08	39.56	92.50	2.34	VII

Table 27: Effect of food plants on the development of *O. fuscovittata* (2009-10)

Food Plants	Average Hopper Duration (days)				Hopper Survival (%)	Growth Index	Rank
	III instar	IV instar	V instar	Total			
Oryza sativa L.	10.55	11.78	12.72	35.05	100.00	2.85	I
Zea mays L.	11.30	12.13	13.33	36.76	97.50	2.65	III
Sorghum bicolor (L.) Moench.	11.57	12.60	13.73	37.90	95.00	2.51	V
Saccharum officinarum L.	11.40	12.33	13.50	37.23	100.00	2.69	VI
Glycime max (L.) Merr.	14.25	15.33	16.58	46.16	72.50	1.57	VIII
Setaria glauca (L.) Beauv.	12.02	12.85	13.97	38.84	95.00	2.45	VI
Cyperus rotundus L.	10.95	11.83	12.88	35.66	100.00	2.80	II
Cynodon dactylon (L.) Pers.	12.58	13.20	14.20	39.98	90.00	2.25	VII

Table 28: Effect of food plants on the food indices for *Oxya fuscovittata* (Marschall)

Food Plants	2008-09			2009-10		
	ECI (%)	AD (%)	ECD (%)	ECI (%)	AD (%)	ECD (%)
Oryza sativa L.	36.30	58.18	44.19	37.08	51.25	44.75
	(35.05)	(72.19)	(48.58)	(36.36)	(73.38)	(49.56)
Zea mays L.	32.11	54.31	40.91	32.40	49.85	41.14
	(28.25)	(65.96)	(42.88)	(28.71)	(66.53)	(43.29)
Sorghum bicolor (L.) Moench.	33.12	55.46	41.55	33.57	47.94	42.05
	(29.85)	(67.85)	(43.99)	(30.57)	(68.15)	(44.86)
Saccharum officinarum L.	33.51	55.69	41.95	34.57	48.90	42.79
	(30.48)	(68.22)	(44.68)	(32.19)	(69.78)	(46.14)
Glycine max (L.) Merr.	19.34	44.08	28.43	20.17	41.81	29.29
	(10.97)	(48.39)	(22.67)	(11.89)	(49.65)	(23.94)
Setaria glauca (L.) Beauv.	30.28	51.66	40.01	30.94	46.59	40.41
	(25.43)	(61.52)	(41.34)	(26.43)	(62.87)	(42.02)
Cyperus rotundus L.	34.76	57.22	42.70	35.77	50.64	43.49
	(32.50)	(70.71)	(45.99)	(34.17)	(72.18)	(47.37)
Cynodon dactylon (L.) Pers.	30.83	52.64	40.15	30.91	46.28	39.73
	(26.27)	(63.17)	(41.58)	(26.39)	(64.53)	(40.86)
S. Em. ±	**0.495**	**0.594**	**0.315**	**0.527**	**0.495**	**0.394**
CD (P=0.05)	**1.50**	**1.80**	**0.95**	**1.59**	**1.50**	**1.19**

Figures in parentheses are re-transformed values

Table 29: Bio-efficacy of chemical pesticides and botanicals against *Oxya fuscovittata* (Marschall) under caged condition (2008-09)

S. No.	Treatments	Mean per cent mortality			
		1 DAT	3 DAT	5 DAT	7 DAT
1.	*A. indica* leaves extract (5%)	-	17.50	37.50	57.50
2.	*A. indica* seed kernel extract (5%)	2.50	25.00	40.00	60.00
3.	*A. indica* oil (2%)	7.50	30.00	65.00	87.50
4.	*P. glabra* oil (2%)	7.50	27.50	60.00	75.00
5.	Fipronil (0.02%)	67.50	100.00	-	-
6.	Carbaryl (0.2%)	65.00	95.00	100.00	-

DAT= Day after treatment

Table 30: Management of *Oxya* spp. through different treatments in paddy nurseries (2009-10)

* $\sqrt{x}$ transformed values; Figures in parenthesis are re-transformed values

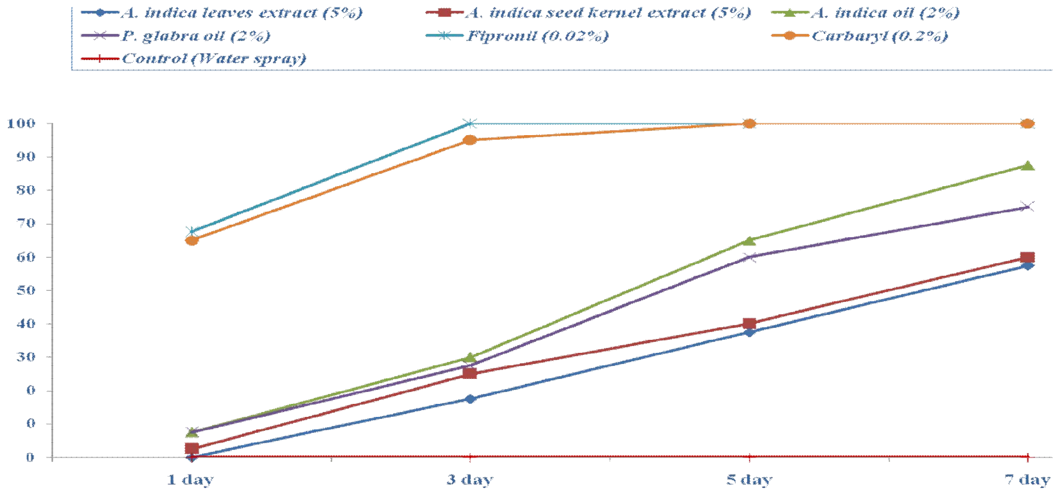
S. No.	Treatments	Population of *Oxya* spp. on paths before Treatment	Population of *Oxya* spp. in paddy nurseries after	
			5 DAT	15 DAT
1.	Unweeded paths	7.50	1.93* (3.75)	2.29 (5.25)
2.	Weeded paths	8.00	1.73 (3.00)	1.93 (3.75)
3.	Unweeded paths +Fipronil (0.02%)	7.25	1.11 (1.25)	1.32 (1.75)
4.	Weeded paths + Fipronil (0.02%)	7.00	1.50 (2.25)	1.65 (2.75)
5.	Unweeded paths + *A. indica* oil (2%)	6.75	1.41 (2.00)	1.73 (3.00)
6.	Weeded paths + *A. indica* oil (2%)	8.50	1.65 (2.75)	1.87 (3.50)
S. Em. ±		-	**0.147**	**0.157**
CD (P=0.05)		-	**0.443**	**0.475**

Table 24: Morphometric Variations in *Oxya fuscovittata* (Marschall)

S. No.	Body parts measured (mm)		Male		Female	
			Mean ± S. Em.	CV (%)	Mean ± S. Em.	CV (%)
1	Length of antenna		9.93 ± 0.10	4.45	9.28 ± 0.10	4.81
2.	Length of parts of antenna	Scape	0.49 ± 0.03	9.49	0.61 ± 0.01	8.35
		Pedicel	0.31 ± 0.02	13.22	0.36 ± 0.01	10.76
		Flagellum	9.13 ± 0.10	4.83	8.31 ± 0.09	5.12
3.	Length of tegmina		17.65 ± .16	4.10	22.03 ± 0.24	4.95
4.	Width of tegmina		2.68 ± 0.03	5.10	4.91 ± 0.11	9.86
5.	Length of wing		16.46 ± 0.17	4.58	20.85 ± 0.21	4.67
6.	Width of wing		7.82 ± 0.12	6.91	9.29 ± 0.11	5.62
7.	Length of body up to genitalia		22.87 ± 0.33	6.46	29.77 ± 0.52	7.85
8.	Length of body up to wing tip		25.70 ± 0.36	6.35	33.24 ± 0.43	5.80
9.	Width of body		4.64 ± 0.07	6.78	5.89 ± 0.11	8.44
10.	Length of pronotum		4.59 ± 0.05	5.46	6.23 ± 0.08	6.25
11.	Width of pronotum		3.22 ± 0.04	5.40	4.93 ± 0.06	5.77
12.	Length of frontal region		5.27 ± 0.06	5.02	7.49 ± 0.08	5.07
13.	Width of frontal region		3.24 ± 0.04	5.79	4.82 ± 0.06	5.48
14.	Vertical diameter of eye		2.31 ± 0.02	3.91	3.02 ± 0.03	4.18
15.	Transverse diameter of eye		1.55 ± 0.01	3.41	1.87 ± 0.02	4.69
16.	Length of sternum region		5.36 ± 0.06	5.01	7.91 ± 0.08	4.87
17.	Width of sternum region		3.19 ± 0.03	4.42	5.24 ± 0.05	8.05

Table 25: Morphometric Variations in legs of *Oxya fuscovittata* (Marschall)

S. No.	Measurements (mm)	Male		Female	
		Mean ± S. Em.	CV (%)	Mean ± S. Em.	CV (%)
1.	Length of fore legs	9.84 ± 0.11	5.20	11.27 ± 0.12	4.77
2.	Length of fore femur	3.58 ± 0.05	5.89	4.26 ± 0.06	7.08
3.	Length of fore tibia	3.12 ± 0.05	6.64	3.72 ± 0.03	4.36
4.	Length of fore tarsus	1.36 ± 0.03	9.96	1.46 ± 0.02	8.87
5.	Length of fore pretarsus	1.77 ± 0.02	5.93	1.83 ± 0.03	7.02
6.	Length of mid leg	11.24 ± 0.14	5.62	13.40 ± 0.21	7.07
7.	Length of mid femur	4.27 ± 0.07	8.04	5.34 ± 0.08	7.22
8.	Length of mid tibia	3.69 ± 0.05	6.18	4.66 ± 0.07	6.97
9.	Length of mid tarsus	1.42 ± 0.03	9.38	1.53 ± 0.03	9.34
10.	Length of mid pretarsus	1.84 ± 0.03	6.78	1.87 ± 0.04	9.86
11.	Length of hind leg	27.43 ± 0.34	5.69	38.11 ± 0.43	5.08
12.	Length of hind femur	12.52 ± 0.16	5.79	17.24 ± 0.22	5.79
13.	Width of hind femur	2.18 ± 0.03	6.78	2.94 ± 0.04	6.44
14.	Length of hind tibia	10.65 ± 0.11	4.74	15.23 ± 0.19	5.77
15.	Length of hind tarsus	1.86 ± 0.05	11.33	2.49 ± 0.05	7.84
16.	Length of hind pretarsus	2.38 ± 0.06	10.57	3.13 ± 0.04	6.53



Mean per cent mortality

ure- 1: Bio-efficacy of chemical pesticides and botanicals against *O. fuscovittata* ler caged condition during 2008-09

Period after treatments

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