Eco-taxonomic studies on the surface grasshopper, *Chrotogonus trachypterus* (Blanchard) in south western Rajasthan

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SHRAVAN LAL JAT

Thesis

Doctor of Philosophy in Agriculture
(Entomology)

2008

DEPARTMENT OF AGRICULTURE ZOOLOGY AND ENTOMOLOGY
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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

SHRAVAN LAL JAT

2008

Maharana Pratap University of Agriculture and Technology, Udaipur

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Dated: / /2008

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Dated: / /2008

This is to certify that the thesis entitled "**Eco-taxonomic studies on the surface grasshopper, *Chrotogonus trachypterus* (Blanchard) in south western Rajasthan**" submitted for the degree of Doctor of Philosophy in Agriculture in the subject of Entomology, embodies bonafide research work carried out by Mr. **Shravan Lal Jat** 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 11th February, 2008.

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ACKNOWLEDGEMENT

First of all, I bow my head to the Almighty for his blessings.

*I express my gratitude to **Dr. R. Swaminathan,** Assoc. Prof., Major Advisor, Deptt. of Agril. Zool. & Entomology, RCA, MPUAT, Udaipur for his keen interest and valuable guidance that has made this investigation a success.*

*I am thankful to the members of my Advisory committee, **Dr. Ashok Kumar**, Assoc. Prof and Head., Deptt. of Agril. Zool. & Entomology, **Dr. U.S. Sharma**, Assoc. Prof., Deptt. of Agril. Zool. & Entomology, **Dr. H. K. Jain**, Assoc. Prof., Deptt. of Statistics, and **Dr. V. Nepalia**, Assoc. Prof., DRI Nominee, Deptt. of Agronomy, MPUAT, Udaipur for their valuable suggestions and generous help.*

*I am indebted to **Dr. H.C.L. Gupta**, Dean Rajasthan College of Agriculture, Udaipur and **Dr. Ashok Kumar**, Head, Deptt of Entomology for providing necessary facilities during the course of investigation.*

*I thank the National Coordinator, **Dr. V.V. Ramamurthy**, ICAR Network Project for the funds that enabled me to conduct the tours.*

*Words can hardly register the sincere and heartfelt feeling, which I have for **Dr. K. L. Jain, Dr. A. K. Shrivastava, Dr. B. S. Rana, Dr. O. P. Ameta, Dr. A. Shrivastava, Dr. T. Husain** , **Dr. K. Singh**, **Sh. K. K. Bathi** and **Dr. N. K. Bajpai,** members of staff of Deptt. of Agril. Zool. & Entomology, RCA, Udaipur for their sincere cooperation.*

*I extend by heartiest thanks to my friends **Dr, Balbir Singh, Dr. Lekha, Dr. R. K. Samota Dr. Madan Mohan, Sh. K. S. Rupawat** and **Pradeep, Subodh, Rohit, Madan, Anil, Kana, Tara, Bhadhur, Amit, Gopal, Mukesh, Hansa** for their help, affection, encouragement and support during the course of study.*

*My special thanks to **Mr. Shankar ji poorbia (Shankar Computers),** for his friendly behaviour and nice computer type setting of this manuscript.*

*How much I owe to my parents **Sh. N. R. Sunda** and **Smt. M. D. Sunda**, who underwent all sorts of hardship and suffering to see my academic aspiration materialize, is just inexpressible without their blessings. A special mention of my Uncle **Sh. M. R. Sunda** and brothers **Sh. Lala Ram**, **Madan Lal** and **Hari Singh** for their love, blessings and inspiration is recorded.*

*I trap these finer moments of life to spill over pile of thanks to my beloved wife **Mrs. Manbhar,** whose sacrifice of her comforts that supported me always during the course of study. The innocent smiles induced in me a feeling of freshness and enthusiasm for work shown by my loving daughter **Kiran** and Son **Babu**.*

Place: Udaipur

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1. INTRODUCTION

A central problem in ecology is to identify and understand patterns in the distribution and abundance of species. Widespread species are generally locally abundant, and have populations that fluctuate than scarce, geographically restricted species. Predicted effects of body size are less well supported, although common, widespread, widely fluctuating species tend to be small (Gaston and Lawton, 1988).

Surface grasshoppers are widely distributed in the Orient and Africa. In India, *Chrotogonus trachypterus* is more common in the north, whereas *C. oxypterus* occurs in the southern regions. The surface grasshopper is a pest of pastures almost throughout the year. The common desert representative of the genus (Kevan, 1959) and all the specimens collected from western Rajasthan appeared to belong to *Chrotogonus trachypterus trachypterus*, being widely distributed in the ground; more frequently collected from the nurseries, gardens and the wheat fields. It is distributed throughout the plains in India including Orissa, South Arcot, Madura, Coimbatore, Bellary, Madhya Pradesh and Rajasthan. A highly dense population, up to 46 per unit area, was noticed in the *Kelwara* area of Udaipur district and a similar incidence was noticed in the other localities as well (Kushwaha and Bhardwaj, 1977). Besides, it is a polyphagous minor pest of agricultural crops and is uniformly distributed throughout the plains of India, having a regular breeding season. Sen-gupta and Behura (1957) reported *Chrotogonus* as a minor pest of sorghum and maize in Orissa. The economic importance of the genus *Chrotogonus* is not easy to assess, but it would appear to be sufficiently great for the insect to have been given several different vernacular names such as '*gaduhya*', '*ghada*', '*tiridda*' , '*kilippuchi*' (Cotes, 1889; 1894).

Species of *Chrotogonus* are geophilous and occur for the most part on bare (including cultivated) soil; especially, where humidity is relatively higher. Some may be found at considerable distances from water and even under very arid conditions, though is not the most favoured microclimate of any species with the probable exception of the subgenus *Obbiacris*. Some species are found among short grass, such as *Cynodon*, but taller vegetation provides entirely unsuitable conditions. There is a general impression that *Chrotogonus* is an insect of the plains and lower elevations, but, in fact, it occurs at very considerable altitudes (over 8000 ft. in parts of S.W. Arabia and the Indo-Iranian regions). The species commonly reported are *C. trachypterus* and *C. oxypterus* (Chahal and Sohi, 1964). Gupta (1972) observed the incidence of this species on early summer fodder crop like cowpea, clusterbean and pearl millet. The occurrence and abundance of the surface grasshopper, *C. trachypterus* on paddy was monitored by Lanjar *et al.* (2002) in Dokri, Pakistan. Akhtar (1971) recorded the nymphs and adults to feed on leaves by cutting germinating plants of cotton, wheat, and others, particularly in areas adjoining wastelands; often, such damaged fields had to be re-sown. The surface grasshoppers are reportedly polyphagous and they feed on a number of cultivated crops too. Hence, keeping these facts in view, the present investigation, "Eco-taxonomic studies on the surface grasshopper [*Chrotogonus trachypterus* (Blanchard)] in south western Rajasthan" was undertaken with the following objectives:

1) To survey the pyrgomorphid fauna in agro-ecosystems of South Western Rajasthan.

2) To quantify the diversity and abundance of the pyrgomorphid population.

3) To study the bionomics of the surface grasshopper, *Chrotogonus trachypterus* (Blanchard) including its systematic account.

4) To evaluate the effect of food plants on the growth and development of C. *trachypterus*.

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2. REVIEW OF LITERATURE

The Orthoptera are a group of large and easily recognized insects that include the grasshoppers, locusts, ground hoppers, crickets, bush crickets, mole crickets and camel crickets as well as some lesser groups. Members of the orthopteran families Acridiidae and Pyrgomorphidae (earlier considered as a sub-family, Pyrgomorphinae, under the family Acridiidae), grasshoppers and surface grasshoppers, are important pests of forage and crop plants. Of the nearly five thousand known species of grasshoppers in the world, only nine are categorized as locusts on account of their capability to devastatingly plague large geographical areas. Surface grasshoppers are widely distributed in the orient and Africa. In India, *C. trachypterus* is common in the north, whereas *C. oxypterus* occurs in the southern regions. The surface grasshopper is a very serious pest of pastures almost throughout the year. It is a polyphagous minor pest of agricultural crops and is uniformly distributed throughout the plains of India, having regular breeding season.

Losses of vegetation due to grasshopper have also been evaluated thoroughly in some other parts of the globe; an estimated 6 to 12 percent of the available forage is consumed by them in U.S.A. (Cowan, 1958). Anderson (1961) reported 25.9 % to 62.1 % loss of forage due to grasshopper in Montana range lands of U.S.A. In the Sadrinuk district of Siberia (former U.S.S.R.) in 1891 grasshoppers destroyed 47 percent of the entire wheat crop and in 1904 the damage of one third of wheat crop was assessed in Tobolsk-province (Tsyplenkov, 1970). Grasshoppers are visually conspicuous primary consumer in most of the temperate and the tropical grassland ecosystem (Rodell, 1977).

2.1 Survey of pyrgomorphid fauna in agro-ecosystems:

Apart from *Hieroglyphus banian* and *H. nigrorepletus*, which may cause serious damage to paddy, millet and sugarcane, grasshoppers appear to be relatively unimportant pests in Orissa. *Chrotogonus trachypterus* is a minor pest of sorghum, maize, groundnut, cotton and tobacco; *Aularches miliaris* of sorghum and maize; *Atractomorpha crenulata* of maize and tobacco; and *Poecilocerus pictus* 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, was emphasized by Ramchandra Rao (1960). *Chrotogonus trachypterus* attacked a variety of germinating crops including cotton, sugarcane, *kharif* fodders, wheat and barley, in almost all districts of the Punjab, particularly in the areas of comparatively low rainfall. Young germinating cotton and wheat were seriously damaged. Both the nymphs and adults fed on the leaves and damaged the young germinating plants. In areas adjoining waste land, germinating cotton and wheat were sometimes so badly damaged that resowing was necessary. The species commonly reported are *C. trachypterous* and *C. oxypterous* (Chahal and Sohi, 1964). Incidence of *Chrotogonus trachypterus* as a serious pest of early summer fodders, cowpea, cluster bean, pearl millet, and combinations of these crops was recorded by Gupta (1972). Misari and Raheja (1976) reported that the most abundant species of pyrgomorphids were *Chrotogonus senegalensis* and *Pyrgomorpha vignaudi*. Khaemba (1979) recorded *Acrotylus patruelis, Chrotogonus hemipterous, Gastrimargus africanus, Morpharis fasciata, Ornithaeris* sp. and *Zonocerus elegans*, as pests of sunflower before the flowering stage.

Ten species of Orthoptera were observed damaging paddy seedlings, more severely in the nursery. The most abundant were *Hieroglyphus banian* (F.), *Oxya fuscovittata* (Marshall) and *Atractomorpha crenulata* (F.). The moderately abundant species were *Acrida exaltata* (Wlk.), *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). Yadav and Yadav (1983) recorded *Chrotogonus trachypterus* (Blanch.) 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. *Aiolopus thalassinus* (F.) formed more than 40 per cent of the grasshoppers collected. The next in abundance were *Acrida exaltata* (walk.), *Aiolopus simulatrix simulatrix* (Wik.), *Chrotogonus trachypterus* (Blanch) and *A. strepens* (Latr.) on vegetables, maize and grasses.

The tettigoniid, *Neoconocephalus* sp., the pyrgomorphid, *Chrotogonus trachypterus* and the acridid, *Atractomorpha crenulata* were recorded as pests of sunflower in North West Frontier Pakistan (Sattar *et al*., 1984). Reddy and Puttaswamy (1984) observed the acridids, *Acrida exaltata* and *Atractomorpha acutipennis*; the pyrgomorphid, *Chrotogonus trachypterus*; the gryllids, *Anaxipha rufonotata*, *Modicogryllus fascialis* and *Plebeiogryllus guttiventris* as important orthopteran pests of chilli (*Capsicum annum* L.) in the nursery. Ram *et al*. (1984) reported that the Indian cowpea varieties IL 118, IL 138 and IL 148 were highly tolerant to the attack by *Chrotogonus trachypterus* and *Atractomorpha crenulata crenulata*. Hoppers of the pyrgomorphid, *Chrotogonus trachypterus* were observed to be associated with *tumba* (*Citrullus colocynthis*) creepers in the desert-habitat in Bikaner, Rajasthan (Chandra, 1984). Deka *et al*. (1987) observed *Chrotogonus trachypterus* (Blanchard) as an occasional pest of chickpea *Cicer arietinum* L.

Thippaiah and Kumar (1999) surveyed the grasshopper fauna on soybean in Karnataka during the *kharif* and summer seasons and reported *Chrotogonus* sp. and *Cyrtacanthacris tatarica* to be most numerous in both seasons. The occurrence and abundance of the surface grasshopper, *C. trachypterus* on paddy was monitored by Lanjar *et al.* (2002) in Dokri, Pakistan. Eight species of grasshoppers were reportedly injurious to the range grasses in Jhansi: *Hieroglyphus nigrorepletus*, *Atractomorpha crenulata*,*Oedaleus abruptus*, *Catantops pinguis* [*Diabolocatantops pinguis*], *Acrida exaltata*, *Thisoicetrus pulcher* [*T. pulchra*], *Cyrtacanthacris tartarica* and *Chrotogonus trachypterus*. *Chrotogonus trachypterus* was the first to appear (May), while *Catantops pinguis* was the last (September). The most abundant grasshoppers were *H. nigrorepletus*, *O. abruptus* and *Catantops pinguis* (Shah, 2001). The four species of grasshoppers infesting paddy were *Hieroglyphus banian*, *Oxya nitidula*, *Chrotogonus trachypterus trachypterus* and *Aiolopus tamulus*. The pyrgomorphid, *C. trachypterus trachypterus* was the maximum (12.8 nymphs and 39.2 adults/observation) during July-October when the mean temperature was 37.97 ºC. Nymphs of *A. tamulus* and *O. nitidula* were 37.6 and 57.0/observation, whereas the adults were 39.0 and 70.0/observation, respectively, and were highest during September – October when the mean temperature ranged from 34.02 - 37.95 ºC. *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 - 37.95 ºC (Lanjar *et al*., 2002). Six orthopteran pests (*Gryllus* sp., *Chrotogonus* sp., *Oxya* sp., *Cyrtacanthacris tatarica*, *Atractomorpha crenulata* and *Pyrgomorpha bispinosa*) were observed to infest soybean at different growth stages (Jayappa *et al*., 2003). The diversity of grasshoppers in rainfed cotton ecosystem included *Chrotogonus oxypterus*, *Chrotogonus trachypterus*, *Atractomorpha crenulata*, *Cyrtacanthacris tartarica*, *Holochlora albida*, *Eyprepocnemis alacris alacris* and *Catantops pinguis* [*Diabolocatantops pinguis*]. *Chrotogonus oxypterus*, *Cyrtacanthacris tartarica* and *A. crenulata* were the most abundant (Balakrishnan *et al*., 2004).

2.2 Quantification of pyrgomorphid diversity and population abundance:

Little information is available in the literature on the quantification of the pyrgomorphid fauna due to earlier consideration of the family Pyrgomorphidae as the sub-family Pyrgomorphinae under family Acridiidae. Otherwise too, the work on pyrgomorphids has been scanty. However, literature on population diversity and abundance for grasshoppers has been presented.

Kushwaha and Bhardwaj (1977) studied 35 species of forage and pasture grasshoppers of Rajasthan. A highly dense population of the pyrgomorphid, *Chrotogonus 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) represented about 80% of the total density, melanoplines (9 species) 15% and locustines (5 species) 5%. Grass feeders (gomphocerines and most locustines) made up 85% of the total density. The dominant species was *Ageneotettix deorum* (Scud.), which contributed 52% of the grasshopper density in 1981 and 37% in 1982. The grasshopper population was at outbreak density in both years (60 and 36/m^2, respectively). The pasture had never been treated with insecticide or herbicide. The Shannon-Wiener index of about 2.00 indicated high grasshopper diversity (Pfadt, 1984).

2.3 Bionomics of the pyrgomorphid, *C. trachypterus*:

Five independent lines of research provide information that is a basis for a number of conclusions regarding the evolution of phallic structures of Acridomorpha, excluding Eumasticoidea. Skeletal portions of the phallus are discussed to clarify terminology and offer evolutionary hypotheses. The terms "pre-epiphallic diverticulum," "arch sclerite," and "antero-ventral flange of endophallic sclerite" are introduced. The phallic muscles of *Romalea microptera* are covered in detail and figured. Homologies with *Atractomorpha sinensis*, *Ommexecha virens*, *Dissosteira carolina*, *Melanoplus differentialis*, *M. bivittatus*, *Paulinia acuminata*, and *Marellia remipes* are discussed. Evolutionary hypotheses regarding the evolution of the endophallus are presented. Pyrgacridinae is removed from Pyrgomorphidae and given status as the family Pyrgacrididae within Acridoidea. Lithidiinae is raised to the level of family within Acridoidea. Dericorythinae, Conophyminae, and Iranellinae (new subfamily), all previously included within Acrididae, are placed in the new family Dericorythidae. The subfamily Illapeliinae is moved to Ommexechidae. Marelliinae is recognized as a new subfamily within Acrididae. Presence of a well-developed arch sclerite should be treated as a crucial character in defining the family Acrididae (David, 2000).

The combination of body coloration and pigmentation, the number of antennal segments, and the measurements of body parts of hoppers of *Chrotogonus trachypterus* are valuable in identifying different stages (Latif *et al*., 1959). Chahal and Sohi (1964) gave a comprehensive account of the life history of *C. trachypterus*, including detailed tabulated information on egg numbers, longevity, sex ratio, and duration of various stages, incubation period and viability. Qayyum *et al*. (1973) reared *Chrotogonus trachypterus* (Blanchard) in the laboratory at 20, 25, 30 and 35 ^{0}C and 33, 52, 75 and 90% R.H. No development took place at 20 ^{0}C, and the nymphs could not complete their development at 25 ^{0}C and died within 20 days at 90% R.H. The longest and the shortest incubation periods were at 25 and 35 ^{0}C, respectively. The optimum conditions for nymphal development appeared to be 35 ^{0}C and 75% R.H. The pre-oviposition period was shortest and the greatest numbers of eggs were laid at 30^{0}C and 90% R.H., and the oviposition period lasted longer at 30 than at 35 ^{0}C. Kushwaha and Bhardwaj (1977) studied the antennal segments and tibial spines of 18 species of grasshoppers, including the surface grasshoppers, at Udaipur. The optimum conditions for the development of eggs of *Chrotogonus trachypterus trachypterus* was 35°C and 8% relative humidity. Eggs did not hatch if maintained at 10°C or at 45°C. Eggs exposed to alternating temperatures of 35°C and 50°C failed to hatch at 35°C if the exposure time to 50°C was longer than one day. The optimum temperature for larval development was 25-30°C. There were six larval instars at all levels of temperature studied (Parihar and Pal, 1978).

Khan *et al.* (1980) observed sand to be the most preferred substrate, followed by red soil, coal-ash and Badarpur sand for oviposition by *C. trachypterus*. The optimum moisture rate for oviposition in the preferred substrates was 4 percent; soil types with zero and 8 percent moisture content were avoided for oviposition. The average numbers of eggs laid by each female and the average percentage hatching were 212 (84%) for broccoli, 126 (88%) for cotton (*Gossypium indicum*), 112 (67%) for tomatoes, 88 (86%) for cabbages, 87 (78%) for *Solanum nigrum*, 63 (76%) for loofah and 24 (52%) for *Calotropis procera*. No eggs were laid by females reared and fed on *Ricinus communis* or aubergine (Chandra and Mital, 1984). Bhargava (1985) developed mathematical parameters for inter- and intra-specific distinction among different grasshopper species and undertook morphometric studies.

In laboratory studies, females of *Chrotogonus oxypterus* preferred soil moisture of 10 per cent to that of 4, 5 and 6 per cent. Males had 5 nymphal instars and females 6; the corresponding nymphal periods were 49.5 and 600 days, respectively (Chandra and Singh, 1993). Asad *et al*. (2001 a) observed the incubation period to be 48.2 ± 10.9, 25.57 ± 4.10 and 19.85 ± 1.12 days at constant temperatures of 25 ± 1, 30 ± 1 and 35 ± 1 ºC, respectively. At 30 ºC, the males and females of *C. trachypterus trachypterus* took 103.0 ± 16.4 and 133.3 ± 13.8 days, respectively, to complete their development. Females lived longer than males. A female, on an average, laid 71.10 ± 24.54 eggs. The highest fertility of egg was observed at an average room temperature of 29.6 °C. The pre-oviposition, oviposition and post-oviposition periods for *C. trachypterus* were 16.4 ± 9.24, 36.9 ± 15.71 and 12.00 ± 9.04 days, respectively.

2.4 Food preference by pyrgomorphid, *C. trachypterus* (Blanchard):

The surface grasshoppers are polyphagous they feed on a number of cultivated crops. Both nymphs and adults feed on leaves by cutting germinating plants, particularly in areas adjoining the wastelands. Often the damaged fields have to be re-sown. In laboratory studies, Singh (1961) recorded 39 species of plants belonging to 21 families to be fed by the surface grasshopper, *C. trachypterus*. The grasshopper was found to feed on young seedling irrespective of any preference. It showed a marked preference for certain *Solanaceous* species, legumes and cucurbits of economic importance, indicating it to be a potential pest. Leaves of jute, berseem, cotton and mustard were preferred by *Chrotogonus trachypterus* (Blanch.) with an average consumption of 68.67, 67.00, 60.67 and 45.00 percent, respectively (Akhtar, 1971). Gupta (1972) recorded the percentage of plants attacked by *Chrotogonus trachypterus* to be none in pearl millet sole, 51 per cent in pearl millet plus cluster bean and 83 per cent in cowpea. Crop combinations with cowpea showed a high percentage of attack. Chandra and Mital (1981) found that on 5 food-plants tested, live weights of *Chrotogonus trachypterus* nymphs increased by factors from 1.12 to 2.66 in each instar. The growth rates of newly emerged adults were higher than for fully grown nymphs that later declined.

Investigating the food consumption and utilization by *C. trachypterus* on different plants *viz.*, *Euphorbia hirta*, rapeseed, cabbage, *Solanum nigrun* and *Cyperus rotundus*, under laboratory conditions, Goel *et al.*, (1983) observed that, except on *C. rotundus*, the consumption and utilization by the surface grasshopper decreased with increasing age. Evaluating the comparative damage to 7 varieties of *Gossypium arboreum* and 4 varieties of *G. hirsutum* by *Chrotogonus trachypterus* at the germinating seedling stage, Singh *et al*. (1990) reported that *G. arboreum* varieties were more susceptible to attack than *G. hirsutum*. Verma (1998) recorded the incidence of *Poekilocerus pictus* on some new hosts in Western Rajasthan; *Plumeria alba*, *Tabernaemontana* and *Chrysanthemum maximum* were preferred for feeding and *Moringa oleifera* for adult congregation.

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. *Oxya 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, were evaluated to assess adaptability by *Oxya 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 percent 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 percent among the different host plants with the highest mean of 8 percent on *P. maximum*. ECI ranged between 2 to 8 percent with the highest mean of 6.8 percent on *P. maximum*. The data suggests that *0. nitidula* is more adapted to *P. maximum* followed by *0. sativa*, *P. glaucum* and *Z. mays* (Priscilla Fanny *et al.*, 1999).

Asad *et al*. (2001 b) reported that when adults of *Chrotogonus trachypterus* were provided leaves of 41 plant species belonging to 25 families as food, 36 were accepted and 5 rejected. It was found that the grasshopper preferred young plants, especially the seedlings of wheat, millet (*Pennisetum glaucum*) and cotton (*G. hirsutum*). The most preferred food plants were berseem (Egyptian clover, *Trifolium alexandrium*), cotton, mustard (*Brassica campestris*), lucerne, potato, and tomato. Further, feeding was observed to be most active around 11.00 a.m. In field studies none of the amaranthus cultivars evaluated for *Chrotogonus* damage were resistant. The cultivar OGA-3 was least susceptible to grasshopper damage (13.86% leaf infestation), whereas cv. OGA-2 recorded the highest leaf infestation (21.07%) and was the most susceptible cultivar (Jena *et al*., 2002). Studies on the consumption, digestion and utilization of cabbage leaves by the surface grasshopper, *Chrotogonus trachypterus* Blanch., reared under 3 conditions (A, B and C) with temperatures of 24, 28 and 32 degrees C, relative humidity of 70, 80 and 90%, photoperiod of 6, 12 and 18, and light intensity of 2.15, 4.50 and 6.84x103, respectively, indicated that approximate digestibility was maximum under condition A;

whereas, consumption index and growth rate were maximum under condition B. The maximum values for the nutritional parameters, coefficient of approximate digestibility, efficiency with which the ingested and digested food is converted to body substance were observed under condition B. The coefficient of approximate digestibility for total and reducing sugars, protein, fat and nitrogen was directly proportional to adult life (Poonia and Gehlot, 2005).

Olfert *et a*l. (1994) reported that the mean dry weight of grasshoppers was significantly higher ($P<0.05$) on Western wheat grass (cv. S-8580) than any other grass, and lowest on smooth brome grass (cv. Carlton and Signal). Development of grasshoppers was significantly more rapid ($P < 0.05$) when feeding on Western wheat grass (cv. 8580) and Intermediate wheat grass (cv. 9051) than any other grass. Smooth brome grass had the greatest negative impact on grasshopper development. Mortality among grasshoppers fed these grasses was not significantly different over the 21 day.

3. MATERIALS AND METHODS

3.1 Survey and quantification of pyrgomorphid fauna:

Surveys to assess the relative incidence of the pyrgomorphids will be conducted in Udaipur, Dungarpur, Banswara, Rajsamand and Sirohi districts of South Western Rajasthan.

(a) Estimation of adults:

The standardized sweep net method were employed to estimate the relative abundance and community composition of grasshoppers (Orthoptera: Pyrgomorphidae), walking through two-metre wide strip 200 metres long and collecting the adults that get trapped from the non-cropped areas. In each area selected, known replicates of 400-m^2 strips were observed at random. The sampling was done in the forenoon from 8 to 10 a.m. and in the afternoon from 4 to 6 p.m. (*cf*. Kushwaha and Bhardwaj, 1977).

(b) Estimation of hoppers:

The "Percentage Infestation" method was employed. Quadrates of vegetation (1 sq. m.) were inspected closely for hoppers at every 10 paces in a given area. Inspection of the crop area and clumps of grass that fall within the unit area at regular intervals were done. The number of stops containing hoppers as a fraction of the total number of 25 such stops made were calculated and expressed as percentage infestation.

(c) Estimation of grasshopper density:

The 18ft^2 sample method at each survey site was employed randomly picking 10 spots on the ground and the total population was expressed for 180 ft^2. The following mathematical/ statistical analyses were made towards estimating the species richness and diversity indices.

(i) Mean Density:

$$\text{Mean Density} = \frac{\sum Xi}{n}$$

Where,

Xi = Number of grasshopper in ith quadrates

n = Total number of quadrates sampled.

(ii) Relative Density (RD %) :

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

(iii) Diversity indices:

(a) Shannon's index (H ') = $\sum_{i=1}^{s}$ (Pi 1n Pi)

Where,

S = Total number of species

P = is the proportional abundance of the ith species

1n = Natural logarithm of n (Log with base e)

(b) Simpson index (λ) = $\sum_{i=1}^{s}$ (Pi^2)

Pi = $\frac{ni}{N}$ i = 1, 2, 3 …………. S

Where,

S = Total number of species

N = Total number of individual

ni = Number of individual

(c) Fiducial limits of population mean at 5% fiducial limits of population mean

$$\overline{X} \pm \frac{\sigma}{\sqrt{N}} \text{ X t }_{0.05}$$

σ	=	Standard deviation of the population
N	=	Number of observations in the sample

3.2 Studies on the bionomics of *C. trachypterus*:

Studies on the biology and bionomics of *C. trachypterus* were carried out under laboratory conditions for two successive *rabi* seasons (Nov. 2005 – March 2006 and Nov. 2006 – March 2007). The surface grasshopper was reared in the laboratory maintaining the room temperature at 28 ± 2 ^{o}C with a relative humidity of 60 ± 5 percent.

(a). Biology :

1. Oviposition in the laboratory: Adults of *C. trachypterus* were collected from wheat and barley fields of farmers within 25 km radius of Udaipur. The collected surface grasshoppers 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 wheat seedlings (*Triticum aestivum*) was provided regularly. The seedlings were kept fresh by inserting the stems in a plastic bowl (500 ml) containing moist sterilized soil. Distilled water was used to prepare fresh food and was provided every alternate day. In order to facilitate climbing, moulting, basking, *etc*. a dry twig with branches was also provided in the cage. Sterilized, sieved dry sand with 15 percent moisture was provided in a plastic bowl (500 ml. cap 18 cm height) for oviposition (Norris, 1968). Two to three containers were provided in each cage, which was replaced every day with fresh container after initiation of oviposition by the female. The egg pods laid by the females were collected for further study.

2. Incubation of eggs: The egg pods laid by the females were kept in a glass vials (100 ml.) separately (one in each vial) and repeated 10 times. The pods were covered with sand (medium) and kept in a BOD incubator at 30^{o}C and 70 percent R.H., as suggested by Pradhan and Peswani (1961). 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 to such sets were maintained. The rearing cages were maintained at 28 ± 2 ^{o}C and relative humidity 60 ± 5 percent. 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 when female started first oviposition 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 egg and number of eggs per pod, the freshly laid eggs within the pod were kept in distilled water over night in a Petri dish. The 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.

(b). Morphometrics:

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. Similarly, counting of number of antennal segments and hind tibial spurs was done using the binocular. Twenty specimens of the grasshopper species were observed for the study during the winter season (*rabi*) 2006-07. The major linear measurements taken have been tabulated hereunder:

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 Effect of food plants on the growth and development of C. *trachypterus*:

Field collected adults of the surface grasshopper reared in the laboratory were provided different food, including weeds and field crops, on weight basis. The live culture was maintained at 32 ± 2 degrees Celsius and 65 ± 5 per cent relative humidity in aluminum frame wire-gauge cages kept on steel racks protected from ants. The adults were sexed and put into the wire-gauge cages (30 x 30 x 30 cm). The cages had four 6-inch egg laying tubes with sand/ soil filled almost up to the brim and moistened with distilled water for proper oviposition by the females.

For host-plant preference studies, newly hatched-out hoppers were maintained on leaves of wheat, until they moulted thrice. Healthy IV instar hoppers, starved for 6 hours were transferred singly 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 10 different treatments, comprising 9 host plants, selecting 5 from cultivated crops and 4 from uncultivated pasture grasses and weeds, and mixed food forming the tenth treatment. Fresh food was provided twice daily. The different host plants selected for the study were:

1.	Wheat	*Triticum sativum* L.
2.	Lucerne	*Medicago sativa* L.
3.	Barley	*Hordeum vulgare* L.
4.	Oat	*Avena sativa* L.
5.	Gram	*Cicer arietinum* L.
6.	Pigweed	*Chenopodium album* L.
7.	Spinach	*Spinacea oleracea* L.
8.	Bermuda grass	*Cynodon dactylon* (L) Pers.
9.	Nutgrass	*Cyperus rotundus* L.
10.	Mixed food plants (Parts from above plants).	

Observations (in days) were recorded for each subsequent hopper period. The sixth instar hopper was weighed and per cent hopper survival on each host plant computed. The time required for adult development on each host plant tested and the survivals of adults were recorded. To compare the relative growth of hoppers on different host plants the growth index was calculated using the following formula:

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

Food utilization indices were calculated on a dry weight basis for the newly formed VI instar hoppers. The hoppers reared on maize right from hatching, were starved overnight, and thereafter provided with the different host-plants until they develop into adults. Fresh, tender green parts of the different host plants were divided into two equal portions. One portion was weighed wet and fed to the newly formed and starved VI 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):

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

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

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

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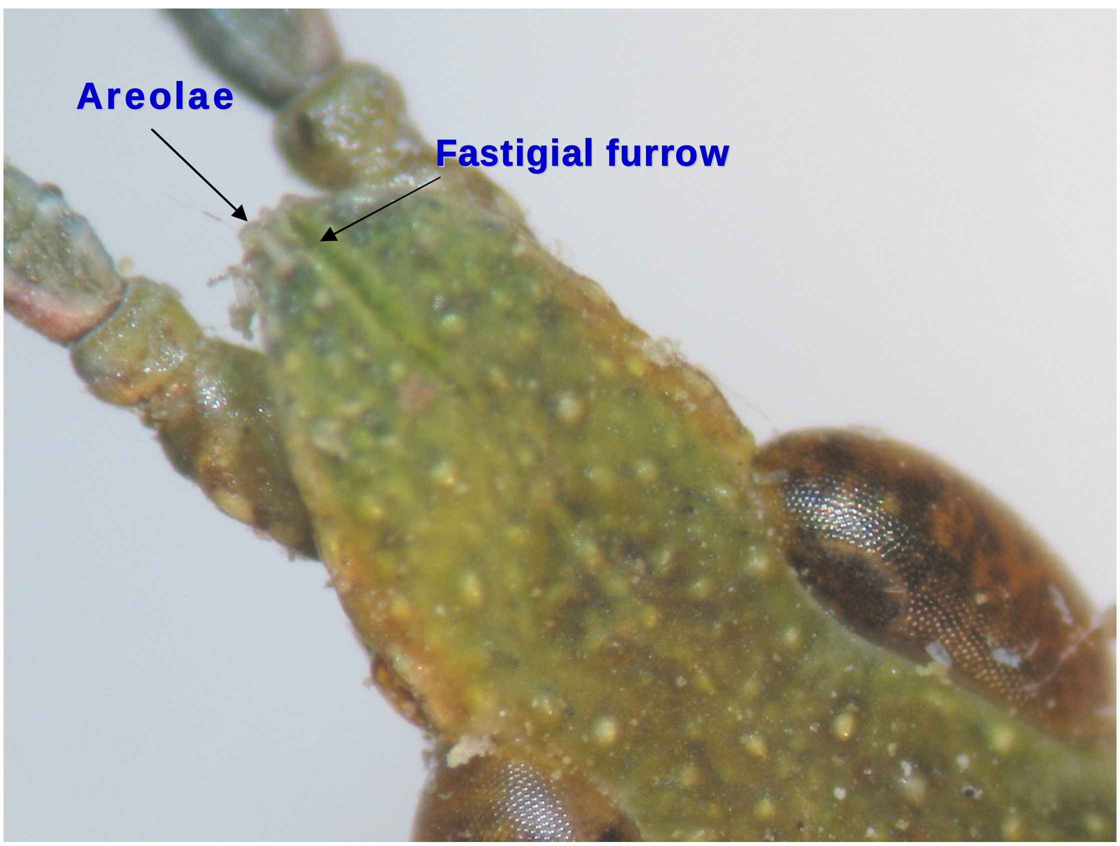
4. RESULTS

4.1 Survey of Pyrgomorphid fauna in the maize-wheat agro-ecosystem of south-western Rajasthan:

4.1.1 Diversity:

Survey conducted in the five districts of Rajasthan *viz.*, Banswara, Dungarpur, Rajsamand, Sirohi and Udaipur during 2005-06 and 2006-07 yielded five different species of short horned grasshoppers belonging to the family Pyrgomorphidae, characterized by the presence of *fastigial furrow* and the apical *areolae*, besides having the lower basal lobe of the hind femora longer than the upper lobe.



The adult Pyrgomorphids, determined on the basis of their morphological features, belonged to four genera (*Chrotogonus*, *Atractomorpha*, *Pyrgomorpha* and *Poekilocerus*) and five species *i.e.*, *Chrotogonus trachypterus* (Blanchard), *Chrotogonus oxypterus* (Blanchard), *Atractomorpha crenulata* Fabricius *Pyrgomorpa bispinosa* Walker and *Poekilocerus pictus* Fabricius (plates II & III). The key on the basis of which the above determinations were made has been presented in 4.2 (c).

The Pyrgomorphid faunal diversity showed little variation in the 5 districts surveyed.

4.1.2 Population abundance of Pyrgomorphids:

(a) Adults:

Both the species of the genus *Chrotogonus* (*C. trachypterus* and *C. oxypterus*) were relatively more abundant in Udaipur district with a respective mean population of 34.78 and 30.75 adults per 400 sq. m., during 2005-06 and 31.89 and 28.22 adults per 400 sq. m., during 2006-07 followed by that in Sirohi. They were less abundant in Dungarpur and Banswara districts during both the years. The genus *Atractomorpha* was almost equally represented in all the five districts surveyed; however, the adult population was relatively more in Banswara district (7.81 and 6.36 adults per 400 sq. m. during 2005-06 and 2006-07, respectively. The genus *Pyrgomorpha* also had a similar representation from all the five districts surveyed, but the adult population was relatively more at Banswara with a mean population of 7.0 and 5.96 adults per 400 square metre during 2005-06 and 2006-07, respectively. The adult population of the colourful grasshopper, *Poekilocerus* was relatively more in the district Rajsamand, as compare to their population in the other 4 districts, with 7.81 and 6.19 grasshoppers per 400 meter square during 2005-06 and 2006-07, respectively (Tables 1 & 2).

The figures drawn (Figures 1 to 10) over the study of relative incidence of the Pyrgomorphid fauna clearly depict that the rise and fall of the grasshopper population happened to vary in the different districts surveyed, which was also species-specific. Both the species of *Chrotogonus* showed a gradual increase and decline during both the years of observation at Udaipur. At Sirohi, the population dynamics was gradual in 2005-06, but steep during 2006-07. In the remaining districts Banswara, Dungarpur and Rajsamand the surface grasshopper population dynamics showed a steep rise and decline during both years. It was notable that the population was found throughout the year with peaks during specific periods of the year.

The rise and fall of the population for *Atractomorpha crenulata* and *Pyrgomorpha bispinosa* was more or less similar in all the districts surveyed during both the years and their population was also present throughout the year with definite peaks.

The grasshopper, *Poekilocerus pictus* showed a similar trend of population built-up and fall in four of the five districts surveyed. The population was recorded from March that continued up to October, from November to March they were not observed. They were not recorded from district Banswara that could be attributed to the relatively more humid climatic conditions and consequent vegetation.

(b) Hoppers:

The mean hopper population of the commonly available Pyrgomorphids in the different districts surveyed have been presented in Tables (3 & 4) , and the month-wise density for each district recorded during both years has been deciphered as a column graph expressing the data as percent infestation (Figures 11 to 20).

The mean hopper population of the surface grasshopper species *C. trachypterus* and *C. oxypterus* was relatively more in Udaipur district with a respective mean population of 6.50 and 5.58 per 25 stops, during 2005-06 and 5.50 and 5.09 hoppers per 25 stops during 2006-07 followed by that in Sirohi. They were least abundant in Banswara district during both the years. The hoppers of the genus *Atractomorpha* was almost equally represented in all the five districts surveyed. However, their population was relatively more in Banswara district (3.83 and 3.08 per 25 stops during 2005-06 and 2006-07, respectively). The genus *Pyrgomorpha* also had a similar representation from all the five districts surveyed, though the hopper population was relatively more at Banswara with a mean population of (3.42 and 1.73 hoppers per 25 stops during 2005-06 and 2006-07, respectively). The hopper population of *Poekilocerus* was relatively more in district Rajsamand with 2.43 and 2.33 hoppers per 25 stops during 2005-06 and 2006-07, respectively.

From the figures (11-20) it becomes evident that both species of *Chrotogonus* had the highest hopper infestation (%) during the month of February in both years at all districts surveyed. The Pyrgomorphids, *A. crenulata* and *P. bispinosa* had the maximum hopper infestation (%) during August and September in all the districts. The grasshopper, *P. pictus* happened to have the maximum hopper infestation during June and July in the four districts during both the years.

4.1.3 Pyrgomorphid population density:

4.1.3 (a) Mean density (expressed as numbers per 180 sq. ft.):

Data on mean density for the 4 grasshopper species encountered in the maize-wheat cropping system in the 5 districts surveyed have been presented district wise in the Tables (5 to 14).

During both the years, either species of the genus *Chrotogonus* had the maximum population density during February that ranged from 10 to 13 grasshoppers per 180 sq. ft. in the different districts surveyed with however the maximum at Udaipur. The mean density for *Atractomorpha crenulata* was the maximum during the month of August and ranged from 2.5 to 4.5 grasshoppers per 180 s. ft. in the different districts observed with the maximum being recorded from district Banswara during 2005-06 and 2006-07. The grasshopper, *Pyrgomorpha bispinosa* also had the maximum mean density in the month of August with a population range from 2.0 to 4.0 grasshoppers per 180 sq. ft. in the districts surveyed and the maximum was recorded from Banswra.

4.1.3 (b) Relative density (expressed as a percentage):

A district-wise comparison of the relative density among the four species of Pyrgomorphids collected during the survey from the maize-wheat cropping systems has been presented in Tables (15 to 24).

The relative densities for the different species of grasshopper showed some variation in the districts surveyed. The species of *Chrotogonus* had their maximum relative density in the month of May in three of the four districts, while in district Dungarpur the relative density was the maximum in May for *C. oxypterus* and in May and June for *C. trachypterus*. The relative density for *A. crenulata* was the maximum in the month of September during the two year study in most districts. Similarly, the relative density for *P. bispinosa* was the maximum in the month of August in the districts surveyed.

4.1.3 (c) Diversity indices:

A year wise comparison of the Pyrgomorphid diversity in the 5 districts has been presented in the Tables (25) and (26).

During the year 2005-06, in all the 5 districts, the maximum pygromorphid diversity as given by Simpson Diversity Index was during August being 3.84, 3.79, 3.97, 3.84 and 3.99 for the districts Udaipur, Sirohi, Rajsamand, Dungarpur and Banswara, respectively. Similarly, on the basis of Shannon Weiner Diversity Index the maximum Pyrgomorphid diversity was in the month of August with the index values being 1.366, 1.358, 1.382, 1.366 and 1.384 for the districts Udaipur, Sirohi, Rajsamand, Dungarpur and Banswara, respectively. During the subsequent year (2006-07), the Simpson Diversity Index and Shannon Weiner Diversity Index values followed a similar pattern as during the previous year 2005-06 and the indices were the maximum during August.

Based on the habitat preference and their behaviour, the Pyrgomorphids could be grouped as the geophilus and arboreal types. A comparison within the geophilus species showed that the Relative Density was nearly equal depicting a 1: 1 ratio at all districts and the diversity indices were 1.923 to 2.00 and 1.906 to 2.00 during 2005-06 and 2006-07 respectively. Similarly, comparison between the other species indicated that their Relative Density was also nearly equal depicting a similar 1: 1 ratio and the diversity indices were 1.00 to 2.00 during both years (Table 27& 28).

4.2 Bionomics of the surface grasshopper, *Chrotogonus trachypterus* (Blanchard):

4.2 (a) Biology:

The data (mean of 10 observations) on the biology and linear measurements of the surface grasshopper have been presented in Tables (29), (30) and Plate (IV). The females laid eggs in moist soil at a depth of 2 to 4 cm. Egg pods were hard, elongated and cylindrical with a slight bend at the middle. The egg pods measured 32.845 ± 0.519 mm long and 2.485 ± 0.029 mm broad, respectively; with an average number of 7.500 ± 0.249

egg pods per female. The freshly laid eggs were yellow that later turned to light brown, having an elongated shape and were tapering at both the ends. The average length and width of the egg was 3.483 ± 0.064 mm and 0.955 ± 0.010 mm, respectively, with an average of 9.050 ± 0.560 eggs per pod. The mean numbers of eggs laid per female were 65.500 ± 4.365. The incubation period was 22.975 ± 1.015 days under laboratory conditions.

The first instar nymph was light yellow in colour with the mean body length, length of antenna , length of head , length of pronotum , width of vertex and length of hind femur as 3.441 ± 0.064, 1.241 ± 0.022, 0.783 ± 0.013, 0.669 ± 0.011, 0.297 ± 0.005 and 1.687 ± 0.015 mm., respectively. The duration of first instar nymph was 9.900 ± 0.238 days. The second instar nymph was yellow in colour immediately after moulting that turned darker later. The duration of the second instar was 8.613 ± 0.302 days, with length of body measuring 6.191 ± 0.114 mm, length of antenna 1.527 ± 0.021 mm, length of head 1.054 ± 0.013 mm, width of pronotum 1.695 ± 0.023 mm and length of hind femur 2.134 ± 0.026 mm. The third instar took 8.300 ± 0.173 days with its body length being 7.005 ± 0.094 mm, antenna length 1.917 ± 0.043 mm, head length 1.359 ± 0.009 mm, pronotum length 2.511 ± 0.033 mm and hind femur length 3.177 ± 0.025 mm. The fourth instar body measured 9.508 ± 0.099 mm long, antennal length 2.745 ± 0.034 mm, head 1.604 ± 0.012 mm, the length of pronotum 2.008 ± 0.026 mm and hind femur length 4.587 ± 0.013 mm, respectively. The duration of fourth instar nymph was 7.186 ± 0.191 days. The fifth instar nymphal period lasted 6.625 ± 0.146 days with body length measuring 10.686 ± 0.120 mm. The length and width of head measured 1.883 ± 0.011 mm and 2.158 ± 0.011 mm respectively. The length of pronotum and hind femur was 2.450 ± 0.012 and 5.342 ± 0.014 mm respectively. The duration of sixth instar nymph was 7.913 ± 0.232 days with length of body measuring 12.409 ± 0.095 mm, length of antenna 3.611 ± 0.018 mm, length of head 2.076 ± 0.017 mm and width of head 2.298 ± 0.011 mm respectively. The width of vertex was 0.852 ± 0.008 mm and the length of pronotum was 2.738 ± 0.014 mm. The total nymphal period took from 43.50 to 53.50 days with an average of 48.513 ± 0.496 days.

The length of adult male body was 14.983 ± 0.077 mm, with antennal length 4.508 ± 0.150 mm. The length and width of head, length and width of pronotum, width of vertex and length of hind femur measured 2.229 ± 0.030 mm, 2.413 ± 0.029 mm, 2.911 ± 0.040 mm, 4.195 ± 0.047 mm, 0.904 ± 0.013 mm and 6.732 ± 0.129 mm respectively. The female was distinctly bigger than the male, with the length and width of body, length of antenna, length and width of head, length and width of pronotum, width of vertex and length of hind femur measuring as 20.436 ± 0.506 mm, 6.797 ± 0.119 mm, 5.291 ± 0.131 mm, 2.791 ± 0.097 mm, 3.625 ± 0.083 mm, 4.250 ± 0.088 mm, 6.791 ± 0.121 mm, 1.275 ± 0.026 mm and 8.953 ± 0.147 mm, respectively. The pre-oviposition, oviposition and post-oviposition periods were 18.000 ± 0.793, 36.150 ± 2.075 and 12.250 ± 1.039 days, respectively. Adult longevity of males and females was observed to be 54.350 ± 3.005 and 66.400 ± 3.210 days, respectively under laboratory conditions.

4.2 (b) Morphometrics:

The linear morphometric variations of the different body parts of the locally collected adult surface grasshoppers, *C. trachypterus* were evident and the mean values with standard deviations have been presented in the Table (31) and Plate (V a). Intra-specific variation for the morphological characters is more often natural and can possibly be attributed to their feeding behaviour. The grasshoppers were collected from wheat/ barley crops with a more or less common weed flora including *Chenopodium murale*, *C. album, Fumaria parviflora*, *Avena* sp., *Cynodon dactylon* and *Phalaris minor*. Feeding on some of these weeds apart from wheat and/ or barley could have implications on the growth and development of the surface grasshoppers. The coefficient of variation worked out for the different morphometric variations was the maximum for the numbers of spines on the outer fore legs in males (19.33 %) and outer middle legs in females (16.15 %). In both males and females the lower sternum width showed the lowest coefficient of variation (3.47 and 4.87% respectively). The lengths of antennae, tegmina, hind wing, body up to genitalia/ wing tip, pronotum, and the sternal region were relatively more for the females than the males; similarly the width of tegmina, body, pronotum, and the sternal region were also relatively more for the females.

From the Tables (32) and (33) depicting the morphometric variations observed in the mouthparts and the legs of the grasshopper, respectively, the females had relatively more length and width than that of the males for the different parameters observed.

Among the variations recorded in the mouthparts, the maximum coefficient of variation was noted for the length of the galea (21.45 %). The variation in the legs of the grasshopper was more pronounced for the tarsal region of the fore legs in either sex of the grasshopper.

A comparison of the compounded ratios for some of the morphological traits as presented in Table (34) showed that the ratio between length of hind femur and width of vertex (F/v) was the maximum (7.335 ± 0.132 and 7.151 ± 0.124) for the males and females, respectively). The lowest ratio happened to be for the ratio between the length and width of the pronotum (P/p) for both the males as well as the females (0.686 ± 0.014 and 0.624 ± 0.009). The male and female genitalia of C. trachypterus have been presented in Plate V (b).

4.2 (c) Systematic Account of the Pyrgomorphid genera:

A comprehensive systematic account of the Pyrgomorphid genera of the Indian sub-continent from available literature and databases has been presented here (Kerby, 1914):

Genus ***Chrotogonus***

Chrotogonus, Serville, Ins. Orth. 1839, p. 702.

Type, *Ommexycha lugubre*, Blanch., from Egypt.

Range, Africa, Asia, Australia.

Size small, body short and stout. Head small, narrowed towards the front; antennae short, filiform, inserted close together between the eyes. Pronotum more or less rugose, much widened behind; hind border obtusely angulated or rounded. Tegmina generally shorter than the abdomen and nodose; wings often abbreviated. Hind femora moderately stout; hind tibiae slightly thickened towards the extremity, with no terminal spine on the upper carina; the other terminal spines of nearly equal length.

***Chrotogonus pallidus*, Blanch.**

Ommexycha pallidum, Blanchard, Ann. Soc. Ent. France, v, 1836, p. 623, pl. xxii, fig. 10.

***Chrotogonus brevis*, Bol.**

Chrotogonus brevis, Bolivar, Bol. Soc. Espan. iv, 1904, pp. 92, 99.

***Chrotogonus incertus*, Bol.**

Chrotogonus incertus, Bolivar, Ann. soc. Espan. xiii, 1884, pp. 38, 45, 494.

***Chrotogonus fuscescens*, sp. nov.**

***Chrotogonus robertsi*, sp. nov.**

***Chrotogonus concavus*, sp. nov**.

***Chrotogonus trachypterus*, Blanch**.

Ommexycha trachypterus, Blanchard, Ann. Soc. Ent. France, v, 1836, p. 618, pl. xxii, fig. 6.

***Chrotogonus liaspis*, Blanch.**

Ommexycha liaspis, Blanchard, Ann. Soc. Ent. France, v. 1836, p. 620, pl. xxii, fig. 8.

***Chrotogonus oxypterus*, Blanch.**

Ommexycha oxypterum, Blanchard, Ann. Soc. Ent. France, v, 1836, p. 622, pl. xxii, fig. 9.

***Chrotogonus saussurei*, Bol.**

Chrotogonus saussurei, Bolivar, Ann. Soc. Espan. xiii, 1884, pp. 39, 47, 494 : id., Bol. Soc. Espan. iv, 1904, pp. 93, 104.

Chrotogonus oxypterus, Bolivar (*nec* Blanch), Ann. Soc. Ent. France, Ixv, 1902, p. 605.

***Chrotogonus brachypterus*, Bol.**

Chrotogonus brachypterus, Bolivar, Ann. Soc. Ent. France, Ixx, 1902, p. 605; id., Bol. Soc. Espan. iv, 1904, pp. 95, 109.

***Chrotogonus sordidus*, sp.n.**

***Chrotogonus hemipterus* Shaum 1853** (Toad Hopper)

C. fumosus l. Bolivar 1884

C. rotundus Kirby 1902

C. rendalli Kirby 1902

***Chrotogonus homalodemus* (Blanchard 1836)**

Ommexecha homalodemum Blanchard 1836

C. lugubris Serville 1839

C. concavus Kirby 1914

***Chrotogonus senegalensis* Krauss 1877**

C. abyssinicus l. bolivar 1904

C. lameerei l. Bolivar 1904

C. lameerei ituriensis Sjostedt 1923

Genus ***Aularches***

Aularches, Stal, CEfv. Vet.-Akad. Forh. xxx (4), 1873, p. 51.

Type, *Gryllus* (*Locusta*) *miliaris*, L.

Range, Indian Region.

Size large, body stout, pronotum tuberculate, wings large, coloured. Head large, smooth; scutellum of the vertex very short, triangular, contracting uninterruptedly into a narrow sulcated frontal ridge ceasing below the antennae; lateral carinae very distinct, running within the eyes, and slightly divergent to the extremity of the clypeus, which is broad and truncated. Antennae rather long, placed between the eyes, and composed of a number of long joints. Pronotum strongly tuberculate above, with two large contiguous humps in front, cut by the three sulci, the last sulcus placed about the middle, the hinder area rugose and deeply pitted at the sides; deflexed lobes rounded behind. Tegmina long, moderately broad, subparallelsided, obtusely rounded behind, with callous spots; wings membranous, opaque, as long as the tegmina, and moderately broad. Abdomen slightly compressed legs long and slender. Hind femora unarmed, and only slightly thickened.

***Aularches miliaris,* L.**

Gryllus (*Locusta*) *miliaris*, Linnaeus, Syst. Nat. (ed. x.) i, 1758, p. 432; Linnaeus, Mus. Lud. Ulric. 1764, p. 142.

Acrydium verrucosum, De Geer, Mem. Ins. iii, 1773, p. 486, pl. xI, fig. 6.

Gryllus (*Locusta*) *scabiosus*, Stool (*nec* Fabr.), spectres, Saut. 1813, p. 18, pl. 76, fig. 24.

Gryllus (*Locusta*) *conspercus*, Stoll, op. cit. 1813, p. 40, pl. 226, fig. 85.

Aularches miliaris, Stal, Recens, Orth. i, 1873, p. 18.

***Aularches punctatus,* Drury.**

Gryllus (*Locusta*) *punctatus*, Drury, III. Exot. Ent. ii, 1773, pl. xIi, fig. 4.

***Aularches scabiosae,* F.**

Gryllus scabiosae, Fabricius, Ent. Syst. ii, 1793, p. 51.

Genus ***Poecilocerus***

Poekilocerus, Serville, Ann. Sci. Nat. xxii, 1831, p. 275; id., Ins. Orth. 1839, p. 595.

Poecilocerus, Stal, CEfv. Vet-Akad. Forh. xxx (4) 1873, p. 51.

Type, *Gryllus pictus*, F.

Range, Indian Region, Western Asia, North and East Africa.

Size large; body stout, subfusiform; wings opaque, coloured. Head and pronotum very slightly carinated, fastigium of the vertex convex, obtusely rounded in front, and distinctly sulcated, passing into the frontal ridge, which is sulcated throughout; lateral carinae only slightly divergent; antennae short and thick, with long joints. Pronotum gradually widened behind, the sulci well marked, the hind sulcus placed about the middle, the hinder lobe raised, and rounded behind; deflexed lobes narrowed below. Abdomen slightly carinated above. Tegmina and wings coloured, about as long as the abdomen. Legs rather stout, the four front tibiae spined beneath at the extremity; hind femora slender, nearly as long as the abdomen, unarmed; hind femora slender, nearly as long as teh abdomen, unarmed; hind tibiae spined above, with nearly equal terminal spines above and below.

***Poecilocerus tessellatus,* Bol**.

Poecilocerus tessellatus, Bolivar, Bol. Soc. Espan. Hist. Nat. iv, 1904, pp. 432-433.

Poecilocerus sp.

***Poecilocerus pictus,* F.**

Gryllus pictus, Fabricius, Syst. Ent. 1775, p. 289.

Poekilocerus sonneratii, Serville, Ann. Sci. Nat. xxxii, 1831, p. 276.

***Poecilocerus punctiventris,* Serv**.

Poekilocerus punctiventris, Serville, Ins. Orth. 1839, p. 601.

***Poecilocerus* (?) *ornatus,* Burm.**

Poecilocera ornata, Burmeister, Handb. Ent. ii, 1838, p. 624.

Genus ***Chlorizeina***

Chlorizeina, Bruner, Ann. Mus. Genova, xxxiii, 1893, p. 130.

Type, *Chlorizeina unicolor*, Brunn.

Range, Burma.

Smooth, slender, subapterous. Fastigium of the vertex rather longer than the eye, sulcated; front very oblique, not sinuated. Antennae filiform, half as long again as the head and pronotum together. Pronotum cylindrical, rounded behind, finely punctured, the sulci slightly marked, the hind sulcus placed beyond the middle. Tegmina and wings rudimentary. Metasternal lobes contiguous in the male, and slightly separated in the female. Hind femora slender, the genicular lobes slightly pointed; hind tibiae hairy, with six or seven spines on the outer carina, besides the apical one. Anal segment of the male triangularly emarginate; supra-anal lamina pointed; tarsi in the male very slender, compressed, curved, and obtuse at the extremity; subgenital lamina of the male slightly compressed and hooked.

***Chlorizeina unicolor,* Brunn.**

Chlorizeina unicolor, Brunner, Ann. Mus. Genova, xxxiii, 1893 p. 131, pl. v, fig. 51.

Genus ***Pyrgomorpha***

Pyrgomorpha, Serville, Ins. Orth. 1839, p. 583.

Type, *Acridium conicum,* Oliv.

Range, Cosmopolitan.

Size small, body slender, more or less granulated. Head conical, fastigium of the vertex projecting considerably before the eyes; antennae inserted between and close to the eyes, short, narrowly ensiform. Pronotum rounded behind, carinated more or less continuously. Tegmina long and narrow, or abbreviated, more or less pointed at the extremity; wings hyaline, or red at the base. Metasternal foveolae separated by a transverse space; abdomen compressed, generally with transverse dark band. Legs long and slender.

***Pyrgomorpha conica,* Oliv.**

Acrydium conicum, Olivier, Encycl. Meth., Ius, vi, 1791, p. 230.

Truxalis grylloides, Latreille, Hist. Nat. Crust. Ins. xii, 1804, p. 148.

Truxalis rosea, Charpentier, Hor. Soc. Ent. Ross. 1825, p. 128, pl. iii, fig. 8.

Truxalis linearis, Chrpentier, op. cit. 1825, p. 129, pl. iii, fig. 2.

Truxalis rhodoptila, Herrich-Schaffer, Panzer, Faun. Ins. Germ. clvii, 1838, pl. 16.

Opomala cingulata, Walker, Cat. Derm. Salt. B.M. iii, 1870, p. 517.

***Pyrgomorpha brachycera,* sp. nov.**

***Pyrgomorpha bispinosa*, Walk.**

Pyrgomorpha bispinosa, Walker, Cat. Derm. Salt. B.M. iii, 1870, p. 499.

Pyrgomorpha indica, Bolivar, Ann. Soc. Ent. France, lxx, 1902, p. 66.

Genus ***Zarytes***

Zarytes, Bolivar, Bol. Soc. Espan. Hist. Nat. iv, 1904, p. 456; id. Gen. Ins. Orth. Acrid. Pyrg. 1909, pp. 27, 32.

Type, *Pyrgomorpha squalina*, Bol.

Range, India.

Long and slender, wings rudimentary. Head conical; fastigium of the vertex slightly contracted, rounded in front, not longer than the eye, and carinated above; front very oblique, frontal ridge compressed between the antennae, and sulcated; sides of face with an oblique row of granules. Antennae rather long and thick, triquetral at the base, brown, inserted between the eyes, which are oblong. Pronotum somewhat compressed, slightly emarginate dorsally in front, rounded behind; tricarinate, with the lateral carinae distinctly arched before the middle, the typical sulcus placed behind the middle; deflexed lobes scarcely higher behind, traversed within by an oblique branch from the carinae of the metazona; the lower margin straight, entire, rectangular behind, the hind border somewhat excised. Tegmina lanceolate, only slightly longer than the intermediate femora, overlaping on the inner edge; wings very short. Prosternum slightly tumid in front; metasternum with a trapezoidal space between the lobes, not twice as broad as the lobes. Legs compressed, front femora of male slightly thickened, hind tibiae with no outer terminal spine. Abdomen compressed, obtusely carinated above value of the ovipositor sinuated.

***Zarytes squalina,* Bol.**

Pyrgomorpha squalina, Bolivar, Ann. Soc. Espan. xiii, 1884, pp. 422 423, 495; id., Ann. Soc. Ent. France, lxx, 1902, p. 606.

Genus ***Anarchita***

Anarchita, Bolivar, Bol. Soc. Espau. Hist. Nat. iv, 1904, p. 459; id., Gen. Ins., Orth. Acrid. Pyrg. 1909, pp. 27, 33.

Type, *Pyrgomorpha aptera*, Bol.

Range. S. India.

Slender, subfusiform, apterous. Head conical, longer than the pronotum, horizontally produced; fastigium horizontal, as long as the eye, tempora separated in front only by a short suture; front very oblique, bisinuate, costal ridge finely sulcated, but much compressed and entire between the antennae. Antennae short, filiform triquetral, but not dilated at the base, and inserted between the eyes; basal joints 3-6 subquadrate and subdilated in the male, in the female subtransverse and slightly expanded. Eyes oblong; cheeks with one oblique row of granules. Pronotum short, sinuated before and behind, the median carina slightly indicated, and interrupted by the principal sulcus much beyond the middle, the intermediate sulcus interrupted and curved forwards; the lateral carinae of the prozona parallel, and slightly curved inwards, those of the metazona diverging in front, and obliquely traversing the lateral lobes; deflexed lobes slightly expanded behind, the lower margin bisinuate, the hinder angle obtuse. Legs very short; four front femora ridged, the intermediate ones scarcely extending to the base of the hind femora; the hind femora shorter than the abdomen, with the externo-median area ridged, and the lower outer area slightly expanded; hind tibiae with rounded spines, and no outer terminal spine; tarsi very short. Prosternum tumid in front; mesosternal lobes separated by a curved trapezoidal space, broader behind; metasternal foveolae separated by a transverse space. Abdomen longitudinally striated; value of the ovipositor sinuated.

***Anarchita aptera*, *Bol*.**

Pyrgomorpha aptera, Bolivar, Ann. Soc. Ent. France, lxx, 1902, p. 607.

Genus ***Tagasta***

Type, *Mestra hoplosterna*, Stal.

Range. Oriental Region

Body subfusiform, slightly compressed, pubescent above. Head conical, shorter than the pronotum, or of equal length; tempora widened in front, only separated by short suture; front very oblique , frontal ridge much flattened, hardly sulcated , shortly compressed between the antennae; the later concolorous, filform, and inserted between the eyes , with joints about three times as long as broad, the basal joints slightly flattened, and the tip extending to the hind border of pronotum; eyes rounded; ocelli distinct, cheeks granulated. Pronotum pubscent, roundly trunked in front, obtusely angulated or rounded behind, with the median carina slightly indicated, or obsolete, and the lateral carinae obsolete; the sulci slightly marked, and the hind sulcus placed behind the middle; the prozona considerably longer than the metazoan; the deflexed lobes distinctly higher behind, the lower margin oblique, subsinuate, bordered with whitish the anal angle obtuse, nearly rectangular. Tegmina not or scarcely longer than the hind femora, with the costal area considerably expanded near the base. Wings distinctly shorter than the tegmina, red or hyaline. Legs long and slender; front femora distinctly thickened in the male, hind femora compressed, the outer area with radiating ridges; hind tibiae with rounded spines, and with an outer apical spine above. Prosternum strumose or armed with a tooth; mesosternal lobes separated by a longer or shorter space; meta sternal foveolae separated by a transverse space. Valves of the ovipositor sinuated.

Tagasta, Bolivar, Bel. Soc. Espan. Hist. Nat. v, 1905, p. 112.

Mestra, Stal (*nec* Hubner), CEfv, Vet.-Akad. forh. xxxiv (10), 1877, p. 52.

***Tagasta notata,* Brunn.**

Mestra notata, Brunner, Ann. Mus. Genova, xxxiii, 1893, p. 130, pl. v, fig. 50.

***Tagasta indica,* Bol.**

Tagasta indica, Bolivar, Bol. Soc. Espan. Hist. Nat. v, 1905, pp. 112, 113.

Genus ***Atractomorpha***

Atractomorpha, Saussure, Ann. Soc. Ent. France, (4) i, 1861, p. 474.

Type, *Truxalis crenulatus*, F.

Range. Ethiopian, Oriental, and Australian Regions.

Body long and slender, compressed. Head conical, rarely longer than the pronotum; fastigium about as long as the eye; front very oblique, frontal ridge compressed between the antennae, and usually sulcated to the extremity. Antennae short, triquetral, subfiliform, very slightly depressed and widened at the base in the female, and inserted at the tip of the fastigium; eyes oblong; cheeks with a row of granules extending to the middle coxae. Pronotum sub-emarginate in front, and obtusely angulated behind, very slightly tricarinate, the hind sulcus placed behind the middle; the deflexed lobes almost perpendicular, broader behind, with the hind margin arcuately incised, and the hinder angle more or less produced behind. Tegmina rather pointed, with the costal area slightly expanded towards the base. Wings nearly as long as the tegmina, pointed at the tip, hyaline, often red at the base. Legs slender, hind femora with the externo-median area somewhat oblique and distinctly broader than the lower area; knees shortly bilobate; hind tibiae smooth, with pointed spines, and an outer terminal spine. Prosternum with an obliquely truncated tubercle in the middle, or submarginate, and concave in frons; metasternal lobes behind the foveolae separated by a transverse space. Abdomen slightly compressed, with the last dorsal segment angularly excised; supra-anal lamina trigonate, cerci short, conical; values of the ovipositor sinuated, and slightly crenulated.

***Atractomorpha crenulata,* F.**

Truxalis crenulatus, Fabricius, Ent. Syst. ii, 1793, p. 28.

Atractomorpha crenulata, Saussure, Ann. Soc. Ent. France, (4) i, 1861, p. 475.

Atractomorpha crenulata, var. prasina, Bolivar, Bol. Soc. Espan. Hist. Nat. v, 1905, pp. 197, 201.

Acridium psittacium, De Haan, pt., Temminck, Verhandel, Orth. 1842, p. 149, pl. xxiii, fig. 1 (*nec* p. 146)

***Atractomrpha scabra,* Thunb.**

Truxalis scaber, Thunberg, Mem. Acad. Petersb. v, 1815, p. 266.

Truxalis porrecta, Walker, Ann. Mag. Nat. Hist. (3) iv, 1859, p. 222.

Atractomorpha consobrina, Saussure, Ann. Soc. Ent. France, (4) i, 1861, p. 475.

***Atractomorpha psittacina,* de Haan.**

Acridium (*Truxalis*) *psittacinum*, De Haan, Temminck, Verhandel., Orth. 1842, p. 146.

Acridium crenulatum, De Haan (*nec* Fabr.), op. cit. 1842, pl. xxiii, fig. 2.

***Atractomorpha burri,* Bol.**

Atractomorpha burri, Bolivar, Bol. Soc. Espan. Hist. Nat. v, 1995, pp. 197, 203.

***Atractomorpha himalayica,* Bol.**

Atractomorpha himalayica, Bolivar, Bol. Soc. Espan. Hist. Nat. v, 1905, pp. 198, 204.

***Atractomorpha blanchardi,* sp. nov.**

Genus ***Orthacris***

Orthacris, Bolivar, Ann. Soc. Espan. xiii, 1884, pp. 24, 439, 496.

Type, *Orthacris filiformis*, Bol.

Range, India, Ceylon.

Body slender, apterous. Head conical, fastigium horizontally produced before the eyes, vertex carinate, tempora very short, with a short suture in front; front very oblique, not sinuated, costal ridge compressed between the antennae, and sulcated throughout, lateral carinae distinct, but interrupted; antennae filiform, inserted between the eyes, joints 3 and 4 triquetral; eyes short, oblong, with a row of granules behind. Pronotum pubescent, not carinated, hardly expanded behind, Pronotum pubescent, not carinated, hardly expanded behind, the hinder sulcus placed at one-fourth of its length, the metazona very short; the deflexed lobes rounded, equally high before and behind and the lower margin more or less thickened. Legs short; four front femora slender, rather compressed, the middle ones extending to the extremity of the hind coxae; hind tibiae pubescent at the base, with rather pointed spines towards the tip; outer terminal spine present or absent. Prosternum with a short pointed tubercle; sternal lamina long; mesosternal lobes rounded within, sub-contigunous, or separated by a very narrow space. Supra-anal lamina lanceolate; cerci curved at the tip in the male, straight and very short in the female; infra-genital lamina in the male hooked and slightly produced at the tip. Valves of the ovipositor sinuate.

***Orthacris filiformis*, Bol.**

Orthaciris filiformis, Bolivar, Ann. Soc. Espan. xiii, 1884, pp. 439, 496, pl. ii, fig. 11.

***Orthacris maindroni*, Bol.**

Orhtacris maindroni, Bolivar, Bol. Soc. Espan. Hist. Nat. v, 1905, p. 278.

***Orthacris ruficornis*, Bol.**

Orthacris ruficornis, Bolivar, Ann. Soc. Ent. France, lxx, 1902, p. 608.

***Orthacris elegans*, Bol.**

Orthacris elegans, Bolivar, Ann. Soc. Ent. France, lxx, 1902, pp. 608, 609.

***Orthacris acuticeps*, Bol.**

Orthacris acuticeps, Bolivar, Ann. Soc. Ent. France, lxx, 1902, pp. 608, 610.

***Orthacris simulans*, Bol.**

Orthacris simulans, Bolivar, Ann. Soc. Ent. France, lxx, 1902, pp. 608, 611.

Genus ***Colemania***

Colemania, Bolivar, Bol. Soc. Espan. Hist. Nat. x, 1910, p. ....

Type, *Colemania sphenarioides*, Bol.

Range, India.

Body long, sub-cylindrical, fusiform in the male, and inflated in the middle. Fastigium of the vertex produced beyond the frontal ridge, longer than the eye, front sloping, slightly sinuated, antennae 19-jointed, tapering from the third joint to the tip; frontal ridge sulcated, compressed at the base, obsolete before the mouth, ridge sulcated, compressed at the base, obsolete before the moth, lateral carinae slightly diverging, genae with a slightly marked row of granules; eyes small, longer than broad, trancated behind; ocelli visible, the middle one between the eyes, and the lateral ocelli placed before the eyes. Pronotum conical in the male. Cylindrical in the female, the two anterior sulci obliterated. The last continuous and placed much beyond the middle; the lateral lobes long, with the margins entire, the front margin oblique, the lower one straight, indistinctly sinuated behind. Tegmina very narrow, longer than the pronotum; wings obsolete. Prosternum acutely spined; mesosternal lobes long, in the male truncated and contiguous behind, in the female expanded in front and rounded behind; metasternal foveolae nearer together in the male than in the female. Legs short, front femora thickened in the male; hind femora slender, with the outer area narrow, with much indistinct pinnate rugae, the rugae, the genicular lobes angulately produced and tibiae slender, the apical third expanded, and smooth above, with nine outer and eleven spines, and apical spines on both sides; hind tarsi slender, the first joint twice as long as the second. Abdomen cylindrical, sub-clavate at the tip; last dorsal segment of the male transverse, trisinuated behind, supra anal lamina forming a long triangle, longer than the cerci sulcated and subulate at the tips in the male, short and straight in the female; subgenital laminae compressed, subcarinate behind; valves of the ovipositor short, sinuate.

Colemania sphenarioides

Colemania sphenarioides, Bolivar, Bol. Soc. Espan. Hist. Nat. x, 1910, p. 320; Coleman, J. Bombay Soc. xx. 1911, p. 879; H. Maxwell Lefroy, J. Bombay Soc. xix, 1910, p. 1007.

Genus ***Trigonopteryx***

Trigonopteryx, Charpenner, Orthopt. 1841 pl. v.

Type, *Trigonopteryx punctata*, Charp.

Range, Oriental Region

Body long, much compressed. Head conical, compressed in front, vertex ascending, fastigium sinuated on the sides, and angulated in front, tempora narrow, separated by a very narrow suture: front oblique, sinuated, the frontal ridge between the antennae and the tip of the antennae raised, the margins separated forming a pyriform foveolae, obsolete before the ocelli; antennae rather long, triquetral, ensiform, externally dentated, inserted near the eyes, the apical joint pubescent; eyes oblong, slightly sinuated, no lateral facial carinae. Pronotum compressed, back narrow, parallel-sided, rounded and slightly sinuated in front, behind obtusely angulated but not produced; the typical sulcus indistinct, placed rather beyond the middle; the deflexed lobes perpendicular, but with obtuse carinae, trapezoidal, considerably raised behind, with the inner margin straight, the hinder margin somewhat sinuated, and the hinder angle acute. Tegmina long, extending much beyond the hind femora, the anal nervure straight. Legs compressed; front femora short, the intermediate femora passing the extremity of the coxae, the hind femora compressed, with external median area well developed; hind tibiae slender, with an outer apical spine; tarsi very short. Prosternum with a short rounded tooth in the middle, sternal lamina very long, in front obtusely angulated; the mesosternal lobes broadly rounded on the inner side, with the intervening space much narrower. Supra-anal lamina in the female long, triangular, sulcated; cerci conical, very short; valves of the ovipositor compressed, sinuated.

***Trigonopteryx punctata*, Charp.**

Trigonopteryx punctata, Charpentier, Orthop. 1841, pl. v.

Key to Species of Pyrgomorphid Fauna in South Western Rajasthan

1 Antennae larger than body, many segmented; tympanum present on fore tibia. ……………………………………………………………………………………… Ensifera

Antennae shorter than body; tympanum present on either side of the first abdominal segment……..………………………… Caelifera………………………………...2

2(1) Face mostly flattened, cubital vein of tegmina and medial vein of hind wing unbranched. Antenna shorter than front femur; basal segment of hind tarsus with serrated margins or with teeth or at least with a basal external tubercle ……………………...………..……………………….…………...Eumasticidae

Face not flattened, cubital vein of tegmina and medial vein of hind wing usually branched, antenna longer than front femur, basal segment of hind tarsus never serrated, never with tooth or tubercle …..…………………………….........……3

3(2) Fastigial furrow present; apical areolae generally present; lower basal lobe of hind femur longer than upper lobe …………..….Pyrgomorphidae …...…………..….…4

Fastigial furrow absent; apical aerolae absent, lower basal lobe of hind femur shorter than or as long as upper lobe...…...………………………...……………. Acrididae

4(3) Anterior margin of pronotum forming wide collar, covering posterior and lower part of mouth……….. …… *Chrotogonus* ……………..……………...……...………5

Anterior margin of pronotum not covering posterior and lower part of mouth ……...6

5(4) Tegmina reaching upto apex of abdominal segment (Plate VI)……………………… ………...…………………………………….……..……*trachypterus* Blanchard

Tegmina reaching up to fourth abdominal segment (Plate VII)…*oxypterus* Blanchard

6(4) Body slender; antennal bases located infront of lateral ocelli ..…………..………... 7

Body robust; antennal bases located between or behind lateral ocelli ………..……10

7(6) Head conical rarely longer than pronotum gena with arrow of granules extending to the middle…………………..*Atractomorpha*.…..…………………….………..……..8

Latero-posterior margin of pronotum with spine-like protrusion…………..…………. …………..…………………….……*Pyrgomorpha*.…...………...……...………9

8(7) Tegmina green, hind wings red at base (Plate VIII)..………………...…...*crenulata* F.

9 (7) Hind wing rather shorter, with the inner part of the disc rosy (Plate IX)…………….. ………………………………..………………………….....…...……….*bispinosa* Walk.

10(6) Posterior lobe of pronotum level, not raised; without rugae…..*Poekilocerus*.…..…11

11(10) Antennae ringed with black and yellow (Plate X) ………….…..……..........*pictus* F.

4.3 Effect of food plants on the growth and development of C. *trachypterus*:

The field collected surface grasshopper adults were maintained in the laboratory under controlled conditions of temperature and humidity on mixed food. In about 3 to 5 days after mating, the gravid females laid eggs in the egg tubes provided at the bottom of the rearing cages. The incubation period ranged from 17 to 30 days. The hoppers hatched out and developed further into fledglings. The first instar hoppers took 8 to 11 days; the second instar 7 to 11 days; third instar 7 to 9 days; fourth instar 6 to 9 days; fifth instar 6 to 8 days and sixth instars 6 to 10 days when the hoppers were maintained on mixed food, comprising tender parts from the 10 different host plants selected for food preference studies.

The food preference studies during 2005-06 indicated that the growth index for hoppers was maximum on lucerne (5.76) followed by that on wheat (5.37), barley (4.91), mixed food (4.24), oats (4.14), gram (4.02), *Bermuda grass* (3.59) and spinach (3.37); on the contrary, for nut grass (2.74) and pigweed (2.48) , the growth index was the lowest. The growth index for hoppers on the host plants evaluated were in the following descending order of Lucerne > wheat > barley > mixed food > oats > gram > Bermuda grass> spinach > nut grass > pigweed. The Table (35) and Graph (21) on the effect of host plants on the developmental potential of the surface grasshopper clearly depicts that hopper duration was shortest when they were fed lucerne; the IV, V and VI instar hoppers taking 5.750, 5.125 and 6.500 days, respectively, totaling to 17.375 days to attain fledgling stage. A comparison among the different food plants showed that on lucerne hoppers took the minimum period (17.375 days) to develop into a fledgling, while on pigweed development took the maximum period (25.250 days). The development period of hoppers from IV instar onwards on the other food plants provided ranged from 17.375 to 25.250 days. Hopper survival on lucerne, wheat and barley was 100 percent and the hopper survival was 100, 90 and 90 percent on mixed food for all the three instars, whereas for oats, the survival was 100, 92.50 and 90 percent for all the three instars. Lowest survival was observed for hoppers reared on *pigweed*, with 82.50, 72.50 and 67.50 percent for the IV, V and VI instars, respectively. However, irrespective of the host plant, the sixth instar hoppers developed into fledglings, showing a 100 percent survival.

The effect of different host plants on food utilization indices (Table 37 and Graph 23 & 24) during 2005-06 by the surface grasshopper evinced that efficiency of conversion of ingested food (ECI) was high, when the hoppers were reared either on wheat (36.53%) or mixed food (35.20%), which in turn significantly differed with the values for gram (27.87%), oat (27.17%), spinach (26.41%) and Bermuda grass (25.06 %). Pigweed (16.21 %) followed by moth (19.28 %) had significantly the lowest ECI. The Approximate digestibility (AD) was equally high, when the hoppers were reared on lucerne (45.20%), and significantly differed with that for wheat (40.82%), spinach (40.80%), Bermuda grass (40.79%) and oat (40.18%). The lowest AD was found in gram (38.39 %) followed by pigweed (38.46%). The efficacy of conversion of digested (ECD) food into body substances was significantly the maximum for hoppers raised on wheat (89.50%) followed by that when reared on mixed food (84.66%), which significantly differed with that for gram (72.61%), Lucerne (71.01%), barley (70.33%), oats (67.61%) and spinach (64.74%). The ECD was significantly the lowest for hoppers on pigweed (42.14%) followed by nut grass (44.91%).

Similar studies conducted during 2006-07 showed that the growth index for hoppers was the maximum on lucerne (5.63) followed by that on wheat (5.26), barley (4.70), mixed food (4.16), oats (4.09), gram (4.07), Bermuda grass (3.63) and spinach (3.42). For pigweed (2.42) and nut grass (2.70) growth index was the lowest (Table 36). The growth index for hoppers on the host plants were in a descending order as lucerne > wheat > barley > mixed food > oats > gram > Bermuda grass > spinach > nut grass > pigweed. The Table (36) and Graph (22) on the effect of host plants on the developmental potential of the surface grasshopper clearly depicts that hopper duration was shortest when hoppers were fed lucerne; the IV, V and VI instar hoppers taking 5.875, 5.250 and 6.625 days, respectively, totaling to 17.750 days to attain fledgling stage. Comparison among the different food plants showed that on lucerne, hoppers took the minimum period (17.750 days), while on pigweed the hoppers required maximum period (25.875 days) to develop into fledgling from the IV instar onwards. The development period of hoppers from the IV instar onwards on the other food plants ranged from 17.750 to 25.875 days. Hopper survival on lucerne and wheat was 100 per cent and the survival was 100, 92.50 and 90 percent on mixed food for all the three instars, whereas on oats, the survival was 100, 95 and 90 percent for all the three instars.

Lowest survival was observed for hoppers reared on pigweed with 82.50, 75 and 62.50 per cent for the IV, V and VI instars, respectively. However, irrespective of the host plants, the sixth instar hoppers developed into fledglings (showing a 100 percent survival). However, no valid reasons can be ascribed to such a phenomenon, as it is basically a natural process.

The effect of different host plants on food utilization indices (Table 37 and Graphs 23 & 24) in 2006-07 for the surface grasshopper evinced that efficiency of conversion of ingested food (ECI) was equally high irrespective of the fact that hoppers were reared on wheat (36.83 %) or mixed food (35.13 %), which in turn significantly differed with that for gram (27.97 %), oats (27.32 %), spinach (25.82 %) and Bermuda grass (25.12 %). Feeding on pigweed (15.49 %) followed by nut grass (19.17 %) had significantly the lowest ECI. Similarly, approximate digestibility (AD) was high when the hoppers were reared on lucerne (45.21 %) that significantly differed for wheat (41.98 %), spinach (40.38 %), Bermuda grass (40.30 %) and oats (40.51 %). The lowest AD was for gram (38.36 %) followed by pigweed (38.59 %). The efficacy of conversion of digested food into body substances was significantly the maximum for hoppers raised on wheat (87.75 %) followed by mixed food (83.54 %), which significantly differed with that for gram (71.97 %), lucerne (70.56 %), barley (70.79 %), oats (67.43 %) and spinach (63.95 %). The ECD was significantly the lowest for hoppers on pigweed (40.14 %) followed by that on nut grass (44.58 %).

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5. DISCUSSION

5.1 Survey of Pyrgomorphid fauna of south-western Rajasthan:

Some members of the Orthopteran families Acrididae and Pyrgomorphidae, commonly known as grasshoppers and surface grasshoppers, have been reported to be important pests of forage and crop plants. The Pyrgomorphids are relatively less important as pests than are the Acridids. Our knowledge of the Indian Acridid (inclusive of the now Pyrgomorphid) field ecology had been practically based almost exclusively on locust research (Hussain *et al*., 1946; Roonwal, 1945; Ramachandra Rao, 1960).

5.1.1 Diversity:

The results of the survey conducted in the five districts of Rajasthan *viz*., Banswara, Dungarpur, Rajsamand, Sirohi and Udaipur during 2005-06 and 2006-07 under the present investigation indicated that five species of short homed grasshoppers belonging to the family Pyrgomorphidae were regularly abundant in the maize-wheat agro-ecosystems. The diversity comprised four genera (*Chrotogonus*, *Atractomorpha*, *Pyrgomorpha* and *Poekilocerus*) and five species *i.e*. *Chrotogonus trachypterus* (Blanchard), *Chrotogonus oxypterus* (Blanchard), *Atractomorpha crenulata* Fabricius *Pyrgomorpha bispinosa* Walker and *Poekilocerus pictus* Fabricius. A study of the literature reveals that surface grasshoppers are widely distributed in the Orient and Africa. In India, *C. trachypterus* is more common in the north, whereas *C. oxypterus* occurs in the southern regions. The surface grasshopper has been recorded as a serious pest of pastures almost throughout the year. It is reportedly a polyphagous minor pest of agricultural crops and is uniformly distributed throughout the plains of India, having regular breeding season. Lefroy (1906, 1907 and 1909), Latif and Haq (1951) and Joyce (1952) observed the insect to be active throughout the year as also by Chahal and Sohi (1964).

Little work seems to have been done on other species of Pyrgomorphids as could be observed from the available literature. However, in a study of the species composition and community structure of the acridoid fauna in selected habitats of a moist deciduous forest in India, Joshi *et al.* (1999) observed that the habitats represented a range of anthropogenic disturbances, including an undisturbed site, a naturally recovering site (deforested and replanted 20 years earlier), a moderately disturbed site (lightly grazed by cattle), and a severely disturbed site (artificially reforested and heavily grazed by livestock). The former three study sites were mixed forests, dominated by *Shorea robusta* Gaertn. f., and *Mallotus philippinensis* Muell- Arg., and the latter site were a plantation of *Tectona grandis* Linn. F. The sites supported a total of nine species of Acrididae and Pyrgomorphidae. *Oxya velox* Fabr. *Cantantops humilis humilis* Serv., and *Atractomorpha crenulata* Fabr. were the most abundant species, representing 17 to 27 percent of the total number of individuals collected. With respect to potential indicator species, 93 to 100 percent of *Tylotropidius varicornis* Walk., *Eupropocnemis alacris* S., and *Chrotogonous trychypterus* Blanchard were found only in the sites that were not currently disturbed. Conversely, in the disturbed habitats, *O. velox* and *A. crenulata* were ca. 1.7 times more abundant than in the other sites. The diversity, evenness and richness of the sites tracked the intensity of disturbance, the greatest values being associated with the undisturbed site, followed by the naturally recovering site, the moderately disturbed site, and the severely disturbed site. The undisturbed site had the greatest acridoid abundance, while the other sites supported less than one-third as many grasshoppers. In all ecological measures, the effects of disturbance were much greater than the changes associated with seasonality. Thus, grasshopper communities are sensitive to anthropogenic disturbance, and the community structure of acridoids may be a viable diagnostic tool in assessing environmental conditions.

5.1.2 Population abundance of Pyrgomorphids:

The genus *Chrotogonus*, represented by *C. trachypterus* and *C. oxypterus*, were relatively more abundant in Udaipur district than in the other four districts surveyed. The climatic conditions at Udaipur with a precipitation range of 500 to 700 mm and an average of 610 mm; annual temperature range of 38.3 to 28.8 ^{o}C during summers and 28.3 to 11.6 ^{o}C during winters favours the multiplication of the species. The hilly tracts with low average soil depth and the plains with more soil depth both provide congenial edaphic conditions for its growth and development. Kevan (1954) observed that the genus *Chrotogonus* Audinet-Serville 1839 contains among its species certain insidious crop pests that the exact status is difficult to determine. This genus has been reported to be destructive both in the Indian region and tropical Africa. Misidentifications such as *C. lugubris* in place of *C. trachypterus* by Cotes (1889), *C. robertsi* incorrectly named for *C. oxypterus* (Ballard, 1921) have also made it difficult for workers to concentrate on this genus. Species of *Chrotogonus* are geophilus and occur for most part on bare soil, especially near water where humidity is relatively higher, some may be found at considerable distances from water and even under relatively dry conditions.

Investigation on the habitat analysis and feeding studies on fourteen species/subspecies of grasshoppers belonging to six subfamilies leading to understanding mouthpart adaptation to provide insight into feeding preferences; differential feeding tests to disclose feeding preferences under conditions of essentially uniform plant availability; and feculae composition to ascertain food selection in nature were carried out by Gangwere *et al.* (1998). Seven of the grasshopper species were phytophilous or thamnophilous, five were geophilous, and two were intermediate in their choice of perch; eight were essentially dicot feeders and six were grass feeders. The geophiles were noted to become scavengers on dried plant debris and sometimes arthropod remains in response to summer drought. *Dericorys* subspecies proved to be specializedfeeders, largely on Chenopodiaceae. Our study of this limited assemblage of grasshoppers demonstrated a relationship between their food availability and food selection and suggested that food availability may be as important a factor as preferences in determining their host plant selection.

In the present investigation, the species *A. crenulata* and *P. bispinosa* had a relatively equal representation in all the districts, but their numerical abundance was a little more in the district Banswara as compared to the other four districts surveyed. The species *P. pictus* was relatively more in district Rajsamand and was not recorded from the district Banswara. The genus has a preference for lower humidity conditions, as can be evidenced from the climatic conditions of Rajsamand district. The annual precipitation range being 500 to 1050 mm, with an average of 775 mm and the annual temperature range from 45 to 25 ^{o}C during summers and above 20 ^{o}C during the winter months.

The climate of the region has a major influence on the diversity and population abundance of the Pyrgomorphids, similar to that for other insects. Of the five species collected it was notable that, sparing the genus *Poekilocerus*, the other four genera were recorded in all the five districts, which can be explained by the relatively more dry conditions preferred by this genus as compared to the other genera, *Chrotogonus*, *Pyrgomorpha* and *Atractomorpha*. The associated vegetation and edaphic conditions are also important in influencing the Pyrgomorphid diversity. *Poekilocerus* prefers relatively light soils than do the other genera for egg laying and prefers to breed well in areas with sparse vegetation than in areas with dense, low-growing vegetation unlike the genus, *Chrotogonus*.

5.1.3 Pyrgomorphid population density:

Based on the mean density data recorded during the investigation during both years, the two species of *Chrotogonus* (*C. trachypterus* and *C. oxypterus*) had the highest mean density in the month of February in all the districts observed. Our results show that in the south-western regions of Rajasthan, the maximum mean density was during February in the cropped areas. However, the mean density when recorded from non-cropped areas is likely to be high during the monsoon period i.e., August – September. Earlier, Grewal and Atwal (1968) observed that for the nymphal development optimum conditions of temperature and humidity appeared to be within the range of 25 to 30^{o} C and 70% relative humidity in the laboratory, and that these favourable conditions in the field are likely to be met during the spring and more assuredly during the monsoon period in Punjab. After the spring there is general drying up of the grasses and food is likely to be a limiting factor combined with the injurious effect of high temperature (40^o C and above) the population built-up is not likely to be very great.

According to population counts made by Grewal and Atwal (1968) in the month of August the maximum number of nymphs and adults (73 per unit space) was found in the fallow fields of sandy soil under low grass, as against 27, 24 and 19 in sandy loam fields under *Cyamopsis tetragonoloba*, *Arachis hypogea* and *Saccharum spontaneum*, respectively. In the case of fallow clay soils and gravel fields, the average number of insects counted over the same distance was as low as 18 and 9, respectively. Much before, Kevan (1954) observed that taller vegetation provide unsuitable habitat for *Chrotogonus* species. *C. trachypterus* was found most abundant in fallow sandy soils covered with grasses and was the least abundant in fallow hard clay and gravel soils or in the fields under tall vegetation. Long back, Cotes (1891 and 1894) reported that the grasshoppers appear in June in Punjab and die in September; while, Uvarov (1927) and Bei-Bienko and Mish (1951) reported that *Chrotogonus trachypterus* hibernated in the nymphal stage during winters that does not hold true anymore.

During the present investigations the relative density of *C. trachypterus* and *C. oxypterus* was the maximum during the month of May in all the districts. In literature, records of relative density for *Chrotogonus* are wanting. The exact determining factors for the fluctuation in numbers are much more complex and the conditions obtained from year to year would indicate the expected levels of population. Due to sparse vegetation during May in most parts of Rajasthan the geophilus species, *Chrotogonus* had relatively the highest Relative Density as compared to the other Pyrgomorphids.

The mean density for *Atractomorpha crenulata* happened to be the maximum during the month of August in all the districts during 2005-06 and 2006-07. The relative density was the highest in August and September for this species. Similar works on bio-ecological studies in the literature are scanty, hence would be difficult to compare.

The grasshopper, *Pyrgomorpha bispinosa* had the maximum mean density during the month of August in most districts. However, it was observed to have two peaks for mean density in district Sirohi (during February and August). The relative density was the highest during August in all the districts. Parihar (1983) recorded two generations in a year for *Pyrgomorpha bispinosa deserti* (Bei-Bienko), based on whether the egg-hatch from the egg-pod was in January or July. Peak hopper population was observed in August whereas adults in September.

The Simpson Diversity Index and Shannon Weiner Diversity Index (Tables 27 & 28) values were the maximum during August during both the years. This conspicuously indicates the fact that the monsoon season (August-September) happened to comprise greater diversity of the Pyrgomorphids than the spring season (February-March).

During the present investigation, the colourful grasshopper, *Poekilocerus pictus* was recorded from four of the five districts; hence, the data were not included in comparisons with other genera commonly found in all the districts. However, our observations indicated that the adult and hopper populations of *Poekilocerus* were relatively more in district Rajsamand during 2005-06 and 2006-07. As the genus *Poekilocerus* prefers relatively light soils than do the other genera for egg laying and prefers to breed well in areas with sparse vegetation than in areas with dense, low-growing vegetation it was obviously more in numbers from Rajsamand and Sirohi distiricts than Udaipur, Dungarpur and Banswara. As reported from Jodhpur, the grasshopper, *P. pictus* has one generation in a year and the maximum population of nymphs was recorded in January, whereas of adults in June (Parihar, 1983). It has been recorded as a pest of agricultural and horticultural crops in the plains of India (Rai and Nagesha Chandra, 1973; Khurana, 1975). In the desert it was confined to some wild plantations (Parihar, 1974) and did little harm to cultivated crops. Host cross over for *P. pictus* from *Calotropis* to other garden plants was the maximum during April to July when the neo-alates developed and started mating. It was observed that plants of Apocynaceae family were most preferred followed by those of Solanaceae. The average numbers of grasshoppers were the maximum on *Tabernaemontana* during April-May and on *Chrysanthemum maximum* during October-March (Verma, 1998).

Based on the data on Mean Density and Relative Density in the surveyed area, comprising south west plains of Rajasthan and Aravalli hills, the Pyrgomorphid population could be classified into three groups – the spring breeders (*Chrotogonus*); the monsoon breeders (*Pyrgomorpha* and *Atractomorpha*) and the summer breeder (*Poekilocerus*).

5.2 Bionomics of the surface grasshopper, *Chrotogonus trachypterus* (Blanchard):

5.2. (a) Biology:

The females laid eggs in moist soil at a depth of 2 to 4 cm. Egg pods were hard, elongated and cylindrical with a slight bend at the middle. The egg pods measured 32.845 ± 0.519 mm long and 2.485 ± 0.029 mm broad, respectively; with an average number of 7.500 ± 0.249 egg pods per female. The average length and width of the egg was 3.483 ± 0.064 mm and 0.955 ± 0.010 mm, respectively, with an average of 9.050 ± 0.560 eggs per pod. The mean numbers of eggs laid per female were 65.500 ± 4.365. The incubation period was 22.975 ± 1.015 days under laboratory conditions. The total nymphal period (six instars) took from 43.50 to 53.50 days with an average of 48.513 ± 0.496 days.

Latif and Haque (1951) made some observations on *C. robertsi* (Kirby) and found that over-wintering eggs in the field took as much as 119 days to develop; whereas, in the laboratory at room temperature during various months of the year the duration of eggs varied from 18 to 51 days. The influence of soil moisture was very pronounced on the viability and rate of egg development in *Chrotogonus* (Parihar and Pal, 1978). Egg-laying was recorded to be throughout the year where the soil water was available especially in the gardens, irrigated crop fields.

The length of adult male body was 14.983 ± 0.077 mm, while that of the female was 20.436 ± 0.506 mm. The female was distinctly bigger than the male. The pre-oviposition, oviposition and post-oviposition periods were 18.000 ± 0.793, 36.150 ± 2.075 and 12.250 ± 1.039 days, respectively. Adult longevity of males and females was observed to be 54.350 ± 3.005 and 66.400 ± 3.210 days, respectively under laboratory conditions.

5.2 (b) Morphometrics:

The linear morphometric variations in the different body parts of the adult surface grasshoppers, *C. trachypterus* were evident as recorded through the mean values with standard deviations. Intra-specific variation for the morphological characters is more often natural and can possibly be attributed to their feeding behaviour. The grasshoppers were collected from wheat/ barley crops with a more or less common weed flora including *Chenopodium murale*, *C. album*, *Fumaria parviflora*, *Avena* sp., *Cynodon dactylon* and *Phalaris minor*. Feeding on some of these weeds apart from wheat and/ or barley could have implications on the growth and development of the surface grasshoppers. The coefficient of variation worked out for the different morphometric variations was the maximum for the numbers of spines on the outer fore legs in males (19.33 %) and outer middle legs in females (16.15 %). In both males and females the lower sternum width showed the lowest coefficient of variation (3.47 and 4.87% respectively). The lengths of antennae, tegmina, hind wing, body up to genitalia/ wing tip, pronotum, and the sternal region were relatively more for the females than the males; similarly the width of tegmina, body, pronotum, and the sternal region were also relatively more for the females. A comparison of the compounded ratios for some of the morphological traits showed that the ratio between length of hind femur and width of vertex (F/v) was the maximum (7.335 $\pm$ 0.132 and 7.151 $\pm$ 0.124) for the males and females, respectively. The lowest ratio happened to be for the ratio between the length and width of the pronotum (P/p) for both the males as well as the females (0.686 $\pm$ 0.014 and 0.624 $\pm$ 0.009).

Studies on biometrics have provided reliable sources of identification pertaining to various species of Acridids. Growth ratio in different instars has been studied for *Poekilocerus pictus* Fabricius (Novak, 1951; Dutta Gupta and Singh, 1957). Chemotaxonomic studies have immense value in taxonomy, especially in phylogenetic relationships, as has been shown by Kulkarni and Mehrotra (1970) in case of desert locust.

The mandibular adaptation of the sixteen species of grasshoppers, including four families, five subfamilies, and five main mandibular types and subtypes, in the grasslands of Inner Mongolia was investigated using scanning electron microscopy. The insects were collected from a wide variety of habitats, ranging from meadow steppe, steppe, semi-desert to desert. The mandible structures of graminvorous and forbivorous forms of these grasshopper species entirely agree with their food-habits. However, the herbivorous mandibles are not distinctly associated with the food-habits of these grasshopper species. The depth of central concavity in molar surface is positively correlated well with the proportion of dicot plants in food utilization (Kang *et al.*, 1999). Kohler *et al.* (2000) investigated the degree of mandible abrasion in three species of adult short-horned grasshoppers reared on grass leaves and cabbage. Age estimation was possible from SEM photographs of right mandibles of female and male *Chorthippus parallelus* from eight age groups (0-7 weeks). More precisely, in this grass-fed species the incisor length/width ratio declined linearly with age. In two other species, *Locusta migratoria* and *Pezotettix giornae*, the length of the second incisor did not change markedly with age. They concluded that mandible wear is a useful measure for adult age in grass-feeding Gomphocerinae in the field.

5.2. (c) Systematic account:

The species of *Chrotogonus* are closely similar and no satisfactory field characters exist by which they may be distinguished. Therefore in areas where more than one species occur, if specific identification is required, specimens must be submitted to an expert. The genus is readily recognized by its squat shape, brown, earthy coloration and dull appearance, strongly rugose integument and extremely slant-faced head. The development of wings is very variable, ranging from fully winged to micropterous, the latter category being readily regarded as apterous. Where wings are developed, the hind wings range from hyaline to heavily infuscate and the degree of infuscation has some diagnostic value. Six species are recognized in the subgenus *Chrotogonus*, One of the which, *C. turanicus* Kuthy 1905, is a rare central Asian species of no economic significance. The other subgenus, *Obbiacris* Kevan 1952, contains two rare

E. African species, which again have no economic significance. A revised check list of the species under the genus *Chrotogonus* has been presented.

In a relatively recent account, Pyrgacridinae is removed from Pyrgomorphidae and given status as the family Pyrgacrididae within Acridoidea. Lithidiinae is raised to the level of family within Acridoidea. Dericorythinae, Conophyminae, and Iranellinae (new subfamily), all previously included within Acrididae, are placed in the new family Dericorythidae. The subfamily Illapeliinae is moved to Ommexechidae. Marelliinae is recognized as a new subfamily within Acrididae. Presence of a well-developed arch sclerite should be treated as a crucial character in defining the family Acrididae (David, 2000).

5.3 Effect of food plants on the growth and development of C. *trachypterus*:

The effect of food plants as indicated by the growth index for hoppers showed the following descending order of preference lucerne > wheat > barley > mixed food > oats > gram > Bermuda grass > spinach > nutgrass > pigweed. The hopper duration was shortest when they were fed Lucerne. Hopper survival on lucerne, wheat and barley was 100 percent, whereas hopper survival was lowest when reared on pigweed; however, irrespective of the host plant, the sixth instar hoppers developed into fledglings, showing a cent per cent survival. The effect of different host plants on food utilization indices evinced that efficiency of conversion of ingested food (ECI) was high, when the hoppers were reared either on wheat or mixed food, but pigweed followed by nutgrass had significantly the lowest ECI. The AD was high when the hoppers were reared on lucerne and significantly low in gram. The efficacy of conversion of digested (ECD) food into body substances was significantly the maximum for hoppers raised on wheat and was significantly the lowest for hoppers on pigweed.

C. trachypterus is known to feed on a variety of food plants (Singh, 1961). Of the 112 plant species evaluated, only *Melia azedarach* and *Azadirachta indica* were refused (Latif and Haq, 1951).

Yousuf and Gour (1993) recorded *P. pictus* feeding on *Acacia senegal*, *Prosopis juliflora* and *Tecomella undulata*. Verma (1998) reported that *Plumeria alba*, *Tabenaemontana* (Apocynaceae) and *Chrysanthemum maximum* (Compositae) were preferred for feeding, while *Moringa oleifera* for congregation, besides *Acacia senegal*, *Prosopis juliflora* and *Tecomella undulata*. Earlier, Haldhar *et al.* (1995) observed that of the 51 plant species belonging to 23 families, 31 were always rejected, with the remaining 46 either sampled briefly or eaten as food by the grasshopper *Acrida exaltata*. Only 15 were regularly accepted as food. Plants of the family Poaceae were most preferred by *A. exaltata*.

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6. SUMMARY

Eco-taxonomic studies on the surface grasshopper [*Chrotogonus trachypterus* (Blanchard)] in south western Rajasthan were undertaken with a view to survey the pyrgomorphid fauna in agro-ecosystems of South Western Rajasthan; to quantify the diversity and abundance of the pyrgomorphid population; to study the bionomics of the surface grasshopper, *Chrotogonus trachypterus* (Blanchard) and its systematic acount and to evaluate the effect of food plants on the growth and development of C. *trachypterus*.

The survey conducted in the five districts of Rajasthan *viz*., Banswara, Dungarpur, Rajsamand, Sirohi and Udaipur during 2005-06 and 2006-07 under the present investigation indicated that five species of short homed grasshoppers belonging to the family Pyrgomorphidae were regularly abundant in the maize-wheat agro-ecosystems. The diversity comprised four genera (*Chrotogonus, Atractomorpha*, *Pyrgomorpha* and *Poekilocerus*) and five species *i.e*. *Chrotogonus trachypterus* (Blanchard), *Chrotogonus oxypterus* (Blanchard), *Atractomorpha crenulata* Fabricius *Pyrgomorpha bispinosa* Walker and *Poekilocerus pictus* Fabricius.

The genus *Chrotogonus*, represented by *C. trachypterus* and *C. oxypterus*, were relatively more abundant in Udaipur district than in the other four districts surveyed. The species *A. crenulata* and *P. bispinosa* had a relatively equal representation in all the districts, but their numerical abundance was a little more in the district Banswara as compared to the other four districts surveyed. The species *P. pictus* was relatively more in district Rajsamand and was not recorded from the district Banswara. The climate of the region has a major influence on the diversity and population abundance of the Pyrgomorphids, similar to that for other insects. Of the five species collected it was notable that, sparing the genus *Poekilocerus*, the other four genera were recorded in all the five districts, which can be explained by the relatively more dry conditions preferred by this genus as compared to the other genera, *Chrotogonus*, *Pyrgomorpha* and *Atractomorpha*. The associated vegetation and edaphic conditions are also important in influencing the Pyrgomorphid diversity. *Poekilocerus* prefers relatively light soils than do the other genera for egg laying and prefers to breed well in areas with sparse vegetation than in areas with dense, low-growing vegetation unlike the genus, *Chrotogonus*.

Based on the mean density data recorded during the investigation during both years, the two species of *Chrotogonus* (*C. trachypterus* and *C. oxypterus*) had the highest mean density in the month of February in all the districts observed. Our results show that in the south-western regions of Rajasthan, the maximum mean density was during February in the cropped areas. However, the mean density when recorded from non-cropped areas is likely to be high during the monsoon period i.e., August – September. The relative density of *C. trachypterus* and *C. oxypterus* was the maximum during the month of May in all the districts. Due to sparse vegetation during May in most parts of Rajasthan the geophilus species, *Chrotogonus* had relatively the highest Relative Density as compared to the other Pyrgomorphids. The mean density for *Atractomorpha crenulata* happened to be the maximum during the month of August in all the districts during 2005-06 and 2006-07. The relative density was the highest in August and September for this species. The grasshopper, *Pyrgomorpha bispinosa* had the maximum mean density during the month of August in most districts. The relative density was the highest during August in all the districts. The Simpson Diversity Index and Shannon Weiner Diversity Index values were the maximum during August during both the years. This conspicuously indicates the fact that the monsoon season (August-September) happened to comprise greater diversity of the Pyrgomorphids than the spring season (February-March). Accordingly, the Pyrgomorphid population could be classified into three groups – the spring breeders (*Chrotogonus*); the monsoon breeders (*Pyrgomorpha* and *Atractomorpha*) and the summer breeder (*Poekilocerus*).

The species of *Chrotogonus* are closely similar and no satisfactory field characters exist by which they may be distinguished. The genus is readily recognized by its squat shape, brown, earthy coloration and dull appearance, strongly rugose integument and extremely slant-faced head. The development of wings is very variable, ranging from fully winged to micropterous, the latter category being readily regarded as apterous. Where wings are developed, the hind wings range from hyaline to heavily infuscate and the degree of infuscation has some diagnostic value.

The females laid eggs in moist soil at a depth of 2 to 4 cm. Egg pods were hard, elongated and cylindrical with a slight bend at the middle. The egg pods measured 32.845 ± 0.519 mm long and 2.485 ± 0.029 mm broad, respectively; with an average number of 7.500 ± 0.249 egg pods per female. The average length and width of the egg was 3.483 ± 0.064 mm and 0.955 ± 0.010 mm, respectively, with an average of 9.050 ± 0.560 eggs per pod. The mean numbers of eggs laid per female were 65.500 ± 4.365. The incubation period was 22.975 ± 1.015 days under laboratory conditions. The total nymphal period (six instars) took from 43.50 to 53.50 days with an average of 48.513 ± 0.496 days.

The length of adult male body was 14.983 ± 0.077 mm, while that of the female was 20.436 ± 0.506 mm. The female was distinctly bigger than the male. The pre-oviposition, oviposition and post-oviposition periods were 18.000 ± 0.793, 36.150 ± 2.075 and 12.250 ± 1.039 days, respectively. Adult longevity of males and females was observed to be 54.350 ± 3.005 and 66.400 ± 3.210 days, respectively under laboratory conditions.

The coefficient of variation worked out for the different linear morphometric variations was the maximum for the numbers of spines on the outer fore legs in males (19.33 %) and outer middle legs in females (16.15 %). In both males and females the lower sternum width showed the lowest coefficient of variation (3.47 and 4.87% respectively). The lengths of antennae, tegmina, hind wing, body up to genitalia/ wing tip, pronotum, and the sternal region were relatively more for the females than the males; similarly the width of tegmina, body, pronotum, and the sternal region were also relatively more for the females. A comparison of the compounded ratios for some of the morphological traits showed that the ratio between length of hind femur and width of vertex (F/v) was the maximum (7.335 ± 0.132 and 7.151 ± 0.124) for the males and females, respectively. The lowest ratio happened to be for the ratio between the length and width of the pronotum (P/p) for both the males as well as the females (0.686 ± 0.014 and 0.624 ± 0.009).

The effect of food plants as indicated by the growth index for hoppers showed the following descending order of preference lucerne > wheat > barley > mixed food > oats > gram > Bermuda grass > spinach > nutgrass > pigweed. The hopper duration was shortest when they were fed on Lucerne. Hopper survival on lucerne, wheat and barley was 100 percent, whereas hopper survival was lowest when reared on pigweed; however, irrespective of the host plant, the sixth instar hoppers developed into fledglings, showing a cent per cent survival. The effect of different host plants on food utilization indices evinced that efficiency of conversion of ingested food (ECI) was high, when the hoppers were reared either on wheat or mixed food, but pigweed followed by nutgrass had significantly the lowest ECI. The AD was high when the hoppers were reared on lucerne and significantly low in gram. The efficacy of conversion of digested food (ECD) into body substances was significantly the maximum for hoppers raised on wheat and was significantly the lowest for hoppers on pigweed.

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ABSTRACT

Title: "Eco-taxonomic studies on the surface grasshopper, *Chrotogonus trachypterus* (Blanchard) in south-west Rajasthan"

S. L. Jat
Research Scholar*

Dr. R. Swaminathan
Major Advisor**

Studies on the pyrgomorphid fauna and the eco-taxonomy of the surface grasshopper [*Chrotogonus trachypterus* (Blanchard)] in south western Rajasthan were undertaken. The survey conducted in the five districts of Rajasthan *viz*., Banswara, Dungarpur, Rajsamand, Sirohi and Udaipur during 2005-06 and 2006-07 resulted in five species of short horned grasshoppers belonging to the family Pyrgomorphidae; *i.e*., *Chrotogonus trachypterus* (Blanchard), *Chrotogonus oxypterus* (Blanchard), *Atractomorpha crenulata* Fabricius *Pyrgomorpha bispinosa* Walker and *Poekilocerus pictus* Fabricius. Of these, *C. trachypterus* and *C. oxypterus* were relatively more abundant in Udaipur district than in the other four districts surveyed. The species *A. crenulata* and *P. bispinosa* had a relatively equal representation in all the districts, but their numerical abundance was a little more in the district Banswara as compared to the other four districts surveyed. The species *P. pictus* was relatively more in district Rajsamand and was not recorded from the district Banswara. During both years, the two species of *Chrotogonus* (*C. trachypterus* and *C. oxypterus*) had the highest mean density in the month of February and maximum relative density in the month of May in all the districts. The mean density for *A. crenulata* was the maximum during the month of August and the relative density in August and September in all the districts. The grasshopper, *Pyrgomorpha bispinosa* had the maximum mean density and relative density as well, during the month of August in all the districts surveyed. The monsoon season (August-September) happened to comprise greater diversity of the Pyrgomorphids than the spring season (February-March) based on the Simpson and Shannon Weiner Diversity Index values.

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The species of *Chrotogonus* are closely similar and no satisfactory field characters exist by which they may be distinguished. A comprehensive systematic account of the Pyrgomorphid genera of the Indian sub-continent from available literature and databases has been presented.

The females laid eggs in moist soil at a depth of 2 to 4 cm. The egg pods measured 32.845 ± 0.519 mm long and 2.485 ± 0.029 mm broad, respectively; with an average number of 7.500 ± 0.249 egg pods per female. The average length and width of the egg was 3.483 ± 0.064 mm and 0.955 ± 0.010 mm, respectively, with an average of 9.050 ± 0.560 eggs per pod. The mean number of eggs laid per female was 65.500 ± 4.365. The incubation period was 22.975 ± 1.015 days under laboratory conditions. The total nymphal period (six instars) took from 43.50 to 53.50 days with an average of 48.513 ± 0.496 days. The length of adult male body was 14.983 ± 0.077 mm, while that of the female was 20.436 ± 0.506 mm. The female was distinctly bigger than the male. The pre-oviposition, oviposition and post-oviposition periods were 18.000 ± 0.793, 36.150 ± 2.075 and 12.250 ± 1.039 days, respectively. Adult longevity of males and females was observed to be 54.350 ± 3.005 and 66.400 ± 3.210 days, respectively under laboratory conditions.

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, l-,y- tkV
'kks/kdrk*

vkj- LokfeukFku
e[; lykgdkj**

nf{k.kh if'peh jktLFkku e lrgh fVMM] [*Chrotogonus trachypterus* ¼Blanchard½] dh ikjh&ofxdh; ij v/;;u] d vUrxr fijxkekjfQM ik.khtkr dk vUo"k.k fd;k x;kA jktLFkku d ikp ftyk cklokMk] Mxjij] jkt leUn] fljkgh vkj mn;ij e 2005&06 vkj 2006&07 dh vof/k e lo{k.k fd;k] ftle fijxkekjfQMh dy d ikp tkfr;k Øe'k% *Chrotogonus trachypterus* ¼Blanchard½] *Chrotogonus oxypetrus* (Blanchard), *Atractomorpha crenulata* Fabricius, *Pyrgomorpha bispinosa* Walker vkj *Poekilocerus pictus* Fabricius ik;h x;hA bue l lo d nkjku *C. trachypterus* ,o *C. oxypterus* vkif{kd :i l mn;ij ftyk e vU; pkj ftyk dh ryuk e vf/kd n[k x;A *A. crenulata* vkj *P. bispinosa* dk lHkh ftyk e leku ifrfuf/kRo ik;k x;k ijUr lkif{kd :i l nlj ftyk d ctk; cklokMk ftyk e FkkM vf/kd ek=k e ik; x;A itkfr *P. pictus* lkif{kd :i l jktleUn ftyk e vf/kd l[;k e ik;h xb ijUr cklokMk ftyk e bl vfHkfyf[kr ugh fd;k x;kA nkuk o"kk dh vof/k e] *C. trachypterus* ,o *C. oxypterus* dk vf/kdre vkIr ?kuRo Qjojh ekg e if{kr fd;k x;k(tcfd] mudk lkif{kd ?kuRo lHkh ftyk e eb ekg e vf/kdre ik;k x;kA *A. crenulata* dk vkIr ?kuRo lHkh ftyk e vxLr ekg e vf/kdre Fkk vkj bldk vf/kdre lkif{kd ?kuRo vxLr o flrEcj ekg e FkkA lHkh ftyk e *P. bispinosa* dh vf/kdre vkIr ?kuRo o lkif{kd ?kuRo vxLr ekg e ik;k x;kA

* fo|k okpLifr Nk=] df"k ik.kh ,o dhV foHkkx] jktLFkku df"k egkfo|ky;] mn;ijA
* lg&vkpk;] df"k ik.kh ,o dhV foHkkx] jktLFkku df"k egkfo|ky;] mn;ijA

flEilu vkj 'kuu fofu;j fofo/krk eY; lpdkd d vk/kkj ij clr _r ¼Qjojh&ekp½ o ekulu _r ¼vxLr&flrEcj½ e fijxkekjfQM dy e vf/kdre fofo/krk ik;h x;hA

Chrotogonus dh itkfr;k d y{k.k cgr leku g rFkk mue dkb Hkh lUrk"ktud {k=h; y{k.k ektn ugh g ftld }kjk mue foHknu fd;k tk ldA Hkkjrh; miegk}hi e miyC/k lkfgR; vkj vkdMk d vk/kkj ij fijxkekjfQM tkfr;k dk ,d 0;kid Øe y[kk d :i e iLrr fd;k x;k gA

eknk, ue enk e 2 l 4 leh dh xgjkb rd v.M nrh gA v.M f'kEc dk eki 32-845 $ 0-519 fefe yEck o 2-485 $ 0-029 fefe pkMk rFkk ,d eknk vkIru 7-500 $ 0-249 v.M f'kEc nrh gA v.M dh vkIru yEckb o pkMkb Øe'k% 3-483 $ 0-064 fefe o 0-955 $ 0-010 fefe Fkh] lkFk e ,d v.M f'kEc e vkIru 9-050 $ 0-560 v.M ik; x;A ,d eknk dh vkIru v.M nu dh {kerk 65-500 $ 4-365 FkhA i;kx'kkyk ifjfLFkfr e v.M dk m"ek;u dky 22-975 $ 1-015 fnu vfdr fd;k tcfd dy f'k'k dky ¼Ng fu:i½ 43-50 l 53-50 fnu rd Fkk] lkFk gh vkIru f'k'k dky 48-513 $ 0-496 fnu ik;k x;kA 0;Ld uj d 'kjhj dh yEckb 14-983 $ 0-077 fefe Fkh tcfd 0;Ld eknk d 'kjhj dh yEckb 20-436 $ 0-506 fefe FkhA eknk d 'kjhj dh yEckb uj dh yEckb l vf/kd FkhA v.M fu{ki.k io vof/k] v.M fu{ki.k vof/k vkj v.M fu{ki.k i'p vof/k Øe'k% 18-000 $ 0-793] 36-150 $ 2-075 vkj 12-250 $ 1-039 fnu FkhA i;kx'kkyk ikfjfLFkfr e o;Ld uj o eknk dk vk;dky Øe'k% 54-350 $ 3-005 vkj 66-400 $ 3-210 fnu ik;k x;kA

fofHkUu j[kh; vkdfreku fofo/krk d fy, fopj.k x.kkd fudkyk x;k tk fd uj d vxikn d ckgjh 'ky ¼19-33 ifr'kr½ o eknk d e/; ikn d ckgjh 'ky vf/kdre ¼16-15 ifr'kr½ FkA uj o eknk nkuk d fupy LVue dh pkMkb dk fopj.k x.kkd dk eku lcl de Øe"k% 3-47 vkj 4-87 ifr'kr FkA eknk d Jfxdk] Vxfeuk] i'pi[k] 'kjhj d tuukx rd@i[k d vfUre flj rd] io{k i"Bd] vkj LVuy {k= dh yEckb lkif{kd :i l eknk e vf/kd FkhA leku :i l Vxfeuk] 'kjhj] io{k i"Bd vkj LVuy {k= dh pkMkb Hkh eknk e vf/kd FkhA dN vkdrh; x.kk dk ryukRed lkefgd vuikr n[kk x;k tk fd Qhej dh yEckb vkj 'kh"k dh pkMkb ¼F/v½ d e/; dk vuikr vf/kdre Øe”kÂ 7-335 $ 0-132 vkj 7-151 $ 0-124 uj o e eknk ik;k x;kA io{k i"Bd dh yEckb o pkMkb ¼P/p½ fuEure vuikr uj o eknk dk Øe'kÂ 0-686 $ 0-014 o 0-624 $ 0-009 FkkA

[kk| ikni dk Qnd ij iHkko of) lpdkd d }kjk fuEufyf[kr vojkgh Øe e ojh;rk d vk/kkj ij fn[kk;k x;k g tkfd fjtdk > xg > tk > fefJr [kk| ikni > tb > puk > nc?kkl > ikyd > ekFkk > cFkvk gA fjtdk] xg vkj tk ij Qnd thork 100 ifr'kr if{kr dh xb tcfd cFkvk ij lcl de Qnd thfork Fkh] gkykfd ?kV fr:i Qnd dh lHkh HkkT; inkFk ij thfork 'kr ifr'kr FkhA fofHkUu [kk| ikuik dk iHkko HkkT; mi;kx lpdkd }kjk n[kk x;k ftle fd xg ;k fefJr ikni ij vUrxghr [kk| :ikUrj.k n{krk ¼ECI½ vf/kd n[kh x;h] yfdu cFkvk d ckn ekFkk dh ECI lkFkd :i l lcl de FkhA Qnd dh lfUudV ikP;rk ¼AD½ vf/kdre fjtd ij Fkh] tcfd U;ure pu ij if{kr dh x;hA xg ij ikfyr Qnd dh ikfpr [kk| dh ng inkFk e :ikUrj.k n{krk lkFkd :i l lcl vf/kd Fkh vkj cFkvk ij ikf"kr Qnd dh ECD lkFkd :i l lcl de FkhA

Table: 1. Comparative Adult Pyrgomorphid Diversity in Different Districts of South-Western Rajasthan during 2005-06

S. No.	Species	Udaipur	Sirohi	Rajsamand	Dungarpur	Banswara
1.	*C. trachypterus*	34.78±7.81 (13.67-54.67)	27.19±6.61 (10.33-45.67)	24.69±6.38 (09.00-41.67)	21.67±5.27 (10.67-36.00)	19.92±5.37 (08.67-34.00)
2.	*C. oxypterus*	30.75±7.07 (12.67-47.67)	25.17±6.52 (09.33-44.67)	23.47±6.44 (07.33-40.67)	20.58±5.16 (09.67-34.33)	19.06±5.16 (08.33-33.33)
3.	*A. crenulata*	06.56±1.81 (02.00-12.33)	05.92±1.50 (01.67-09.67)	06.92±1.45 (02.67-10.67)	04.72±1.49 (00.33-08.00)	07.81±1.75 (03.00-12.33)
4.	*P. bispinosa*	05.17±1.55 (01.00-09.67)	04.83±1.41 (01.00-08.33)	06.22±1.42 (02.33-10.00)	04.39±1.55 (00.00-06.67)	07.00±1.55 (03.00-11.67)
5.	*P. pictus*	06.33±3.15 (01.00-11.33)	06.10±2.84 (01.33-11.67)	07.81±2.98 (03.33-12.33)	04.00±2.07 (01.00-06.67)	00.00±0.00 (00.00-00.00)

Table: 2. Comparative Adult Pyrgomorphid Diversity in Different Districts of South-Western Rajasthan during 2006-07

S. No.	Species	Udaipur	Sirohi	Rajsamand	Dungarpur	Banswara
1.	*C. trachypterus*	31.89±7.45 (12.33-51.00)	24.19±6.28 (08.00-41.33)	22.42±6.28 (06.67-39.00)	19.14±5.13 (09.33-32.67)	17.86±5.32 (07.33-32.67)
2.	*C. oxypterus*	28.22±6.79	22.42±6.23	21.31±6.28	17.67±4.86	16.72±5.08

		(11.33-45.33)	(07.00-40.33)	(06.00-38.33)	(08.33-31.00)	(07.00-31.00)
3.	*A. crenulata*	05.05±1.44 (01.00-08.33)	04.33±1.38 (00.33-08.33)	05.58±1.42 (01.33-09.33)	03.39±1.24 (00.33-06.67)	06.36±1.56 (02.67-11.00)
4.	*P. bispinosa*	04.08±1.44 (00.67-08.33)	03.61±1.35 (01.00-08.00)	04.72±1.37 (01.00-08.67)	03.31±1.24 (00.00-06.00)	05.69±1.52 (02.00-10.33)
5.	*P. pictus*	05.33±2.95 (00.67-10.00)	04.90±2.49 (01.00-10.33)	06.19±2.66 (02.00-10.00)	02.83±1.91 (00.33-05.33)	00.00±0.00 (00.00-00.00)

Note: Data presented are mean values ± Fiducial limits
Figures in parenthesis are population range

Table: 3. Comparative Diversity of Pyrgomorphid Hoppers in Different Districts of South-Western Rajasthan during 2005-06

S. No.	Species	Udaipur	Sirohi	Rajsamand	Dungarpur	Banswara
1.	*C. trachypterus*	6.50 (01-13)	5.17 (01-12)	4.36 (01-09)	4.18 (01-10)	4.10 (01-09)
2.	*C. oxypterus*	5.58 (01-12)	4.80 (01-10)	3.30 (01-07)	4.10 (01-09)	3.73 (01-08)
3.	*A. crenulata*	2.75 (01-07)	1.78 (01-04)	1.82 (01-05)	2.22 (01-05)	3.83 (01-08)
4.	*P. bispinosa*	2.00 (01-05)	2.00 (01-05)	1.90 (01-04)	1.43 (01-03)	3.42 (01-07)
5.	*P. pictus*	2.00 (01-04)	2.17 (01-04)	2.43 (01-05)	1.25 (01-02)	0.00 (00-00)

Table: 4. Comparative Diversity of Pyrgomorphid Hoppers in Different Districts of South-Western Rajasthan during 2006-07

S. No.	Species	Udaipur	Sirohi	Rajsamand	Dungarpur	Banswara
1.	*C. trachypterus*	5.50 (01-12)	4.73 (01-11)	3.90 (01-08)	3.80 (01-09)	3.56 (01-08)
2.	*C. oxypterus*	5.09 (01-11)	4.44 (01-09)	2.89 (01-06)	3.30 (01-08)	3.30 (01-07)
3.	*A. crenulata*	2.17 (01-06)	1.57 (01-03)	1.60 (01-05)	1.57 (01-04)	3.08 (01-07)
4.	*P. bispinosa*	2.00 (01-05)	1.78 (01-04)	1.90 (01-03)	1.43 (01-03)	2.73 (01-05)
5.	*P. pictus*	1.75 (01-03)	1.60 (01-03)	2.33 (01-05)	1.25 (01-02)	0.00 (00-00)

Note: Data presented are mean values
Figures in parenthesis are population range

Table: 13. Mean Density of Common Pyrgomorphids in Maize-Wheat Cropping System at Rajsamand during 2005-06

S. No.	Species	Number of adult grasshoppers/ 180 ft^2											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	5.50	6.00	7.75	11.25	9.00	8.00	7.25	6.00	5.00	3.25	3.00	2.25
2.	*C. oxypterus*	5.00	5.50	7.25	10.75	8.75	7.50	6.50	5.00	4.50	3.00	2.50	1.75
3.	*A. crenulata*	1.25	1.25	2.50	2.75	2.75	2.50	0.75	1.00	2.00	3.00	2.75	2.50
4.	*P. bispinosa*	1.00	0.75	2.00	2.50	2.25	1.50	0.50	0.75	1.50	2.50	1.75	1.75

Table: 14. Mean Density of Common Pyrgomorphids in Maize-Wheat Cropping System at Rajsamand during 2006-07

S. No.	Species	Number of adult grasshoppers/ 180 ft^2											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	5.25	5.75	7.50	11.00	9.00	7.75	7.00	5.50	4.75	3.00	2.50	2.50
2.	*C. oxypterus*	4.75	5.00	7.00	10.25	8.50	7.25	6.25	4.75	4.50	2.75	2.25	2.00
3.	*A. crenulata*	1.00	1.00	2.25	2.50	2.50	2.25	0.50	0.75	1.75	2.75	2.50	2.25
4.	*P. bispinosa*	0.75	0.50	1.75	2.25	2.00	1.25	0.25	0.50	1.25	2.50	1.50	1.50

Table: 9. Mean Density of Common Pyrgomorphids in Maize-Wheat Cropping System at Dungarpur during 2005-06

S. No.	Species	Number of adult grasshoppers/ 180 ft^2											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	5.25	6.00	9.00	11.50	10.25	7.75	6.00	5.00	4.00	3.75	3.00	3.00
2.	*C. oxypterus*	5.00	5.50	8.75	11.00	9.50	7.25	5.75	4.50	3.75	3.25	2.00	2.75
3.	*A. crenulata*	1.00	1.25	2.00	2.50	2.00	1.25	0.25	0.25	1.50	2.50	1.75	1.25
4.	*P. bispinosa*	0.75	1.00	1.75	1.50	1.75	1.00	0.00	0.25	1.25	2.25	1.50	1.00

Table: 10. Mean Density of Common Pyrgomorphids in Maize-Wheat Cropping System at Dungarpur during 2006-07

S. No.	Species	Number of adult grasshoppers/ 180 ft^2											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	5.00	5.75	8.75	11.00	10.25	7.50	5.75	4.75	3.75	3.50	2.75	2.75
2.	*C. oxypterus*	4.75	5.25	8.50	10.50	9.25	7.00	5.50	4.25	3.50	3.00	1.75	2.50
3.	*A. crenulata*	0.75	1.00	1.75	2.00	2.00	1.00	0.00	0.25	1.25	2.50	1.50	1.00
4.	*P. bispinosa*	0.50	0.50	1.50	1.25	1.50	0.75	0.00	0.00	1.00	2.00	1.25	0.75

Table: 11. Mean Density of Common Pyrgomorphids in Maize-Wheat Cropping System at Sirohi during 2005-06

S. No.	Species	Number of adult grasshoppers/ 180 ft^2											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	5.50	6.25	9.00	12.00	10.00	8.50	8.00	6.25	5.50	4.75	3.50	4.00
2.	*C. oxypterus*	5.00	6.00	8.75	11.50	9.75	8.25	7.50	6.00	5.00	4.50	2.75	3.75
3.	*A. crenulata*	1.25	1.50	2.00	2.50	2.25	1.50	0.50	1.00	2.00	3.00	2.00	1.50
4.	*P. bispinosa*	0.75	1.25	1.75	2.75	1.75	1.25	0.00	0.50	1.50	2.75	1.75	1.25

Table: 12. Mean Density of Common Pyrgomorphids in Maize-Wheat Cropping System at Sirohi during 2006-07

S. No.	Species	Number of adult grasshoppers/ 180 ft^2											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	5.25	6.00	8.50	11.50	9.50	8.25	7.50	6.00	5.25	4.50	3.50	3.75
2.	*C. oxypterus*	5.25	5.75	8.50	11.25	9.25	7.75	7.00	5.75	4.75	4.25	3.00	3.50
3.	*A. crenulata*	1.00	1.25	1.75	2.25	1.75	1.25	0.25	1.00	1.75	2.75	1.75	1.25
4.	*P. bispinosa*	0.50	1.00	1.50	2.50	1.50	1.00	0.00	0.50	1.25	2.25	1.50	1.25

Table: 5. Mean Density of Common Pyrgomorphids in Maize-Wheat Cropping System at Udaipur during 2005-06

S. No.	Species	Number of adult grasshoppers/ 180 ft^2											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	6.75	7.25	10.50	13.00	11.50	9.50	9.00	7.00	5.50	5.25	4.00	4.00
2.	*C. oxypterus*	6.00	6.50	9.25	12.25	10.50	9.25	8.00	6.50	5.00	4.25	3.50	3.00
3.	*A. crenulata*	2.00	1.50	3.00	3.00	3.00	2.00	1.00	1.50	2.50	3.75	3.00	2.00
4.	*P. bispinosa*	1.50	1.25	2.50	2.75	2.50	1.50	0.50	1.25	2.00	3.00	2.25	1.75

Table: 6. Mean Density of Common Pyrgomorphids in Maize-Wheat Cropping System at Udaipur during 2006-07

S. No.	Species	Number of adult grasshoppers/ 180 ft^2											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	6.50	7.00	10.00	12.75	11.25	9.25	8.75	6.75	5.25	5.00	3.75	3.75
2.	*C. oxypterus*	5.75	6.25	9.00	12.00	10.25	9.00	7.75	6.25	4.75	4.00	3.25	3.25
3.	*A. crenulata*	1.75	1.25	2.75	3.00	2.75	1.75	0.75	1.25	2.25	3.75	2.75	1.75
4.	*P. bispinosa*	1.25	1.00	2.25	2.50	2.25	1.25	0.25	1.00	1.75	2.75	2.00	1.50

Table: 7. Mean Density of Common Pyrgomorphids in Maize-Wheat Cropping System at Banswara during 2005-06

S. No.	Species	Number of adult grasshoppers/ 180 ft^2											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	5.00	5.50	8.50	11.00	9.25	7.50	6.50	5.00	5.00	4.50	2.00	3.00
2.	*C. oxypterus*	4.75	5.25	8.00	10.00	8.75	7.00	6.25	4.75	4.50	4.00	2.00	2.75
3.	*A. crenulata*	2.00	1.75	3.00	3.25	3.00	2.50	1.50	2.00	3.00	4.50	3.00	2.50
4.	*P. bispinosa*	1.50	1.25	2.50	3.00	2.50	2.00	1.25	1.75	2.75	4.00	2.75	2.00

Table: 8. Mean Density of Common Pyrgomorphids in Maize-Wheat Cropping System at Banswara during 2006-07

S. No.	Species	Number of adult grasshoppers/ 180 ft^2											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	4.75	5.25	8.00	10.75	9.00	7.00	6.25	4.75	4.75	4.00	1.75	3.25
2.	*C. oxypterus*	4.25	5.00	7.75	9.50	8.50	6.75	6.00	4.50	4.75	3.50	1.75	2.50
3.	*A. crenulata*	2.00	1.50	2.75	3.00	2.75	2.25	1.25	1.75	2.75	4.25	2.75	2.25
4.	*P. bispinosa*	1.25	1.00	2.25	2.75	2.00	1.75	1.00	1.50	2.50	3.75	2.50	1.75

Table: 23. Relative Density (%) of Common Pyrgomorphids in Maize-Wheat Cropping System at Rajsamand during 2005-06

S. No.	Species	Relative density (%)											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	43.14	44.44	39.74	41.28	39.56	41.03	48.33	47.06	38.46	27.66	30.00	27.27
2.	*C. oxypterus*	39.22	40.74	37.18	39.45	38.46	38.46	43.33	39.22	34.62	25.53	25.00	21.21
3.	*A. crenulata*	9.80	9.26	12.82	10.09	12.09	12.82	5.00	7.84	15.38	25.53	27.50	30.30
4.	*P. bispinosa*	7.84	5.56	10.26	9.17	9.89	7.69	3.33	5.88	11.54	21.28	17.50	21.21

Table: 24. Relative Density (%) of Common Pyrgomorphids in Maize-Wheat Cropping System at Rajsamand during 2006-07

S. No.	Species	Relative density (%)											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	44.68	46.94	40.54	42.31	40.91	41.89	50.00	47.83	38.78	27.27	28.57	30.30
2.	*C. oxypterus*	40.43	40.82	37.84	39.42	38.64	39.19	44.64	41.30	36.73	25.00	25.71	24.24
3.	*A. crenulata*	8.51	8.16	12.16	9.62	11.36	12.16	3.57	6.52	14.29	25.00	28.57	27.27
4.	*P. bispinosa*	6.38	4.08	9.46	8.65	9.09	6.76	1.79	4.35	10.20	22.73	17.14	18.18

Table: 19. Relative Density (%) of Common Pyrgomorphids in Maize-Wheat Cropping System at Dungarpur during 2005-06

S. No.	Species	Relative density (%)											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	43.75	43.64	41.86	43.40	43.62	44.93	50.00	50.00	38.10	31.91	36.36	37.50
2.	*C. oxypterus*	41.67	40.00	40.70	41.51	40.43	42.03	47.92	45.00	35.71	27.66	24.24	34.38
3.	*A. crenulata*	8.33	9.09	9.30	9.43	8.51	7.25	2.08	2.50	14.29	21.28	21.21	15.63
4.	*P. bispinosa*	6.25	7.27	8.14	5.66	7.45	5.80	0.00	2.50	11.90	19.15	18.18	12.50

Table: 20. Relative Density (%) of Common Pyrgomorphids in Maize-Wheat Cropping System at Dungarpur during 2006-07

S. No.	Species	Relative density (%)											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	45.45	46.00	42.68	44.44	41.00	46.15	51.11	51.35	39.47	31.82	37.93	39.29
2.	*C. oxypterus*	43.18	42.00	41.46	42.42	37.00	43.08	48.89	45.95	36.84	27.27	24.14	35.71
3.	*A. crenulata*	6.82	8.00	8.54	8.08	16.00	6.15	0.00	2.70	13.16	22.73	20.69	14.29
4.	*P. bispinosa*	4.55	4.00	7.32	5.05	6.00	4.62	0.00	0.00	10.53	18.18	17.24	10.71

Table: 21. Relative Density (%) of Common Pyrgomorphids in Maize-Wheat Cropping System at Sirohi during 2005-06

S. No.	Species	Relative density (%)											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	44.00	41.67	41.86	41.74	42.11	43.59	50.00	45.45	39.29	31.67	35.00	38.10
2.	*C. oxypterus*	40.00	40.00	40.70	40.00	41.05	42.31	46.88	43.64	35.71	30.00	27.50	35.71
3.	*A. crenulata*	10.00	10.00	9.30	8.70	9.47	7.69	3.13	7.27	14.29	20.00	20.00	14.29
4.	*P. bispinosa*	6.00	8.33	8.14	9.57	7.37	6.41	0.00	3.64	10.71	18.33	17.50	11.90

Table: 22. Relative Density (%) of Common Pyrgomorphids in Maize-Wheat Cropping System at Sirohi during 2006-07

S. No.	Species	Relative density (%)											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	43.75	42.86	41.98	41.82	43.18	45.21	50.85	45.28	40.38	32.73	35.90	38.46
2.	*C. oxypterus*	43.75	41.07	41.98	40.91	42.05	42.47	47.46	43.40	36.54	30.91	30.77	35.90
3.	*A. crenulata*	8.33	8.93	8.64	8.18	7.95	6.85	1.69	7.55	13.46	20.00	17.95	12.82
4.	*P. bispinosa*	4.17	7.14	7.41	9.09	6.82	5.48	0.00	3.77	9.62	16.36	15.38	12.82

Table: 15. Relative Density (%) of Common Pyrgomorphids in Maize-Wheat Cropping System at Udaipur during 2005-06

S. No.	Species	Relative density (%)											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	41.54	43.94	41.58	41.94	41.82	42.70	48.65	43.08	36.67	32.31	31.37	37.21
2.	*C. oxypterus*	36.92	39.39	36.63	39.52	38.18	41.57	43.24	40.00	33.33	26.15	27.45	27.91
3.	*A. crenulata*	12.31	9.09	11.88	9.68	10.91	8.99	5.41	9.23	16.67	23.08	23.53	18.60
4.	*P. bispinosa*	9.23	7.58	9.90	8.87	9.09	6.74	2.70	7.69	13.33	18.46	17.65	16.28

Table: 16. Relative Density (%) of Common Pyrgomorphids in Maize-Wheat Cropping System at Udaipur during 2006-07

S. No.	Species	Relative density (%)											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	42.62	45.16	41.67	42.15	42.45	43.53	50.00	44.26	37.50	32.26	31.91	36.59
2.	*C. oxypterus*	37.70	40.32	37.50	39.67	38.68	42.35	44.29	40.98	33.93	25.81	27.66	31.71
3.	*A. crenulata*	11.48	8.06	11.46	9.92	10.38	8.24	4.29	8.20	16.07	24.19	23.40	17.07
4.	*P. bispinosa*	8.20	6.45	9.38	8.26	8.49	5.88	1.43	6.56	12.50	17.74	17.02	14.63

Table: 17. Relative Density (%) of Common Pyrgomorphids in Maize-Wheat Cropping System at Banswara during 2005-06

S. No.	Species	Relative density (%)											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	37.74	40.00	38.64	40.37	39.36	39.47	41.94	37.04	32.79	26.47	20.51	29.27
2.	*C. oxypterus*	35.85	38.18	36.36	36.70	37.23	36.84	40.32	35.19	29.51	23.53	20.51	26.83
3.	*A. crenulata*	15.09	12.73	13.64	11.93	12.77	13.16	9.68	14.81	19.67	26.47	30.77	24.39
4.	*P. bispinosa*	11.32	9.09	11.36	11.01	10.64	10.53	8.06	12.96	18.03	23.53	28.21	19.51

Table: 18. Relative Density (%) of Common Pyrgomorphids in Maize-Wheat Cropping System at Banswara during 2006-07

S. No.	Species	Relative density (%)											
		Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
1.	*C. trachypterus*	38.78	41.18	38.55	41.35	40.45	39.44	43.10	38.00	32.20	25.81	20.00	33.33
2.	*C. oxypterus*	34.69	39.22	37.35	36.54	38.20	38.03	41.38	36.00	32.20	22.58	20.00	25.64
3.	*A. crenulata*	16.33	11.76	13.25	11.54	12.36	12.68	8.62	14.00	18.64	27.42	31.43	23.08
4.	*P. bispinosa*	10.20	7.84	10.84	10.58	8.99	9.86	6.90	12.00	16.95	24.19	28.57	17.95

Table: 25. Simpson and Shannon Weiner Diversity Indices for Districts of South-Western Rajasthan during 2005-06

Months	Simpson index					Shannon's index				
	Udaipur	Sirohi	Rajsamand	Dungarpur	Banswara	Udaipur	Sirohi	Rajsamand	Dungarpur	Banswara
Nov.	3.100	2.720	2.810	2.660	3.260	1.210	1.127	1.157	1.106	1.268
Dec.	2.760	2.850	2.670	2.750	3.030	1.142	1.168	1.107	1.137	0.998
Jan.	3.020	2.810	3.090	2.810	3.190	1.215	1.155	1.232	1.155	1.254
Feb.	2.860	2.850	2.900	2.680	3.090	1.172	1.168	1.183	1.112	1.231
March	2.860	2.780	3.040	2.730	3.110	1.192	1.145	1.218	1.131	1.236
April	2.720	2.640	2.950	2.580	3.130	1.127	1.099	1.194	1.080	1.239
May	2.340	2.120	2.350	2.080	2.820	0.968	0.810	0.977	0.780	1.150
June	2.780	2.480	2.600	2.200	3.340	1.146	1.152	1.088	0.890	1.283
July	3.440	3.190	3.280	3.250	3.760	1.301	1.252	1.272	1.266	1.355
Aug.	3.840	3.790	3.970	3.840	3.990	1.366	1.358	1.382	1.366	1.384
Sept.	3.840	3.720	3.860	3.720	3.870	1.365	1.349	1.368	1.350	1.370
Oct.	3.600	3.250	3.900	3.350	3.920	1.332	1.266	1.374	1.285	1.376

Table: 26. Simpson and Shannon Weiner Diversity Indices for Districts of South-Western Rajasthan during 2006-07

Months	Simpson index					Shannon's index				
	Udaipur	Sirohi	Rajsamand	Dungarpur	Banswara	Udaipur	Sirohi	Rajsamand	Dungarpur	Banswara
Nov.	2.910	2.550	2.670	2.500	3.250	0.973	1.063	1.111	1.045	1.263
Dec.	2.650	2.740	2.530	2.530	2.910	1.105	1.330	1.056	1.052	1.184
Jan.	2.970	2.740	3.020	2.730	3.150	1.203	1.133	1.213	1.130	1.244
Feb.	2.840	2.800	2.850	2.590	3.040	1.166	1.153	1.167	1.078	1.219
March	2.880	2.670	2.960	2.990	3.000	1.175	1.111	1.198	1.195	1.208
April	2.640	2.550	2.870	2.470	3.070	1.098	1.065	1.170	1.033	1.791
May	2.230	2.070	2.220	2.00	2.710	0.903	0.766	0.897	0.692	1.124
June	2.670	2.500	2.270	2.100	3.250	1.110	1.235	1.033	0.797	1.265
July	3.360	3.090	3.160	3.130	3.690	1.288	1.220	1.246	1.238	1.343
Aug.	3.840	3.710	3.980	3.840	3.980	1.366	1.346	1.384	1.365	1.384
Sept.	3.820	3.580	3.860	3.640	3.840	1.361	1.327	1.367	1.340	1.365
Oct.	3.510	3.230	3.880	3.190	3.810	1.315	1.262	1.369	1.252	1.362

Table: 27. Comparative Simpson Diversity Indices for the Grasshopper Groups in South-Western Rajasthan during 2005-06

Months	*C. trachypterus* and *C. oxypterus*					*P. bispinosa* and *A. crenulata*				
	Udaipur	Sirohi	Rajsamand	Dungarpur	Banswara	Udaipur	Sirohi	Rajsamand	Dungarpur	Banswara
Nov.	1.993	1.995	1.995	1.999	1.999	1.960	1.882	1.975	1.960	1.960
Dec.	1.994	1.999	1.996	1.996	1.999	1.984	1.984	1.882	1.976	1.946
Jan.	1.992	2.000	1.998	2.000	1.998	1.984	1.991	1.976	1.991	1.984
Feb.	1.998	1.999	1.999	1.999	1.995	1.996	1.995	1.995	1.882	1.997
March	1.996	2.000	2.000	1.997	1.998	1.984	1.969	1.980	1.991	1.984
April	2.000	2.000	1.998	1.998	1.998	1.960	1.984	1.882	1.976	1.976
May	1.993	1.998	1.994	1.999	1.999	1.800	1.000	1.923	1.999	1.984
June	1.997	1.999	1.984	1.994	1.999	1.984	1.800	1.960	2.000	1.991
July	1.995	1.995	1.994	1.998	1.994	1.876	1.960	1.960	1.984	1.996
Aug.	1.978	1.998	1.997	1.990	1.993	1.876	1.996	1.984	1.994	1.993
Sept.	1.991	1.991	1.986	1.923	2.000	1.960	1.991	1.906	1.998	1.996
Oct.	1.960	1.998	1.969	1.996	1.996	1.991	1.984	1.940	1.976	1.976

Table: 28. Comparative Simpson Diversity Indices for the Grasshopper Groups in South-Western Rajasthan during 2006-07

Months	*C. trachypterus* and *C. oxypterus*					*P. bispinosa* and *A. crenulata*				
	Udaipur	Sirohi	Rajsamand	Dungarpur	Banswara	Udaipur	Sirohi	Rajsamand	Dungarpur	Banswara
Nov.	1.993	2.000	1.995	1.999	1.994	1.946	1.800	1.960	1.923	1.899
Dec.	1.994	1.999	1.990	1.996	1.999	1.976	1.976	1.800	1.996	1.923
Jan.	1.992	2.000	1.998	2.000	2.000	1.980	1.988	1.969	1.988	1.980
Feb.	1.998	2.000	1.998	1.999	1.992	1.984	1.994	1.994	1.899	1.996
March	1.996	2.000	1.976	1.995	1.998	1.980	1.988	1.976	1.991	1.951
April	2.000	1.998	1.998	1.998	1.999	1.946	1.976	1.849	1.960	1.969
May	1.993	1.998	1.994	1.999	1.999	1.600	1.000	1.800	0.000	1.976
June	1.997	1.999	1.989	1.994	1.998	1.976	1.800	1.923	1.000	1.988
July	1.995	1.995	1.999	1.998	2.000	1.969	1.946	1.946	1.976	1.995
Aug.	1.976	1.998	1.996	1.988	1.991	1.954	1.980	1.995	1.976	1.992
Sept.	1.990	1.988	2.000	1.906	2.000	1.950	1.988	1.899	1.984	1.995
Oct.	1.990	1.998	1.991	1.995	1.969	1.988	1.998	1.946	1.960	1.969

Table: 30. Mean Linear Morphometric Data of Different Life Stages of *C. trachypterus*

S. No.	Measurement (mm)		Nymphs						Adults	
			I instar	II instar	III instar	IV instar	V instar	VI instar	Male	Female
1.	Length of body	Mean ± S. Em.	3.441± 0.064	6.191± 0.114	7.005± 0.094	9.508± 0.099	10.686± 0.120	12.409± 0.095	14.983± 0.077	20.436± 0.506
2.	Width of body	Mean ± S. Em.	1.363± 0.028	2.134± 0.058	2.743± 0.055	3.264± 0.034	3.889± 0.040	4.271± 0.036	4.733± 0.037	6.797± 0.119
3.	Length of antenna	Mean ± S. Em.	1.241± 0.022	1.527± 0.021	1.917± 0.043	2.745± 0.034	3.310± 0.007	3.611± 0.018	4.508± 0.150	5.291± 0.131
4.	Length of head	Mean ± S. Em.	0.783± 0.013	1.054± 0.013	1.359± 0.009	1.604± 0.012	1.883± 0.011	2.076± 0.017	2.229± 0.030	2.791± 0.097
5.	Width of head	Mean ± S. Em.	0.857± 0.010	1.035± 0.013	1.487± 0.019	1.967± 0.013	2.158± 0.011	2.298± 0.011	2.413± 0.029	3.625± 0.083
6.	Length of pronotum	Mean ± S. Em.	0.669± 0.011	0.876± 0.017	1.390± 0.031	2.008± 0.026	2.450± 0.012	2.738± 0.014	2.911± 0.040	4.250± 0.088
7.	Width of pronotum	Mean ± S. Em.	1.299± 0.023	1.695± 0.023	2.511± 0.033	2.778± 0.014	3.477± 0.018	4.004± 0.018	4.195± 0.047	6.791± 0.121
8.	Width of vertex	Mean ± S. Em.	0.297± 0.005	0.362± 0.006	0.420± 0.029	0.670± 0.011	0.745± 0.010	0.852± 0.008	0.904± 0.013	1.275± 0.026
9.	Length of femur	Mean ± S. Em.	1.687± 0.015	2.134± 0.026	3.177± 0.025	4.587± 0.013	5.342± 0.014	6.013± 0.015	6.732± 0.129	8.953± 0.147

Table: 29. Duration of Biological Stages of the Surface Grasshopper, *C. trachypterus*

S. No.	Biological Parameters (days)	2005-06			2006-07		
		Mean ± S. Em	Max.	Min.	Mean ± S. Em	Max.	Min.
1.	Adult longevity male	54.20± 3.038	72.000	33.000	54.50± 2.972	72.000	32.000
2.	Adult longevity female	66.100± 3.247	87.000	43.000	66.70± 3.186	90.000	44.000
3.	Pre-oviposition period	17.850± 0.789	24.000	13.000	18.15± 0.796	25.000	13.000
4.	Oviposition period	36.150± 2.129	52.000	25.000	36.15± 2.020	52.000	24.000
5.	Post-oviposition period	12.100± 1.078	19.000	4.500	12.40± 0.999	18.000	5.000
6.	No. of egg pods/female	7.350± 0.254	10.000	6.000	7.650± 0.244	10.000	6.000
7.	No. of eggs/pod	8.950± 0.555	13.000	5.000	9.150± 0.564	13.000	5.000
8.	Total eggs/female	65.400± 4.412	96.000	40.000	65.60± 4.318	94.000	38.000
9.	Incubation period	23.100± 1.071	30.000	17.000	22.85± 0.958	31.000	17.000
10.	I instar	9.750± 0.237	11.500	8.000	10.05± 0.238	12.000	8.000
11.	II instar	8.650± 0.319	11.000	6.500	8.575± 0.284	11.500	7.000
12.	III instar	8.225± 0.160	9.000	7.000	8.375± 0.185	9.500	7.000
13.	IV instar	7.100± 0.187	8.500	6.000	7.275± 0.194	9.000	6.000
14.	V instar	6.500± 0.158	7.500	5.500	6.750± 0.133	7.500	6.000
15.	VI instar	7.850± 0.233	9.500	6.500	7.975± 0.231	10.000	6.000

16.	Total nymphal period	48.025± 0.518	53.500	43.500	49.00± 0.473	53.000	45.000

Table: 31. Variation in Adult Morphometry of Surface Grasshopper, *C. trachypterus*

S. No	Body parts measured (mm)		Male		Female	
			Mean ± S. Em	CV %	Mean ± S. Em	CV %
1	Length of antenna		4.48±0.103	10.29	5.34±0.091	07.60
2	Length of parts of antenna	Scape	0.46±0.015	14.88	0.54±0.011	08.71
3		Pedicel	0.25±0.006	11.12	0.21±0.007	11.11
4		Flagellum	3.78±0.098	11.61	4.49±0.079	07.86
5	Length of tegmina		8.71±0.205	10.50	12.58±0.162	05.75
6	Width of tegmina		1.68±0.029	07.59	2.92±0.031	04.79
7	Length of wing		8.06±0.104	05.76	10.12±0.097	04.28
8	Width of wing		5.16±0.064	05.56	5.68±0.138	10.91
9	Length of body up to genitalia		13.17±0.227	07.72	20.47±0.290	06.34
10	Length of body up to wing tip		13.82±0.215	06.96	21.36±0.334	06.99
11	Width of body		3.93±0.109	12.43	6.83±0.081	05.30
12	Length of pronotum		2.79±0.041	06.65	4.26±0.065	06.87
13	Width of pronotum		4.08±0.080	08.74	6.83±0.082	05.35
14	Length of head		2.14±0.043	08.97	2.87±0.074	11.50
15	Width of head		2.37±0.031	05.94	2.37±0.031	05.94
16	Width of vertex		0.90±0.009	04.68	1.26±0.017	06.09
17	Vertical diameter of eye		1.23±0.017	06.23	1.37±0.021	06.82
18	Transverse diameter of eye		1.09±0.021	08.71	1.22±0.029	10.67
19	Length of sternum region		3.33±0.040	05.35	4.74±0.570	05.41
20	Width of sternum region		4.10±0.032	03.47	6.88±0.075	04.87
S. No	Body parts counted (No.)		Male		Female	
1	No. of antennal segments		11.85±0.167	06.29	12.40±0.152	05.49

2	Tibial spines on fore legs	Inner	3.20±0.092	12.82	3.35±0.109	14.61
3		Outer	2.60±0.112	19.33	2.80±0.092	14.66
4	Tibial spines on mid-legs	Inner	2.95±0.050	07.58	3.15±0.082	11.63
5		Outer	2.70±0.105	17.41	2.75±0.099	16.15
6	Tibial spines on hind legs	Inner	7.45±0.114	06.85	7.80±0.117	06.71
7		Outer	7.10±0.100	06.30	6.60±0.134	09.06

Table: 32. Mean Linear Morphometric Variations in Mouth Parts of *C. trachypterus*

S. No	Measurements (mm)		Male		Female	
			Mean ± S. Em	CV (%)	Mean ± S. Em	CV (%)
1	Length of labrum		1.05±0.045	19.03	1.36±0.052	17.14
2	Width of labrum		1.63±0.041	11.33	2.22±0.063	12.65
3	Length of mandible		1.11±0.030	12.20	1.52±0.059	17.26
4	Width of mandible		1.10±0.018	07.36	1.48±0.036	10.81
5	Length of lacinia		0.84±0.014	07.32	1.19±0.024	09.01
6	Length of galea		0.76±0.029	16.98	1.23±0.059	21.45
7	Length of segments of maxillary palpi	I	0.24±0.007	13.54	0.29±0.010	15.30
		II	0.23±0.006	12.47	0.24±0.006	12.13
		III	0.32±0.007	09.67	0.39±0.011	12.74
		IV	0.37±0.011	13.02	0.46±0.013	12.91
		V	0.57±0.011	08.90	0.57±0.013	10.26
8	Length of labium		0.82±0.027	14.81	1.09±0.044	17.93
9	Width of labium		1.22±0.026	09.63	1.56±0.048	13.63
I0	Length of segments of labial palpi	I	0.29±0.005	07.86	0.40±0.010	10.67
		II	0.31±0.006	08.92	0.40±0.013	14.51
		III	0.51±0.012	10.85	0.59±0.020	15.49

Table: 33. Mean Linear Morphometric Variations in Legs of *C. trachypterus*

S. No	Measurements (mm)	Male		Female	
		Mean ± S. Em	CV (%)	Mean ± S. Em	CV (%)
1	Length of fore leg	5.62±0.147	11.63	7.02±0.155	09.82
2	Length of fore femur	2.33±0.071	13.61	2.97±0.074	11.21
3	Length of fore tibia	2.04±0.063	13.82	2.69±0.066	11.02
4	Length of fore tarsus	0.67±0.020	15.86	0.72±0.021	12.75
5	Length of fore pretarsus	0.62±0.020	14.65	0.64±0.016	11.19

6	Length of mid-leg	7.12±0.089	5.58	9.02±0.162	08.01
7	Length of mid femur	2.99±0.035	05.26	3.78±0.090	10.61
8	Length of mid tibia	2.74±0.054	08.72	3.56±0.072	09.06
9	Length of mid tarsus	0.72±0.017	10.43	0.91±0.020	09.63
10	Length of mid pretarsus	0.67±0.015	10.18	0.78±0.015	08.56
11	Length of hind leg	14.17±0.19	05.93	19.11±0.22	05.16
12	Width of hind femur	1.99±0.025	05.72	2.92±0.042	06.48
13	Length of hind femur	6.57±0.105	07.14	9.00±0.091	04.51
14	Length of hind tibia	5.62±0.068	05.43	7.61±0.133	07.83
15	Length of hind tarsus	1.08±0.024	09.83	1.46±0.029	08.98
16	Length of hind pretarsus	0.91±0.025	12.08	1.07±0.020	08.55

Table: 34. Compounded Ratios of the Linear Measurements for *C. trachypterus*

S. No.	Ratio	Males		Female	
		Mean ± S.Em	CV (%)	Mean ± S.Em	CV (%)
1	T/ F	1.331±0.035	11.80	1.401±0.023	07.44
2	T/ t	5.166±0.057	04.96	4.304±0.030	03.14
3	T/ h	3.676±0.074	08.95	5.326±0.093	07.81
4	F/ h	2.776±0.047	07.61	3.810±0.057	06.70
5	P/ h	1.178±0.021	07.85	1.803±0.036	08.87
6	P/ p	0.686±0.014	09.30	0.624±0.009	06.44
7	p/ h	1.723±0.029	07.61	1.803±0.036	08.87
8	O/ v	1.373±0.022	07.15	1.089±0.024	09.72
9	F/ v	7.335±0.132	08.07	7.151±0.124	07.72

Compounded Ratio for:
(T/F) - length of tegmina/length of hind femur; (T/t) - length of tegmina/width of tegmina; (T/h) - length of tegmina/width of head; (F/h) - length of hind femur/ width of head; (P/h) - length of pronotum/ width of head; (P/p) - length of pronotum/ width of pronotum; (p/h) - width of pronotum/ width of head; (O/v) – length of vertical eye/width of vertex; (F/v) - length of hind femur/ width of vertex

Table: 35. Comparative Effect of Host Plants on the Developmental Potential of the Surface Grasshopper, *C. trachypterus* during 2005-06

Host plats	Average hopper duration (days)				Hopper survival (%)			Growth index	Rank
	IV instar	V instar	VI instar	Total	IV instar	V instar	VI instar		
Wheat	6.000	5.625	7.000	18.625	100	100	100	5.37	II
Lucerne	5.750	5.125	6.500	17.375	100	100	100	5.76	I
Barley	6.375	6.250	7.750	20.375	100	100	100	4.91	III
Oat	6.875	6.875	8.000	21.750	100	92.50	90.00	4.14	V
Gram	6.500	6.250	7.750	20.500	100	92.50	82.50	4.02	VI
Nut grass	8.250	8.000	8.375	24.625	90	75.00	67.50	2.74	IX
Spinach	7.750	7.250	8.750	23.750	97.50	90.00	80.00	3.37	VIII
Pig weed	8.000	7.750	9.50	25.250	82.50	72.50	62.50	2.48	X
Mixed	6.750	6.125	8.375	21.250	100	90.00	90.00	4.24	IV

Bermuda grass	7.500	7.250	8.250	23.000	97.50	92.50	82.50	3.59	VII

Table: 36. Comparative Effect of Host Plants on the Developmental Potential of the Surface Grasshopper, *C. trachypterus* during 2006-07

Host plats	Average hopper duration (days)				Hopper survival (%)			Growth index	Rank
	IV instar	V instar	VI instar	Total	IV instar	V instar	VI instar		
Wheat	6.125	5.750	7.125	19.000	100	100	100	5.26	II
Lucerne	5.875	5.250	6.625	17.750	100	100	100	5.63	I
Barley	6.500	6.375	7.875	20.750	100	100	97.50	4.70	III
Oat	7.000	6.875	8.125	22.000	100	95.00	90.00	4.09	V
Gram	6.625	6.375	7.875	20.875	100	95.00	85.00	4.07	VI
Nut grass	8.375	8.125	8.500	25.000	90.00	75.00	67.50	2.70	IX
Spinach	7.850	7.375	8.875	24.100	97.50	92.50	82.50	3.42	VIII
Pig weed	8.125	7.875	9.875	25.875	82.50	75.00	62.50	2.42	X
Mixed	6.875	6.250	8.500	21.625	100	92.50	90.00	4.16	IV

Bermuda grass	7.625	7.375	8.375	23.375	100	95.00	85.00	3.63	VII

Table: 37. Effect of Host Plants on Food Utilization for Surface Grasshopper, *C. trachypterus*

Host plats	2005-06			2006-07		
	ECI (%)	AD (%)	ECD (%)	ECI (%)	AD (%)	ECD (%)
Wheat	37.18 (36.53)	39.71 (40.82)	71.09 (89.50)	37.36 (36.83)	40.38 (41.98)	69.51 (87.75)
Lucerne	34.51 (32.09)	42.24 (45.20)	57.43 (71.01)	34.39 (31.90)	42.25 (45.21)	57.14 (70.56)
Barley	32.85 (29.42)	40.30 (41.84)	56.99 (70.33)	32.86 (29.44)	40.15 (41.58)	57.28 (70.79)
Oat	31.42 (27.17)	39.34 (40.18)	55.31 (67.61)	31.51 (27.32)	39.53 (40.51)	55.20 (67.43)
Gram	31.87 (27.87)	38.28 (38.39)	58.44 (72.61	31.93 (27.97)	38.56 (38.36)	58.04 (71.97)
Nut grass	26.04 (19.28)	40.94 (42.93)	42.08 (44.91)	25.97 (19.17)	40.98 (43.01)	41.89 (44.58)
Spinach	30.93 (26.41)	39.70 (40.80	53.57 (64.74)	30.54 (25.82)	39.45 (40.38)	53.10 (63.95)
Pig weed	23.74 (16.21)	38.33 (38.46)	40.48 (42.14)	23.18 (15.49)	38.40 (38.59)	39.31 (40.14)
Mixed	36.39 (35.20)	40.15 (41.58)	66.94 (84.66)	36.35 (35.13)	40.43 (42.05)	66.06 (83.54)
Bermuda grass	30.04 (25.06)	39.69 (40.79)	51.62 (61.44)	30.08 (25.12)	39.41 (40.30)	51.70 (61.59)
S.Em ±	1.820	1.133	2.922	1.804	1.135	2.899
C.D. (5%)	3.720	2.314	5.966	3.704	2.318	5.921
C.V. (%)	4.760	1.858	4.572	4.864	2.017	4.651

APPENDIX-I

ANOVA: Effect of different host plants on the efficiency of conversion of ingested food in 2005-06

Source of variation	d. f.	Sum of squares	Mean sum of squares	Variance ratio (F)
Replication	3	67.500	22.500	0.846
Treatments	9	565.984	62.887	2.366
Error	30	797.500	26.583	

APPENDIX-II

ANOVA: Effect of different host plants on the approximate digestibility in 2005-06

Source of variation	d. f.	Sum of squares	Mean sum of squares	Variance ratio (F)
Replication	3	16.475	5.492	0.534
Treatments	9	191.719	21.302	2.073
Error	30	308.250	10.275	

APPENDIX-III

ANOVA: Effect of different host plants on the efficiency of conversion of digested food in 2005-06

Source of variation	d. f.	Sum of squares	Mean sum of squares	Variance ratio (F)
Replication	3	192.500	64.167	0.939
Treatments	9	3325.309	369.479	5.410
Error	30	2049.000	68.300	

APPENDIX-IV

ANOVA: Effect of different host plants on the efficiency of conversion of ingested food in 2006-07

Source of variation	d. f.	Sum of squares	Mean sum of squares	Variance ratio (F)
Replication	3	70.075	23.358	0.887
Treatments	9	595.304	66.145	2.513
Error	30	789.750	26.325	

APPENDIX-V

ANOVA: Effect of different host plants on the approximate digestibility in 2006-07

Source of variation	d. f.	Sum of squares	Mean sum of squares	Variance ratio (F)
Replication	3	19.475	6.492	0.630
Treatments	9	202.976	22.553	2.188
Error	30	309.250	10.308	

APPENDIX-VI

ANOVA: Effect of different host plants on the efficiency of conversion of digested food in 2006-07

Source of variation	d. f.	Sum of squares	Mean sum of squares	Variance ratio (F)

Replication	3	195.800	65.267	0.970
Treatments	9	3151.701	350.189	5.206
Error	30	2018.000	67.267	

Figure: 1. Relative Incidence of the Pyrgomorphid Fauna at Udaipur during 2005-06

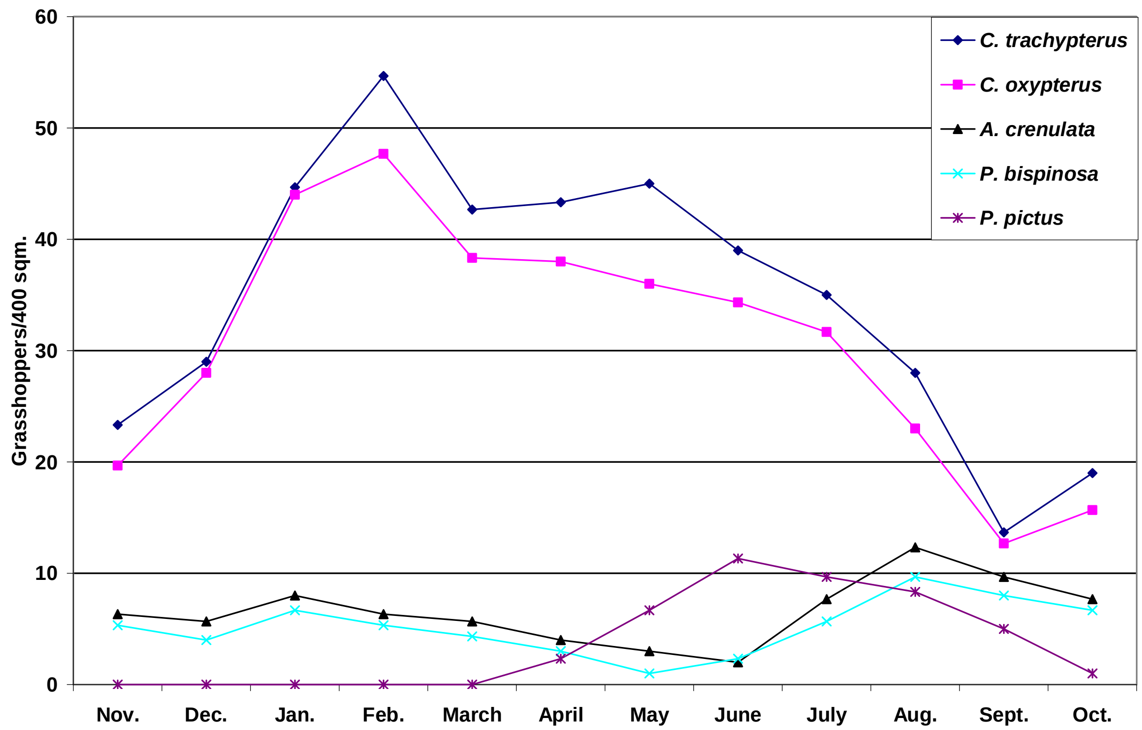

Figure: 2. Relative Incidence of the Pyrgomorphid Fauna at Udaipur during 2006-07

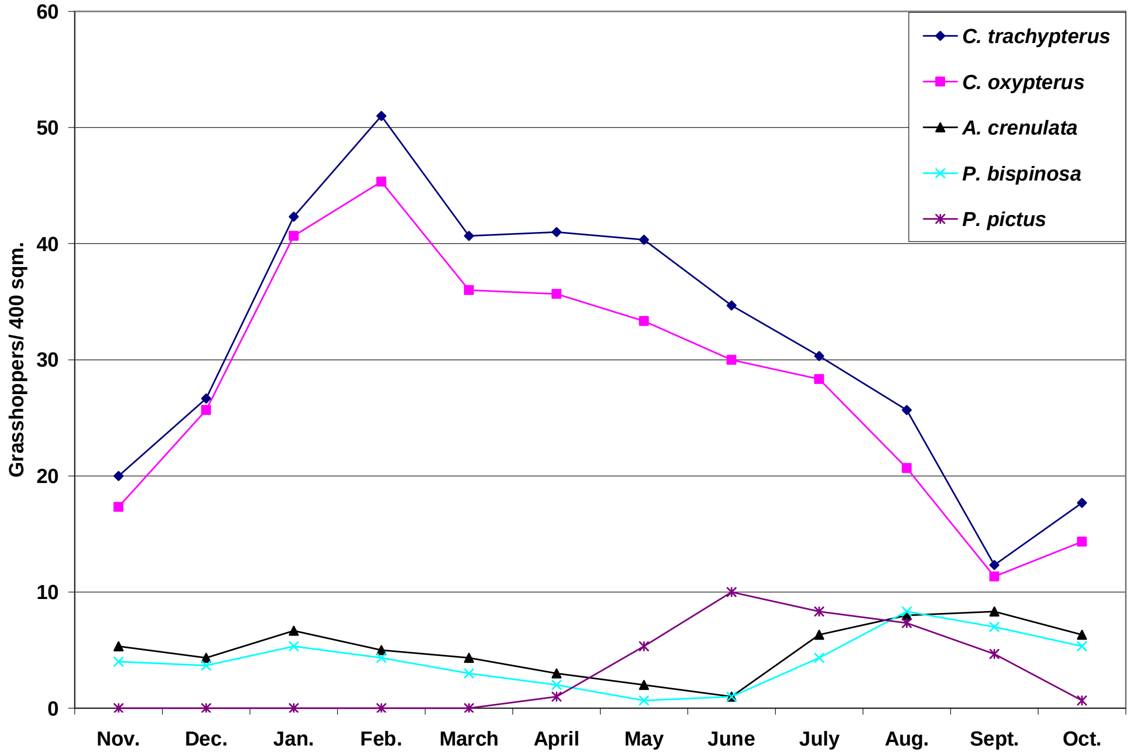

Figure: 3. Relative Incidence of the Pyrgomorphid Fauna at Banswara during 2005-06

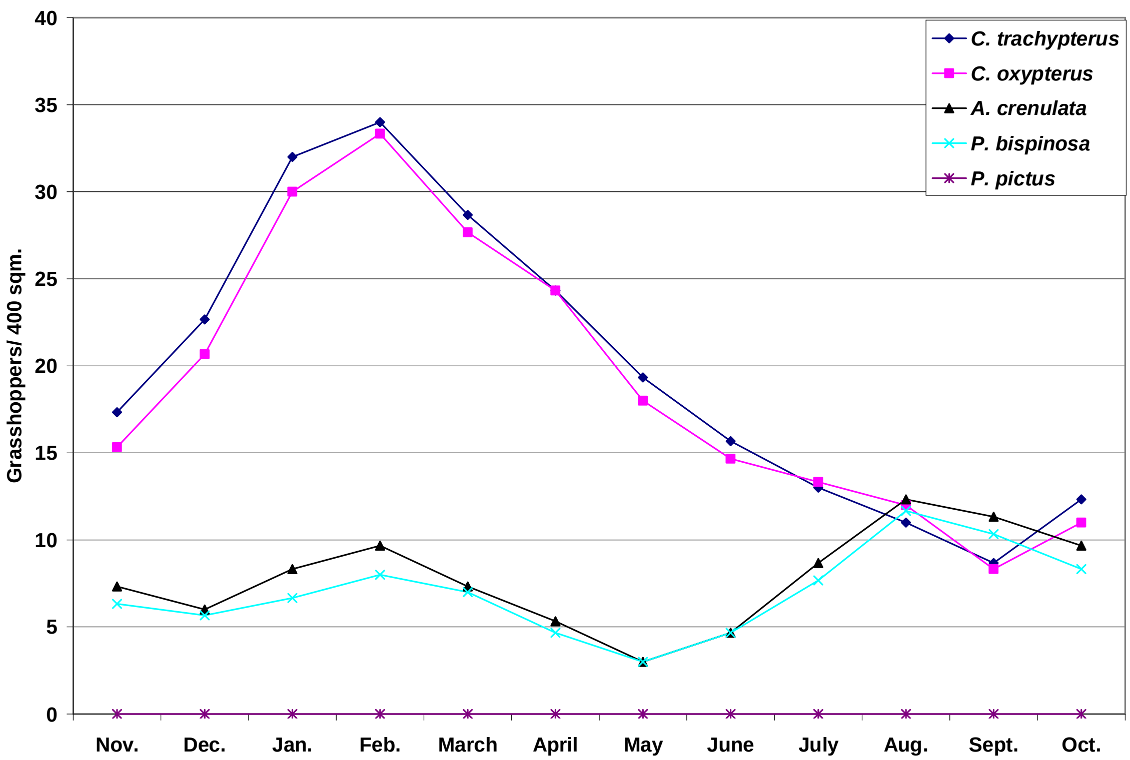

Figure: 4. Relative Incidence of the Pyrgomorphid Fauna at Banswara during 2006-07

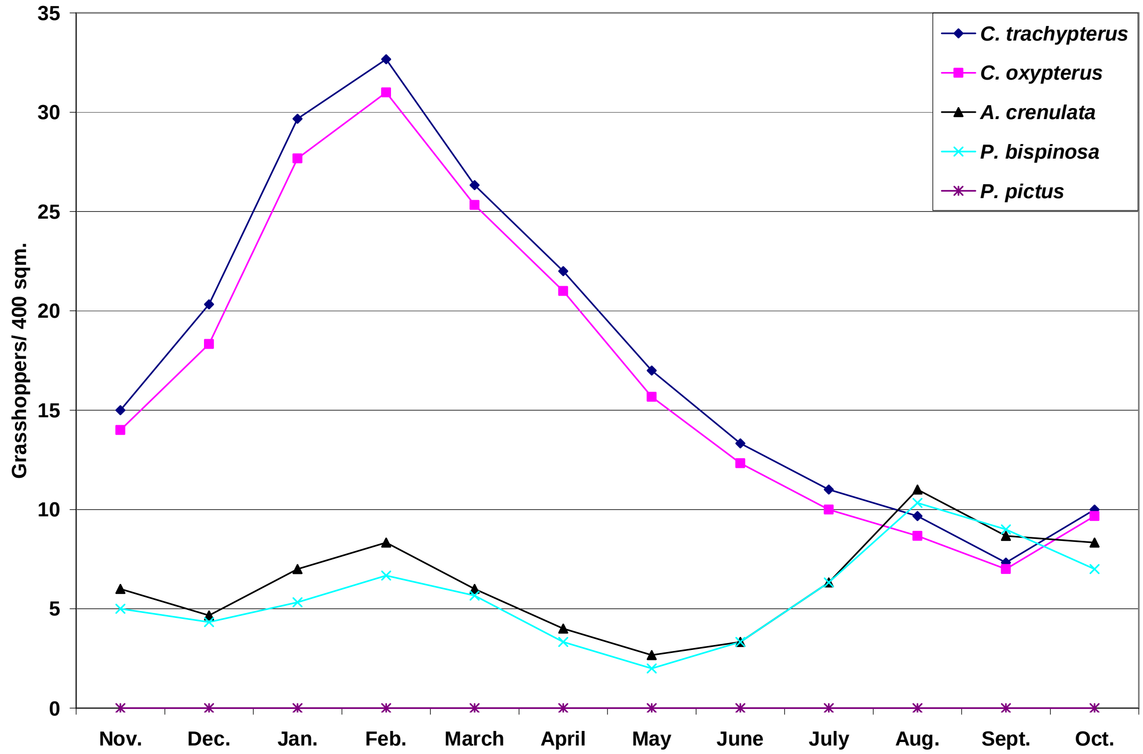

Figure: 5. Relative Incidence of the Pyrgomorphid Fauna at Dungarpur during 2005-06

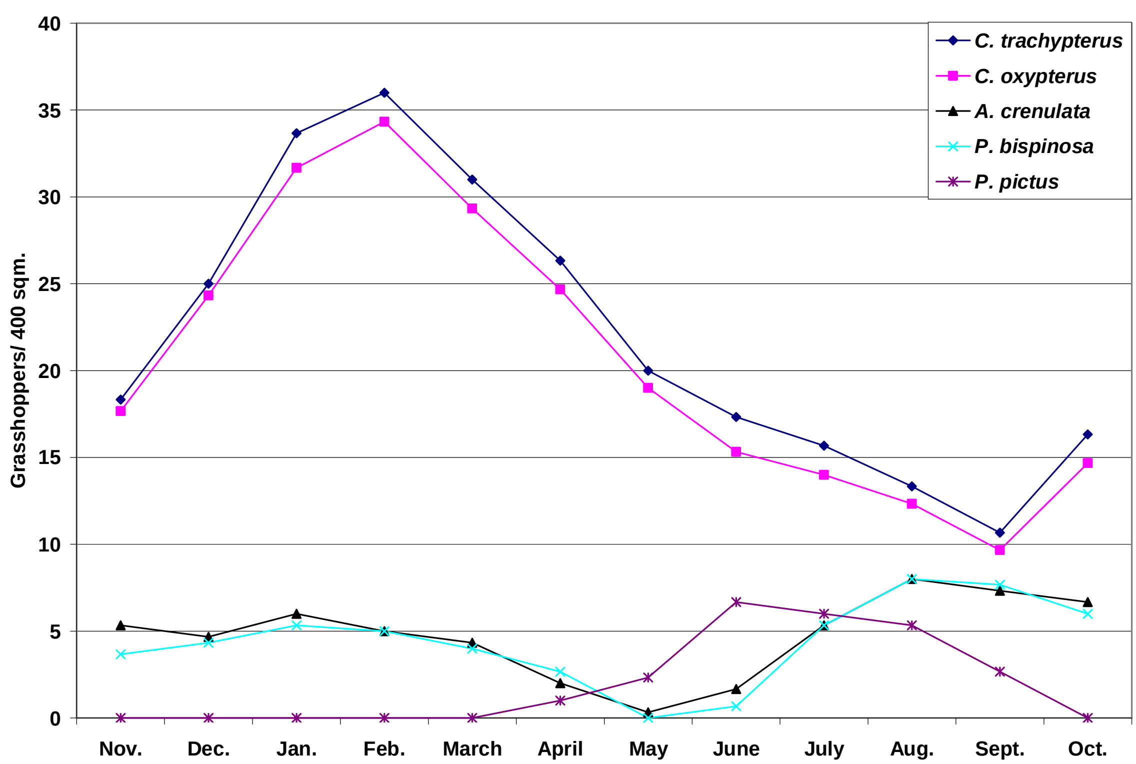

Figure: 6. Relative Incidence of the Pyrgomorphid Fauna at Dungarpur during 2006-07

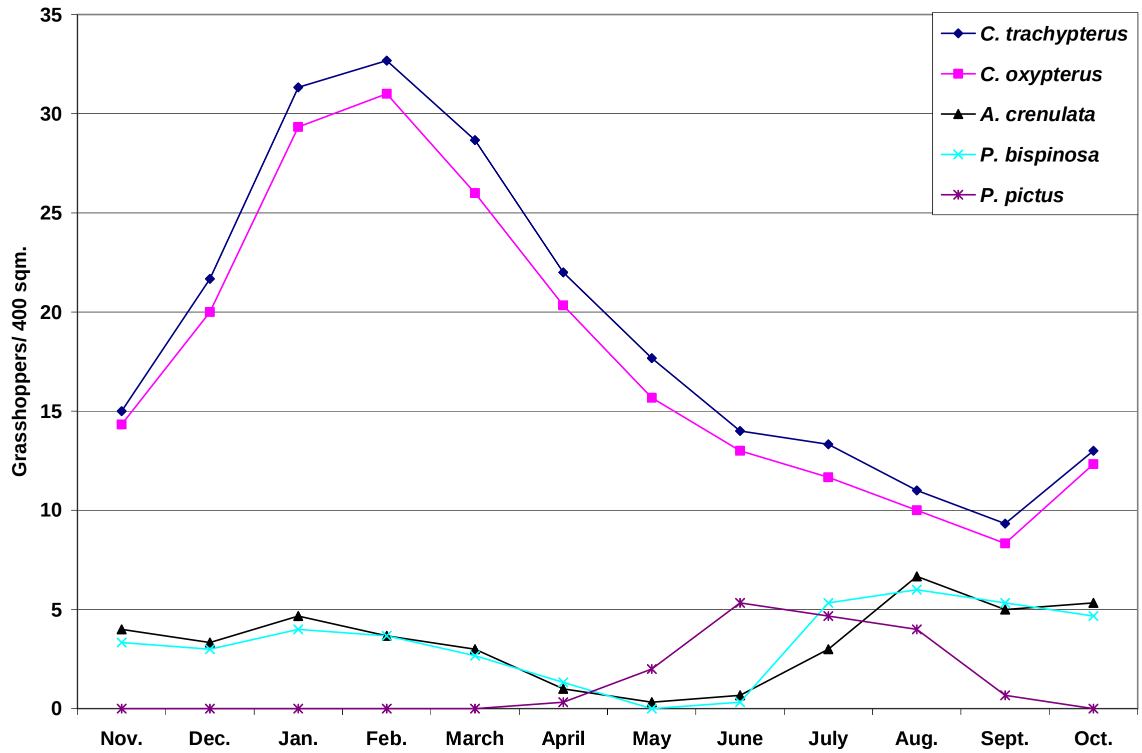

Figure: 7. Relative Incidence of the Pyrgomorphid Fauna at Sirohi during 2005-06

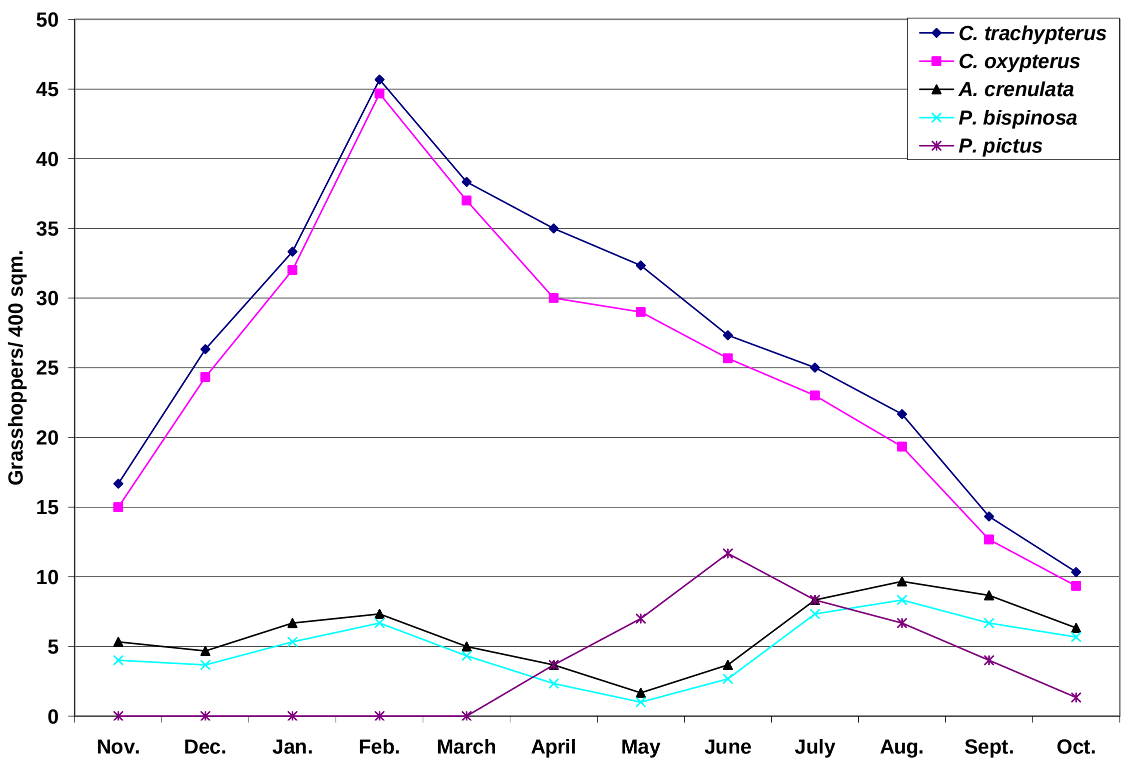

Figure: 8. Relative Incidence of the Pyrgomorphid Fauna at Sirohi during 2006-07

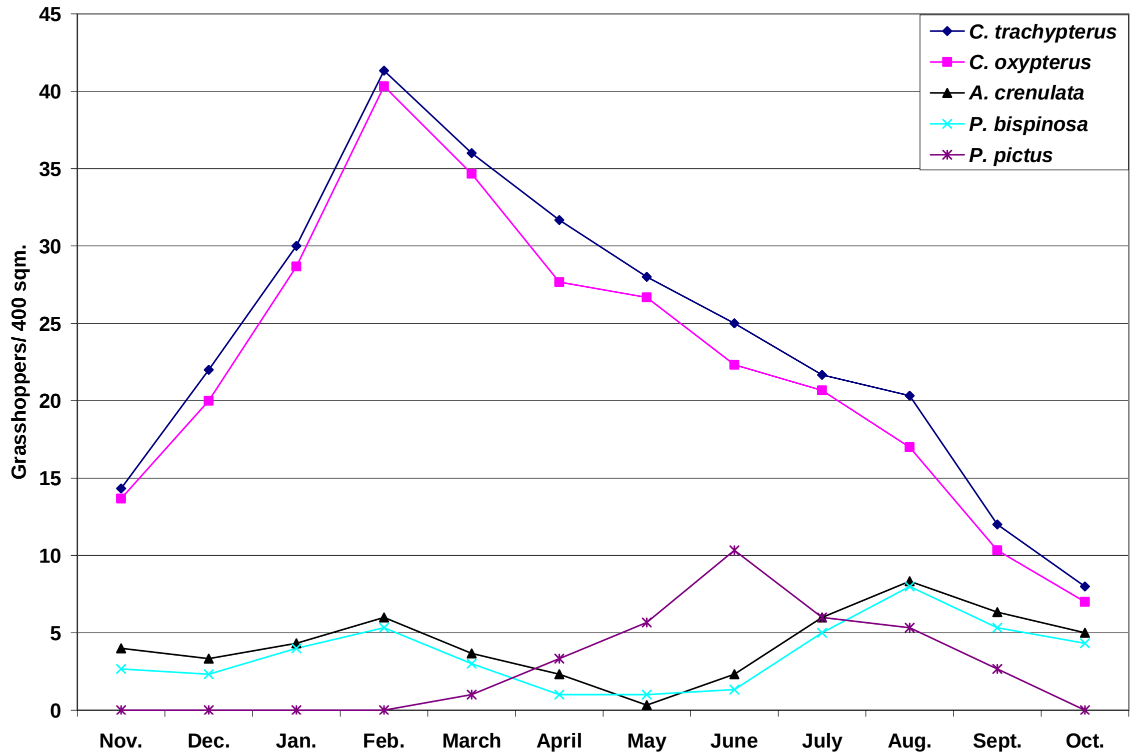

Figure: 9. Relative Incidence of the Pyrgomorphid Fauna at Rajsamand during 2005-06

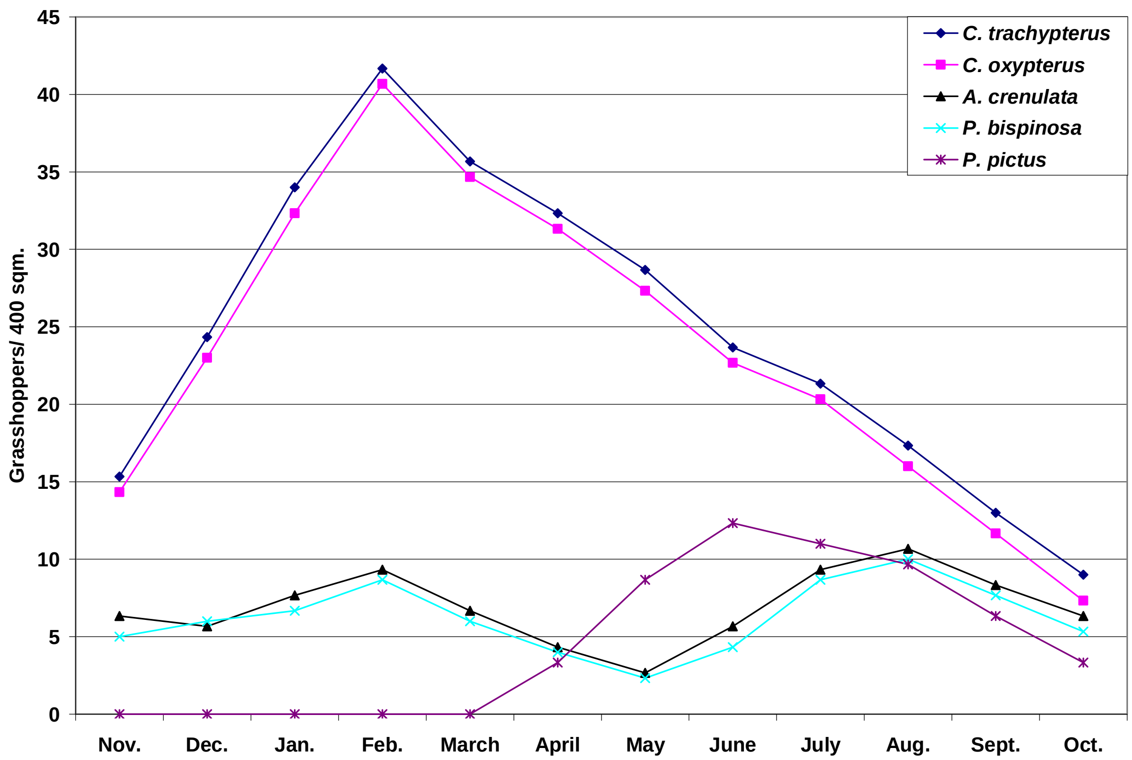

Figure: 10. Relative Incidence of the Pyrgomorphid Fauna at Rajsamand during 2006-07

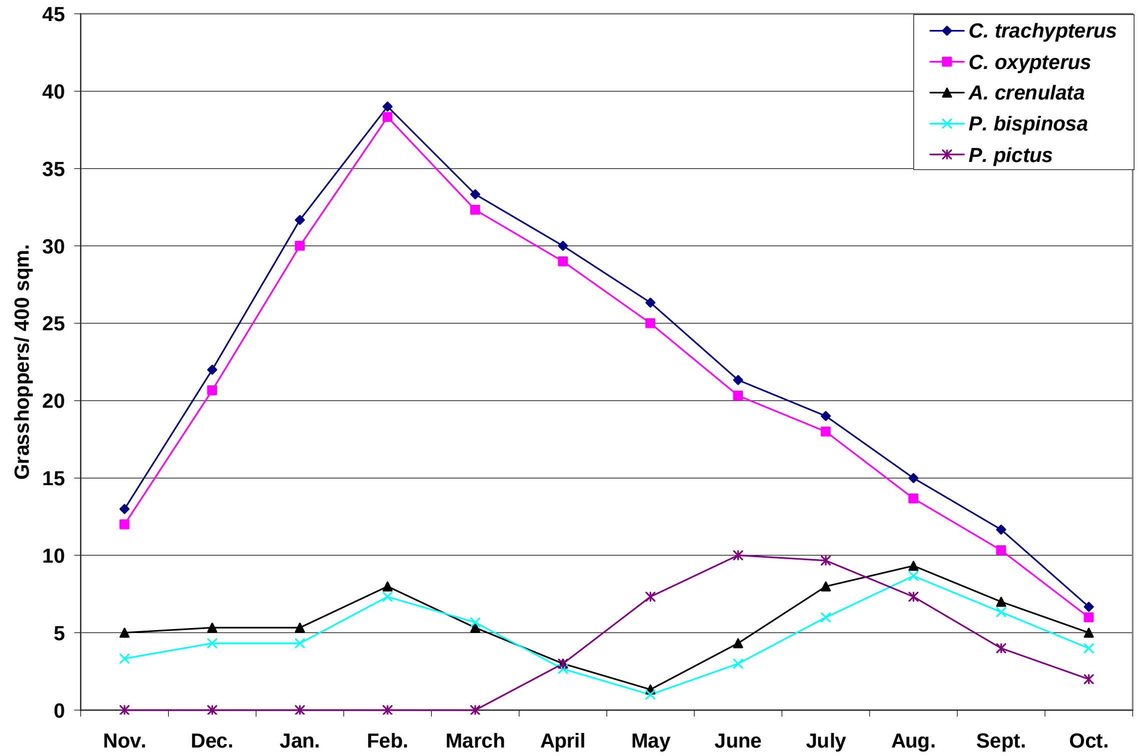

Figure: 11. Hopper Infestation (%) of Pyrgomorphids at Udaipur during 2005-06

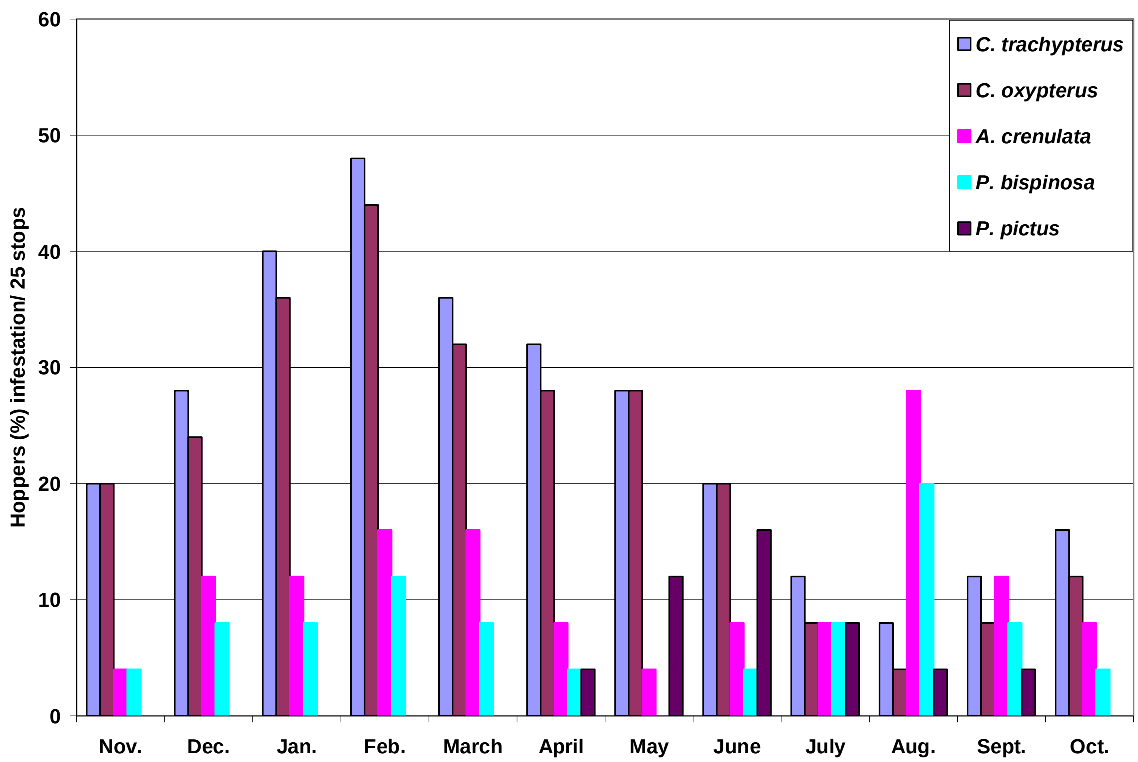

Figure: 12. Hopper Infestation (%) of Pyrgomorphids at Udaipur during 2006-07

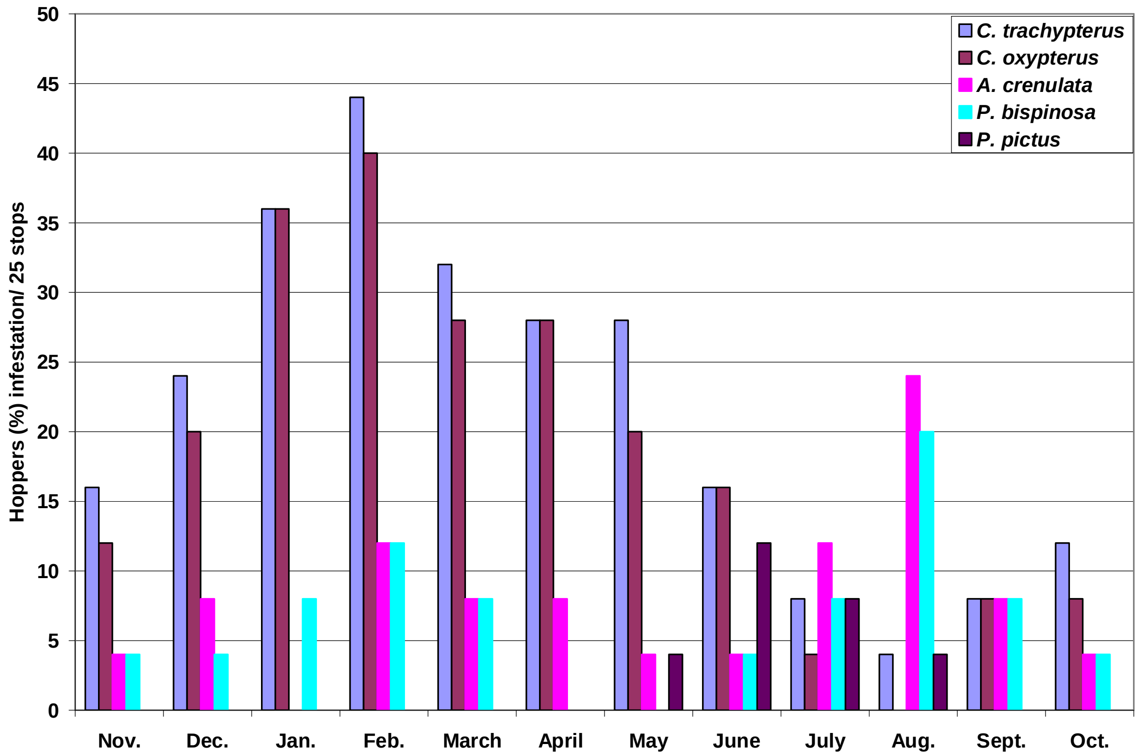

Figure: 13. Hopper Infestation (%) of Pyrgomorphids at Banswara during 2005-06

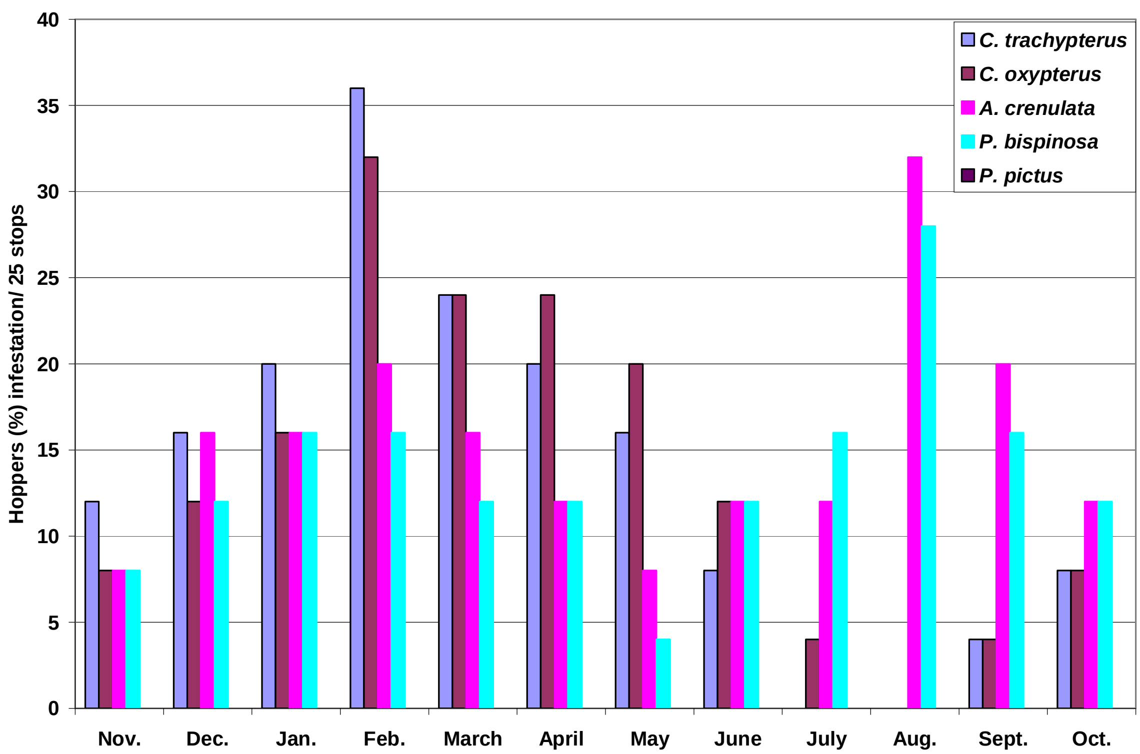

Figure: 14. Hopper Infestation (%) of Pyrgomorphids at Banswara during 2006-07

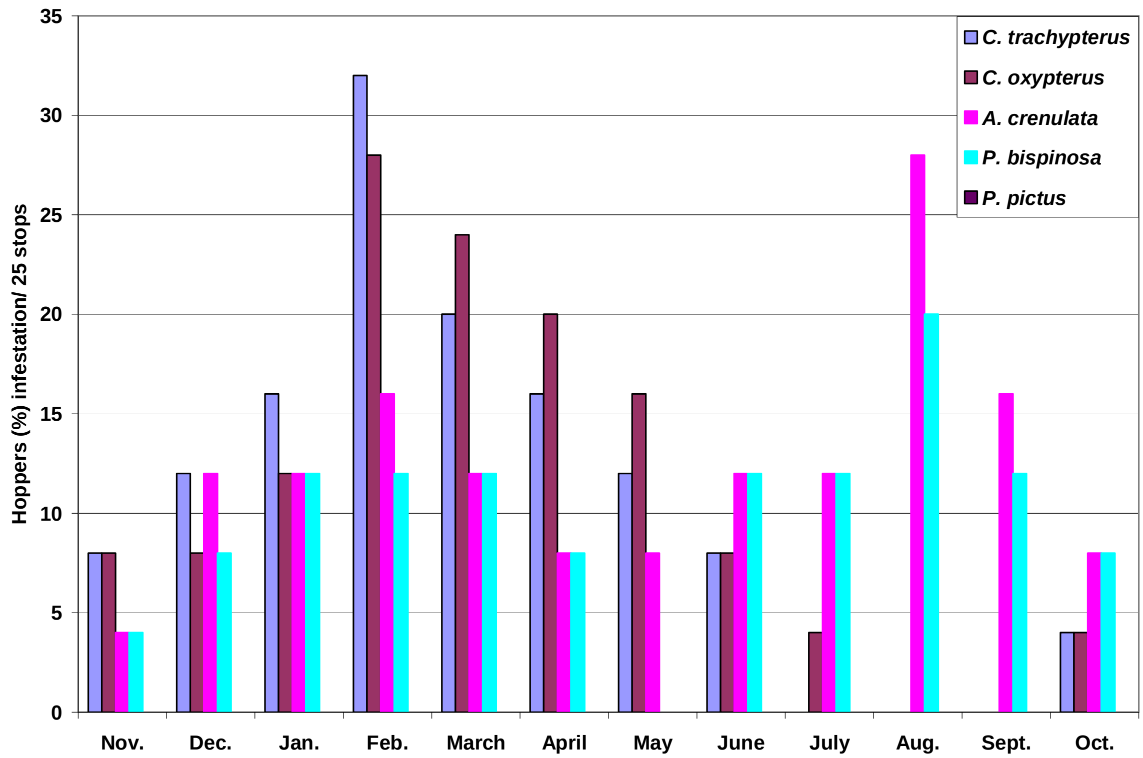

Figure: 15. Hopper Infestation (%) of Pyrgomorphids at Dungarpur during 2005-06

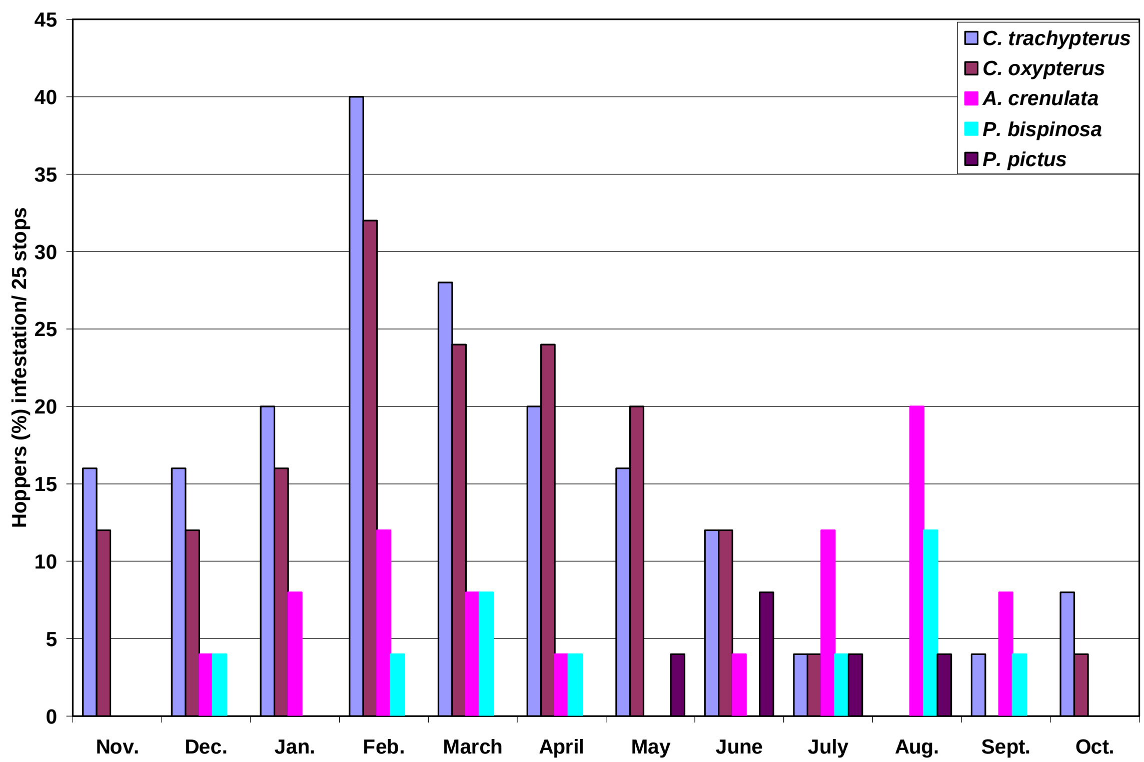

Figure: 16. Hopper Infestation (%) of Pyrgomorphids at Dungarpur during 2006-07

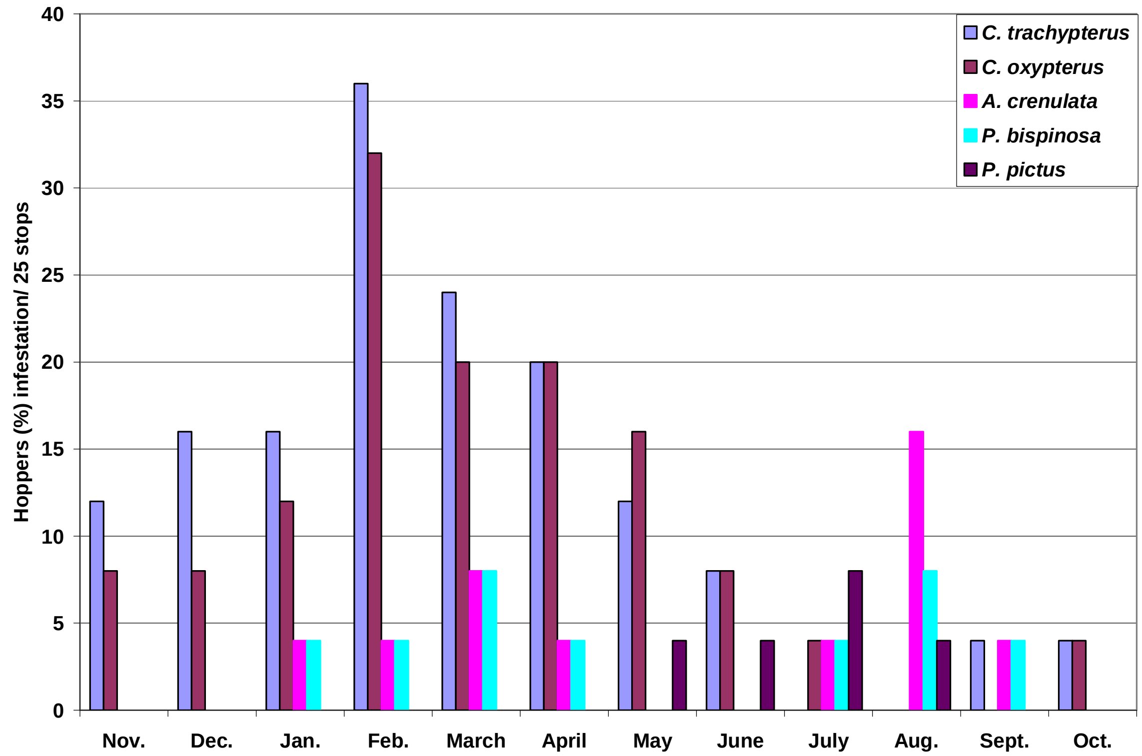

Figure: 17. Hopper Infestation (%) of Pyrgomorphids at Sirohi during 2005-06

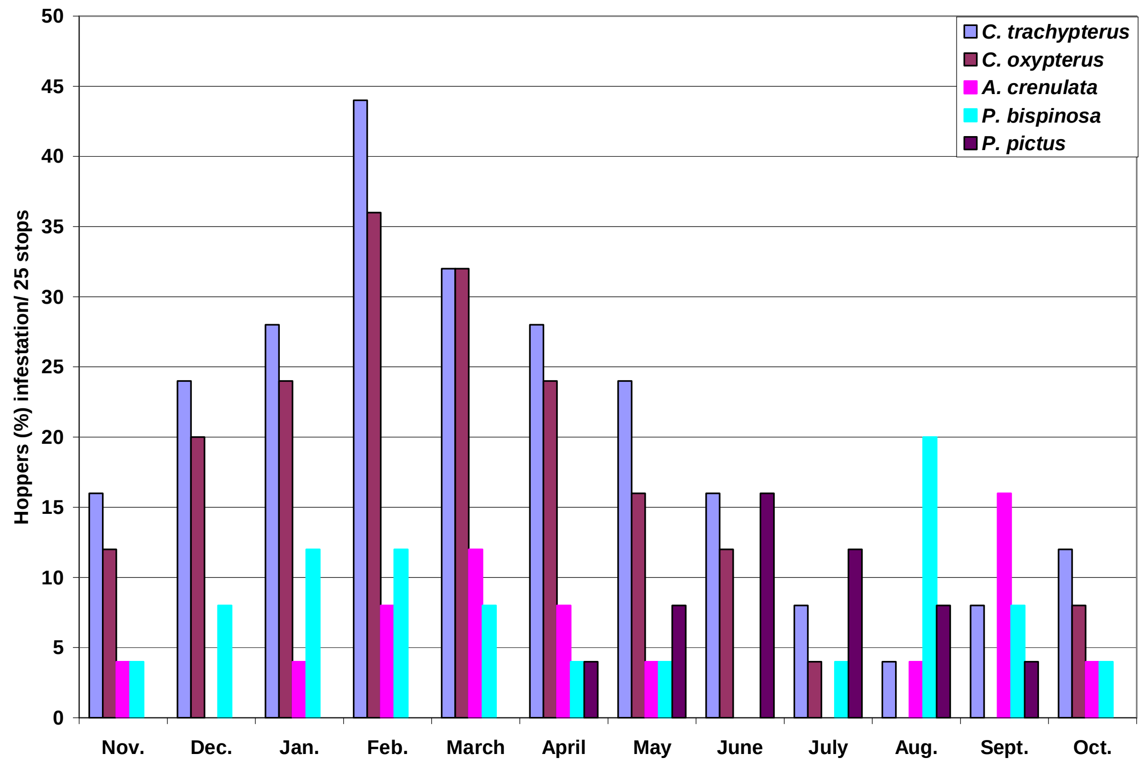

Figure: 18. Hopper Infestation (%) of Pyrgomorphids at Sirohi during 2006-07

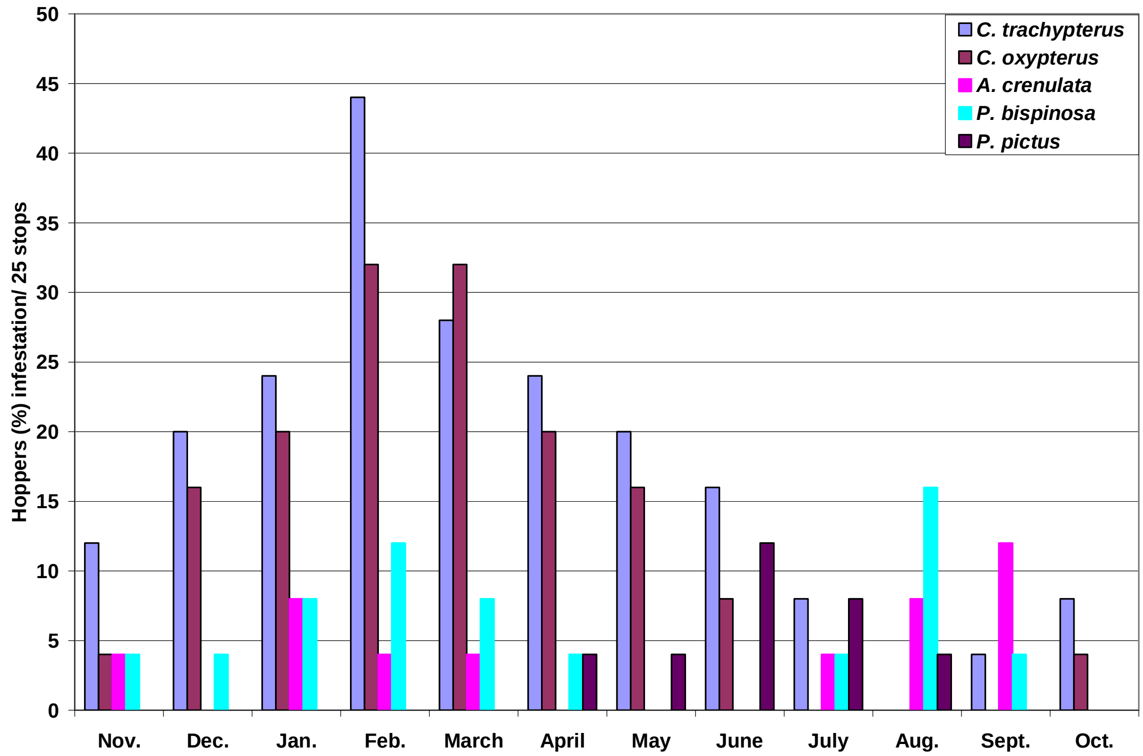

Figure: 19. Hopper Infestation (%) of Pyrgomorphids at Rajsamnad during 2005-06

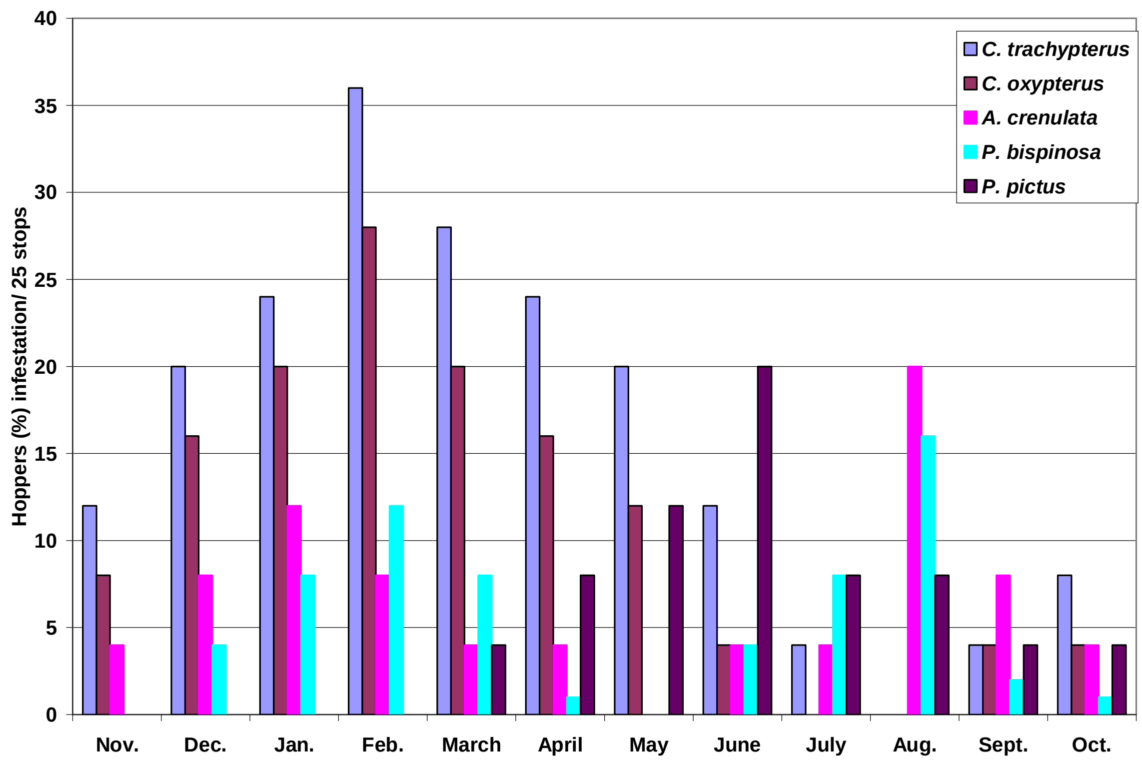

Figure: 20. Hopper Infestation (%) of Pyrgomorphids at Rajsamnad during 2006-07

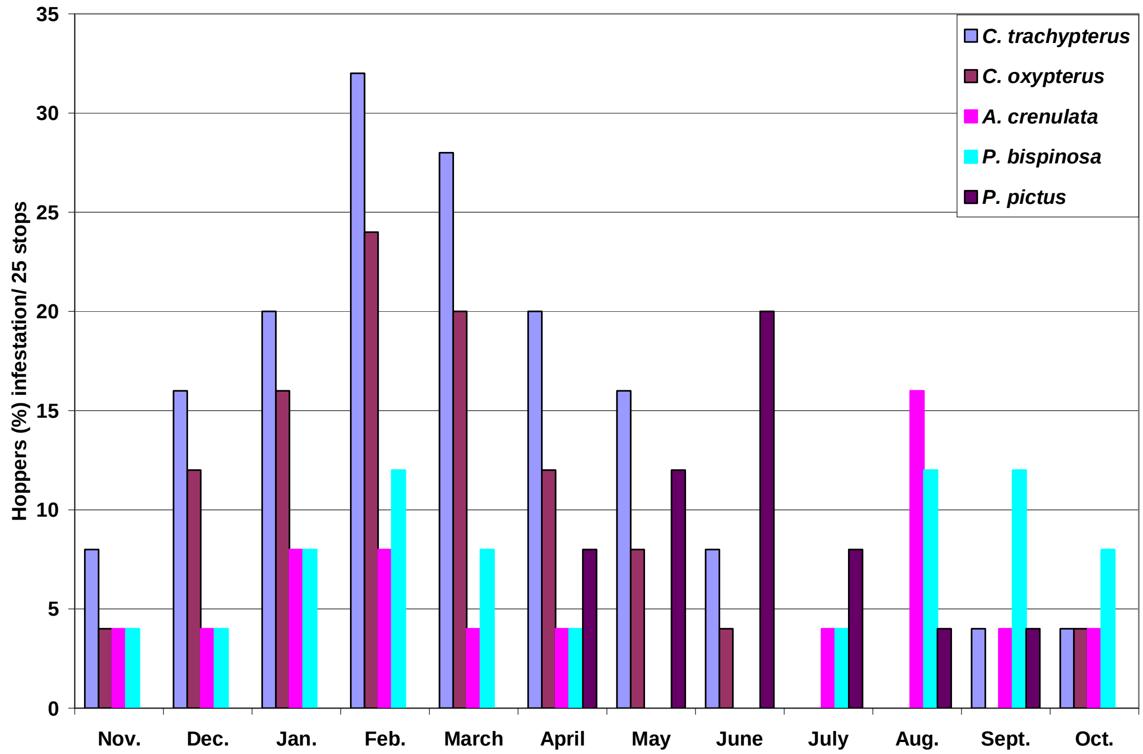

Figure: 21. Effect of Host Plant on Developmental Potential of *C. trachypterus* [2005-06]

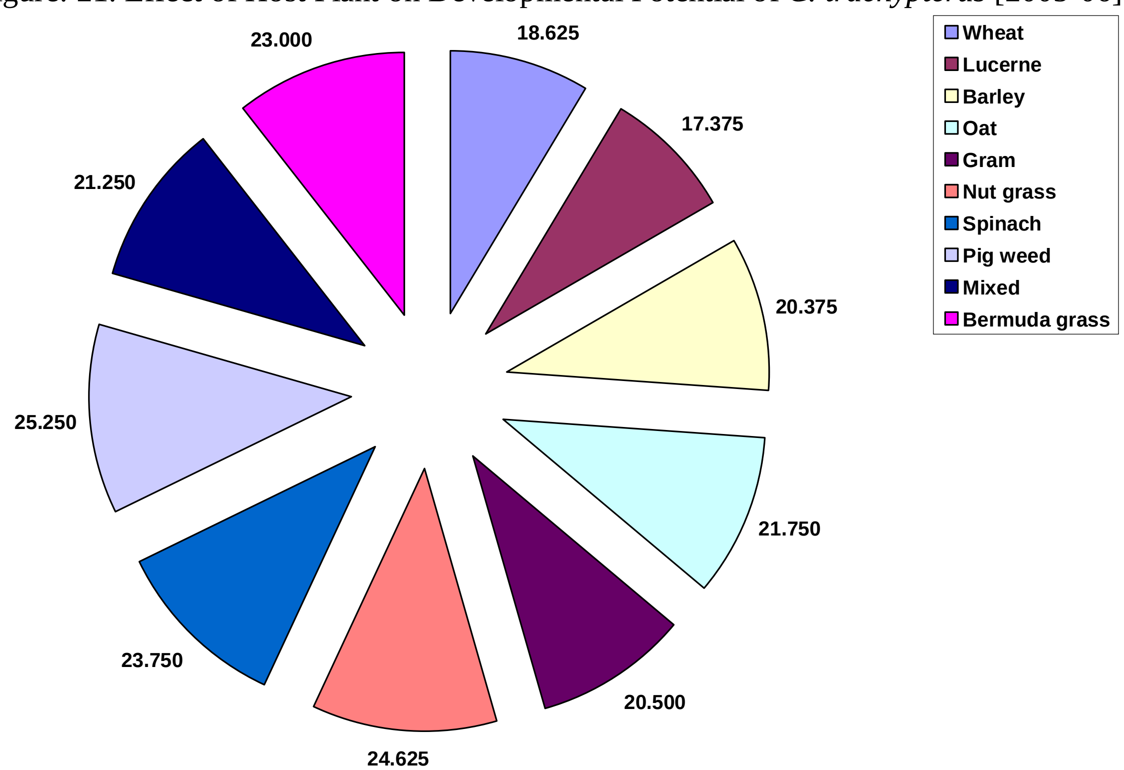

Figure: 22. Effect of Host Plant on Developmental Potential of *C. trachypterus* [2006-07]

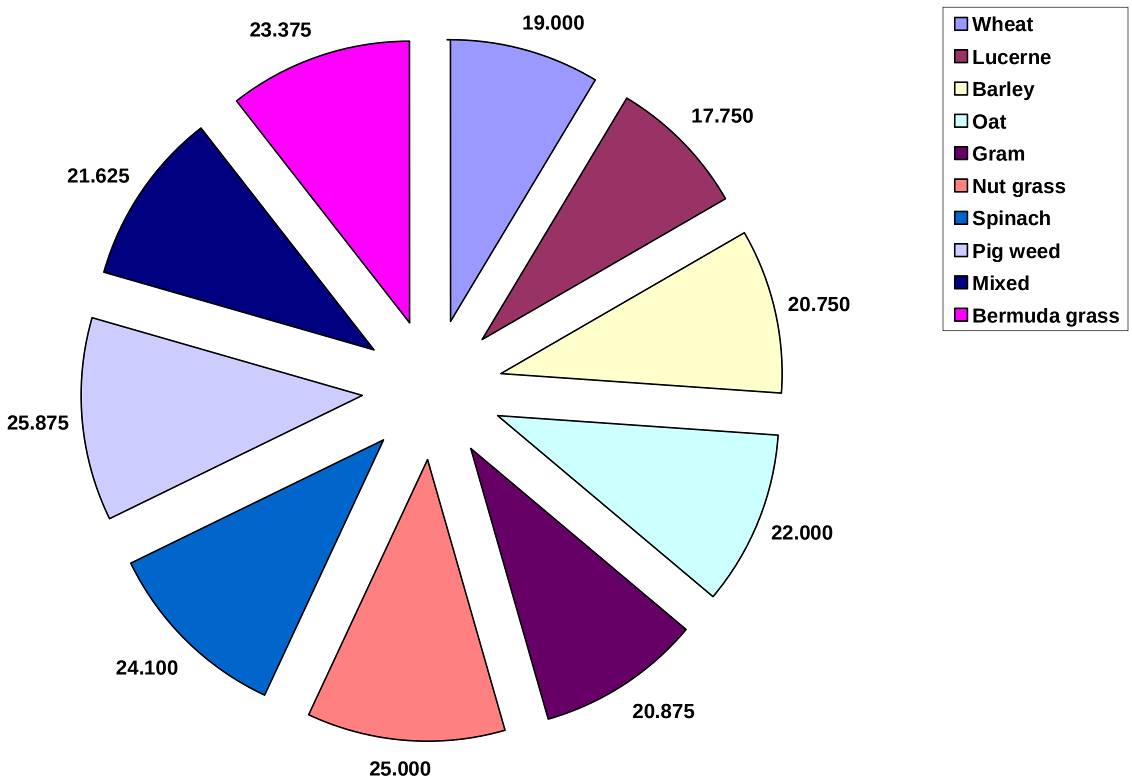

Figure: 23. Effect of Host Plant on Food Utilization for *C. trachypterus* during 2005-06

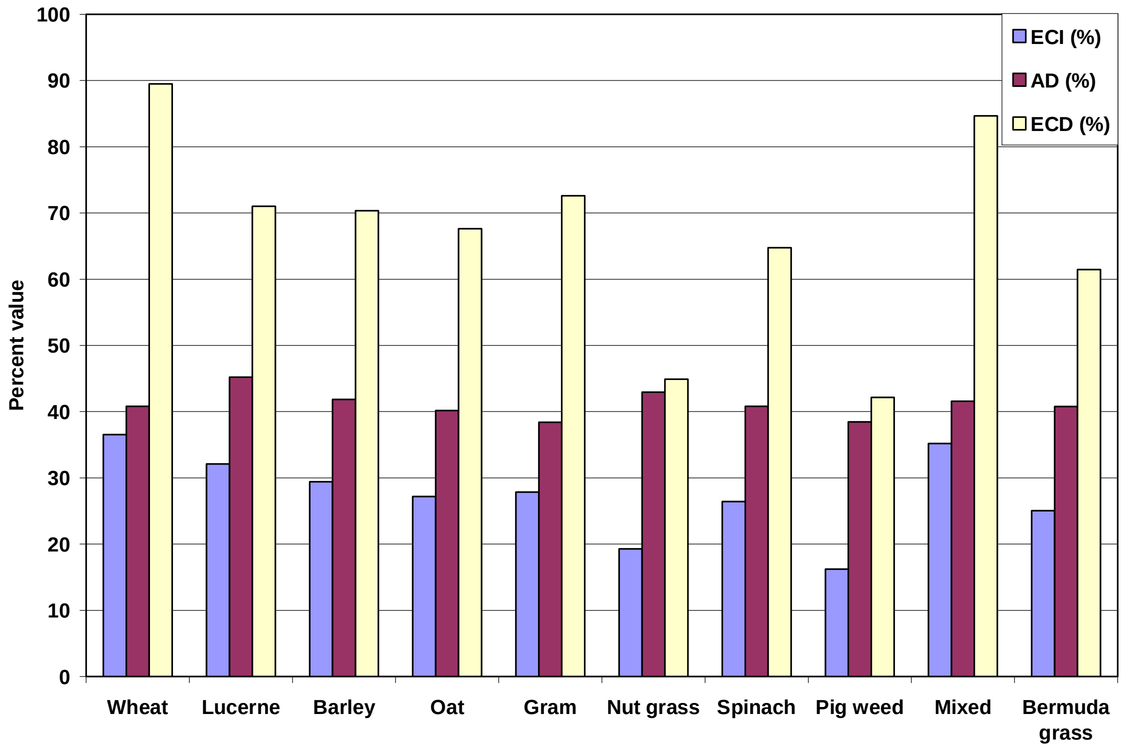

Figure: 24. Effect of Host Plant on Food Utilization for *C. trachypterus* during 2006-07