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Relationship between Grasshoppers and crops in an Agroecosystem of Tamil Nadu, India

Mit zwei Figuren und drei Tabellen

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Abstract

1. Grasshoppers were sampled in an agroecosystem of Tamil Nadu on major crops such as *Oryza sativa*, *Arachis hypogaea*, *Phaseolus radiatus*, *Sorghum vulgare*, as well as on fodder crops *Coix lachryma* and *Panicum maximum* for an entire year on a monthly basis with a view to analyse the association of plants and grasshoppers in an agroecosystem.
2. Grasshoppers are less diverse in an agroecosystem in terms of their species composition.
3. The total grasshopper population did not differ significantly with seasons on all the crops surveyed except *A. hypogaea* and *P. radiatus*. Also within a crop, the diversity of grasshopper species attacking it did not vary with season.
4. The total yearly grasshopper faunal load in the agroecosystem was 1533.13.
5. *P. maximum* supported maximum number of grasshoppers in the ecosystem.
6. A bimodal distribution of diet breadth (B_i) values was observed for the grasshoppers with specialized species being more abundant on all the crops.
7. The fraction of a plants faunal load made up of oligophagous grasshoppers showed good correlation with the fraction made up of specialist grasshoppers.

Key Words:
Insect-plant relations, Orthoptera, Grasshopper diversity, density, agro-ecosystem, diet breadth, faunal load.

Introduction

Ever since the analysis of coevolution between the butterflies and the larval hosts by EHRLICH & RAVEN (1964), the study of the interaction between plants and herbivores have attracted a number of scientists (FEENY, 1976; RHOADES & CATES, 1976; FUTUYMA, 1976). Most of these analyses pivoted on the study of the defences of the plants and the corresponding counter adaptations of the herbivores. Millennia have passed since historically cognizant and educable hominids have mentally recorded the obligate, omnipresent association between herbivores and their host plants; yet we are still unable both to describe with certainity the process by which the observed associations are established, or to predict with confidence the outcome of any such active interaction (SPENCER, 1988). The natural interactions together with modern cultural practices in agriculture have affected the patterns of community structure at various levels. At present, there has emerged a concern on the patterns of insect community structure that may arise from long term interactions. The agroecosystem represent a system of maximum human interference. An understanding of the extent of insect species diversity and density upon specific plants, the distribution of the diet breadth of the herbivores in terms of the relative incidence of specialised and generalized insects and the patterns of overlap in the insect diet, appear important for the analysis of the community structure. In this paper an attempt is made to analyse the

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association of grasshoppers in agricultural ecosystems of Tamil Nadu taking into consideration the number of species of grasshoppers on different crops, their periodicity of occurence in different seasons and the distribution of diet breadth of the grasshoppers.

Methodology

Tamil Nadu, a state in the south eastern part of peninsular India, has nearly 60 lakh hectares of land under cultivation. Paddy (*O. sativa*), ground nut (*Arachis hypogaea*), cholam (*Sorghum vulgare*) and greengram (*Phaseolus radiatus*) are the major crops grown here besides the fodder crops *Coix lachryma* and *Panicum maximum*. In addition small pockets also grow ragi (*Eleusine coracana*), cambu (*Pennisetum typhoideum*) and cotton (*Gossypium hirsutum*).
An attempt was made to quantitatively sample each of the major crops grown in Tamil Nadu for various species of grasshoppers on a monthly basis. Paddy, cholam, groundnut, greengram and the fodder crops *Coix lachryma* and *Panicum maximum* were chosen for this study. Sweepnet technique was adopted for population estimations using nets of 30 cm diameter and 75 cm conical height. Five sweeps were made with the net at randomly selected areas of the plot for each crop plant. Hoppers collected and identified were counted and immediately released into the habitat. All insect species of which less than 3 specimens were collected during the study were deleted from consideration, since the 'niche breadth' of a species cannot be validly estimated if the number of specimens are fewer than the number of host species (COLWELL & FUTUYMA, 1971; INGER & COLWELL, 1977). The patterns of interaction between the grasshopper and the crop was studied using the following parameters:
Grasshopper density:
The density of grasshopper (i) on crop (j) is calculated as

$$d_{ij} = N_{ij}/W_j,$$

where N_{ij} is the total number of grasshopper species (i) collected from plant species (j). W_j is the estimated dry weight of foliage sampled from plant species (j).
The sum of the insect densities over hosts represent the 'abundance' of the insect and is represented by

$$A_i = {}^{r}\Sigma_{j=1}\, d_{ij}.$$

Faunal load of crop plant:
The faunal load of a crop(j) is estimated as the sum of its insect densities and is given by

$$L_j = {}^{s}\Sigma_{i=1}\, d_{ij}.$$

Grasshopper diet breadth:
This is estimated as

$$B_i = [- {}^{r}\Sigma_{j=1}\, p_{ij} \log p_{ij}]/\log r$$

where $p_{ij} = d_{ij}/A_i$, the proportion of the sample insect (i) taken from plant (j), 'r' is the number of plant species.

Grasshopper diversity on crop plant:
This is estimated as

$$H_j = [- {}^{s}\Sigma_{i=1}\, q_{ij} \log q_{ij}]/\log s$$

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where $q_{ij} = d_{ij}/L_j$, the proportion of plant j's insect made up of insect 'i' and 's' is the number of insect species.

Observations

Seasonal changes

Tamil Nadu is a state of comparative high temperatures and receives rains from the northeast and southwest monsoons. As such the region has three seasons of hotness namely 1) summer, the hottest period extending from April to July when the temperatures are above 33°c 2) a less hot rainy season during August to November with temperatures averaging 29°c and 3) a warm (pleasant) period between December and March with a temperature range of 26-33°c.

By far agricultural plots chosen for this study included only the well irrigated crop fields. Population counts of grasshoppers (Table 1) made during the three seasons were analysed for variance on all crop plants. The results indicate that the total grasshopper population did not significantly differ with the three seasons on all the host plants except in groundnut and greengram. On groundnut, the population of grasshoppers during the summer season differed significanlty from the rainy season whereas on greengram the population during the rainy season differed from that of the other two seasons. No seasonal differences were observed with respect to the grasshopper species diversity on crop plants.

Grasshopper diversity:

Table 2 enlists the various species of grasshoppers and the plant species associated/encountered during the survey. It is interesting to note that this part of the country has grasshoppers belonging to only two families of the order Orthoptera namely Pyrgomorphidae and Acrididae. Of the 33 species observed in the agroecosystem, the following 10 species are more commonly encountered and are regarded as core species: *Acrida exaltata, Aiolopus thalassinus, Atractomorpha crenulata, Diabolocatantops pinguis, Eyprepocnemis alacris alacris, Oxya nitidula, Oxya fuscovittata, Spathosternum prasiniferum prasiniferum, Orthacris maindroni* and *Chrotogonus oxypterus*. The estimated seasonal diversity of grasshoppers on various crops (figure 1) indicate that within a crop, the diversity of grasshoppers attacking it did not differ with seasons. A low level of significant difference ($P < 0.1$) between crops and their grasshopper diversity was observed. Statistically the grasshopper species diversity on groundnut differed with all the other crops except paddy.

FIG 1 GRASSHOPPER DIVERSITY ON CROPS

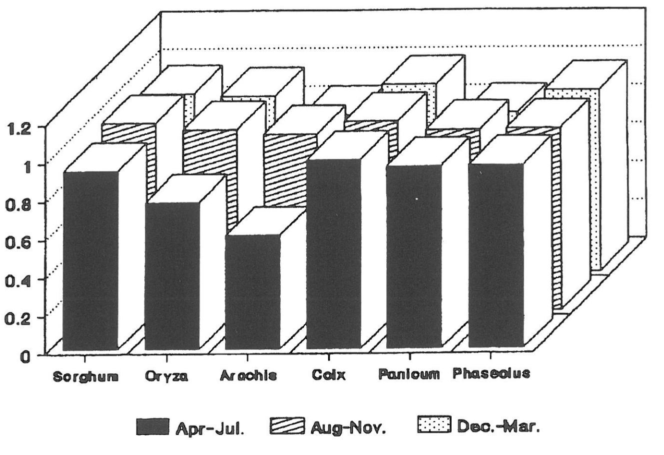

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Table 1: Seasonal Collection of Grasshoppers from different crops

Crop	Grasshopper	Apr-Jul	Aug-Nov	Dec-Mar
Sorghum vulgare	A.c	127	125	73 B
	S.p	98	100	84 AB
	A.e	88	104	69 AB
	O.n	250	112	201 C
	O.f	255	63	157 BC
	A.t	0	0	0 A
	D.p	0	0	0 A
	C.o	0	0	0 A
	O.m	0	0	0 A
	E.a	0	0	0 A
		A	A	A
Oryza sativa	A.c	210	181	131 C
	S.p	136	150	81 B
	A.e	117	125	83 B
	O.n	335	299	260 D
	O.f	81	97	93 B
	A.t	0	0	0 A
	D.p	0	0	0 A
	C.o	0	0	0 A
	O.m	0	0	0 A
	E.a	0	0	0 A
		A	A	A
Arachis hypogaea	A.c	21	65	40 AB
	S.p	0	0	0 A
	A.e	0	0	0 A
	O.n	0	0	0 A
	O.f	3	24	21 A
	A.t	0	0	0 A
	D.p	3	101	54 B
	C.o	0	0	8 A
	O.m	0	0	5 A
	E.a	0	34	9 A
		A	B	AB
Coix lachryma	A.c	0	0	0 A
	S.p	0	0	0 A
	A.e	0	0	0 B
	O.n	408	315	387 C
	O.f	513	400	530 A
	A.t	0	0	0 A
	D.p	0	0	0 A
	C.o	0	0	0 A
	O.m	0	0	0 A
	E.a	0	0	0 A
		A	A	A

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	A.t	0	0	0 A
	D.p	0	0	0 A
	C.o	0	0	0 A
	O.m	0	0	0 A
	E.a	0	0	0 A
		A	A	A
Panicum maximum	A.c	0	0	0 A
	S.p	0	0	0 A
	A.e	0	0	0 A
	O.n	394	329	626 C
	O.f	0	0	0 A
	A.t	236	188	223 B
	D.p	0	0	0 A
	C.o	0	0	0 A
	O.m	0	0	0 A
		A	A	A
Paseolus radiatus	A.c	19	51	24 AB
	S.p	0	0	0 A
	A.e	0	0	0 A
	O.n	0	0	0 A
	O.f	0	45	29 AB
	A.t	0	0	0 A
	D.p	17	86	26 B
	C.o	12	33	11 AB
	O.m	24	24	18 AB
	E.a	8	34	8 AB
		A	B	A

A.c = *Atractomorpha crenulata*
S.p = *Spathosternum prasniferum*
A.e = *Acrida exaltata*
O.n = *Oxya nitidula*
O.f = *Oxya fuscovittata*
A.t = *Aiolopus thalassinus*
D.p = *Diabolocatantops pinguis*
C.o = *Crotogonus oxypterus*
O.m = *Orthacris maindroni*
E.a = *Eyprepocnemis alacris*

Rows and columns having common letters indicate means are not significantly different at P = 0.05

Grasshopper density in agroecosystem:

The density of grasshoppers in different crop plants surveyed during the three seasons is provided in table 3. Five grasshopper species namely *A. crenulata*, *S. rasiniferum*, *A. exaltata*, *O. nitidula* and *O. fuscovittata* were observed to feed on cholam and paddy. Although the table 3 indicates that *C. oxypterus*, *O. maindroni* and *E. alacris* were present only in greengram crops, they have also been collected in few numbers from *C. lachryma* and *P. maximum* fields. A total faunal load of 1533.13 was computed for an agricultural ecosystem of Tamil Nadu for an year taking into account only the grasshoppers collected from the six crop plants.

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Table 2

Grasshopper species	Family	Plants associated/Encountered
Acrida exaltata	Acrididae	Paddy, Cholam, Ragi
Acrotylus humbertianus	do	Paddy, Ragi
Aiolopus thalassinus	do	Paddy, Ragi, Panicum
Cyrtacanthacris tatarica	do	Cotton, ragi
Diabolocatantops pinguis	do	Groundnut, greengram
Eyprepocnemis alacris	do	Paddy, Panicum, greengram
Epistaurus sinetyi	do	Paddy, groundnut
Gonista sagitta	do	Panicum
Tristria pulvinata	do	Cholam, vegetables
Stenocatantops splendens	do	Paddy, cholam
Xenocatantops humilis	do	Paddy, cholam, ragi
Heteracris pulcher	do	Paddy, cholam, Panicum
Tylotropidius varicornis	do	Coix, cholam
Scintharista blanchardiana	do	Cholam
Oxya nitidula	do	Coix, Panicum, paddy
Oxya fuscovittata	do	Cholam, Coix, groundnut
Oxya hyla hyla	do	Paddy
Hieroglyphus banian	do	Paddy, Coix
Morphacris fasciata sulcata	do	Ragi, cholam, paddy
Gastrimargus africanus	do	Cholam, Coix
Oedaleus abruptus	do	Paddy, cholam, ragi
Oedaleus senegalensis	do	Cholam, ragi
Leva curciata	do	Paddy
Dnopherula luteipes	do	Paddy, cambu, Coix
Trilophidia annulata	do	Paddy, Panicum, cholam
Truxalis indica	do	Paddy, Panicum
Leptacris vittata	do	Cholam
Gesonula punctifrons	do	Panicum
Atractomorpha crenulata	Pyrogomorphidae	Paddy, ragi, groundnut, vegetables, cholam, castor
Spathosternum prasiniferum	do	Sugarcane, paddy, ragi, cholam, cambu
Orthacris maindroni	do	Greengram, Panicum
Crotogonus oxypterus	do	Groundnut, paddy, greengram
Pyrgomorpha bispinosa	do	Groundnut

A. crenulata is well represented in the agroecosystem and was collected from four of the six crop plants surveyed. They were more abundant during April to November. However, they constituted only 9.95 % of the grasshopper faunal load in the ecosystem.

S. prasiniferum and *A. exaltata* were collected only from cholam and paddy fields and accounted for a total yearly abundance of 115.68 and 105.14 respectively. A comparison of the density of the two grasshopper species on paddy and cholam, indicate that cholam support greater number of these grass-

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Table 3: Seasonal density of Grasshoppers over crops and the faunal load of crops

Sp	*S. vulgare*	*O. sativa*	*A. hypogaea*	*C. lachryma*	*P. macimum*	*P. radiatus*
A.c	29.47	28.81	0.68	0.00	0.00	0.31
S.p	22.74	18.56	0.00	0.00	0.00	0.00
A.e	20.42	16.04	0.00	0.00	0.00	0.00
O.n	58.00	45.95	0.00	31.46	107.94	0.00
O.f	59.16	11.11	0.09	39.55	0.00	0.00
A.t	0.00	0.00	0.00	0.00	64.66	0.00
D.p	0.00	0.00	0.09	0.00	0.00	0.27
C.o	0.00	0.00	0.00	0.00	0.00	0.19
O.m	0.00	0.00	0.00	0.00	0.00	0.38
E.a	0.00	0.00	0.00	0.00	0.00	0.13
$L_j(1)$	189.79	120.47	0.86	71.01	172.60	1.28
A.c	29.00	24.83	2.09	0.00	0.00	0.82
S.p	23.20	20.58	0.00	0.00	0.00	0.00
A.e	24.13	17.15	0.00	0.00	0.00	0.00
O.n	25.98	41.02	0.00	24.29	90.14	0.00
O.f	14.62	13.31	0.77	30.48	0.00	0.73
A.t	0.00	0.00	0.00	0.00	51.51	0.00
D.p	0.00	0.00	3.26	0.00	0.00	1.39
C.o	0.00	0.00	0.00	0.00	0.00	0.53
O.m	0.00	0.00	0.00	0.00	0.00	0.39
E.a	0.00	0.00	1.98	0.00	0.00	0.55
$L_j(2)$	116.93	116.89	8.10	54.77	141.65	4.41
A.c	16.94	17.97	1.29	0.00	0.00	0.39
S.p	19.49	11.11	0.00	0.00	0.00	0.00
A.e	16.01	11.39	0.00	0.00	0.00	0.00
O.n	46.64	35.67	0.00	29.84	171.51	0.00
O.f	36.43	12.76	0.68	40.86	0.00	0.47
A.t	0.00	0.00	0.00	0.00	61.09	0.00
D.p	0.00	0.00	1.74	0.00	0.00	0.42
C.o	0.00	0.00	0.26	0.00	0.00	0.18
O.m	0.00	0.00	0.16	0.00	0.00	0.29
E.a	0.00	0.00	0.29	0.00	0.00	0.13
$L_j(3)$	135.51	88.90	4.42	70.70	232.60	1.88
*	442.23	326.26	13.38	196.48	546.85	7.57

* represents the yearly faunal load of the crop
For expansion of sp. see table 2
$L_j(1\text{-}3)$ = Faunal load at 1) Apr-Jul 2) Aug-Nov 3) Dec-Mar

hoppers than paddy and also the population of *S. prasiniferum* was always more than *A. exaltata*. Both the species of Oxya studied had high populations on cholam, paddy and Coix. In addition *P. maximum* supported high populations of *O. nitidula* and a low population of *O. fuscovittata*. The largest share of the grasshopper abundance in the agroecosystem was due to these two species of Oxya. Also *O. nitidula* recorded the highest grasshopper abundance in all the three seasons. A 46.21% of the grasshopper faunal load was made up of *O. nitidula* and 17.03 % of *O. fuscovittata*.

Although *A. thalassinus* is a polyphagous species, among the crop plants surveyed, they were present only in the fields of *P. maximum* constituting about 11.56 % of the grasshopper faunal laod of the

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ecosystem. Low populations of *D. pinguis* was recorded in all the seasons on *A. hypogaea* while greengram supported low populations of *C. oxypterus, O. maindroni* and *E. alacris*.

A comparison of the grasshopper density on all the crop plants indicate the maximum grasshopper faunal load (546.85) on *P. maximum* followed by cholam (442.23) and paddy (326.26). Greengram supported the least (1.88) number of grasshoppers.

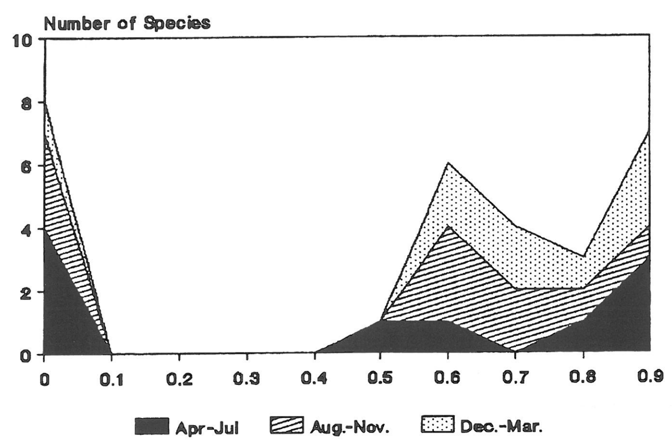
Grasshopper diet breadth:

Diversity measures B_i and H_j are more useful than calculating 'species richness' on plant and 'diet richness' because rare occurrences of insects on plants inflate the estimates of both an insects' host range and a plants' variety of insect associates above the levels apparent in the field (FUTUYMA & GOULD, 1979). B_i measures not the actual distribution of the population over plants, but the variety of plants acceptable to insect 'i', given that they have been encountered. A bimodal distribution of B_i values was observed in the present study (Fig. 2). Generalized and specialized species are common among the grasshoppers, with the specialised ones feeding on particular plant species, or on plants belonging to specific family. Laboratory studies on the feeding preference and host selection indicate *A. crenulata, A. thalassinus, O. maindroni* and *E. alacris* to be generalized species capable of feeding on a number of unrelated plants whereas *S. prassiniferum, O. nitidula, O. fusocovittata* and *A. exaltata* show feeding preference only for the monocots, while *D. pinguis* and *C. oxypterus* prefer dicot plants. It is interesting to compute and understand if the most abundant grasshoppers on a plant in the natural habitat belong to specialised species or generalized specieis. To do this, variance was analysed by weighting B_i with the relative abundance on the plant of species 'i'. The results indicate that specialized grasshoppers were more abundant on all the crop plants and seasons showed no differrence in the relative grasshopper abundance. The weighted mean breadth of diet of the grasshoppers was not correlated with the faunal load ($r = 0.07$; $P = 0.89$).

The sum of B values for the grasshopper species over different host plants facilitate distinguishing the species into specialist, generalist and oligophagous species. Insects with a value < 0.25 are specialist, those between 0.25 and 0.5 oligophagous and those > 0.5 generalists. Accordingly, *A. crenulata, O. nitidula, O. fuscovittata* and *A. thalassinus* are generalists, *S. prasiniferum* and *D. pinguis* are oligophagous while *C. oxypterus, O. maindroni*, and *E. alacris* are specialists as far as the agroecosystem is considered.

The fraction of the faunal load comprised of the generalist grasshoppers showed no correlation ($r = 0.37$; $P = 0.46$) with the faunal laod. Similarly, no correlation was observed between the faunal load and either oligophagous ($r = -0.26$; $P = 0.61$) or specialist ($r = -0.41$; $P = 0.4$) grasshoppers.

FIG 2 GRASSHOPPER DIET BREADTH



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It is interesting to compute and analyse if different species of grasshoppers are differentially affected by the variation among plant species. The fraction of a plants faunal load comprising of specialised ($B_i \leq 0.25$) grasshoppers is not correlated ($r = -0.76$; $P = 0.07$) with the fraction made up of generalized ($B_i \geq 0.5$) grasshoppers. Similarly no correlation was observed between the fractions made up of oligophagous and generalized grasshoppers ($r = -0.63$; $P = 0.17$). However, the fraction made up of oligophagous and specialist grasshoppers showed good correlation ($r = 0.97$; $P = 9.4 \times 10^{-4}$).

Discussion

Tropical countries are rich in their insect species diversity. The number of species in an area is determined by its evolutionary history, the pattern of interaction among the species of the community, the fluctuation of the physical variables of the environment and the spatial heterogenity of the habitat (POOLE, 1974). In the agroecosystem surveyed, the grasshoppers are less diverse in terms of their species composition and only 33 species of grasshoppers were observed belonging to only two families namely Pyrgomorphidae and Acrididae. Agroecosystems represents a simplified system in which there are fewer plant species available for the insect. Moreover most of the crops are so selected that they have greater resistance to insect attack and therefore would attract fewer species of insects. The availability of host plants of the insects in the habitat is vital for its colonization. The type of vegetation in a habitat is influenced by variations in the precipitation/elevation of the region. Plant and grasshopper species composition changes over environmental gradients and the habitat type influences not only species presence, but also the relative abundance (KEMP et al, 1990). The importance of vegetation for nutritional and ecological needs of grasshoppers have been reported by a number of investigators (OTTE & JOERN, 1977; MULKERN, 1980; JOERN, 1982; PFADT, 1982). The agroecosystem surveyed in the present study was limited to the plains and as such no details are available on the effect of elevation either on the grasshopper species diversity nor its relative abundance. However, vegetation does have a profound effect on the grasshoppers as is evident by the crops showing different grasshopper faunal load values. Disturbances in the habitat appear important in structuring grasshopper community composition. Agricultural lands appear to be the most highly disturbed area wherein spraying of insecticides, deweeding and other cultural practices effect the grasshopper community. Periodic harvesting of the crops make the grasshoppers to shift to other areas within the habitat.

Grasshopper communities are known to be shaped directly by environmental factors and indirectly by differences in vegetation (SCHOENER, 1986; KINGSOLVER, 1989). On majority of the crops, the total grasshopper population computed for the three climatic seasons showed no significant differences. The agricultural cultural practices in this part of India provides a habitat with host plants available for the grasshopper continuously throughout the year. This serves as a positive factor for the continuous occurrence of the population in the habitat. There is evidence to indicate that the abundance and accessibility of host plants have greater influence on the number of grasshopper species than the number of plant species (PFADT, 1984). Climatic changes appeared to influence the population of grasshoppers only on groundnut and greengram. The cultural practices followed for the two crops indicate that the seeds are sown after the rains and the crop matures during the summer. As the plant ages, the nutritive value declines and this could serve as a factor for the decline in the grasshopper population. Again, discontinuity in the availability of host plants in the habitat with seasons results in dispersal of the grasshoppers to other localities thereby resulting in a decline in the population.

Grasshoppers are classified as polyphagous (euryphagous), oligophagous, and monophagous (GANGWERE et al., 1989). This classification is apparently based on the behaviour of individual species of grasshoppers. The present investigation reveals specialized (oligophagous) grasshoppers to be more abundant on the crops than the generalists (polyphagous). Since the plant species diversity in agroecosystem is less, the number of plant species available as food for generalist grasshoppers become restricted. This would result in the otherwise generalized grasshopper becoming specialist and

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restricted to a fewer plants of the agroecosystem. The diet breadth calculated for the agroecosystem grasshoppers therefore classifies *C. oxypterus, O. maindroni*, and *E. alacris alacris* as specialized grasshoppers. Although these species have a wide host range, many of their host plants are not available in the agroecosystem. Hence, they tend to become specialized. Moreover, due to their lesser flying and dispersal capabilities, they remain in the habitat for several generations. Feeding behaviour of insects governs their dispersal and migration over time and space (SOLBRECK et al., 1990). Generalised grasshoppers show lesser movement in space and feed on any of the available plants in the habitat. Specialised grasshoppers on the other hand are known to spend energy and time in search of their specific host plants. Strict monophagy has not been reported among grasshoppers (UVAROV, 1977) and most species tend to be oligophagous if not polyphagous. Therefore feeding behaviour would restrict the movement of grasshoppers in general. Evolution therefore leads to greater number of specialised insects (POOLE, 1974).

When a plant supports a number of species of insects, there is scope for competetion between the species. If there is competetion then a correlation would exists between their population abundance. No competetion was observed between the specialists and generalist grasshoppers and similarly no competetion was observed between the oligophagoous and generalists species. However, the fractions made up of oligophagous and specialist grasshoppers showed good positive correlation. This indicates that the two groups divide the plant host suitably for co-existance. Also, plant characteristics responsible for the attraction of the grasshoppers may be similar for specialist and oligophagous species.

The abundance and diversity of grasshoppers vary greatly among the crop plants of the agroecosystem. Grasshopper species does not seem to be equitably distributed over potential crop plants. The occurrence and distribution of the grasshoppers cannot easily be explained by the differences in the plant abundance and distribution. The most abundant crop in the ecosystem did not necessarily have the richest grasshopper fauna. Therfore it seems likely that variation in the associated grasshopper fauna is atleast in part due to the differences in the physical and chemical characteristics of the plant to which the insects are adapted in varying degrees (SANJAYAN & ANANTHAKRISHNAN 1987, GANGWERE et al. 1989). Nonetheless, most of the crop plants are endowed with secondary compounds and other defensive properties which confer resistance to the plant. The fact that the grasshoppers are able to feed and survive on these crops indicate that they have overcome the resistant mechanism of the plants. Many of these crops bear both specialized and generalized grasshopper species and therefore presumably have characteristics that evoke a specialized response by some insects but not others. The differential response of grasshoppers to the variation among hosts could be due to their responses to a multitude of plant physical and chemical charateristiacs. It is this multiplicity of defence features that is responsible for the apparent bimodality of the breadth of diet among the grasshoppers of this ecosystem.

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