

**Effect of diet components on the postembryonic development  
and reproductive biology of some seed-feeding polyphagous  
heteropteran pests ( Hemiptera : Insecta )**

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THESIS SUBMITTED FOR THE DEGREE OF  
DOCTOR OF PHILOSOPHY (SCIENCE)  
OF THE  
UNIVERSITY OF NORTH BENGAL  
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*By*  
**BISWAJIT SAHA**  
DEPARTMENT OF ZOOLOGY  
UNIVERSITY OF NORTH BENGAL  
INDIA

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Dedicated With Love And Gratitude  
To  
My Parents



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WEST BENGAL, INDIA, SILIGURI—734430.  
PHONE : BDR. 498

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SUPERVISOR'S CERTIFICATE

This is to certify that Mr. Biswajit Saha, M.Sc., CSIR Research Fellow, Department of Zoology, and presently a central school teacher, has worked on the problem entitled "*Effect of diet components on the postembryonic development and reproductive biology of some seed-feeding polyphagous heteropteran pests (Hemiptera: Insecta)*" under my supervision and guidance, and that he has fulfilled the requirements and regulations relating to the nature and period of research. This is also to certify that the research work embodies original results based on well-planned investigation made by Mr. Saha. The dissertation submitted herewith is for fulfilment of the degree of *Doctor of Philosophy in Science (Zoology)* of the University of North Bengal, and has not been submitted for any degree whatsoever by him or any one else. I sincerely wish Mr. Saha and his endeavour SUCCESS.

*Aruna Mukhopadhyay*

A. Mukhopadhyay

Senior Lecturer

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*Biswajit Saha*  
( BISWAJIT SAHA ) 31.5.93.

# **INTRODUCTION**

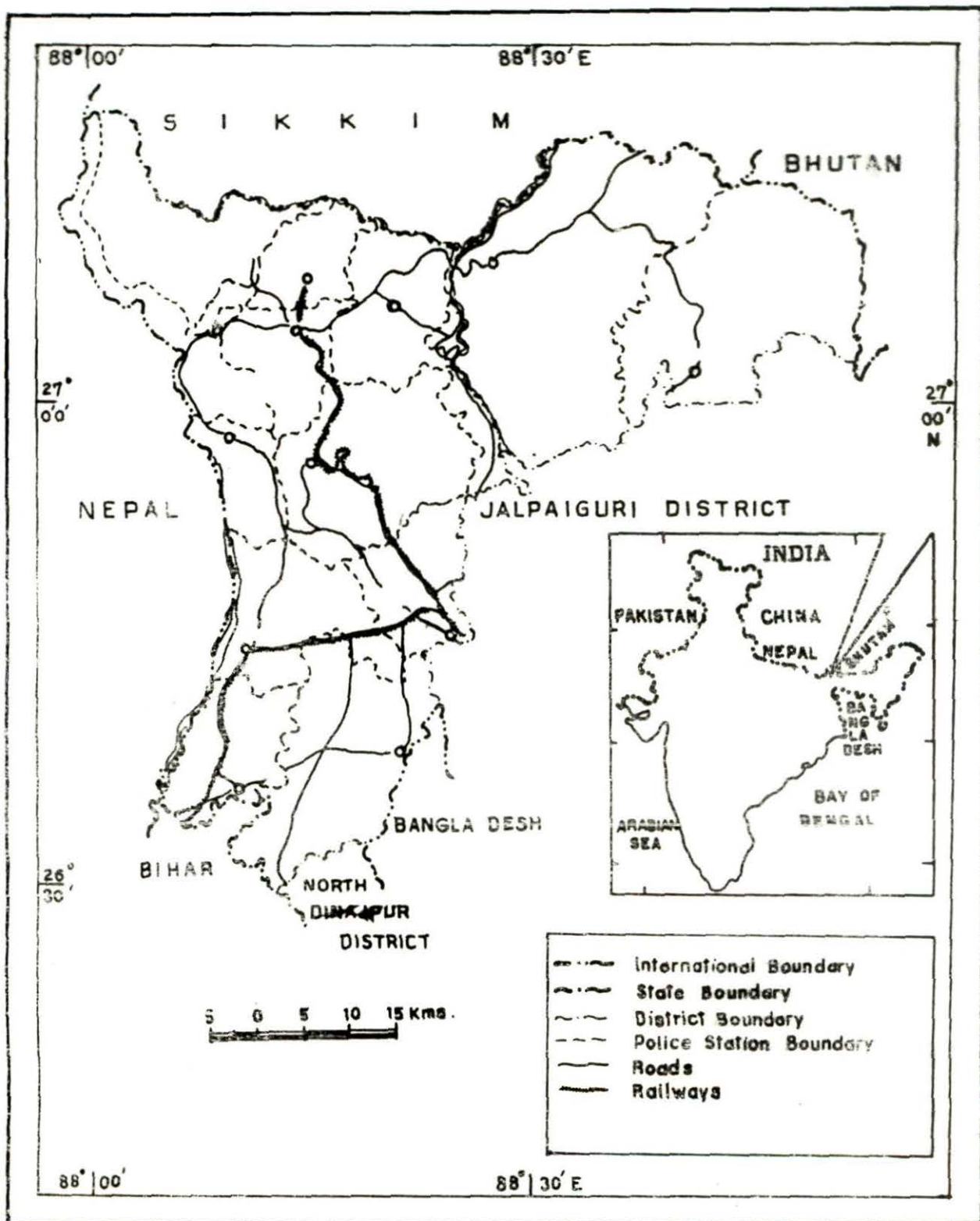


Fig.1. Map showing location of district Darjeeling

## 1. INTRODUCTION

Nutrition is the study of the food requirements of insects (or any organism), where as dietetics may be called the study of practical nutrition. The two are intimately related subjects and where analysis allows some chemical definition of natural foods, nutritional inferences may be gleaned (Singh, 1977). Nutritional quality and dietary proportions of host plants have been shown to influence their utilization by insects. Apparent food values of different acceptable hosts, evaluated through insect performance like mortality, rate of nymphal development and weight gain, adult longevity and fecundity, are distinctly more variable than could be accounted for on the basis of qualitative and quantitative estimation of the nutrient contents. Obviously, host plant utilization depends on more than the plants content of the specific nutrient biochemicals required by the insect : the plant also contains a typical complex of non-nutritional allelochemicals, and it is this complex profile of substances with which the insects must cope (Beck and Reese, 1975).

The relations among dietary attributes, their consumption, utilization, and subsequent insect performance are a primary focus of insect nutritional ecology. Development

of effective host plant resistance tactics requires an understanding of these links to successfully manipulate insect pest performance (Slansky, 1990).

Seed predation is wide spread among hemipteran families of Lygaeidae, Pyrrhocoridae, Coreidae, Rophalidae and Cydnidae, and occasionally among Pentatomidae, Scutelleridae and Miridae (Slater, 1972; Janzen, 1978; Schaefer, 1980; Mc Pherson, 1982; Schaefer and Mitchell, 1983; Mukhopadhyay, 1988).

The fact that seeds are nutrient rich seems indisputable. They have little weight and bulk that is not of direct resource value to a seed predator. Since seeds are likely to have more balanced diet than other plant parts, they would be preferred by a large number of consumers; but their depredation is largely restricted and specified by presence of some defensive compounds mostly belonging to the non-nutritional or allelochemic part of the diet (Janzen, 1978). Information on nutritional ecology of seed-suckers has direct, applied value because of the significant pest status of many species. A number of aspects of seed-suckers' nutritional ecology are highly relevant to current hypothesis of plant-insect interactions. The role of basic nutrients and allelochemicals in influencing feeding behaviour and post-feeding performance of seed-sucking insects is to a

large extent unknown (Slansky and Scriber, 1985). How the polyphagous seed feeders (generalists) are able to deal with great variation in seed nutrients that they encounter while feeding on various seeds is also unknown. Clearly, much of the detailed information that is available on the nutrient and allelochemical composition of seed has yet to be related more meaningfully to the nutritional ecology of seed-sucking insects. Continued research on nutritional ecology of the seed-sucking insects can provide valuable insight into the adaptive strategies associated with utilizing ephemeral resources (short duration seed crops) and in understanding the life-style of these species (Slansky and Panizzi, 1987). Effect of variation in diet is measured in terms of growth, development, reproduction, mortality, longevity and morphological abnormalities (Singh, 1977).

Postembryonic development begins with the rupture of chorion of the egg by the young insect, which from then onwards becomes an independent organism. Generally two distinct periods, metabolic and postmetabolic, may be distinguished in the postembryonic development of most insects. The metabolic period ends when the young insect becomes a sexually mature adult, often passing through a series of moultings and changes in external form and internal organization (Mani, 1982). However, unlike many butterflies

(holometabolans), bugs (paurometabolans) usually derive most resources for egg production from feeding and metabolic activity during adult stage (Solbreck et al., 1989b).

Reproduction is a function of the sexually mature adults. A variety of factors, both external and internal, may influence reproductive potential specially egg production in insects. Nutrition, which has been found to affect the total egg output in several ways, is probably the most important single factor in majority of the insect species (Engelmann, 1970). Some other aspects of reproductive biology like onset of mating, oviposition period, rate of egg laying, weight gain and reproductive trade offs in females may also have a bearing on the natural diet supplied to the concerned insect species, when other major physical and biotic parameters are kept the same (ambient) during rearing in an environmental chamber . So, a comparison of these aspects of reproductive biology may also help to some extent in evaluating the nutritional value of a natural diet and vis-a-vis understand their effects.

The Himalayan foothill region (Terai) of North Bengal (India) represents a separate agroclimatic zone which differs in physiognomy from hill slopes in the north and the Gangetic plain in the south (Jain, 1990) (Fig.1). Since the purpose of this study is partly to know the performance of

the polyphagous seed-suckers that occur and attack economic and non-economic seeds of this region, locally available insect specimens (population) and host seed varieties have mostly been used. From the available literature such a study does not seem to have been undertaken in the past, especially from terai region of North-East India and in a comparative manner with the representative species of the related pentatomorph families, Lygaeidae, Pyrrhocoridae, and Coreidae. So, the present investigation through causal-effect studies related to the dietary components of the range of natural diets (host seeds) and fitness of the seed-suckers would expectedly bring to knowledge some common bases (principles) of nutritional effects. All the same, the study would help to reveal the diversity and the differential performance that exist at specific levels while appropriating the range of acceptable host-seeds. Further, such inferences and understanding of the relation of the components of natural diets and the performance of the free-seed-feeders during post-embryonic development and adult stages may help in designing the chemically defined diets for future research.

Spilostethus hospes (Fabricius) [Lygaeidae], Dysdercus koenigii (Fabricius) [Pyrrhocoridae] and Cletus bipunctatus (West W.) [Coreidae] were chosen as representative species and reared on some of their host seeds for a

detailed study of their biological performance. Initially the preference exercised by a species among three of four of its host seeds was investigated with early, advanced nymphs, males, and females separately. This was followed by a study on postembryonic stages, which included nymphal development period, nymphal mortality, and dry body weight changes in adults. The other study on reproductive biology of adults included fecundity, male and female longevity, and egg hatchability. As a supplementary study to the changes in the body weight, dry mass budgets (nutrient budget) in advanced nymphs and adults were also envisaged. The dietary components of the various seeds that were considered in this study could be grouped under basic nutrients and non-nutritional components (allelochemicals + moisture). The basic nutrient accounted, were : storage proteins, nutritive carbohydrates, lipids and free amino acids while non-nutritional compounds included, phenols, tannins, alkaloids and moisture. The supplementary information on mass budget may help in better understanding of the bases of acquisition, utilization, and allocation of nutrients by the representative species of the three heteropteran families in light of the dietary profiles of their host seeds.

## PRINCIPAL OBJECTIVES

1. To know the acceptability of the host seeds (ranges) by nymphs and adults of the representative species of three families of seed-suckers.
2. To know the development periods and mortality of the postembryonic stages on the host seed ranges.
3. To know the adult reproductive performance in terms of fecundity, longevity, and hatchability on respective host-ranges.
4. To know the body weight changes of males & females during first four weeks on the host ranges.
5. To know the mass budget of IVth & Vth and adults on the host-ranges.
6. To know the biochemical profile of each seed in terms of the basic nutrients and some non-nutrients.
7. To relate these dietary factors with the above mentioned performances of the representative seed-feeding species, and find out the common bases or diversities that exist among these.

**REVIEW  
OF  
LITERATURE**

## 2. REVIEW OF LITERATURE

### 2.1 Selected bibliography on nutritional ecology of insects

Literature on nutritional ecology and related insect performance of immature and adult insects is vast and scattered. Scientific research on feeding activities of insects and related dietetic aspects has a history of over a century. A pioneering publication on "phytophagic varieties and phytophagous species" by Walsh dates back to 1864. Since literature on insect nutritional ecology is too voluminous to summarise here, references are being made only to the recent literature which provide a comprehensive account. Dadd (1973) in an article on insect nutrition has given an account of the current developments of metabolic implications of dietetics. Worth mentioning comprehensive articles are found in the proceedings of the annual meetings of Phytochemical Society of North America, appearing as recent advances in phytochemistry. "Biochemical interaction between plant and insects" edited by Wallace and Mansell (1976) is one such volume. Another edited book by Harborne (1978) dealing in "Biochemical aspects of plant and animal coevolution" collates a number of useful papers on plant - insect interactions. This includes literature on host plant

chemistry and their impact on insect performance. Barbosa and Letourneau (1988) edited a book on novel aspects of insect-plant interaction. A collection of articles on nutrition and adaptation can be found in the book 'Insect and mite nutrition', with significance and implication in ecology and pest management edited by Rodriguez (1972). The proceedings of the 5th international symposium on "Insect-plant relationship" also include a number of important papers like one by Llewellyn (1982) on hemipteran nutritional ecology and energy budget. In 1982, Slansky and Scriber published a selected bibliography and summary of quantitative food utilization by immature insects, and in a critical review on food utilization by insects Slansky (1985) furnished interpretation on observed differences between dry weight and energy efficiencies. The monumental 13-volumes of "Comprehensive insect physiology, biochemistry and pharmacology" edited by Kerkut and Gilbert (1985) provide a wide ranging series of reviews and discussion on topics relevant to the consumption & utilization of food. A book on "Molecular aspects of Insect-plant associations" edited by Brattsten and Ahmad (1986) holds a good collection of paper on plant allelochemicals and their implication in insect-pest management tactice. In 1987, Slansky and Rodriguez have given an elaborate coverage of literature in their edited book "Nutritional ecology of insects, mites, spiders

and related invertebrates". A useful information on quantifying food consumption and growth of insects is provided by Farrar et al. (1989). Some major works from Indian authors in the field of insect-plant interaction and insect energetics are by Saxena (1969), Panda (1979), Muthukrishnan and Pandian (1987), Ananthakrishnan and Raman (1988), Ananthakrishnan (1992).

## 2.2 An overview on nutritional ecology of some seed-sucking hemipteran families

Primary interest in the nutritional ecology of seed-suckers has centred on several economic pest of seed crops and the related literatures are available from Janzen (1971, '78), Miller (1971), Slater (1972), Bohart and Koerber (1972), De Witt and Godfrey (1972), Tingey and Pillemer (1977), Singh et al. (1978), Panizzi and Slansky (1985), Slansky and Panizzi (1987). Damage and utilization of economic seeds and grains as food by Miridae is known from publications of Meredith (1970), Cressey et al. (1987) on wheat ; and Uyemoto et al. (1986) on pistochio ; Herimath (1986), Natarajan and Babu (1988) on sorghum ; Camprag et al. (1986) on sunflower and castor. Hori and Hanada (1970) on red clover cruciferous plants and wheat ; Wheeler and Henry (1985) on oats ; Kamm (1987) on red clover seed.

Literature on Pentatomid seed feeders are restricted to Hall and Teetes (1982) on sorghum; Afren-Nuamah (1983) on winged bean; Viator et al. (1983) and Cressy et al. (1987) on wheat; Hill (1983) on rice and also on Blue bugs attacking sorghum, sunflower and castor; Panizzi and Meneguim (1989) Panizzi and Machado-Neto (1992) on soybean and sunflower; Apriyanto et al. (1989 a & b) on corn. Banerjee and Chatterjee (1985) reported on seasonal changes in feeding and ovarian conditions of Nezara viridula L. from south Bengal.

As bioecological information on the seed feeding families of Lygaeidae, Pyrrhocoridae and Coreidae are substantial and more relevant to the present work, they are being presented under respective family-heads.

Lygaeidae : The major bulk of literature on seed suckers are available from family Lygaeidae, which are also known as seed bugs (Sweet, 1960, '64). Some species of this family may survive on vegetative (non-seed) food (Blakley 1980; Mukhopadhyay et al., 1991), and some others by consuming insect preys or blood of homoeotherms. Most of the literature available on nutritional ecology and performance of lygaeids is based on studies on Oncopeltus fasciatus by Johansson (1958), Caldwell and Dingle (1967), Bonger and Müermann (1973), Auclair et al. (1973), Ralph

(1976), Ross (1978), Walker (1978), Klausner et al. (1980), Slansky (1980 a & b), Chaplin and Chaplin (1981), Auclair (1982). Further, literature on seed attacking lygaeids and their performance is available from the works of Negron and Riley (1985; '90) on Chinch bug, and Broadley et al. (1986) on Rutherglen bug on sunflower, while Slater (1972) gives a general account of lygaeid bugs as seed predators. A fair account on biology of seed feeding lygaeid from Australia and Newzeland is provided by Malipatil (1979). Some relevant literature on life history of migratory lygaeids and their responses to food shortage is available from works of Solbreck (1989 a & b). Some more information on impact of different natural foods on lygaeid biology is available from works of Eyles (1964), Kugelberg (1973). In India, most of the bioecological work on seed-sucking lygaeids have been done from North India by Bhattacharjee (1959), Mukhopadhyay et al. (1981; '90), Mukhopadhyay (1983; '85; '88; '89), and on feeding ecology of lygaeids and their performance by Mukhopadhyay and Saha (1992a,b,c, & '93) some biological notes on host plants are also available from works of Chopra and his co-workers (1982, 1988). From South India significant information on bioecology has been provided by Thangavelu (1978a & b), and by the same author (1979) on pest status and biology of Spilostethus pandurus. In recent past some relevent papers on Lygaeid-host seed

interaction and feeding preference are available from studies of Ananthakrishnan et al. (1982) and Sanjayan and Ananthakrishnan (1987).

Pyrrhocoridae : Genus Dysdercus typically represent the family Pyrrhocoridae. Some studies on biology and ecology of Dysdercus have been conducted by Derr et al. (1981), Odhiambo and Arora (1973), Nobrega (1989). Most investigations in India on host plant and nutritional ecology of Pyrrhocorids have been carried out by Saxena (1963; '69), Shahi and Krishna (1979; '80; '81), Kshemkalyani et al. (1989). An important literature on effect of different host plants on the development of red cotton bug is available from western India (Singh and Ram, 1987),

Coreidae : Information on bionomics of Coreids are available from the publications of Goodchild (1977),

Ito (1984; 1987); and on food plant from the literature of Ahmad et al. (1977), Schaefer (1980), and more comprehensively on five Coreid families from Schaefer and Mitchell (1983). Chandrasekar (1988) has published a paper on host preference and feeding behaviour on three species of coreid from South India. Some information on the host plants of Cletus spp. is available from works of Shanthichandra et al. (1990) from Srilanka and Agarwal and Dhiman (1989) from North India. Some general information on

bionomics of other seed-sucking pests including two species of Leptocorisa from India and S.E. Asia are available from the books on insect pests by Hill (1983), Nair (1975), Atwal (1976) and a few more.

Since the literature hunting has been done manually using the available abstracts and journals, books & reprints, the possibility of some slips is not ruled out. Nevertheless, the best of knowledge and efforts have been put behind in collecting all the references felt important and relevant to my present work.

**MATERIALS  
AND  
METHODS**

### 3. MATERIALS AND METHODS

#### 3.1 Insects and seeds used for experimental studies

Representatives of seed feeding heteropteran were chosen from three related families. Seeds used as food in the experimental studies were either reported or personally observed to be infested and consumed by the concerned species of seed suckers.

<u>Family</u>	<u>Species</u>	<u>Host seed</u>
Lygaeidae	<u>Spilostethus hospes</u> (Fabricius)	(i) Milkweed ( <u>Calotropis gigantea</u> R.Br)
		(ii) Brinjal ( <u>Solanum melongena</u> L.)
		(iii) Khasianum-brinjal ( <u>Solanum myriacanthum</u> L.)
		(iv) Sunflower ( <u>Helianthus annuus</u> L.)
Pyrrhocoridae	<u>Dysdercus koenigii</u> (Fabricius)	(i) Lady's finger ( <u>Hibiscus esculentus</u> L.)
		(ii) Kapas cotton ( <u>Gossypium hirsutum</u> L.)

<u>Family</u>	<u>Species</u>	<u>Host seed</u>
Pyrrhocoridae	<u>Dysdercus koenigii</u> (iii) (Fabricius)	Deccan hemp or Mesta ( <u>Hibiscus cannabinus</u> L.)
		(iv) Silk cotton ( <u>Bombax ceiba</u> L.)
Coreidae	<u>Cletus bipunctatus</u> (West W.)	(i) Goosefoot ( <u>Chenopodium album</u> L.)
		(ii) Cock's comb ( <u>Celosia cristata</u> L.)
		(iii) Oriental pepper ( <u>Polygonum orientale</u> L.)

### 3.2 Food preference by post embryonic and adult stages

Orientation response and food preference tests were carried out with a little modification (Sanjayan and Ananthakrishnan, 1987) in an 'X'-shaped glass apparatus. Various stages of the lygaeid, pyrrhocorid and coreid species in question (i) early nymphs (2nd & 3rd instars) (ii) advance nymphs (4th & 5th instars) (iii) males and (iv) females were separately subjected to food preference experiment.

Different host seeds, wetten in water, were supplied at the end of arms of the 'X' shaped apparatus

enclosed in transparent nylon net. Starved insects (24 hrs.) of each category were introduced separately in batches. Ten observations were taken for each category which were based on release of twenty individuals. Counts of their visit to seeds were taken at an interval of 15 minutes. Before setting a new experiment with fresh seeds the apparatus was deodorized and sterilized with 90% alcohol. The position of the apparatus was rotated through  $180^{\circ}$  and the individuals disturbed at the end of each observations. The individuals not attending the seed or present in seed free arm or region of the apparatus were counted as control, and tabulated as blank.

### 3.3 Post embryonic development and nymphal mortality

Rearing of all the species were done in an improvised BOD at  $30 \pm 1^{\circ}\text{C}$ , relative humidity  $80 \pm 5\%$ , and L : D 12 hours each. Seeds and water in siphon were provided ad libitum in rearing containers (5.5 x 4 cm dia.) with muslin cloth cover. Observations were made based on 30 replicates. The tests for each species were carried out with stock raised separately on the respective seeds. Adults of D.koenigii raised on H.esculentus were used for experimentation with B.ceiba, as on the latter seed nymphal development was incomplete. The stadial periods were determined by detecting the exuviae.

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### 3.4 Reproductive performance and longevity

Influence of different seed-diets on the fecundity, egg laying rate (fecundity/oviposition period), percent hatchability and longevity of both sexes of the three insect species i.e., S.hospes, D.koenigii and C. bipunctatus were studied by pairing single male and female in sterilized plastic containers (5.5 x 4 cm dia.) supplied with water siphon. The sets were covered with muslin cloth and kept in BOD under conditions mentioned earlier. The observations were made with 10 replicates.

### 3.5 Nutrient (mass) budget for advanced nymphs and adults

Nutrient (mass) budget was calculated using formula of Waldbaur (1968), IBP formula after Petruszewicz and Macfadyen (1970), Muthukrishnan and Pandian (1987) and Farrer et al. (1989). The estimation and calculations of the nutritional indices and budget were done on a dry mass basis. Units used : weights in mg, time in days, and efficiency in percent.

$$a. \text{ Consumption (C) = FU + P + R} \quad \left[ \begin{array}{l} \text{FU = Egestion;} \\ \text{P = Production;} \\ \text{R = Respiration} \end{array} \right]$$

$$b. \text{ Assimilation (A) = C - FU}$$

c. Production (P) = Final body weight ( $W_2$ ) - Initial body weight ( $W_1$ )

d. Respiration (R) = A - P

e. Maintenance cost = R/P

f. Production index = P/A

g. Assimilation efficiency (Ae) =  $\frac{A}{C} \times 100$

h. Relative consumption rate (RCR) =  $\frac{C}{\overline{BA} \times T}$

i. Relative growth rate (RGR) =  $\frac{P}{\overline{BA} \times T}$

Where,  $\overline{BA}$  = arithmetic mean of body weight of a stage.  
T = feeding period in days.

As the monopan electrical balance used had a limited sensitivity (0.01 mg). Food utilization values and budget could be calculated for  $\overline{IV}$  &  $\overline{V}$  stage nymphs and adults only; because small amount of food consumed and weight gain by early instars make accurate quantification difficult (Slansky and Scriber, 1982).

Dry body weight observations were based on 10 replicates using virgin males and females on all categories of host seeds. Adult weights were recorded weekly since emergence upto 4 weeks. Drying was done at 50°C in an oven until constant weight was attained.

### 3.6 Biochemical estimation of host seeds

#### a. Preparation of seed powder

The seed used was initially oven dried (50°C) to a constant weight. This was ground in a mixer-grinder (Bajaj Sumeet make). The powder obtained was made fat-free by treating with petroleum ether. Fixed weight of the fat-free powder was taken for extraction of the respective dietary components.

#### b. Storage protein (Draper, 1976 and Lowry et al., 1951)

#### EXTRACTION

(i) The seed powder was extracted with 5%  $K_2SO_4$  overnight and filtered. The filtrate was used for the estimation of salt soluble proteins i.e., albumin and globulins.

(ii) The residue was ground with 70% ethanol kept at 50°C for 4-5 hours and filtered while hot. The filtrate was used for the estimation of prolamins.

(iii) The residue was treated with .05 N NaOH in 50% (v/v) ethanol over night and filtered, which was used for estimation of glutelin.

### ESTIMATION

An 'alkaline solution' was prepared by mixing 50 ml of alkaline  $\text{Na}_2\text{CO}_3$  solution (20 g/l  $\text{Na}_2\text{CO}_3$  in 0.1 mol/l NaOH) and 1 ml of  $\text{CuSO}_4$  - sodium potassium tartrate solution (5g/l  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  in 10g/l Na, K tartrate).

5 ml of the 'alkaline solution' was added to 1 ml of the test solution, mixed thoroughly and allowed to stand at room temperature for 10-15 minutes, 0.5 ml of diluted Folin-Ciocalteu reagent (1:1) was added rapidly with immediate mixing. Reading was taken in a spectrophotometer (Systronics model-106) against an appropriate blank at 750 nm after 30 minutes. BSA (Bovine serum albumin) was used as standard. The quantities of the above classes of proteins were added to give total dietary protein in mg/g.

- c. Nutritive carbohydrate (Ananthakrishnan, 1990 and Plummer, 1979)

### EXTRACTION

The seed powder was taken in 80% ethanol and heated in a water bath for 5 minutes. The extract was then blended with chromic acid treated sand and squeezed through a thick cloth. The residue was reextracted for 5 minutes,

cooled and squeezed again. This was followed by treatment of the residue with HCl and heated for extraction of starch.

### ESTIMATION

The test solution was initially made protein free to avoid interference (and better results) by adding 1.5 ml of water to 0.1 ml of test solution followed by 0.2 ml of barium hydroxide and 0.2 ml of aqueous zinc sulphate with thorough shaking and centrifuge. The supernatant was used for further analysis.

To 1 ml of protein free solution was added 4 ml of anthrone reagent (2g/l in conc.  $H_2SO_4$ ) and mixed rapidly in test tube. The test tubes were placed in boiling water bath for 10 minutes with a marble on top<sup>to</sup> prevent loss of water by evaporation. This was followed by cooling and reading the extinction at 620 nm against a reagent blank. Glucose was used as standard. Mono-, oligo-, and polysaccharides (starch) were added to give the total nutritive carbohydrate in mg/g. The nutritive carbohydrate has been symbolically represented as (CHO) in the text at times, for sake of brevity.

d. Total lipid (Ananthakrishnan, 1990)

The extraction and estimation of total lipid in the dried seed powder were done by gravimetric method. 500 mg of seed powder was ground with petroleum ether and filtered in a previously weighed glass tube. The residue was homogenised again with petroleum ether and filtered. Five such replications were done. The filtrate was placed in an oven at 50°C for complete evaporation. The test tubes were reweighted and the difference in weight gave an account of the lipid present in mg/g.

e. Free amino acid (Draper, 1976 and Plummer, 1979)

EXTRACTION

500 mg of seed powder was macerated in 20 ml of 80% ethanol with a little acid-washed sand. The mixture was then filtered through filter paper (Whatman No.1). The filtrate was used for estimation.

ESTIMATION

Freshly prepared 2ml of buffered ninhydrin reagent (0.8 g of ninhydrin, 0.12 g hydrindantin in 30 ml of methyl cellosolve and 10 ml of acetate buffer) was added to 3 ml

of the test solution and heated in a boiling water bath for 15 minutes. It was cooled at room temperature and 3 ml of 50% ethanol was added. The reading was taken after 10 minutes at 570 nm. D-L Alanine was used as standard and quantity was expressed in mg/g.

f. Total phenol (Hori, 1974)

EXTRACTION

500 mg of seed powder (fat free) was homogenized with 20 ml of trisglycine (Tris 6g, Glycine 28.8g in 1000ml distilled water) buffer of pH 8.6.

ESTIMATION

0.1 ml of test solution was made upto 1 ml with distilled water and 3 ml water was then added for further dilution 0.1 ml of Folin reagent (1:1) was added followed by adding of 1 ml saturated sodium bicarbonate ( $\text{Na}_2\text{CO}_3$ ) after 10minutes. The reading was taken 30 minutes later at 660 nm. Quantity was expressed in percent. Pyrogallol was used as standard.

g. Soluble and condensed tannin (Harborne, 1973 ;  
Bate-Smith 1973 and Swain, 1979)

EXTRACTION

500 mg of seed powder was treated with hot 50%

aqueous methanol. The residue obtained after filtration was retreated for further extraction.

### ESTIMATION

For the estimation of soluble tannin a known volume of extract was mixed with an equal volume of fresh sample of diluted human blood (1:50 with water). The mixture was centrifuged to remove the tannin-protein precipitate. The residual haemoglobin was determined by its absorbance at 578 nm and from this the TAE (tannic acid equivalent) in percent calculated. Tannic acid was used as standard.

The condensed tannin was estimated by concentrating a known volume of the extract to 1/3 in volume by heating with n-butanol containing 5% conc. HCl (0.5 ml extract with 4 ml reagent) for two hours at 95°C. The absorbance was then measured at 545 nm (for cyanidin) and at 560 nm (for delphinidin). Catechin was used as standard. Quantity was expressed in percent.

h. Alkaloids (Finar, 1956).

### EXTRACTION

1g of seed powder was boiled with 20 ml of methanol. The solvent was evaporated off and the residue

was treated with conc. HCl, where upon the bases were extracted as their soluble salts. The free bases were liberated by the addition of sodium carbonate.

The filtrate was centrifuged in a previously weighed centrifuge tube and dried in an oven at 50°C . The difference in the final weight and the initial weight gave an estimate of the amount of alkaloids present. Quantity was expressed in percent.

#### i. Moisture content (Ananthakrishnan, 1990)

The amount of moisture in the seeds was determined by weighing a certain amount of fresh seed materials. This was kept at 50°C in an incubator till a constant weight was obtained. The difference between the initial and final weight gave an estimate of the moisture content; expressed in percent.

### 3.7 Statistical calculations and computer software

The essential statistical calculations were done using standard methods available from Daniel (1974), Bailey (1985), Palani Chamy and Monoharan (1990) and calculator of model Casio FX 82C. Computer software used for P.C. of ET & T Cp. India were based on programmes of HPG (Harvard

presentation graphics), DMRT (Duncan's multiple range test). The programmes were available from or developed by N.B.University Computer Centre and Commerce Department of the University.

# **RESULTS**

**Spilostethus hospes (Fabricius)**  
( Lygaeidae )

Fig. 2a. Spilostethus hospes (Fabricius)

Fig. 2b. Host seeds of S. hospes



Fig. 2a

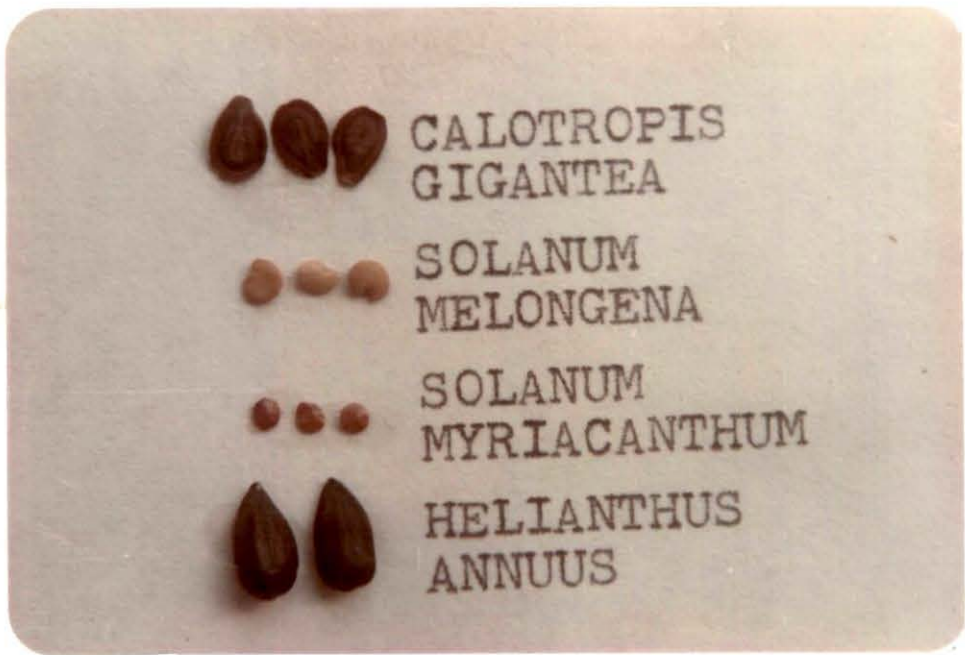


Fig. 2b

#### 4. PERFORMANCE OF NYMPHS AND ADULTS OF SPILOSTETHUS HOSPES ON FOUR SELECTED HOST SEEDS (FIG. 2a & b)

##### 4.1 Seed preference by different stages and sexes (Table - 4.1)

Early - , advanced nymphs and females always showed a preference for C.gigantea over the rest of the seeds, While preference between two species of Solanum varied only to a limited extent, a poor preference was found for H.annuus. The blank end always had the lowest number of visitors. Males, however, did not exercise any strong preference for any particular seed (Figs.3a,b,c & d).

##### 4.2 Postembryonic development period and nymphal mortality (Table- 4.2)

In all instars the stadial periods were found to be shortest on C.gigantea leading to the overall shortest postembryonic development on this seed (Fig. 4). Only in advanced nymphs a clear significant difference in stadial periods was apparent. On C.gigantea and S.melongena the periods were significantly shorter than that on H.annuus and S.myriacanthum. Lowest mortality was recorded on C.gigantea followed by higher mortality on H.annuus , S.myriacanthum and S.melongena (Fig. 5).

#### 4.3 Reproductive performance and longevity

(Table - 4.3)

Highest fecundity and egg-laying rate was recorded on C.gigantea followed by that on S.myriacanthum and S.melongena. The latter two differed between themselves insignificantly (Fig. 6). Though fecundity was lowest on H.annuus yet the egg-laying rate on this seed was better and stood between the last two seeds mentioned. No significant difference was noted in hatchability and in male longevity. Female longevity was shortest on C.gigantea and insignificantly differed from that on S.melongena which again insignificantly differed from H.annuus. Highest longevity was on S.myriacanthum but the life span insignificantly exceeded that on H. annuus (Fig.7).

#### 4.4 Change in adult body weight (Table-4.4a, b)

Body weight (dry) of male S.hospes was the highest throughout the month of observation on C.gigantea. On this seed, significant increase took place in the first week and also on the fourth week. Weight increase on S.melongena and H.annuus was significantly different from that on C.gigantea but did not differ much between themselves. On two of these seeds significant increase in the

body weight took place after second week but never reached the level attained in C.gigantea at the end of the month. On S.myriacanthum, gradual increase in body weight took place at a poor pace and the final body weight attended was also the poorest (Fig. 8).

Body weight (dry) of female S.hospes on C.gigantea was the highest in all the weeks. Weight gain on H.annuus was consistently higher throughout the month than that on S.melongena. On S.myriacanthum it was significantly low in all the weeks which also showed the poorest weight at the end of the month. Unlike that of males the weight gain in females significantly took place on all the seeds in the first week. Excepting on S.myriacanthum a decrease in the body weight was recorded on all the three seeds during fourth week (Fig. 9).

#### 4.5 Dry mass (nutrient) budget and food utilization efficiency (Table-4.5a,b,c,d) (Figs. 10 & 11)

In fourth instar consumption was highest on S.melongena followed by C.gigantea and H.annuus. Production was highest on S.melongena followed closely by C.gigantea. Consumption, assimilation and production on S.myriacanthum was the lowest. Best performance of relative consumption rate (RCR) and relative growth rate (RGR) was found on

S.melongena. On the same seed the production index (P/A) was found to be the highest with a low maintenance cost (R/P).

In fifth instar the performance somewhat change; inspite of highest consumption and RCR on S.melongena the production was recorded to be higher on C.gigantea and H.annuus. Performance was the poorest on S.myriacanthum as far as consumption and production were concerned. Production index (P/A) was the high on C.gigantea and insignificantly followed that of H.annuus ; on these seeds the maintenance cost (R/P) was also notably low.

In male, consumption of C.gigantea was found to be significantly lower than S.melongena and S.myriacanthum, nevertheless the production of body mass was the highest on the C.gigantea seed. Interestingly, inspite of higher consumption and assimilation, the production was found to be lower on both species of Solanum. Respiration was found to be very high on these two seeds. H.annuus showed a poor consumption, production, & assimilation values. Production index (P/A) was the highest on C.gigantea with a substantially low maintenance cost (R/P).

In female, consumption, assimilation and production were found to significantly higher on C.gigantea than that on rest of the seeds. Although consumption values on

S.melongena and H.annuus were close, production was significantly higher on H.annuus. On S.myriacanthum consumption was the lowest but production was to the tune of H.annuus. The relative consumption and growth rate was found to be significantly high on this seed. The high production indices (P/A) and low maintenance costs (R/P) were found common to the seeds C.gigantea and S.myriacanthum.

#### 4.6 Biochemical estimation of basic nutrients and some non-nutritional components (Table-4.6a,b)(Fig.12)

C.gigantea had the highest protein, second highest carbohydrate, lipid, and free amino acid. H.annuus showed high protein, lowest carbohydrate, highest lipid and amino acid. S.melongena had a reasonable amount of protein, carbohydrate and lipid but free amino acid was relatively low. S.myriacanthum had a low protein content with very high carbohydrate, low lipid and free amino acid. The CHO/protein ratio had the lowest value for C.gigantea and increased by steps in H.annuus, S.melongena and S.myriacanthum.

Phenol was recorded highest in H.annuus followed by C.gigantea and low values of S.melongena and S.myriacanthum. TAE (soluble tannin) was highest in H.annuus and

lowest in C.gigantea. Two other seeds had intermediate and same values. Condensed tannin was highest in C.gigantea followed by S.myriacanthum then S.melongena and finally lowest in H.annuus. C.gigantea was richest in alkaloid content followed by that of H.annuus and S.melongena. S.myriacanthum was poorest in alkaloid content. Highest moisture was recorded in S.myriacanthum followed by a fair content in C.gigantea. Moisture was lowest in S.melongena followed closely by the value of H.annuus.

Table 4.1. Seed preference<sup>1</sup> (attendance) by different stage and sexes of S.hospes with percentage preference (Pr.).

Host seed	Early nymphs		Advanced nymphs		Male		Female	
	Mean +S.E.	Pr.	Mean +S.E.	Pr.	Mean +S.E.	Pr.	Mean +S.E.	Pr.
<u>C.gigantea</u>	6.2 a +0.63	31.00	7.0 a +0.65	35.00	4.4 a +0.29	22.00	5.2 a +0.37	26.00
<u>S.melongena</u>	4.4 b +0.67	22.00	3.1 bc +0.22	15.50	4.3 a +0.35	21.50	4.9 a +0.43	24.50
<u>S.myriacanthum</u>	4.4 b +0.62	22.00	4.2 b +0.49	21.00	4.4 a +0.35	22.00	4.3 ab +0.25	21.50
<u>H.annuus</u>	3.3 bc +0.55	16.50	3.2 bc +0.19	16.00	4.3 a +0.53	21.50	3.3 bc +0.43	16.50
Blank	1.7 c +0.38	8.50	2.5 c +0.29	12.50	2.6 b +0.29	13.00	2.3 c +0.20	11.50

<sup>1</sup> Means followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

Table 4.2. Postembryonic development period (Days, Mean±S.E.)<sup>1</sup> and nymphal mortality (%) of S.hospes on different host seeds.

Host seed	1st instar		2nd instar		3rd instar		4th instar		5th instar		Total nymphal duration	Total nymphal mortality(%)	
<u>C.gigantea</u>	3.14	aA	2.68	aB	2.86	aB	3.07	aAB	5.00	aC	16.74	a	10.00
	±0.07		±0.10		±0.19		±0.11		±0.16		±0.17		
<u>S.melongena</u>	4.00	bA	3.04	bB	3.08	abB	3.04	aB	5.42	abC	18.58	b	20.00
	±0.06		±0.04		±0.06		±0.04		±0.13		±0.14		
<u>S.myriacanthum</u>	4.46	cA	3.15	bB	2.85	aB	3.85	bC	5.84	bD	20.16	c	16.67
	±0.11		±0.09		±0.10		±0.12		±0.22		±0.24		
<u>H.annuus</u>	4.00	bA	3.00	bB	3.41	bC	3.66	bC	5.69	bD	19.73	c	13.33
	±0.05		±0.05		±0.12		±0.18		±0.09		±0.10		

<sup>1</sup> Means followed by the same alphabet in each column and same alphabet (bold) in each row are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

Table 4.3. Reproductive performance and longevity (Mean±S.E.)<sup>1</sup>  
of S.hospes on different host seeds.

Host seed	Fecundity	Egg laying rate (eggs/day)	% hatchability <sup>2</sup> (per batch)	Male longevity	Female longevity
<u>C.gigantea</u>	567.80 a ±80.42	36.82 a ±3.09	75.09 a ±3.67	36.40 a ±3.11	23.80 a ±2.02
<u>S.melongena</u>	407.90 a ±38.53	21.48 b ±1.75	76.38 a ±2.45	28.80 a ±1.95	27.00 ac ±2.33
<u>S.myriacanthum</u>	460.40 a ±46.27	20.86 b ±0.85	73.43 a ±3.97	37.80 a ±1.79	35.80 b ±2.15
<u>H.annuus</u>	329.30 b ±50.33	22.28 b ±1.95	71.31 a ±4.79	34.40 a ±2.52	33.20 bc ±2.26

<sup>1</sup> Means followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

<sup>2</sup> Data transformed to arcsine for statistical analysis.

Table 4.4a. Dry body weight (mg) of male S.hospes of different ages (Mean±S.E.)<sup>1</sup> fed on different host seeds.

Host seed	1st day		8th day		15th day		22nd day		29th day	
<u>C.gigantea</u>	14.28	aA	15.38	aB	15.62	aB	15.91	aB	16.81	aC
	±0.35		±0.09		±0.08		±0.05		±0.13	
<u>S.melongena</u>	12.01	bA	12.41	bAB	12.88	bBC	13.39	bCD	14.05	bD
	±0.29		±0.22		±0.23		±0.17		±0.19	
<u>S.myriacanthum</u>	8.68	cA	9.16	cB	9.45	cBC	9.62	cCD	9.95	cD
	±0.10		±0.11		±0.13		±0.11		±0.09	
<u>H.annuus</u>	12.45	bA	12.71	bA	13.18	bB	13.55	bB	13.23	dB
	±0.14		±0.14		±0.15		±0.09		±0.10	

<sup>1</sup> Means followed by the same alphabet in each column and same alphabet (bold) in each row are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

Table 4.4b. Dry body weight (mg) of female S.hospes of different ages (Mean  $\pm$  S.E.)<sup>1</sup> fed on different host seeds.

Host seed	1st Day	8th Day	15th Day	22nd Day	29th Day
<u>G.gigantea</u>	18.34 aA $\pm 0.51$	24.91 aB $\pm 0.30$	25.37 aB $\pm 0.42$	26.15 aB $\pm 0.53$	23.51 aC $\pm 0.23$
<u>S.melongena</u>	13.54 bA $\pm 0.18$	14.06 bB $\pm 0.14$	14.38 bB $\pm 0.15$	14.92 bCD $\pm 0.32$	14.50 bBD $\pm 0.14$
<u>S.myriacanthum</u>	8.28 cA $\pm 0.07$	9.52 cB $\pm 0.07$	10.13 cC $\pm 0.09$	11.02 cD $\pm 0.12$	11.59 cE $\pm 0.15$
<u>H.annuus</u>	14.14 bA $\pm 0.08$	15.55 dB $\pm 0.34$	17.45 dC $\pm 0.35$	17.93 dC $\pm 0.29$	17.43 dC $\pm 0.28$

<sup>1</sup> Means followed by the same alphabet in each column and same alphabet (bold) in each row are not significantly different at 5% level using ANOVA and Duncan's multiple tange test (1955).

Table 4.5a. Nutrient budget (Mean±S.D., in mg)<sup>1</sup> of fourth instar S.hospes on four host seeds.

Host seed	C	FU	A	P	R	RCR	RGR	Ae(%) <sup>2</sup>	R/P	P/A
<u>C.gigantea</u>	8.83 a ±0.45	0.25 a ±0.02	8.58 a ±0.41	5.14 a ±0.42	3.59 a ±0.14	0.29 a ±0.01	0.17 a ±0.01	97.17 a ±0.09	0.70 a ±0.03	0.60 a ±0.02
<u>S.melongena</u>	9.43 b ±0.48	0.10 b ±0.01	9.34 b ±0.48	5.85 b ±0.10	3.49 a ±0.58	0.56 b ±0.02	0.35 b ±0.02	98.99 b ±0.00	0.60 b ±0.11	0.63 b ±0.04
<u>S.myriacanthum</u>	6.41 c ±0.56	0.07 b ±0.02	6.34 c ±0.54	3.58 c ±0.08	2.76 b ±0.46	0.44 c ±0.03	0.25 c ±0.01	98.93 b ±0.22	0.77 a ±0.11	0.57 c ±0.04
<u>H.annuus</u>	8.35 d ±0.25	0.70 c ±0.05	7.65 d ±0.20	4.00 d ±0.08	3.66 a ±0.13	0.38 d ±0.01	0.18 a ±0.01	91.69 c ±0.30	0.92 c ±0.02	0.53 d ±0.01

<sup>1</sup> Means followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

<sup>2</sup> Data transformed to arcsine for statistical analysis.

N.B. (i) Abbreviation explained under materials and methods.

(ii) R/P and P/A calculated based on data observed during the stadia period.

Table 4.5b. Nutrient budget (Mean±S.D., in mg)<sup>1</sup> of fifth instar S.hospes on four host seeds.

Host seed	C	FU	A	P	R	RCR	RGR	Ae(%) <sup>2</sup>	R/P	P/A
<u>C.gigantea</u>	16.15 a ±0.63	0.95 a ±0.05	15.21 a ±0.67	5.85 a ±1.19	9.37 ac ±0.52	0.21 a ±0.01	0.08 a ±0.02	94.14 a ±0.51	1.69 a ±0.43	0.38 a ±0.06
<u>S.melongena</u>	21.47 b ±0.91	1.53 b ±0.18	19.94 b ±0.73	4.14 b ±0.21	15.81 b ±0.94	0.38 b ±0.03	0.07 a ±0.00	92.90 b ±0.54	3.85 b ±0.42	0.23 b ±0.00
<u>S.myriacanthum</u>	13.64 c ±0.29	0.79 c ±0.04	12.86 c ±0.26	3.19 c ±0.14	9.67 c ±0.12	0.33 c ±0.01	0.08 a ±0.01	94.25 c ±0.14	3.04 c ±0.09	0.25 b ±0.01
<u>H.annuus</u>	15.40 a ±1.46	1.10 d ±0.01	14.30 d ±1.45	5.56 a ±0.45	8.74 a ±1.00	0.25 d ±0.01	0.09 b ±0.00	92.83 b ±0.65	1.57 a ±0.06	0.39 a ±0.01

<sup>1</sup> Means followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

<sup>2</sup> Data transformed to arcsine for statistical analysis.

N.B. (i) Abbreviation explained under materials and methods.

(ii) R/P and P/A calculated based on data observed during the stadial period.

Table 4.5c. Nutrient budget (Mean±S.D., in mg)<sup>1</sup> of male S.hospes on four host seeds.

Host seed	C	FU	A	P	R	RCR	RGR	Ae(%) <sup>2</sup>	R/P	P/A
<u>C.gigantea</u>	29.20 a ±0.59	2.39 a ±0.44	26.81 a ±0.15	3.03 a ±0.20	23.78 a ±0.34	0.27 a ±0.00	0.03 a ±0.01	91.84 a ±1.34	7.90 a ±0.62	0.12 a ±0.01
<u>S.melongena</u>	34.34 b ±1.19	2.78 b ±0.05	31.56 b ±1.14	2.34 b ±0.03	29.32 b ±1.11	0.39 b ±0.03	0.04 b ±0.01	91.91 a ±0.15	12.49b ±0.32	0.08 b ±0.01
<u>S.myriacan- thum</u>	30.06 c ±0.66	1.59 c ±0.01	28.47 c ±0.65	1.27 c ±0.03	27.20 c ±0.62	0.47 c ±0.03	0.02 c ±0.00	94.71 b ±0.08	21.42c ±0.02	0.04 c ±0.00
<u>H.annuus</u>	21.95 d ±0.31	2.46 a ±0.11	19.49 d ±0.20	0.88 d ±0.01	18.61 d ±0.19	0.24 d ±0.02	0.02 c ±0.01	88.82 c ±0.33	21.15c ±0.03	0.05 d ±0.00

<sup>1</sup> Means followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955)

<sup>2</sup> Data transformed to arcsine for statistical analysis.

N.B. (i) Abbreviation explained under materials and methods.

(ii) R/P and P/A calculated based on data observed during first 4 weeks.

Table 4.5d. Nutrient budget (Mean±S.D., in mg)<sup>1</sup> of female S.hospes on four host seeds.

Host seed	C	FU	A	P	R	RCR	RGR	Ae(%) <sup>2</sup>	R/P	P/A
<u>C.gigantea</u>	41.55 a ±0.77	3.38 a ±0.32	38.17 a ±1.09	5.17 a ±0.88	33.00 a ±1.97	0.25 a ±0.02	0.04 a ±0.01	91.85 a ±0.92	6.64 a ±1.51	0.14 a ±0.03
<u>S.melongena</u>	37.32 b ±0.88	3.00 b ±0.59	34.32 b ±0.29	1.92 b ±0.08	32.41 a ±0.37	0.39 b ±0.03	0.02 b ±0.00	92.00 a ±1.40	16.96 b ±0.86	0.06 b ±0.01
<u>S.myriacan- thum</u>	30.72 c ±2.35	2.45 b ±0.04	28.28 c ±2.39	3.31 c ±0.27	24.97 b ±2.66	0.46 c ±0.05	0.05 c ±0.00	91.99 a ±0.73	7.66 a ±1.43	0.12 ac ±0.02
<u>H.annuus</u>	38.81 b ±3.17	6.79 c ±1.54	32.02 d ±1.63	3.29 c ±0.62	28.73 c ±1.01	0.34 d ±0.01	0.04 a ±0.00	82.71 b ±2.56	9.01 c ±1.38	0.11 c ±0.02

<sup>1</sup> Means followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955)

<sup>2</sup> Data transformed to arcsine for statistical analysis.

N.B. (i) Abbreviation explained under materials and methods.

(ii) R/P and P/A calculated based on data observed during first 4 weeks.

Table 4.6a. Estimation of basic nutrients and free amino acid (mg/g) of different host seeds of S.hospes.

Host seed	Storage protein	Nutritive carbohydrate	CHO/protein ratio	Lipid	Free amino acid
<u>C.gigantea</u>	196.32 a	159.47 a	0.81 a	170.07 a	12.22 a
<u>S.melongena</u>	128.28 b	150.33 b	1.17 b	144.62 b	5.19 b
<u>S.myriacanthum</u>	104.91 c	209.74 c	2.00 c	88.08 c	4.74 c
<u>H.annuus</u>	159.95 d	137.48 d	0.86 a	316.12 d	31.10 d

Values followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955)

N.B. Mean values have been presented.

Table 4.6b. Comparative estimation on some secondary plant compounds and moisture (in %) of different host seeds of S.hospes.

Host seed	Phenol	TAE	Condensed tannin	Alkaloid	Moisture
<u>C.gigantea</u>	1.37 a	0.26 a	5.26 a	4.13 a	5.63 a
<u>S.melongena</u>	0.83 b	0.34 b	1.46 b	2.20 b	4.76 b
<u>S.myriacanthum</u>	0.87 c	0.34 b	3.80 c	1.63 c	7.59 c
<u>H.annuus</u>	2.26 d	0.47 c	0.51 d	2.56 b	4.90 b

Values followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

N.B. Mean values have been presented.

# Seed preference of *S. hospes*

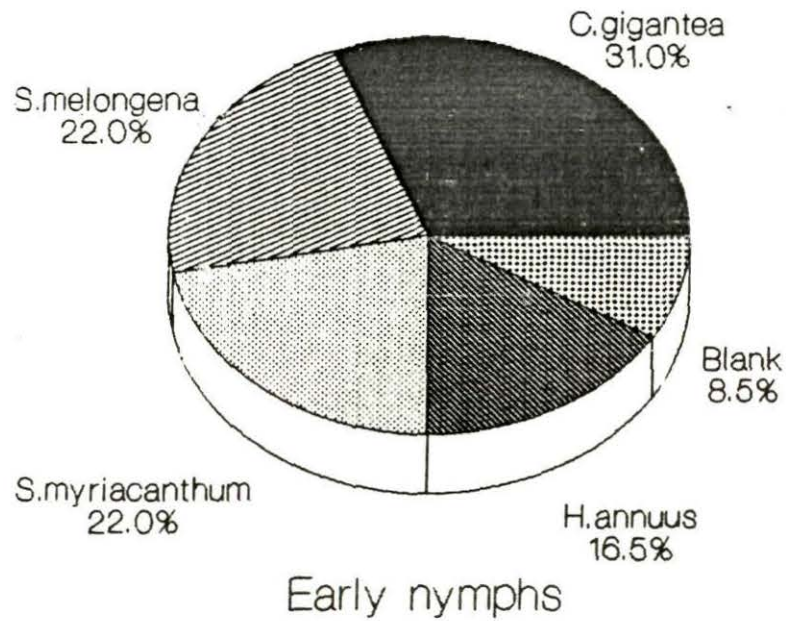


Fig. 3a Seed preference by early nymphs of *S. hospes*

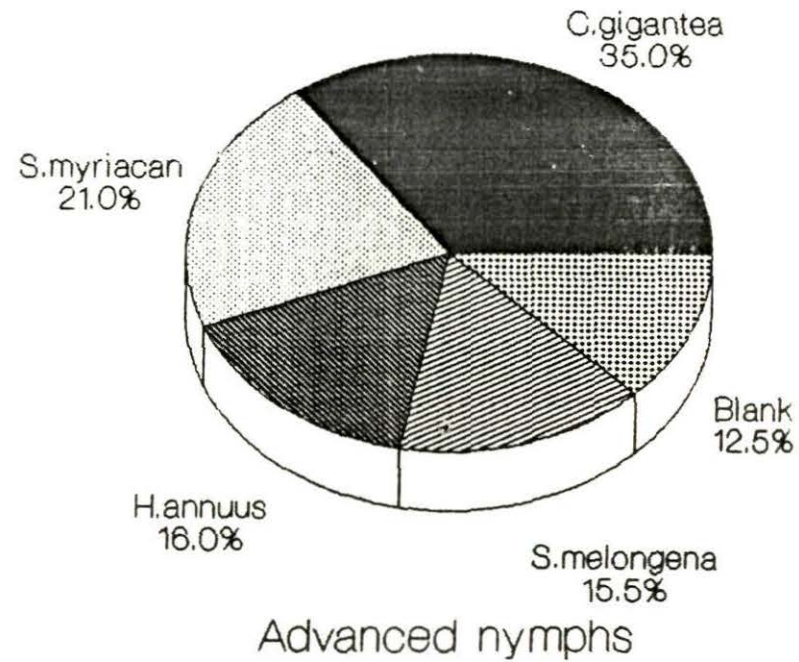


Fig. 3b Seed preference by advanced nymphs of *S. hospes*

# Seed preference of *S. hospes*

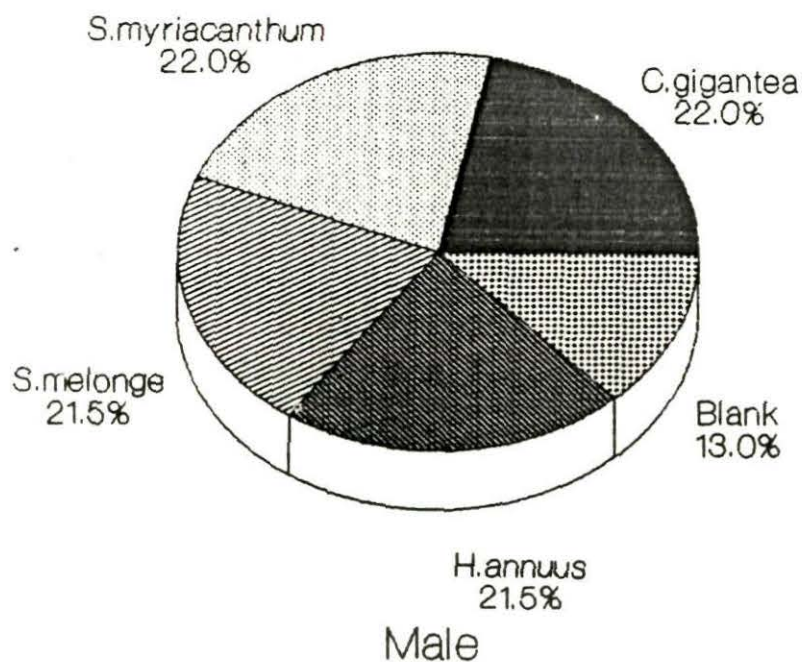


Fig. 3c Seed preference by males  
of *S. hospes*

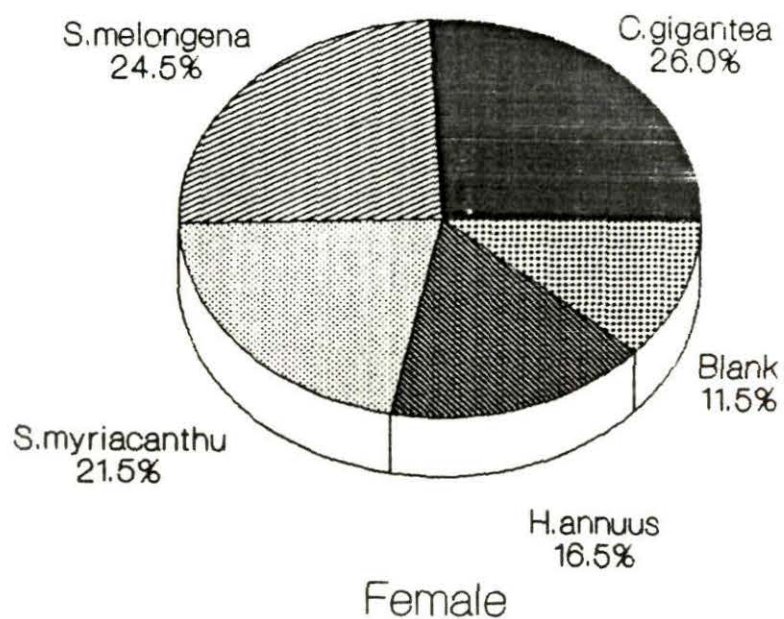


Fig. 3d Seed preference by females  
of *S. hospes*

## Postembryonic Development Period

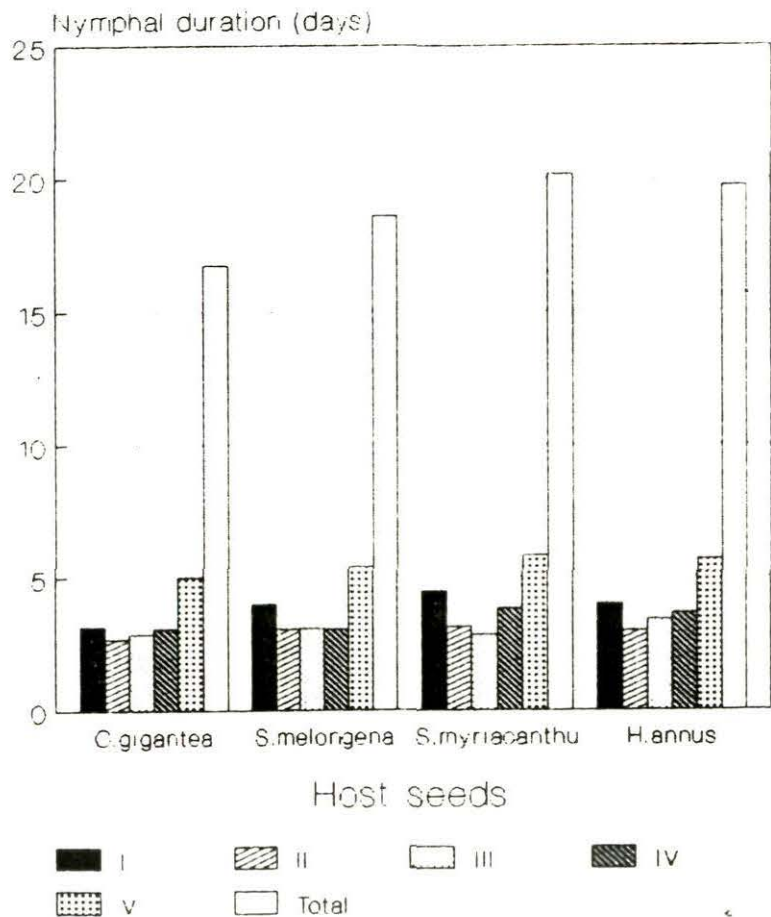


Fig. 4. Postembryonic development periods of nymphs of S.hospes on four host seeds.

## Nymphal mortality

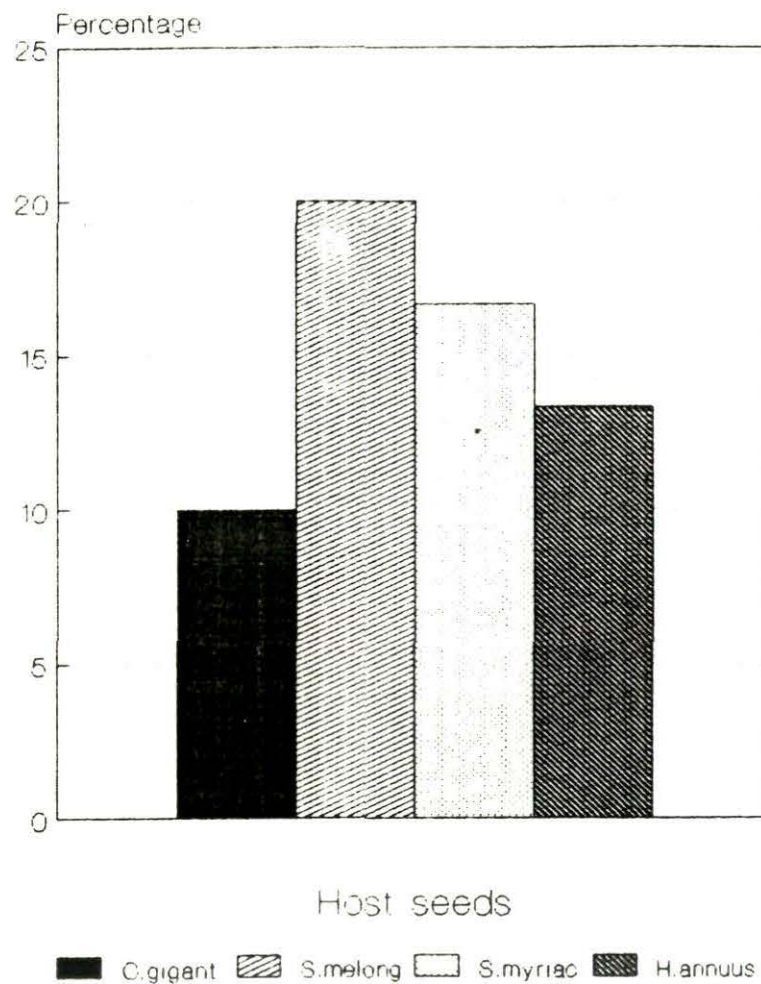
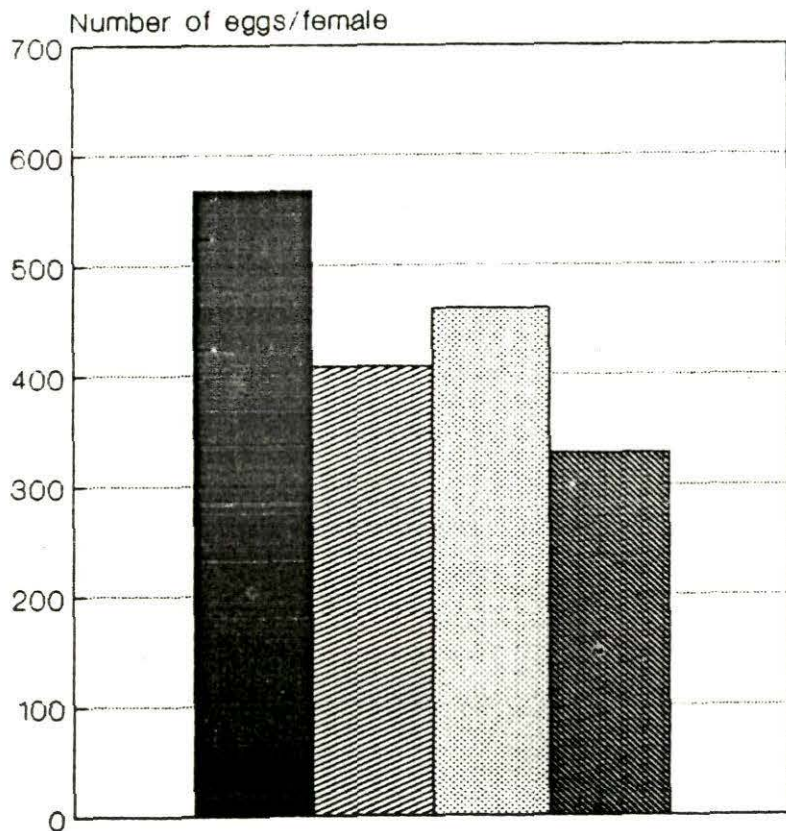


Fig. 5. Nymphal mortality of S.hospes on four host seeds.

## Fecundity

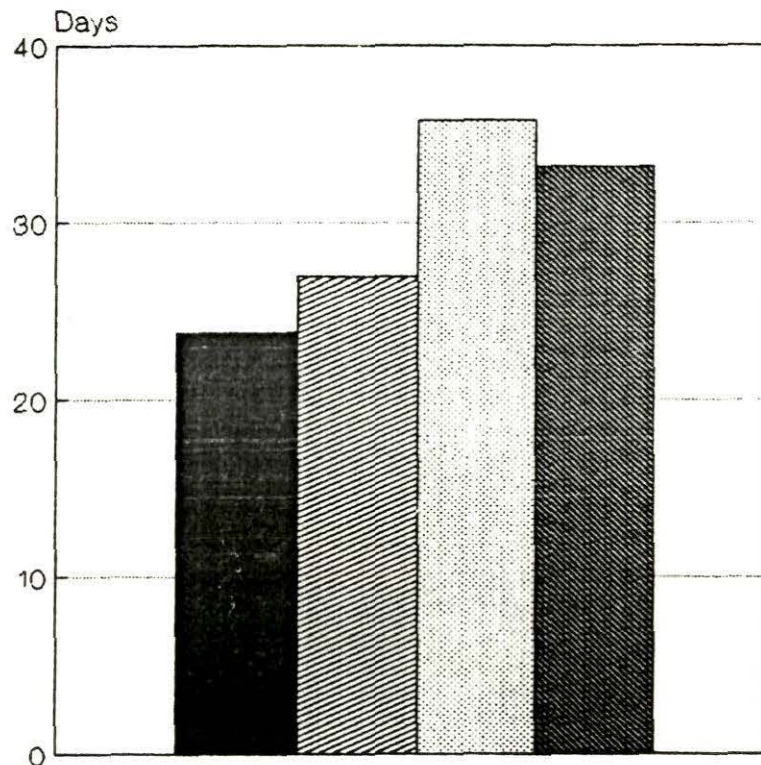


Host seeds

■ C.gigant    ▨ S.melong    ▩ S.myriac    ▤ H.annuus

Fig. 6 Total eggs laid per female of S.hospes on four host seeds

## Longevity Female

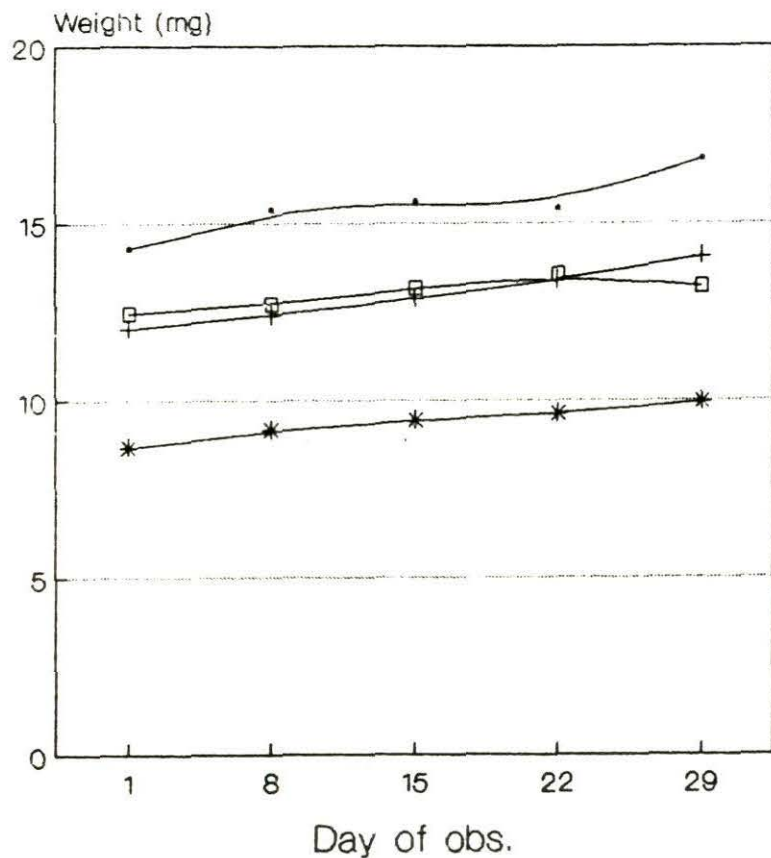


Host seeds

■ C.gigant    ▨ S.melong    ▩ S.myriac    ▤ H.annuus

Fig. 7 Longevity of S.hospes females on four host seeds

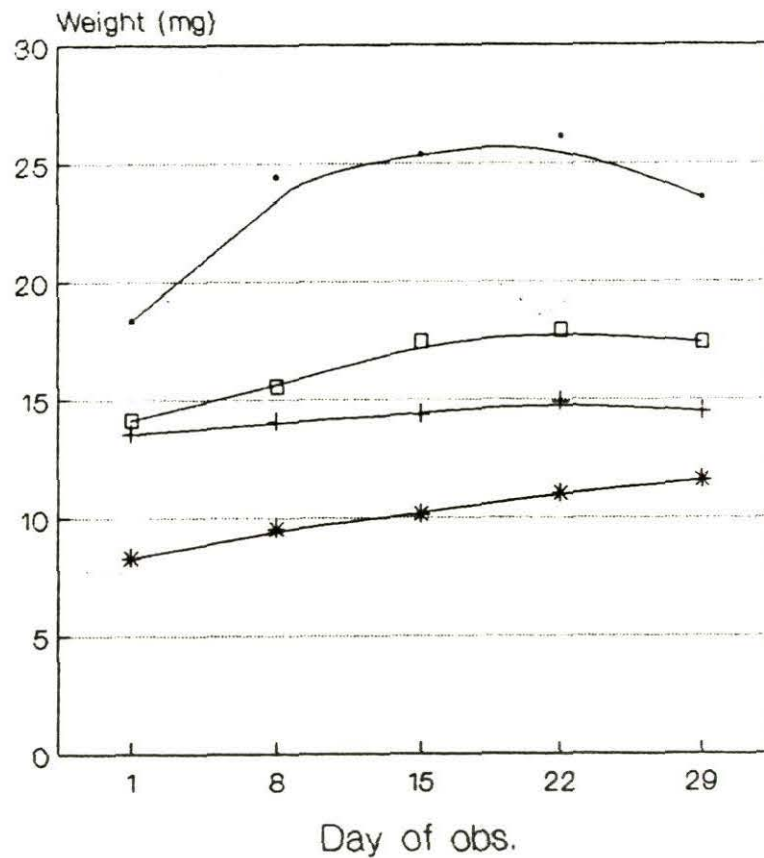
## Body wt. change Male



—●— C.gigant —□— S.melong —\*— S.myriac —+— H.annuus

Fig. 8 Change in dry body weight of male S.hospes on four host seeds

## Body wt. change Female



—●— C.gigant —□— S.melong —\*— S.myriac —+— H.annuus

Fig. 9 Change in dry body weight of female S.hospes on four host seeds

# Production index

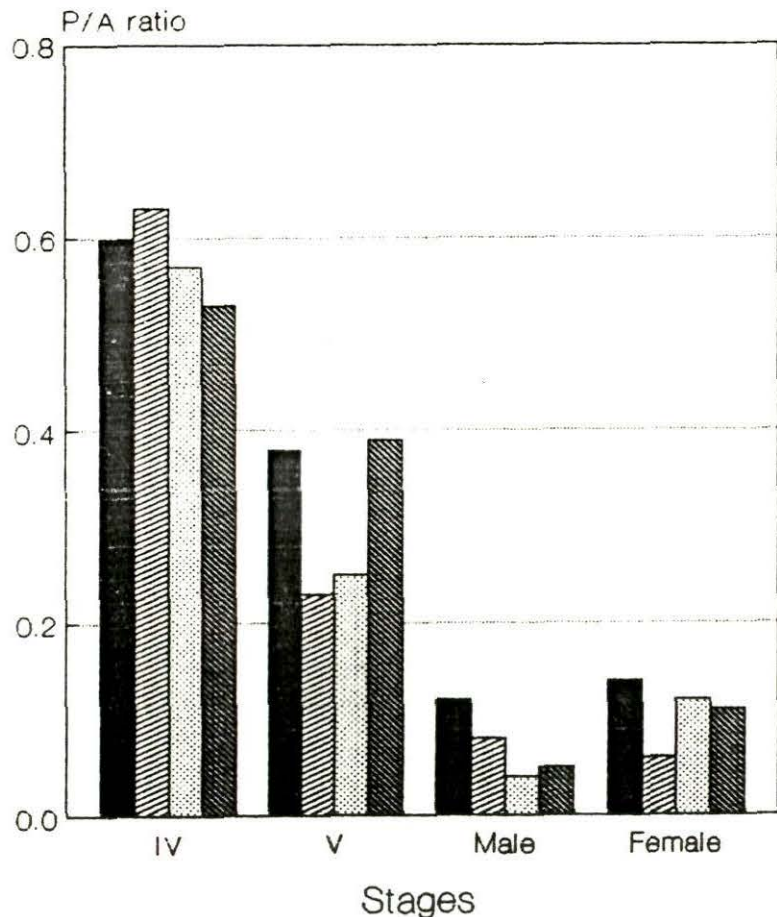


Fig. 10 Comparison of production index (P/A ratio) of advanced instars, males and females of S.hospes on four host seeds

# Maintenance cost

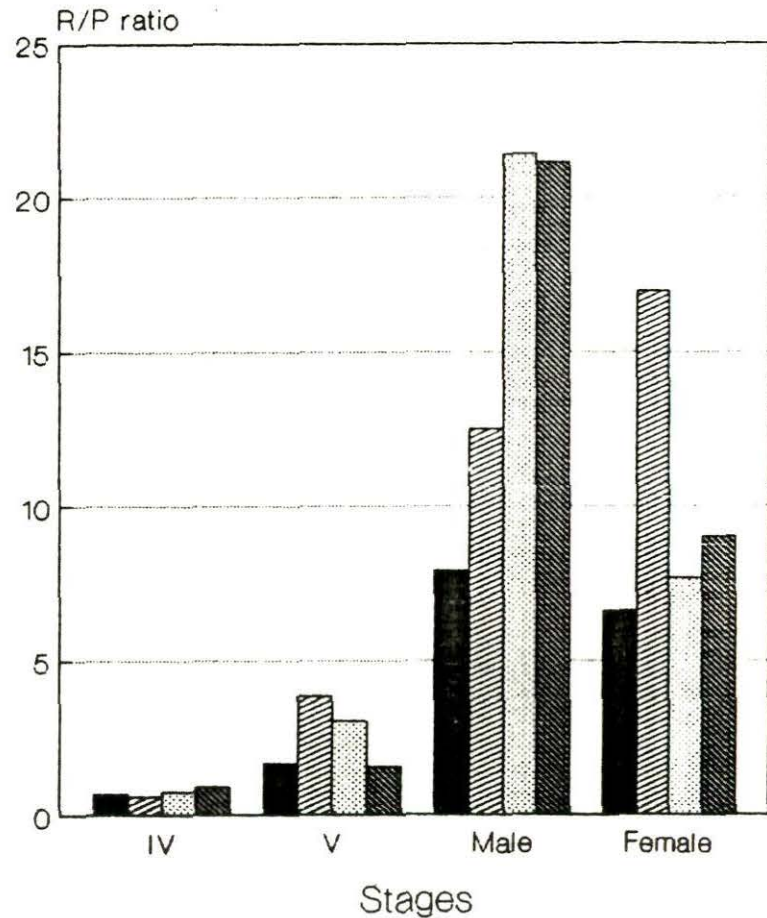


Fig. 11 Comparison of maintenance cost (R/P ratio) of advanced instars, males and females of S.hospes on four host seeds

# Biochemical profile of seeds of *S.hospes*

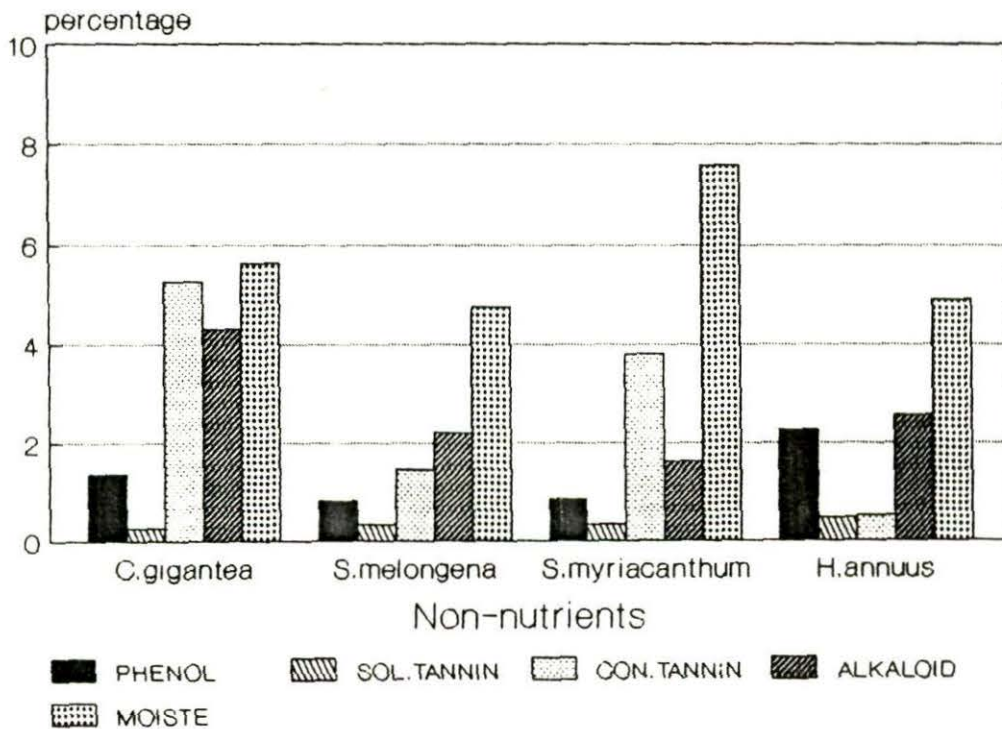
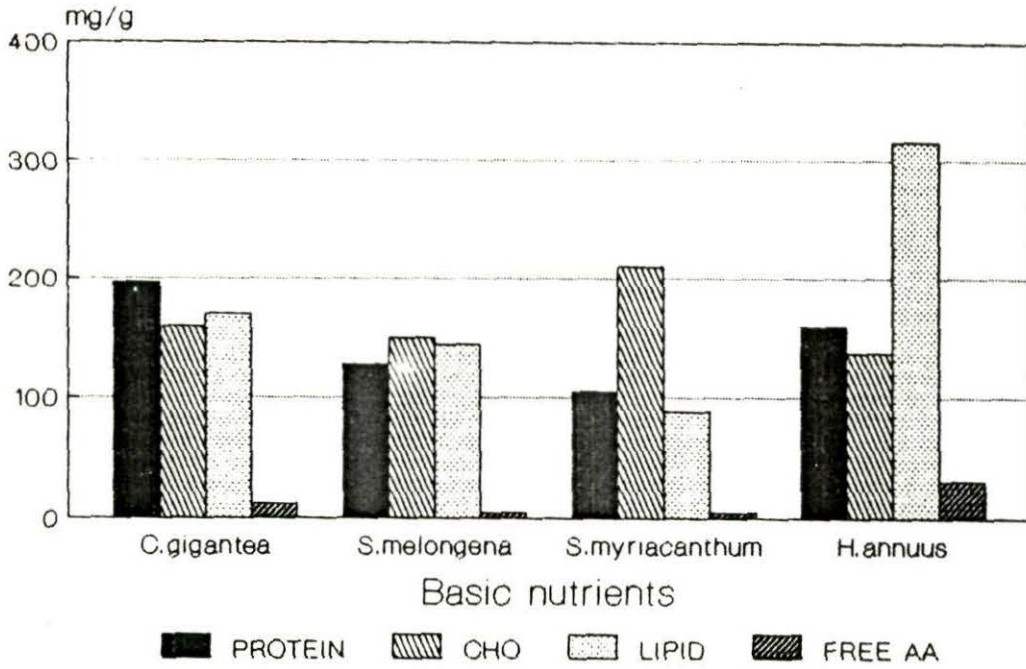


Fig. 12 Diet components comprising the basic nutrients and nonnutrients of four host seeds of *S.hospes*

**Dysdercus koenigii (Fabricius )**  
**( Pyrrhocoridae )**

Fig. 13a. Dysdercus koenigii (Fabricius)

Fig. 13b. Host seed of D.koenigii.

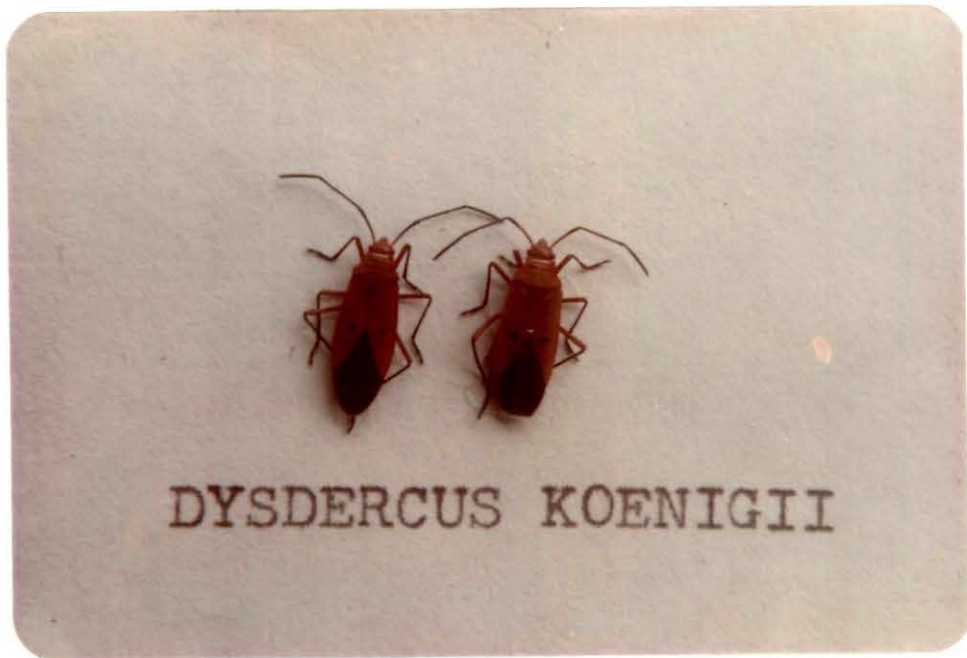


Fig. 13a

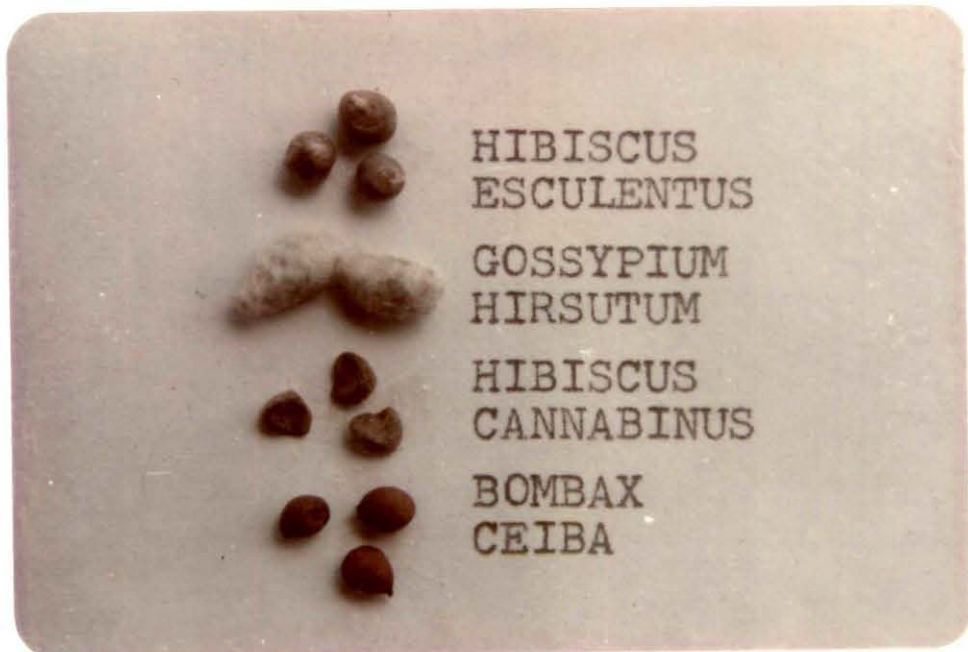


Fig. 13b

5. PERFORMANCE OF NYMPHS AND ADULTS OF DYSDERCUS  
KOENIGII ON FOUR SELECTED HOST SEEDS (FIG.13a & b)

5.1 Seed preference by different stages and sexes  
(Table - 5.1)

Food finding and seed preference experiments indicated that in all stages the blank end (without seed) recorded minimum attendance. Percentage preference for H.esculentus was the highest and was closely followed by that of G.hirsutum in all stages excepting the early nymphs. Least preferred among the seeds was B.ceiba. On H.cannabinus the preference exercise was only slightly different from that on G.hirsutum (Figs. 14a,b,c & d).

5.2 Postembryonic development period and nymphal mortality (Table 5.2)

Short nymphal development was noted on H.esculentus and H.cannabinus. It was significantly prolonged on G.hirsutum and was incomplete on B.ceiba. On B.ceiba development of nymphs took place only upto fifth instar with a very high mortality. Although some overlapping of the first and second stadial periods on G.hirsutum and first and third stadial periods on H.cannabinus was present yet stadial periods for

the advanced nymphs significantly differed (Figs.15 & 16) and was found to be the longest in the fourth instar on B.ceiba.

### 5.3 Reproductive performance and longevity

(Table - 5.3)

Adult longevity on H.esculentus and G.hirsutum overlapped and was higher than those recorded on H.cannabinus and B.ceiba. Fecundity was maximum on G.hirsutum and was insignificantly followed by that on H.esculentus and significantly that on H.cannabinus (Fig. 17). The picture, however reversed when egg-laying rate were compared. No significant difference in percentage hatchability was recorded among eggs laid on various host seeds. No egg laying took place when adult pairs were maintained on B.ceiba (Fig. 18).

### 5.4 Change in adult body weight (Table - 5.4a,b)

Body weight (dry) of male did not show any significant change for over a month since emergence on H.esculentus, G.hirsutum and H.cannabinus. However, a late increase in body weight was recorded on 22nd and 29th day on H.cannabinus as compared to the earlier weights. Difference in body weight changes was mostly insignificant and closely comparable on all the weeks on H.esculentus and G.hirsutum. The weight

remained significantly low on H.cannabinus and still lower on B.ceiba (Fig. 19).

Body weight (dry) of female showed a general reduction at the end of the first week which again picked-up by the end of second week and showed further increase in the third and the fourth week. Initial body weight was substantially higher on G.hirsutum but the final body weight at the end of the month was significantly high on H.esculentus. Body weight gain was the poorest on B.ceiba and could be recorded only upto fifteen days because of adult mortality (Fig. 20).

#### 5.5 Dry mass (nutrient) budget and food utilization efficiency (Table-5.5a,b,c,d) (Figs. 21 & 22)

In fourth instar, consumption on H.esculentus, G.hirsutum, H.cannabinus was not much different. However, the production on G.hirsutum significantly exceeded the values of those on other seeds. A comparison of relative consumption rate (RCR), revealed insignificant difference between H.esculentus and H.cannabinus which is also reflected in values of relative growth rate (RGR). Constrastingly, growth index (P/A) on B.ceiba was found to be the highest inspite of low consumption and production. Maintenance cost (R/P) was the highest on H.cannabinus followed by values of H.esculentus and significantly lower values of the other two seeds.

In fifth instar, consumption was found to be highest on H.esculentus followed by that on G.hirsutum and H.cannabinus. Correspondingly the production was also found to be highest on H.esculentus followed by those on G.hirsutum and H.cannabinus. The RCR and RGR, however, showed a higher value on H.cannabinus which are in contrast to the consumption (C) and production (P) values on this seed. No significant difference in the growth indices (P/A) as well as maintenance costs (R/P) were found. As fifth instar stage did not complete its stadium successfully on B.ceiba, no data could be taken.

In males, consumption values (C) on H.esculentus and G.hirsutum were significantly higher than that on H.cannabinus, but were insignificant between themselves. However, the production (P), its index (P/A) and the maintenance (R/P) values showed significant difference on the first two seeds.

In females the consumption (C) and the relative consumption rate (RCR) were significantly higher on H.esculentus and G.hirsutum than on H.cannabinus. However, total production (P) its index (P/A) and relative growth rate (RGR) were the poorest on G.hirsutum. Respiration (R)

and maintenance cost (R/P) were the maximum on G.hirsutum and were recorded to be the lowest on H.esculentus.

#### 5.6 Biochemical estimation of basic nutrients and some nonnutritional components (Table-5.6a,b)(Fig.23)

Storage protein was highest in H.esculentus followed by values of G.hirsutum and H.cannabinus. It was lowest in B.ceiba. Highest value for nutritive carbohydrate was recorded in H.cannabinus followed by values of H.esculentus and G.hirsutum. It was lowest in B.ceiba. CHO/protein ratio was the narrowest in H.esculentus and highest in B.ceiba. H.esculentus showed highest lipid content followed by values of H.cannabinus, G.hirsutum and lowest of B.ceiba. Free amino acid was fairly high in H.cannabinus and almost half its value in H.esculentus and G.hirsutum, lowest was recorded in B.ceiba.

G.hirsutum contained highest phenol and H.esculentus the lowest. TAE (soluble tannin) was found highest in B.ceiba and very little in G.hirsutum. Condensed tannin was found to be very high on H.cannabinus, followed by comparatively very low values in rest of the seeds. Alkaloid content of B.ceiba was the highest and followed closely by G.hirsutum. H.esculentus had the lowest alkaloid content. Moisture content was slightly higher in H.esculentus and G.hirsutum compared to that of the other seeds.

Table 5.1. Seed preference<sup>1</sup> (attendance) by different stage and sexes of D.koenigii with percentage preference (Pr.)

Host seed	Early nymphs		Advanced nymphs		Male		Female	
	Mean ±S.E.	Pr.	Mean ±S.E.	Pr.	Mean ±S.E.	Pr.	Mean ±S.E.	Pr.
<u>H.esculentus</u>	4.6 a ±0.25	23.00	6.1 a ±0.48	30.50	3.8 a ±0.37	25.33	4.5 a ±0.32	30.00
<u>G.hirsutum</u>	5.0 a ±0.35	25.00	4.0 b ±0.37	20.00	3.4 ab ±0.29	22.67	3.8 a ±0.19	25.33
<u>H.cannabinus</u>	4.0 ab ±0.37	20.00	4.4 b ±0.51	22.00	3.1 abc ±0.30	20.67	3.0 b ±0.28	20.00
<u>B.ceiba</u>	3.5 bc ±0.32	17.50	3.6 b ±0.62	18.00	2.5 bc ±0.29	16.67	2.7 b ±0.25	18.00
Blank	2.9 c ±0.39	14.50	1.9 c ±0.17	9.50	2.2 c ±0.19	14.66	1.0 c ±0.24	6.67

<sup>1</sup> Means followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

Table 5.2. Post-embryonic development period (Days, Mean  $\pm$  S.E.)<sup>1</sup> and nymphal mortality (%) of D.koenigii on different host seeds.

Host seed	1st instar	2nd instar	3rd instar	4th instar	5th instar	Total nymphal duration	Total nymphal mortality (%)
<u>H.esculentus</u>	2.04 aA $\pm 0.04$	5.10 aB $\pm 0.28$	4.20 aC $\pm 0.11$	3.25 aD $\pm 0.10$	6.35 aE $\pm 0.16$	20.80 a $\pm 0.26$	33.33
<u>G.hirsutum</u>	2.87 bA $\pm 0.06$	3.25 bA $\pm 0.12$	5.05 bB $\pm 0.39$	6.17 bC $\pm 0.59$	7.72 bD $\pm 0.33$	25.17 b $\pm 0.99$	40.00
<u>H.cannabinus</u>	3.26 cA $\pm 0.08$	4.06 cB $\pm 0.06$	3.31 cA $\pm 0.12$	6.44 bC $\pm 0.48$	5.06 cD $\pm 0.27$	22.00 a $\pm 0.56$	46.67
<u>B.ceiba</u>	3.00 bA $\pm 0.00$	7.82 dB $\pm 0.64$	4.67 abcC $\pm 1.36$	10.00cD $\pm 0.82$	-	-	100.00

<sup>1</sup> Means followed by the same alphabet in each column and same alphabet <sup>(bold)</sup> in each row are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

Table 5.3 Reproductive performance and longevity (Mean±S.E.)<sup>1</sup>  
of D.Koenigii on different host seeds.

Host seed	Fecundity	Egg laying rate (egg/day)	% hatchability <sup>2</sup> (per batch)	Male longevity	Female longevity
<u>H.esculentus</u>	150.10 a ±20.20	9.07 a ±0.60	70.80 a ±3.00	34.20 a ±1.16	30.10 a ±1.34
<u>G.hirsutum</u>	182.50 a ±22.17	16.43 b ±2.01	74.57 a ±3.51	30.33 a ±2.22	30.33 a ±2.36
<u>H.cannabinus</u>	89.50 b ±6.92	17.94 b ±1.20	67.09 a ±2.76	23.00 b ±1.79	18.75 b ±1.01
<u>B.ceiba</u>	-	-	-	10.33* c ±0.73	12.33* c ±1.85

<sup>1</sup> Means followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955)

<sup>2</sup> Data transformed to arcsine for statistical analysis.

\* Adults used are raised on H.esculentus.

Table 5.4a Dry body weight (mg) of male D.koenigii of different ages (Mean±S.E.)<sup>1</sup> fed on different host seeds.

Host seed	1st Day	8th Day	15th Day	22nd Day	29th Day
<u>H.esculentus</u>	12.96 aA ±0.34	12.54 aA ±0.32	13.80 aA ±0.33	14.35 aA ±0.41	15.53 aA ±0.40
<u>G.hirsutum</u>	12.54 aA ±0.08	12.00 aA ±0.11	13.88 aA ±0.04	14.25 aA ±0.08	14.49 bA ±0.07
<u>H.cannabinus</u>	8.70 bA ±0.15	8.51 bA ±0.16	9.02 bA ±0.18	11.16 bB ±0.69	11.45 cB ±0.19
<u>B.ceiba</u>	5.01 cA ±0.14	4.38 cB ±0.19	5.38 cA ±0.15	-	-

<sup>1</sup> Means followed by the same alphabet in each column and same bold alphabet in each row are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

Table 5.4b. Dry body weight (mg) of female D.koenigii of different ages (Mean±S.E.)<sup>1</sup> fed on different host seeds.

Host seed	1st Day	8th Day	15th Day	22nd Day	29th Day
<u>H.esculentus</u>	21.52 aA ±0.34	20.58 aB ±0.29	21.88 aA ±0.31	25.39 aC ±0.31	30.95 aD ±0.25
<u>G.hirsutum</u>	23.31 bA ±0.18	23.38 bA ±0.18	24.68 bB ±0.20	25.48 aC ±0.20	27.25 bD ±0.19
<u>H.cannabinus</u>	17.84 cA ±0.06	16.81 cB ±0.08	19.02 cC ±0.07	21.36 bD ±0.03	22.00 cE ±0.05
<u>B.ceiba</u>	10.16 dA ±0.20	9.16 dB ±0.18	10.04 dA ±0.16	-	-

<sup>1</sup> Means followed by the same alphabet in each column and same bold alphabet in each row are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

Table 5.5a Nutrient budget (Mean±S.D., in mg)<sup>1</sup> of fourth instars D.koenigii on four host seeds.

Host seed	C	FU	A	P	R	RCR	RGR	Ae(%) <sup>2</sup>	R/P	P/A
<u>H.esculentus</u>	8.20 ab ±0.35	0.07 a ±0.02	8.14 ab ±0.34	4.11 a ±0.16	4.03 a ±0.18	0.38 a ±0.05	0.19 a ±0.03	99.21a ±0.15	0.98 a ±0.01	0.51 a ±0.01
<u>G.hirsutum</u>	7.83 a ±1.36	0.05 b ±0.01	7.78 a ±1.35	5.13 b ±0.83	2.66 b ±0.53	0.25 b ±0.02	0.17 b ±0.02	99.42b ±0.04	0.52 b ±0.02	0.66 ad ±0.01
<u>H.cannabinus</u>	8.68 b ±0.83	0.05 b ±0.02	8.64 b ±0.82	4.08 a ±0.76	4.56 c ±0.06	0.40 a ±0.01	0.19 a ±0.02	99.55c ±0.08	1.16 c ±0.21	0.47 c ±0.05
<u>B.ceiba</u>	3.63 c ±0.18	0.03 c ±0.00	3.60 c ±0.18	2.52 c ±0.19	1.08 d ±0.36	0.14 c ±0.00	0.10 c ±0.01	99.17a ±0.04	0.45 b ±0.18	0.71 d ±0.09

<sup>1</sup> Means followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955)

<sup>2</sup> Data transformed to arcsine for statistical analysis.

N.B. (i) Abbreviation explained under materials and methods.

(ii) R/P and P/A calculated based on data observed during the stadial period.

Table 5.5b. Nutrient budget (Mean±S.D., in mg)<sup>1</sup> of fifth instar D.koenigii on four host seeds.

Host seed	C	FU	A	P	R	R CR	RGR	Ae(%) <sup>2</sup>	R/P	P/A
<u>H.esculentus</u>	19.37 a ±3.48	0.15 a ±0.01	19.22 a ±3.47	11.35a ±2.48	8.27 a ±0.59	0.21 a ±0.00	0.12 a ±0.01	99.23 a ±0.11	0.80 a ±0.17	0.56 a ±0.05
<u>G.hirsutum</u>	15.95 ab ±5.30	0.17 a ±0.02	15.79 ab ±5.29	9.92 a ±4.36	5.87 b ±0.93	0.17 b ±0.02	0.10 a ±0.02	98.87 b ±0.28	0.69 a ±0.21	0.61 a ±0.08
<u>H.cannabinus</u>	12.55 b ±4.30	0.19 b ±0.04	12.36 b ±4.26	7.46 a ±3.94	4.90 c ±0.32	0.27 c ±0.02	0.15 b ±0.04	98.41 c ±0.23	0.88 a ±0.42	0.56 a ±0.13
<u>B.ceiba</u>	-	-	-	-	-	-	-	-	-	-

<sup>1</sup> Means followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955)

<sup>2</sup> Data transformed to arcsine for statistical analysis.

N.B. (i) Abbreviation explained under materials and methods.

(ii) R/P and P/A calculated based on data observed during the stadial period.

Table 5.5c. Nutrient budget (Mean±S.D., in mg)<sup>1</sup> of male D.koenigii on four host seeds.

Host seed	C	FU	A	P	R	RCR	RGR	Ae(%) <sup>2</sup>	R/P	P/A
<u>H.esculentus</u>	23.75 a ±1.40	0.90 a ±0.15	22.85 a ±1.25	2.57 a ±0.26	20.29 a ±1.00	0.25 a ±0.00	0.03 a ±0.01	96.24 a ±0.41	7.95 a ±0.40	0.12 a ±0.01
<u>G.hirsutum</u>	24.25 a ±0.60	1.05 bc ±0.04	23.21 a ±0.57	1.95 b ±0.01	21.26 b ±0.56	0.26 b ±0.01	0.02 b ±0.01	95.69 b ±0.04	10.90 b ±0.23	0.09 b ±0.01
<u>H.cannabinus</u>	21.95 b ±0.90	0.98 ac ±0.06	20.98 b ±0.96	2.75 c ±0.12	18.23 c ±0.84	0.33 c ±0.00	0.05 c ±0.01	95.54 b ±0.43	6.63 c ±0.02	0.13 c ±0.00
<u>B.ceiba</u>	-	-	-	-	-	-	-	-	-	-

<sup>1</sup> Means followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955)

<sup>2</sup> Data transformed to arcsine for statistical analysis.

N.B. (i) Abbreviation explained under materials and methods.

(ii) R/P and P/A calculated based on data observed during first 4 weeks.

Table 5.5d. Nutrient budget (Mean±S.D., in mg)<sup>1</sup> of female D.koenigii on four host seeds.

Host seed	C	FU	A	P	R	RCR	RGR	Ae(%) <sup>2</sup>	R/P	P/A
<u>H.esculentus</u>	31.51 a ±1.06	1.03 a ±0.13	30.48 a ±0.93	9.44 a ±0.29	21.05 a ±0.65	0.19 a ±0.00	0.05 a ±0.00	96.76 a ±0.29	2.23 a ±0.00	0.31 a ±0.00
<u>G.hirsutum</u>	31.25 a ±0.60	1.11 b ±0.01	30.14 a ±0.61	3.94 b ±0.04	26.20 b ±0.65	0.19 a ±0.01	0.02 b ±0.00	96.45 b ±0.10	6.65 b ±0.23	0.13 b ±0.00
<u>H.cannabinus</u>	30.25 b ±0.60	0.92 c ±0.03	29.33 b ±0.57	4.35 c ±0.15	24.98 c ±0.72	0.23 b ±0.01	0.04 c ±0.01	96.96 c ±0.04	5.76 c ±0.37	0.15 c ±0.01
<u>B.ceiba</u>	-	-	-	-	-	-	-	-	-	-

<sup>1</sup> Means followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955)

<sup>2</sup> Data transformed to arcsine for statistical analysis.

N.B. (i) Abbreviation explained under materials and methods.

(ii) R/P and P/A calculated based on data observed during first 4 weeks.

Table 5.6a. Estimation of basic nutrients and free amino acid (mg/g) of different host seeds of D.koenigii.

Host seeds	Storage protein	Nutritive carbohydrate	CHO/protein ratio	Lipid	Free amino acid
<u>H.esculentus</u>	104.66 a	198.43 a	1.90 a	128.89 a	5.83 a
<u>G.hirsutum</u>	95.03 b	193.75 b	2.04 b	108.04 b	4.26 b
<u>H.cannabinus</u>	86.87 c	240.04 c	2.76 c	127.65 a	10.61 c
<u>B.ceiba</u>	48.01 d	137.59 d	2.87 d	83.62 c	3.58 d

Values followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955)

N.B. Mean values have been presented.

Table 5.6b. Comparative estimation on some secondary compounds and moisture (in %) of different host seeds of D.koenigii.

Host seed	Phenol	TAE	Condensed tannin	Alkaloid	Moisture
<u>H.esculentus</u>	0.46 a	0.23 a	0.87 a	0.34 a	7.41 a
<u>G.hirsutum</u>	1.43 b	0.02 b	1.36 b	2.28 b	6.80 b
<u>H.cannabinus</u>	0.51 c	0.24 a	24.53 c	0.94 c	5.70 c
<u>B.ceiba</u>	0.58 d	0.32 c	1.44 b	2.32 b	5.77 c

Values followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

N.B. Mean values have been presented.

# Seed preference of *D. Koenigii*

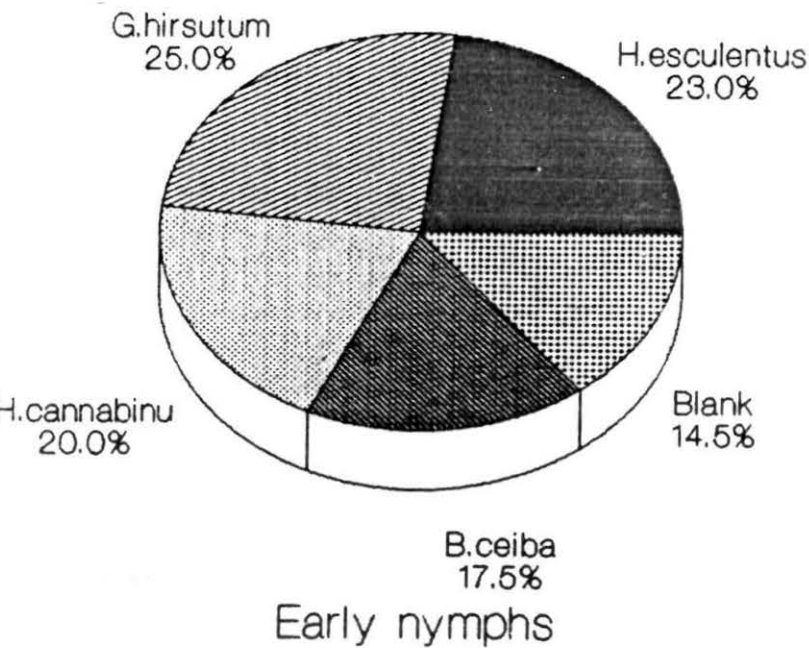


Fig. 14a Seed preference by early nymphs of *D. koenigii*

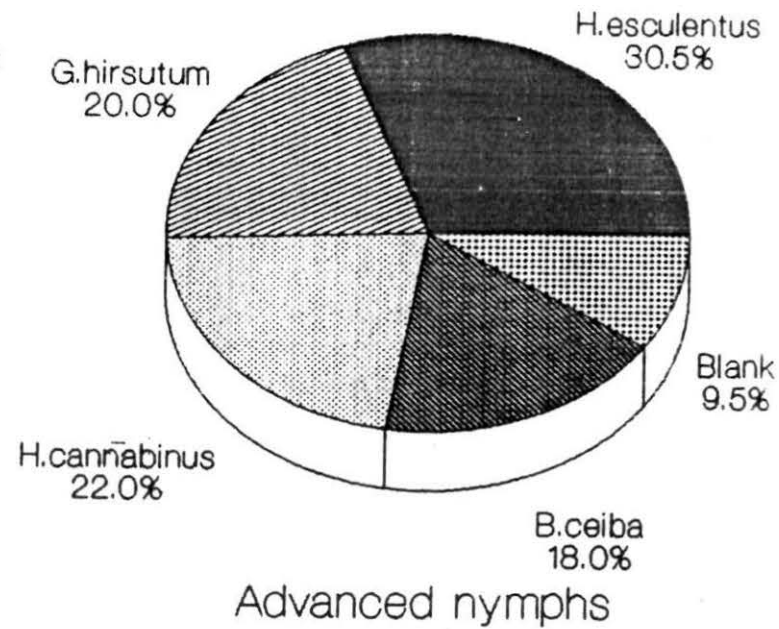


Fig. 14b Seed preference by advanced nymphs of *D. koenigii*

# Seed preference of *D. Koenigii*

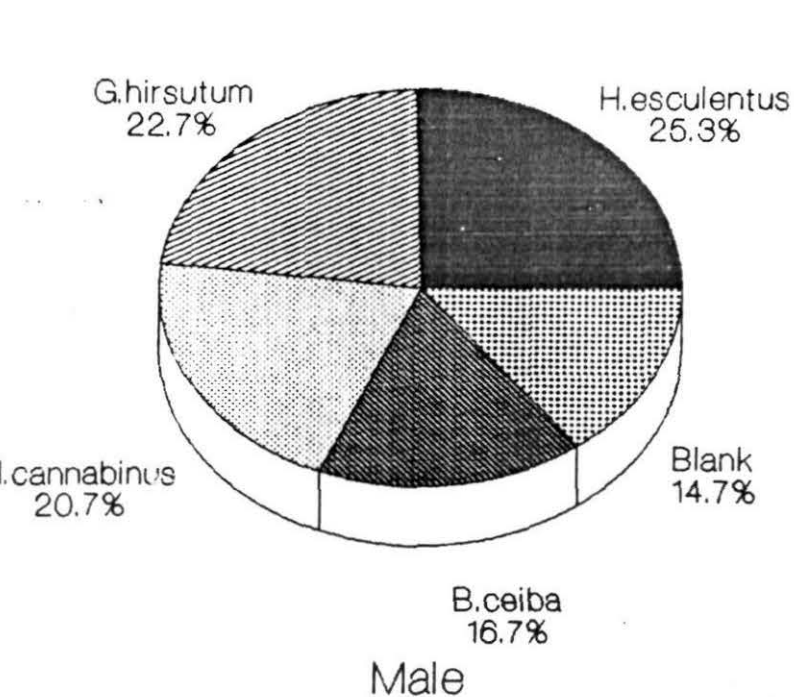


Fig. 14c Seed preference by males of *D.koenigii*

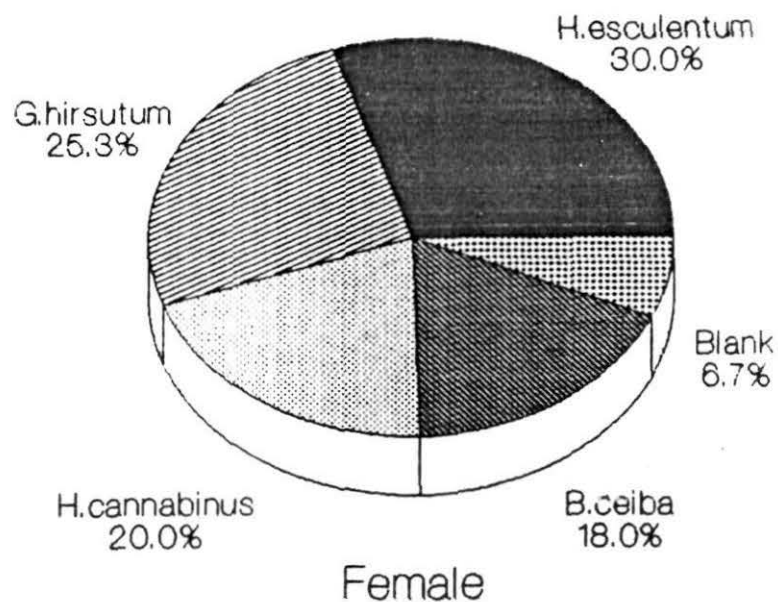


Fig. 14b Seed preference by females of *D.koenigii*

## Postembryonic Development Period

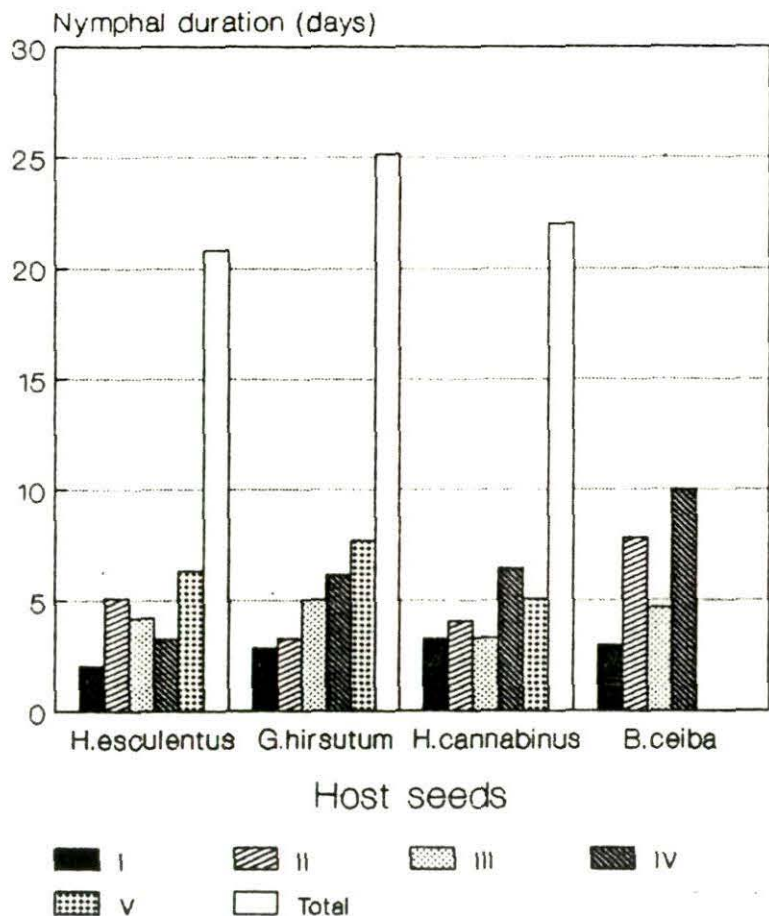


Fig. 15 Postembryonic development periods of nymphs of D. koenigii on four host seeds

## Nymphal mortality

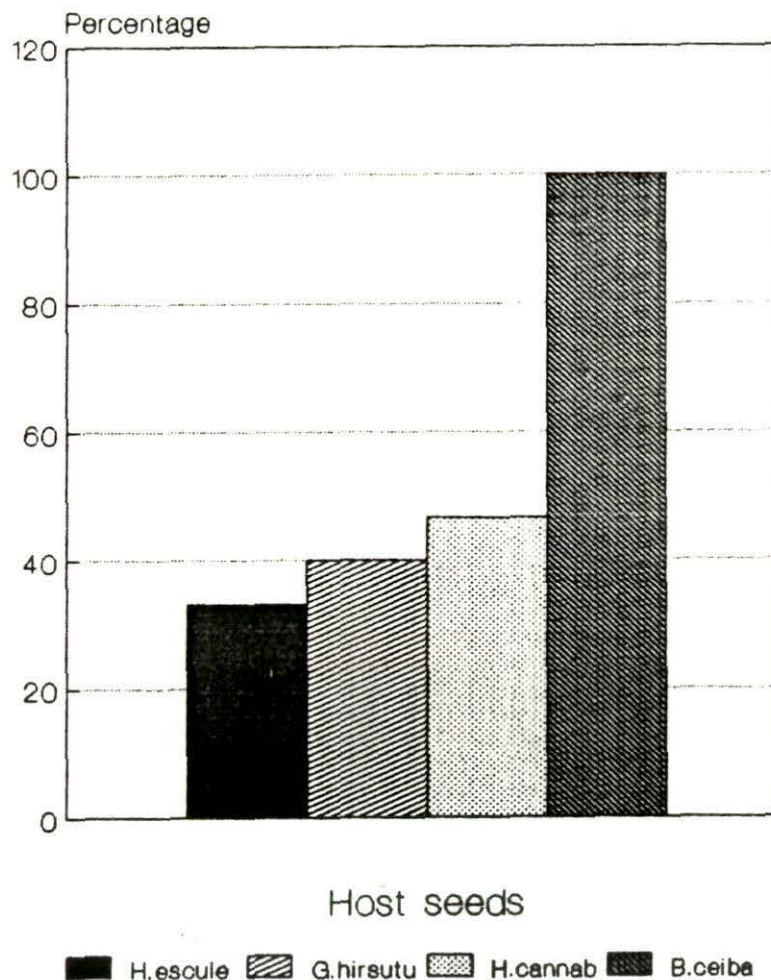
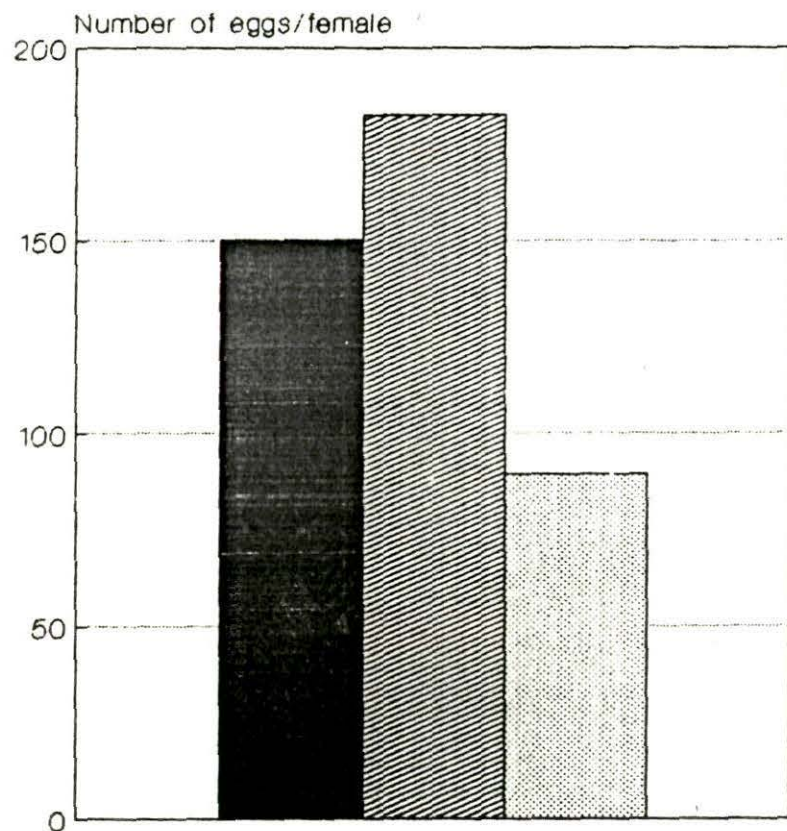


Fig. 16 Nymphal mortality of D. koenigii on four host seeds

## Fecundity

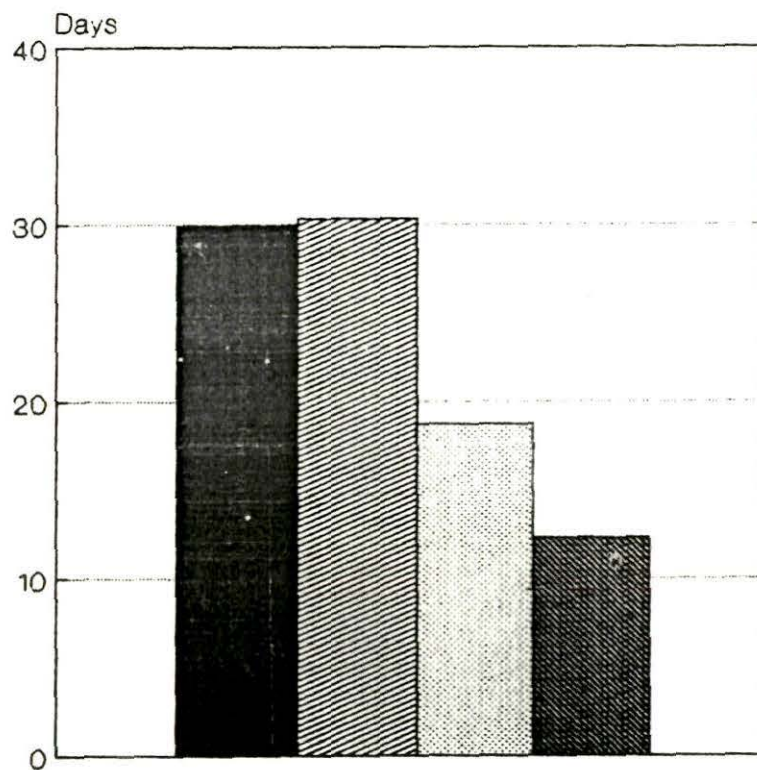


Host seeds

■ H. esculentum    ▨ G. hirsutum    ▩ H. cannabinus

Fig. 17 Total eggs laid per female of D. koenigii on four host seeds

## Longevity Female



Host seeds

■ H. esculentum    ▨ G. hirsutum    ▩ H. cannabinus    ▤ B. ceiba

Fig. 18 Longevity of D. koenigii females on four host seeds

## Body wt. change Male

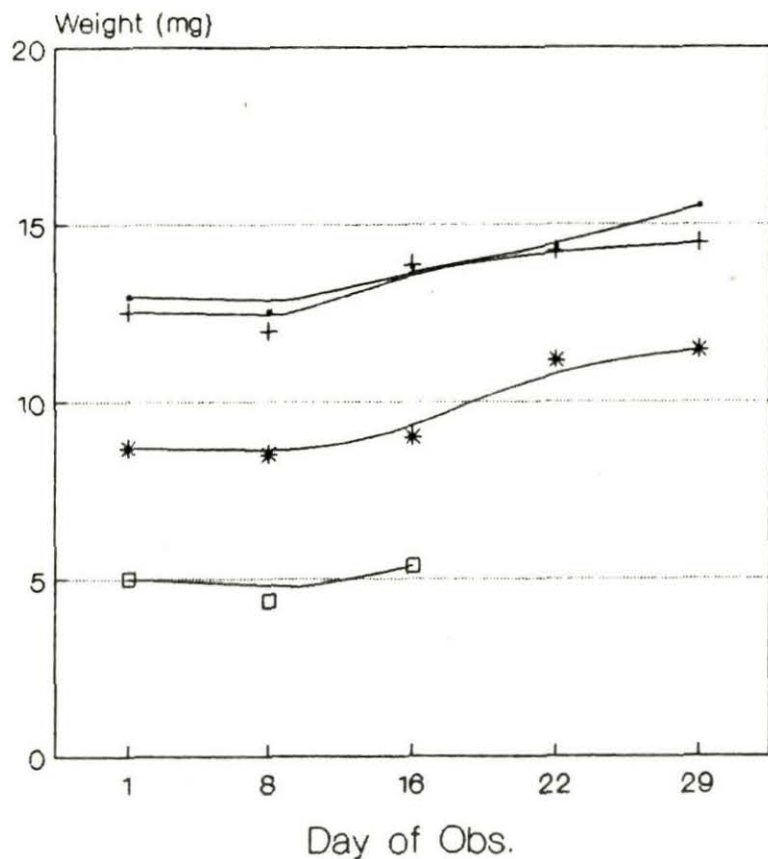


Fig. 19 Change in dry body weight of male *D. koenigii* on four host seeds

## Body wt. change Female

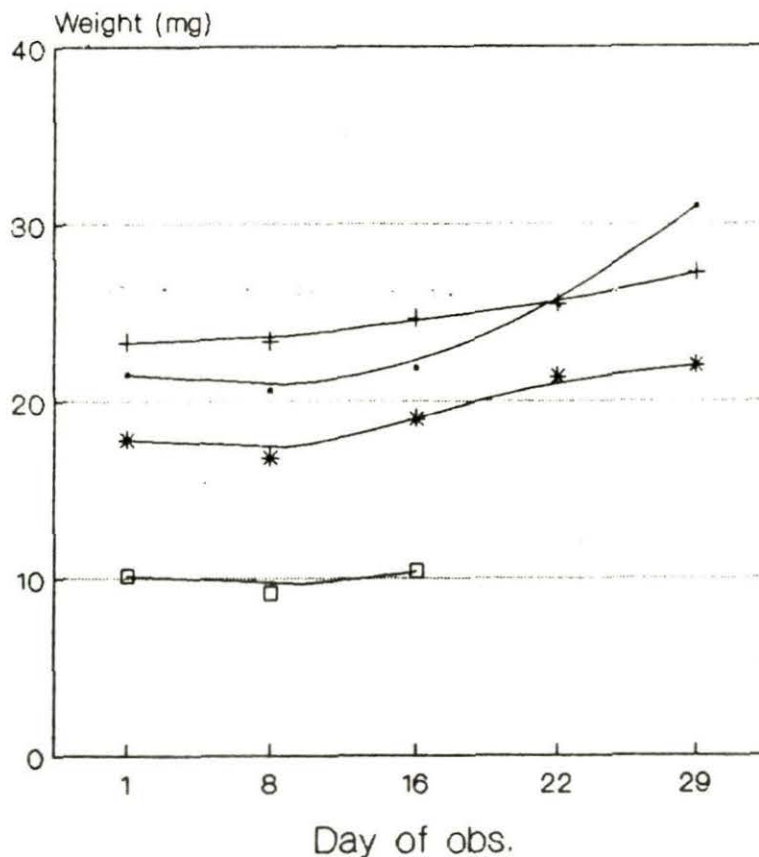
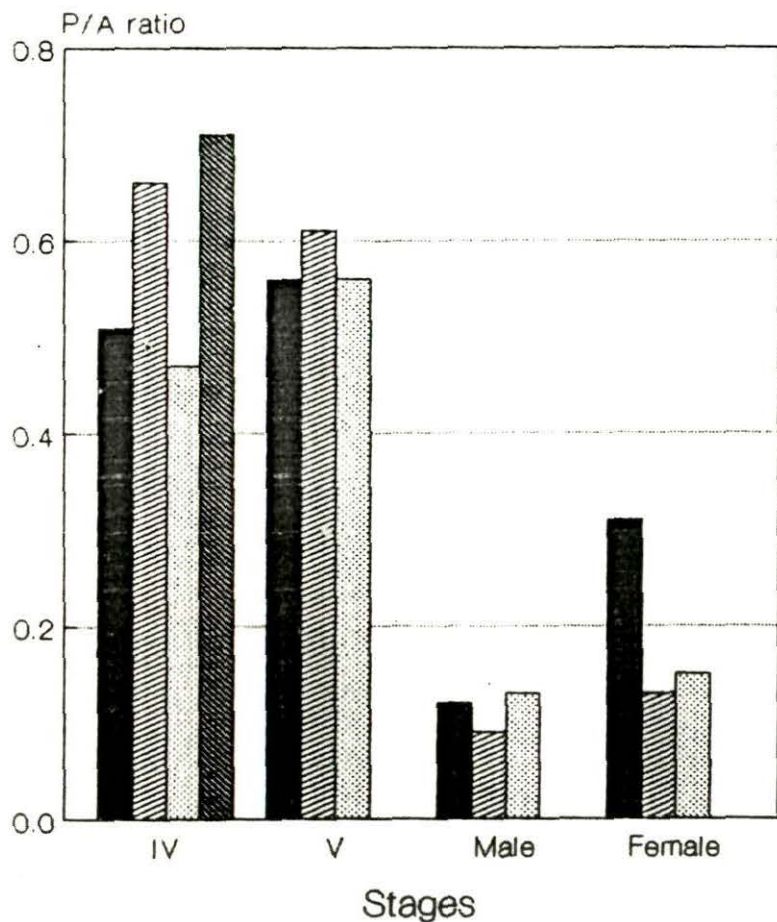
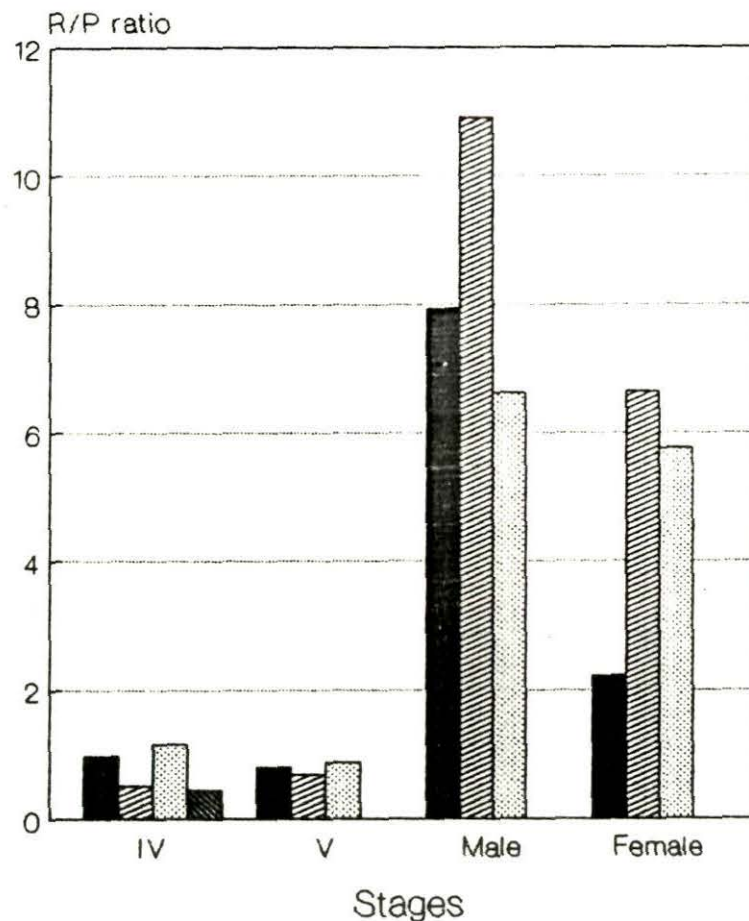


Fig. 20 Change in dry body weight of female *D. koenigii* on four host seeds

# Production Index



# Maintenance Cost



■ H.escule    ▨ G.hirsutu    ▩ H.cannab    ▤ B.ceiba

Fig. 21 Comparison of production index (P/A ratio) of advanced instars, males and females of D.koenigii on four host seeds

■ H.escule    ▨ G.hirsutu    ▩ H.cannab    ▤ B.ceiba

Fig. 22 Comparison of maintenance cost (R/P ratio) of advanced instars, males and females of D.koenigii on four host seeds

# Biochemical profile of seeds of *D.koenigii*

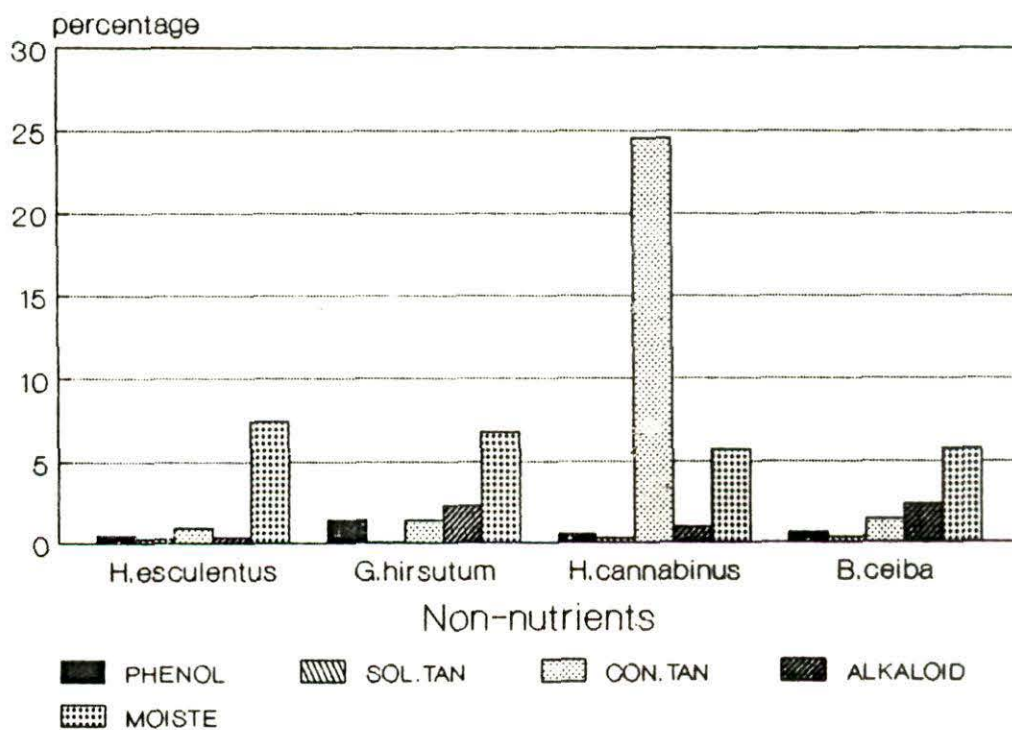
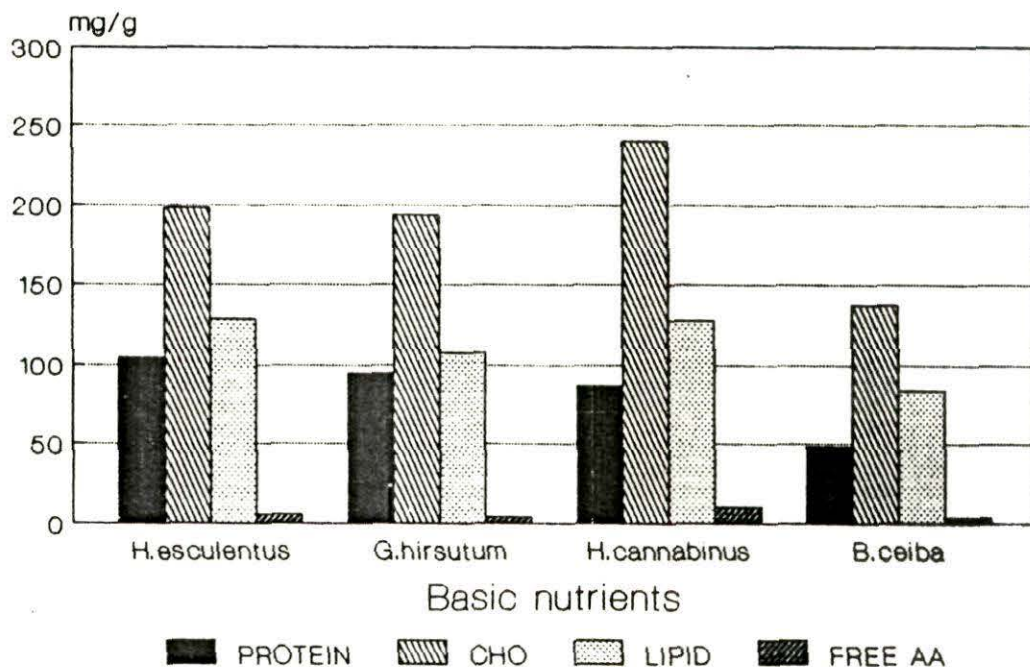


Fig. 23 Diet components comprising the basic nutrients and nonnutrients of four host seeds of *D.koenigii*

**Cletus bipunctatus (West W.)**  
**( Coreidae )**

Fig. 24a. Cletus bipunctatus (West w.)

Fig. 24b. Host seeds of C.bipunctatus.

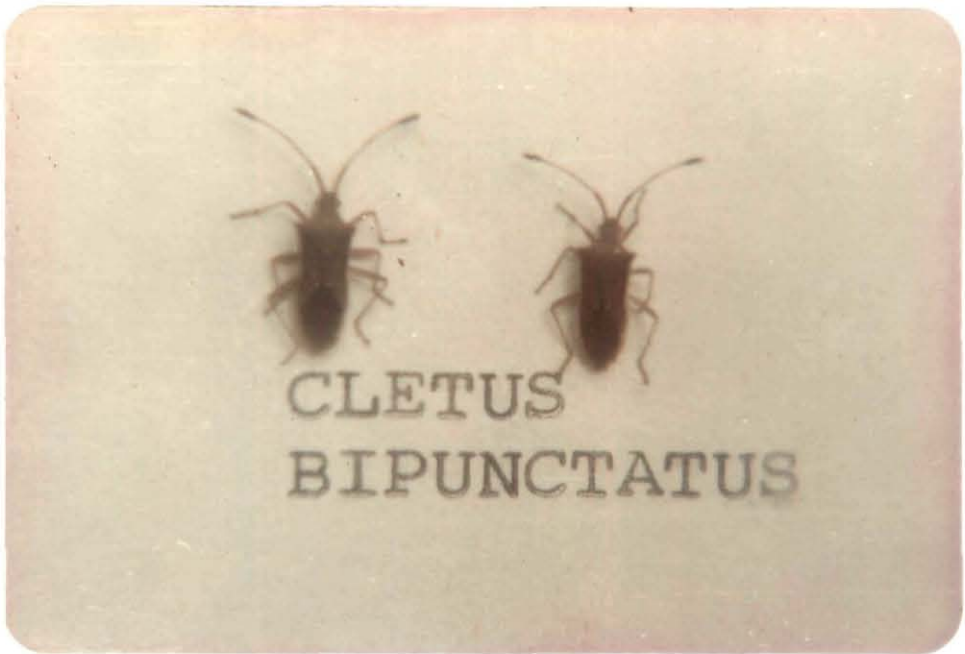


Fig. 24a

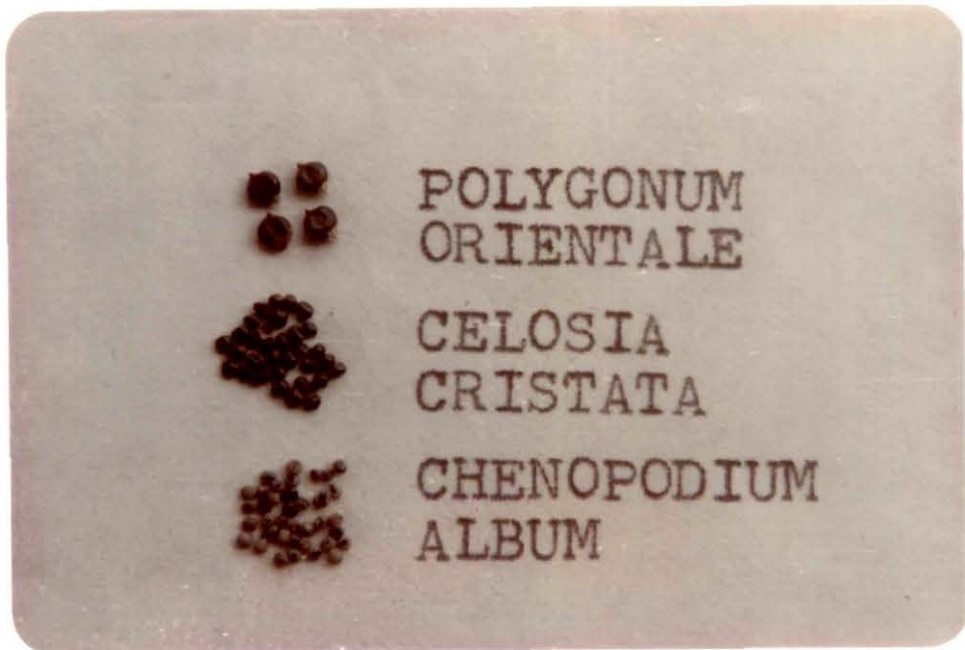


Fig. 24b

6. PERFORMANCE OF NYMPHS AND ADULTS OF CLETUS BIPUNCTATUS  
(COREIDAE) ON THREE SELECTED HOST SEEDS (FIG.24a & b)

6.1 Seed preference by different stages and sexes  
(Table - 6.1)

The early instar nymphs did not show any marked preference for any particular seed. Advanced nymphs exercised a clear preference for C.album and C.cristata over P.orientale. The males had a higher preference for two of the former seeds but not significantly different (at 5% level) from that of P.orientale. The females did not distinguish much among the host seeds. All stages, however, showed a higher attendance on the seeds over the blank (control) end (Figs. 25a,b,c, & d).

6.2 Postembryonic development period and nymphal mortality (Table - 6.2)

Total postembryonic development time was noted to be the shortest on C.cristata, closely followed by those on P.orientale and C.album. The stadia periods of advanced nymphs were significantly longer than those of the early nymphs. (Fig. 26).

Nymphal mortality (%) was highest on C.cristata and lowest on C.album. Mortality was intermediate on P.orientale (Fig. 27).

### 6.3 Reproductive performance and longevity

(Table - 6.3)

Total eggs laid by females in their life time (fecundity) was highest on P.orientale followed by that on C.album and C.cristata (Fig. 28). The rate of egg-laying also followed the same pattern with significantly higher rate on P.orientale. Although hatchability in general was poor, no significant difference was noted.

Male longevity was not affected significantly when feeding on the host seeds in question. However, female longevity was significantly reduced when feeding on P.orientale (Fig. 29).

### 6.4 Changes in the adult body weight

(Table - 6.4)

In general, an increase in dry body weight was noted both in male and in female on all the host seeds across the month of observation.

The gain in body weight by male was overlapping and higher on C.album and P.orientale than on C.cristata. In female, the gain in body weight showed a clear difference on the three different host seeds. Highest gain in female weight was observed on P.orientale, excepting some insignificant difference at initial and final weight on C.album. Weight on C.cristata kept low throughout the month of observation (Figs. 30 & 31).

#### 6.5 Dry mass (nutrient) budget and food utilization efficiency (Table-6.5a,b,c,d) (Figs. 32 & 33)

Consumption as well as relative consumption rate (RCR) in fourth instar was observed to be highest on P.orientale followed by that on C.cristata and C.album. Production on all the three seeds, however, differed insignificantly. Relative growth rate (RGR) and production index (P/A) was significantly higher on C.album followed by the values on C.cristata and P.orientale. The low production, RGR & (P/A) on P.orientale was matched with high respiration and maintenance cost (R/P).

Consumption and RCR was highest in fifth instar stage on P.orientale followed by values on C.cristata and C.album. Production and production index (P/A) were the

highest on C.album and lowest on P.orientale. RGR, however, showed some variation and was highest on P.orientale. Respiration value and (R/P) were the lowest on C.album and quite high in P.orientale.

Values of consumption and RCR in males overlapped, though C.album had a slight edge over the other two host seeds. Production was relatively low on P.orientale but RGR and (P/A) values were close to that of the other two seeds. Respiration values and maintenance costs were by and large overlapping on the host seeds.

Consumption and RCR in female did not differ significantly on the host seeds. Although values of RGR and (P/A) on all the three seeds varied insignificantly yet a marked difference in the overall production was noted, the value being the highest on P.orientale. The respiration values and maintenance costs (R/P) did not differ much being insignificant at 5% level.

#### 6.6 Biochemical estimation of basic nutrients and nonnutritional components (Table-6.6a,b) (Fig. 34)

Of the basic nutrients, storage protein and free amino acids were significantly high in P.orientale.

Carbohydrate and lipid contents were highest in C.cristata. CHO/protein ratio was the narrowest for P.orientale, and the ratio was about  $2\frac{1}{2}$  times higher in two other host seeds.

Phenol and alkaloid levels were found to be the highest in C.album among the nonnutritional components. Soluble (TAE) and condensed tannins were found to be the highest in P.orientale seeds, especially the level of the latter allelochemical being stupendous.

Table 6.1. Seed preference<sup>1</sup> (attendance) by different stage and sexes of C.bipunctatus with percentage preference (Pr.)

Host seed	Early nymphs		Advanced nymphs		Male		Female	
	Mean ±S.E.	Pr.	Mean ±S.E.	Pr.	Mean ±S.E.	Pr.	Mean ±S.E.	Pr.
<u>C.album</u>	6.8 a ±0.24	34.00	6.2 a ±0.42	31.00	4.5 a ±0.71	30.00	4.4 a ±0.57	29.33
<u>C.cristata</u>	6.1 a ±0.30	30.50	6.0 a ±0.32	30.00	4.6 a ±0.64	30.67	4.2 a ±0.56	28.00
<u>P.orientale</u>	5.9 a ±0.36	29.50	4.7 b ±0.40	23.50	3.6 ab ±0.35	24.00	4.4 a ±0.49	29.33
Blank	1.2 b ±0.31	6.00	3.1 c ±0.46	15.50	2.3 b ±0.35	15.33	2.0 b ±0.42	13.34

<sup>1</sup> Means followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

Table 6.2. Postembryonic development period (Days, Mean±S.E.)<sup>1</sup> and nymphal mortality (%) of C.bipunctatus on different host seeds.

Host seed	1st instar	2nd instar	3rd instar	4th instar	5th instar	Total nymphal duration	Total nymphal mortality(%)
<u>C.album</u>	3.00 aA ±0.07	3.00 aA ±0.07	2.08 aB ±0.06	2.65 aC ±0.10	6.40 aD ±0.24	17.00 a ±0.20	33.33
<u>C.cristata</u>	2.09 bA ±0.06	2.95 aB ±0.05	2.68 bB ±0.15	3.56 bC ±0.16	4.89 bD ±0.21	16.05 b ±0.24	40.00
<u>P.orientale</u>	2.12 bA ±0.06	3.90 bB ±0.07	2.50 bC ±0.13	3.50 bD ±0.17	4.42 bE ±0.14	16.47 ba ±0.26	36.67

<sup>1</sup> Means followed by the same alphabet in each column and same alphabet<sub>1</sub> in each row are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955). (bold)

Table 6.3 Reproductive performance and longevity (Mean±S.E.)<sup>1</sup> of C.bipunctatus on different host seeds.

Host seed	Fecundity	Egg laying rate(eggs/day)	% hatchability <sup>2</sup> (per batch)	Male longevity	Female longevity
<u>C.album</u>	107.40 a +4.28	10.83 a +0.66	53.03 a +1.83	15.50 a +0.43	14.20 a +0.44
<u>C.cristata</u>	96.20 a +3.39	9.54 a +0.28	50.35 a +0.93	15.30 a +0.58	15.40 a +0.29
<u>P.orientale</u>	125.70 b +8.00	12.94 b +0.63	55.50 a +1.69	14.50 a +0.35	13.30 b +0.65

<sup>1</sup> Means followed by the same alphabet in each column are not significantly at 5% level using ANOVA and Duncan's multiple range test (1955).

<sup>2</sup> Data transformed to arcsine for statistical analysis.

Table 6.4a. Dry body weight (mg) of male C.bipunctatus of different ages (Mean±S.E.)<sup>1</sup> fed on different host seeds.

Host seed	1st Day	8th Day	15th Day	22nd Day	29th Day
<u>C.album</u>	4.87 aA ±0.01	5.70 aB ±0.02	6.28 aC ±0.02	6.70 aD ±0.03	6.92 aE ±0.03
<u>C.cristata</u>	4.53 bA ±0.03	5.13 bB ±0.01	5.60 bC ±0.00	5.83 bD ±0.01	6.63 bE ±0.01
<u>P.orientale</u>	5.15 bA ±0.04	5.82 cB ±0.01	6.11 cC ±0.02	6.43 cD ±0.01	7.02 cE ±0.00

<sup>1</sup> Means followed by the same alphabet in each column and same bold alphabet in each row are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

Table 6.4b. Dry body weight (Mg) of female C.bipunctatus of different ages (Mean±S.E.)<sup>1</sup> fed on different host seeds.

Host seed	1st Day	8th Day	15th Day	22nd Day	29th Day
<u>C.album</u>	5.60 aA ±0.04	6.13 aB ±0.07	6.58 aC ±0.05	7.08 aD ±0.06	7.69 aE ±0.08
<u>C.cristata</u>	4.85 bA ±0.04	5.24 bB ±0.03	5.81 bC ±0.04	6.91 bD ±0.07	6.75 bE ±0.11
<u>P.orientale</u>	5.53 aA ±0.02	6.81 cB ±0.05	7.38 cC ±0.01	7.50 cD ±0.01	7.89 aE ±0.01

<sup>1</sup> Means followed by the same alphabet in each column and same alphabet (bold) in each row are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

Table 6.5a. Nutrient budget (Mean±S.D., in mg)<sup>1</sup> of fourth instar C.bipunctatus on three host seeds.

Host seed	C	FU	A	P	R	RCR	RGR	Ae(%) <sup>2</sup>	R/P	P/A
<u>C.album</u>	3.27 a ±0.27	0.11 a ±0.01	3.16 a ±0.27	1.90 a ±0.17	1.27 a ±0.44	0.56 a ±0.01	0.33 a ±0.01	96.75 a ±0.42	0.66 a ±0.18	0.60 a ±0.00
<u>C.cristata</u>	4.22 b ±0.38	0.10 a ±0.02	4.12 b ±0.37	1.95 a ±0.25	2.17 b ±0.12	0.55 a ±0.00	0.26 b ±0.01	97.65 b ±0.26	1.13 b ±0.08	0.47 b ±0.02
<u>P.orientale</u>	6.74 c ±0.11	0.16 b ±0.01	6.58 c ±0.10	1.87 a ±0.11	4.71 c ±0.01	0.75 b ±0.04	0.21 c ±0.00	97.63 b ±0.11	2.53 c ±0.16	0.29 c ±0.02

<sup>1</sup> Means followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955)

<sup>2</sup> Data transformed to arcsine for statistical analysis.

N.B. (i) Abbreviation explained under materials and methods.

(ii) R/P and P/A calculated based on data observed during the stadial period.

Table 6.5b. Nutrient budget (Mean±S.D., in mg)<sup>1</sup> of fifth instar C.bipunctatus on three host seeds.

Host seed	C	FU	A	P	R	RCR	RGR	$\bar{A}e(\%)^2$	R/P	P/A
<u>C.album</u>	5.76 a ±0.08	0.18 a ±0.03	5.58 a ±0.05	2.15 a ±0.11	3.44 a ±0.06	0.22 a ±0.02	0.08 a ±0.00	96.97 a ±0.40	1.61 a ±0.06	0.39 a ±0.02
<u>C.cristata</u>	6.39 b ±0.94	0.22 a ±0.06	6.18 b ±0.89	1.67 b ±0.16	4.51 b ±0.73	0.33 b ±0.03	0.09 b ±0.01	96.69 a ±0.37	2.69 b ±0.19	0.28 b ±0.02
<u>P.orientale</u>	7.28 c ±0.14	0.19 a ±0.01	7.09 c ±0.15	1.92 c ±0.05	5.17 c ±0.20	0.37 c ±0.01	0.10 c ±0.01	97.39 b ±0.19	2.70 b ±0.18	0.27 b ±0.01

<sup>1</sup> Means followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

<sup>2</sup> Data transformed to arcsine for statistical analysis.

N.B. (i) Abbreviation explained under materials and methods.

(ii) R/P and P/A calculated based on data observed during the stadial period.

Table 6.5c. Nutrient budget (Mean±S.D., in mg)<sup>1</sup> of male C.bipunctatus on three host seeds.

Host seed	C	FU	A	P	R	RCR	RGR	Ae(%) <sup>2</sup>	R/P	P/A
<u>C.album</u>	25.29 a ±3.19	2.03 a ±0.28	23.26 a ±2.91	2.05 a ±0.11	21.21 a ±2.80	0.63 a ±0.08	0.04 a ±0.00	91.99 a ±0.10	10.30 a ±0.81	0.09 a ±0.01
<u>C.cristata</u>	22.18 b ±1.58	1.83 b ±0.09	20.35 b ±1.49	2.08 a ±0.09	18.28 b ±1.58	0.58 a ±0.04	0.06 b ±0.00	91.74 a ±0.19	8.85 b ±1.12	0.10 b ±0.01
<u>P.orientale</u>	24.13 ab ±0.26	1.17 c ±0.13	22.96 a ±0.38	1.87 b ±0.13	21.10 a ±0.26	0.58 a ±0.01	0.05 c ±0.01	95.17 b ±0.57	11.36c ±0.63	0.09 a ±0.01

<sup>1</sup> Means followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

<sup>2</sup> Data transformed to arcsine for statistical analysis.

N.B. (i) Abbreviation explained under materials and methods.

(ii) R/P and P/A calculated based on data observed during first 4 weeks.

Table 6.5d. Nutrient budget (Mean±S.D., in mg)<sup>1</sup> of female C.bipunctatus on three host seeds.

Host seed	C	FU	A	P	R	RCR	RGR	Ae(%) <sup>2</sup>	R/P	P/A
<u>C.album</u>	30.37 a ±4.93	1.70 a ±0.08	28.67 a ±4.85	2.09 a ±0.12	26.59 a ±4.74	0.68 a ±0.11	0.05 a ±0.01	94.30 a ±0.67	12.64 a ±1.55	0.08 a ±0.01
<u>C.cristata</u>	27.67 a ±0.99	1.68 a ±0.10	25.99 a ±0.89	1.90 b ±0.22	24.09 a ±0.67	0.69 a ±0.01	0.05 a ±0.01	93.94 a ±0.15	12.81 a ±1.14	0.08 a ±0.01
<u>P.orientale</u>	31.64 a ±4.62	2.72 b ±0.27	28.92 a ±4.35	2.37 c ±0.05	26.55 a ±4.39	0.66 a ±0.10	0.05 a ±0.00	91.34 b ±0.41	10.27 a ±3.02	0.09 a ±0.02

<sup>1</sup> Means followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

<sup>2</sup> Data transformed to arcsine for statistical analysis.

N.B. (i) Abbreviation explained under materials and methods.

(ii) R/P and P/A calculated based on data observed during first 4 weeks.

Table 6.6a. Estimation of basic nutrients and free amino acid (mg/g) of different host seeds of C.bipunctatus.

Host seed	Storage protein	Nutritive carbohydrate	CHO/protein ratio	Lipid	Free amino acid
<u>C.album</u>	39.23 a	414.95 a	10.59 a	29.85 a	20.42 a
<u>C.cristata</u>	51.51 b	518.43 b	10.07 b	40.94 b	14.49 b
<u>P.orientale</u>	71.54 c	350.17 c	4.89 c	6.88 c	33.42 c

Values followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

N.B. Mean values have been presented.

Table 6.6b. Comparative estimation on some secondary compounds and moisture (in %) of different host seeds of C.bipunctatus.

Host seed	Phenol	TAE	Condensed tannin	Alkaloid	Moisture
<u>C.album</u>	0.89 a	0.46 a	2.01 a	1.55 a	7.02 a
<u>C.cristata</u>	0.34 b	0.46 a	0.38 b	0.63 b	7.82 b
<u>P.orientale</u>	0.35 b	0.66 b	75.34c	0.36 c	7.41 c

Values followed by the same alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

N.B. Mean values have been presented.

# Seed preference of *C. bipunctatus*

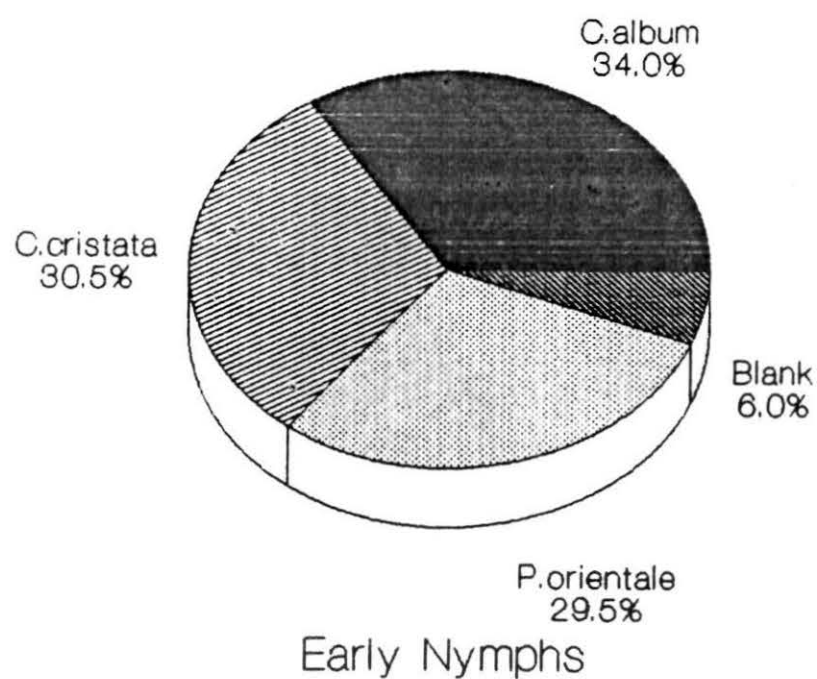


Fig. 25a Seed preference by early nymphs of *C. bipunctatus*

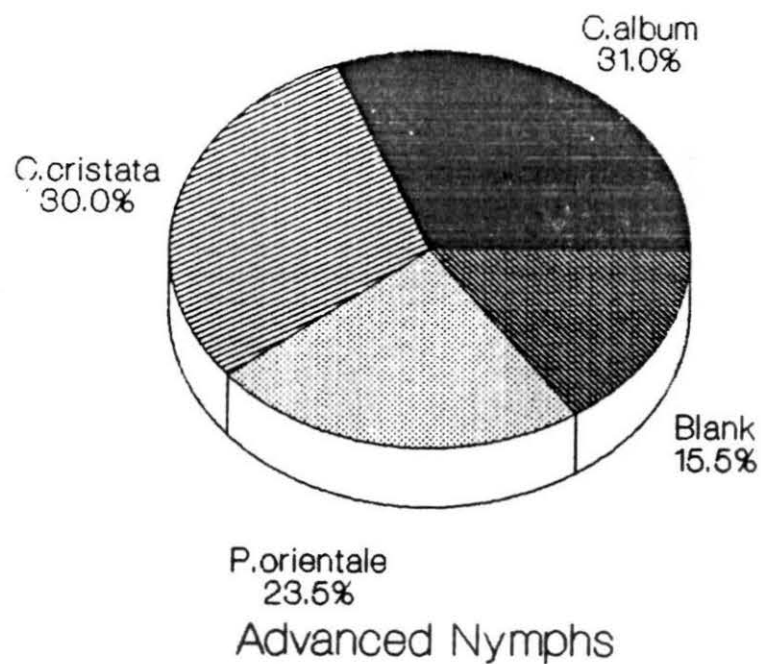


Fig. 25b Seed preference by advanced nymphs of *C. bipunctatus*

# Seed preference of *C. bipunctatus*

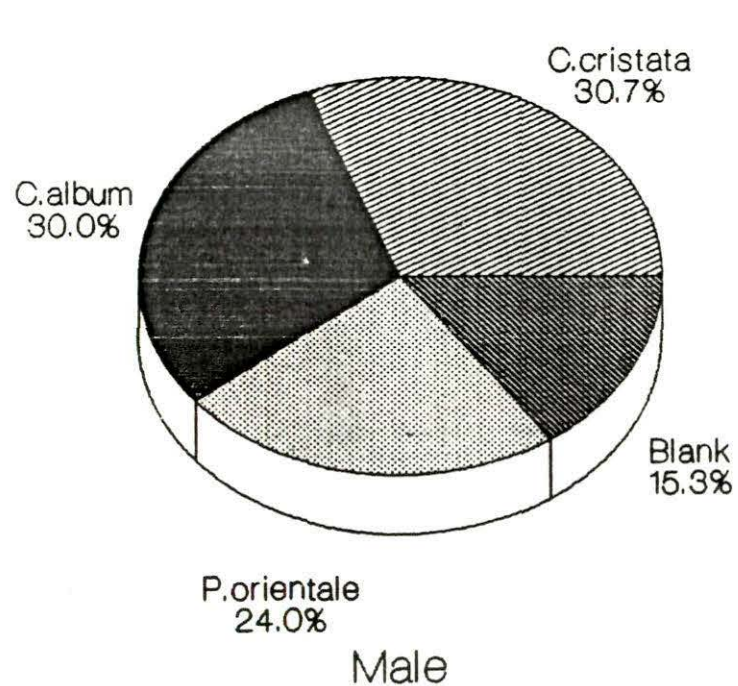


Fig. 25c Seed preference by males  
of *C. bipunctatus*

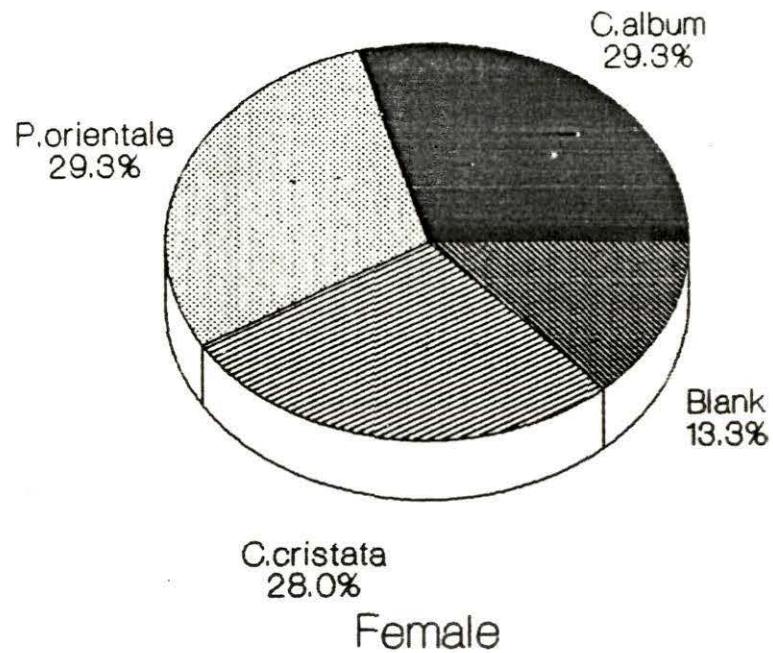


Fig. 25d Seed preference by females  
of *C. bipunctatus*

## Postembryonic Development period

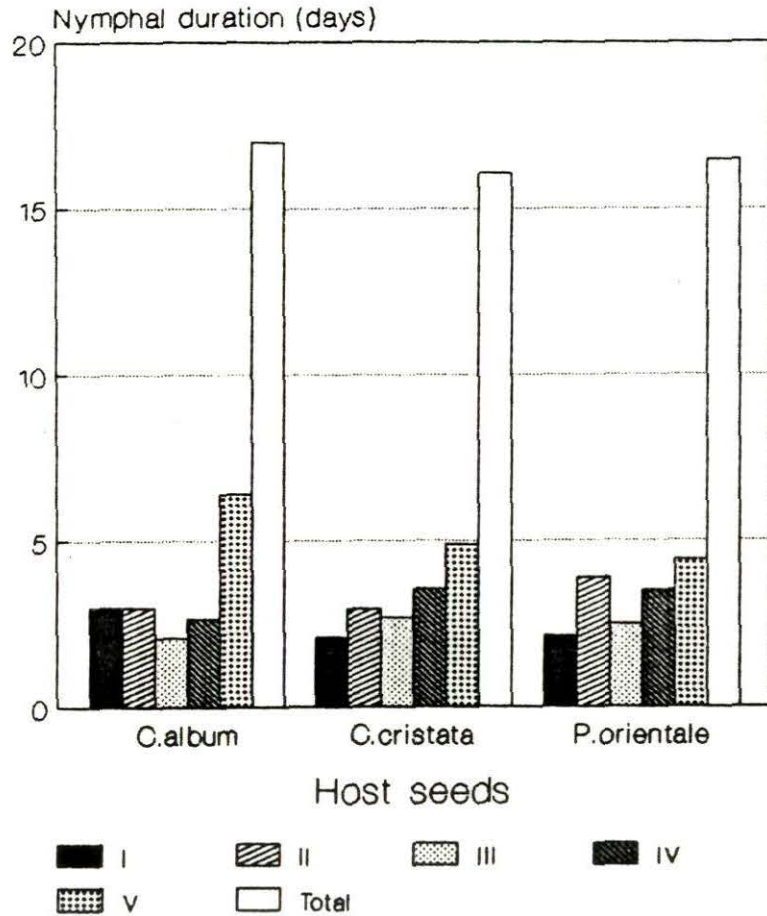


Fig. 26 Postembryonic development periods of nymphs of C. bipunctatus on three host seeds

## Nymphal Mortality

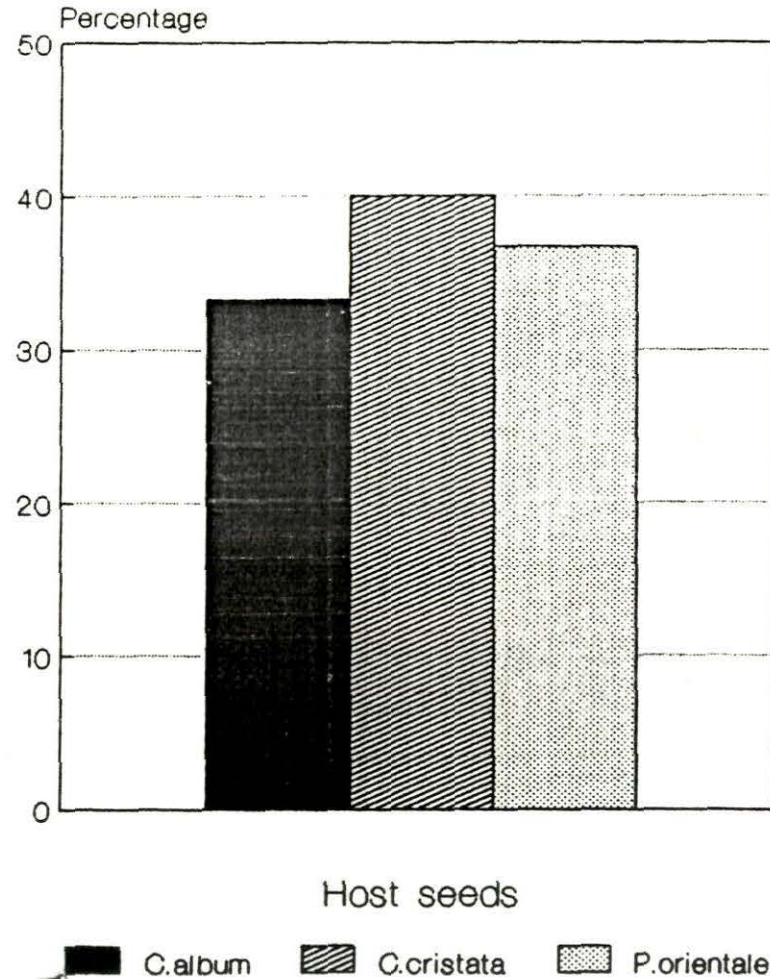


Fig. 27 Nymphal mortality of C. bipunctatus on three host seeds

## Fecundity

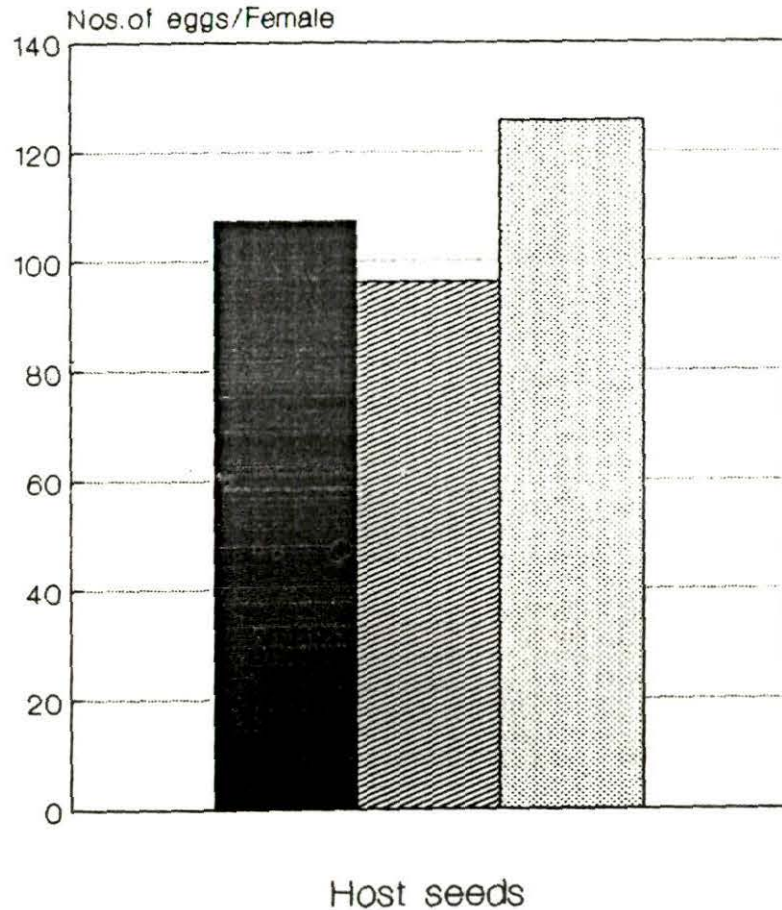


Fig. 28 Total eggs laid per female of C. bipunctatus on three host seeds

## Longevity Female

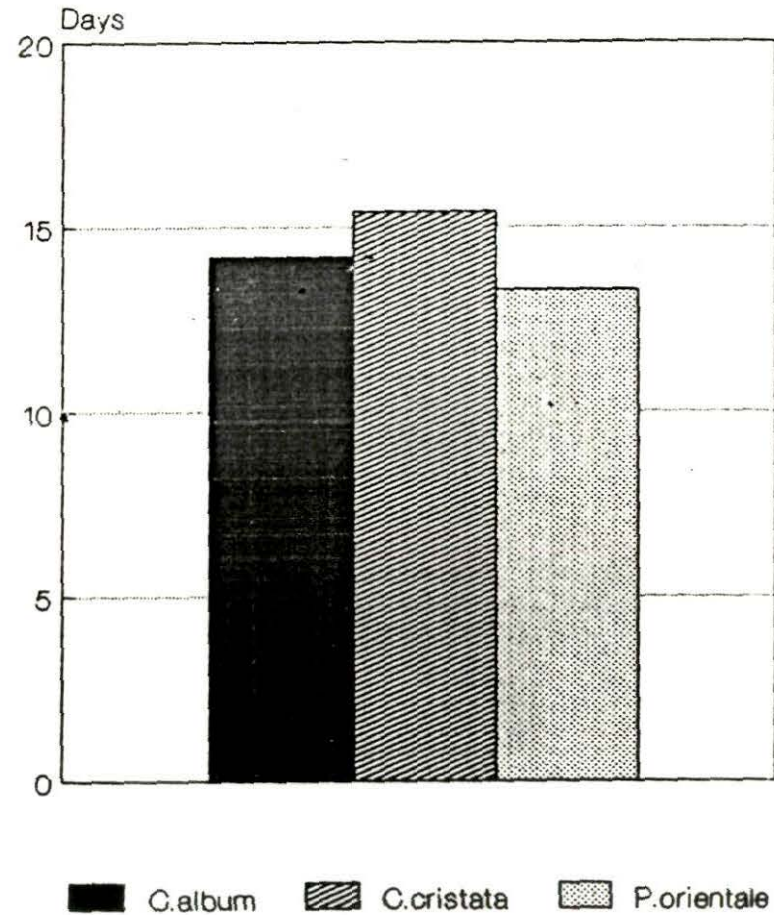
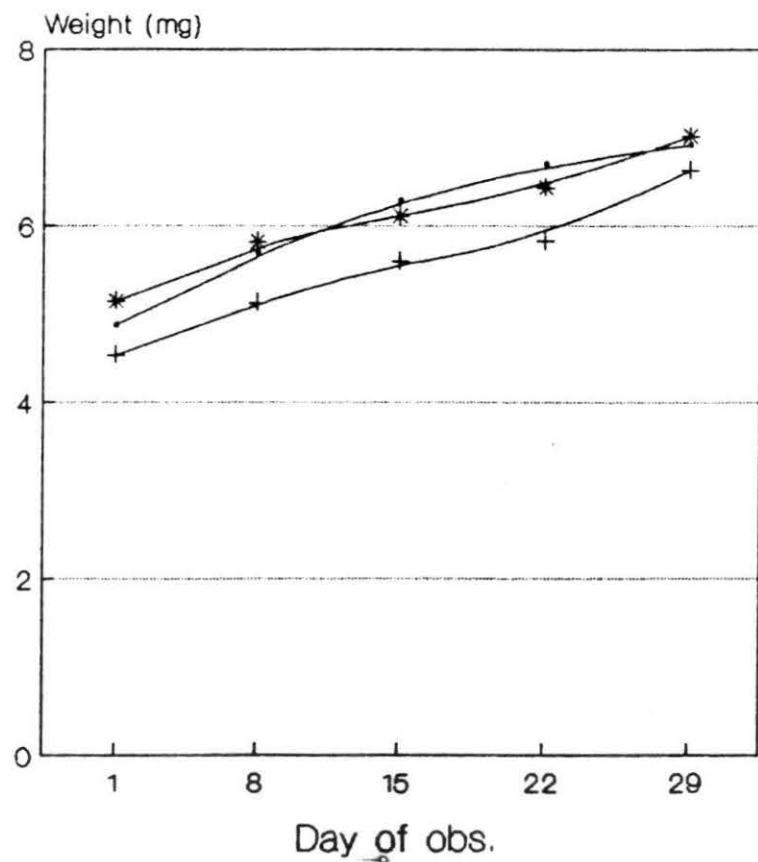


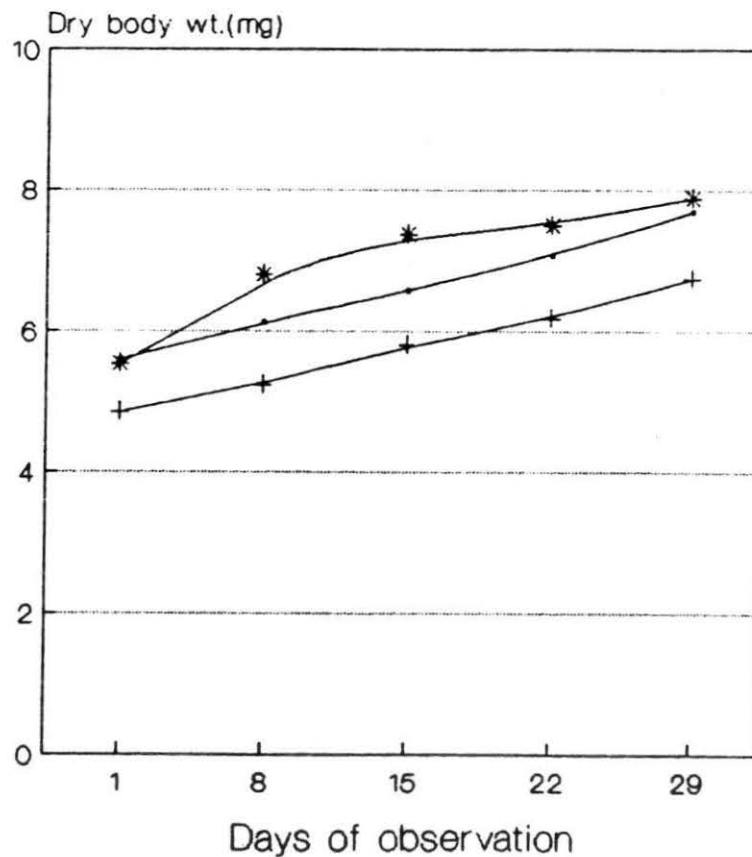
Fig. 29 Longevity of C. bipunctatus females on three host seeds

## Body wt.change Male



—●— C. album    + C. cristata    \* P. orientale  
 Fig. 30 Change in dry body weight of male *C. bipunctatus* on three host seeds

## Body Wt. change Female



—●— C. album    + C. cristata    \* P. orientale  
 Fig. 31 Change in dry body weight of female *C. bipunctatus* on three host seeds

## Production Index

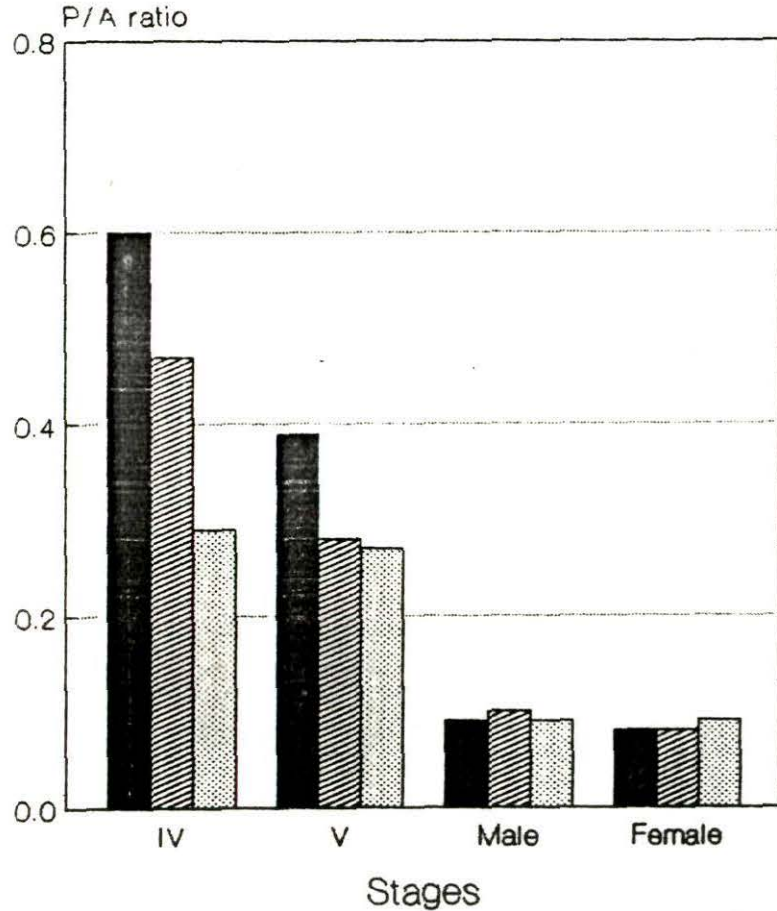


Fig. 32 Comparison of production index (P/A ratio) of advanced instars, males and females of C. bipunctatus on three host seeds

## Maintenance Cost

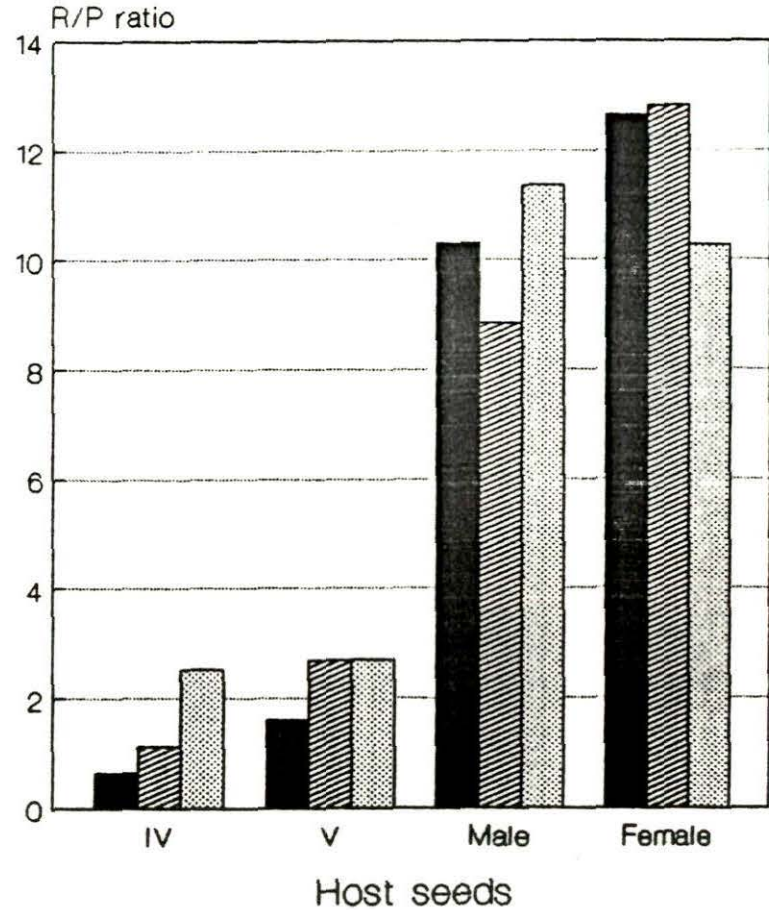


Fig. 33 Comparison of maintenance cost (R/P ratio) of advanced instars, male and females of C. bipunctatus on three host seeds

# Biochemical profile of seeds of *C.bipunctatus*

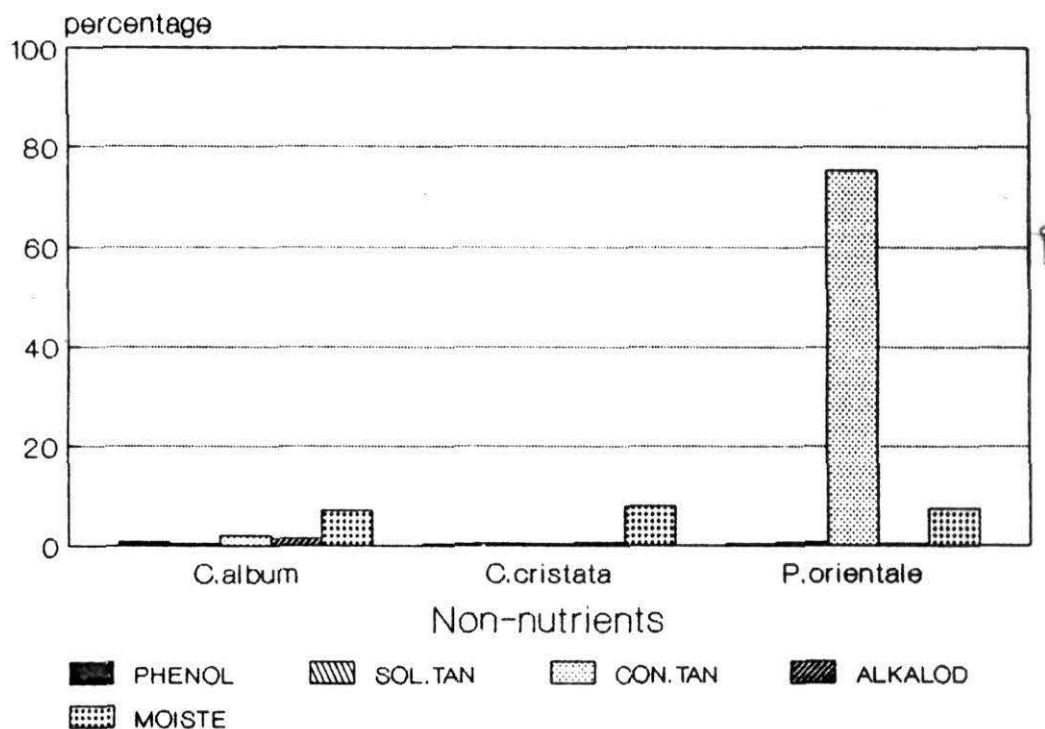
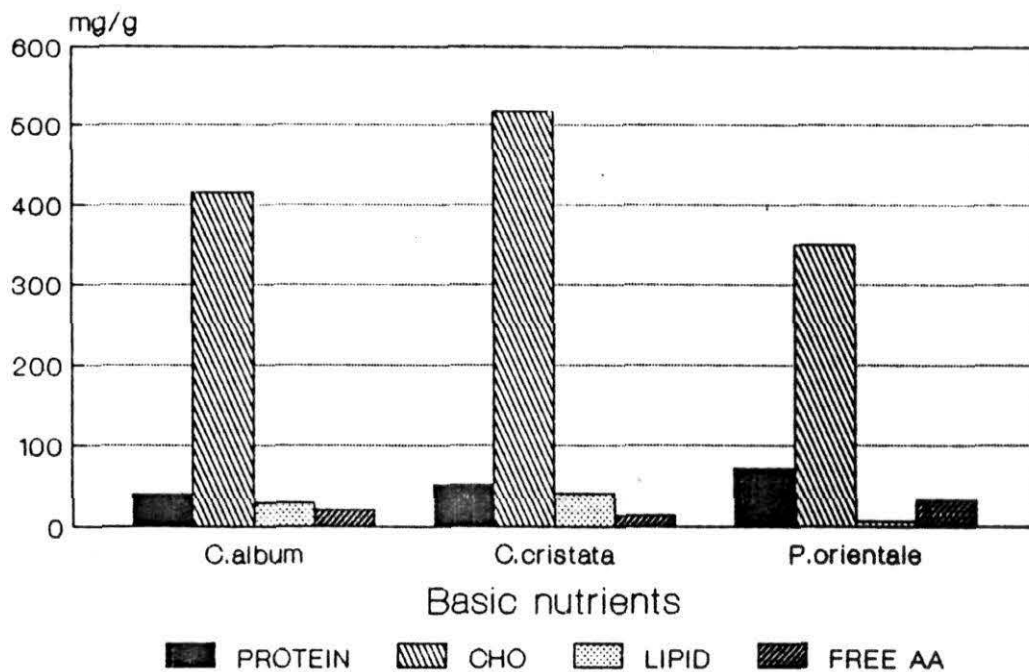


Fig. 34 Diet components comprising the basic nutrients and nonnutrients of three host seeds of *C.bipunctatus*.

# **DISCUSSION**

## 7. DISCUSSION

### I. Host seed preference

The mechanism of host-plant selection in phytophagous insects is a complex phenomenon involving host habitat finding, host finding, host recognition, acceptance and host suitability (Dethier, 1954). Laboratory trials on host preference tend to produce more positive responses than is representative of the wild animal. The relevant data arising out of restricted choice in laboratory experiment are the differences in the apparent palatability among the host plants or host seeds tested. A more generalist feeder should discriminate less strongly in favour of any particular species, but would still be expected to discriminate strongly against relatively unpalatable species (Rowell et al., 1983).

Insect herbivores possess sensitive receptor system that allow them to detect a variety of phytochemicals; thus, within a host range the choice of a particular food is usually dependent on its phytochemical composition. Some specialized insects feed on plants generally containing a particular category of allelochemical. Other more generalized insect may avoid consuming certain plants because of

their allelochemical content and may choose others because of their energy and/or nutrient contents (Slansky, 1992).

In seed preference behaviour, the extent to which seed quality influence host choice by seed-suckers is virtually unknown (Slansky and Panizzi, 1987). The same authors also indicated that the degree to which the heteropteran nymphs remain monophagous on the same species of plant throughout their development or switch to other host species, has apparently not been studied.

An analysis of the host seeds and the corresponding preference exercised by the seed-suckers showed that within a host range, the seeds with high protein, low carbohydrate, narrow CHO/protein ratio, low soluble tannin (TAE), and high moisture were usually preferred (Figs. 12, 23 & 34, Figs. 3, 14 & 25). Seeds with high phenol and soluble tannin and with a low moisture were least attractive. This supports the observation on some lygaeid species by Ananthakrishnan et al. (1982) and Sanjayan and Ananthakrishnan (1987), where a narrow C/N-ratio (= carbohydrate/nitrogen) was computed for most preferred seeds.

In one of the few studies Chaplin (1980) found that the qualitative difference among seeds from different species of milkweeds had some influence on host choice by

Oncopeltus; triglycerides and ether soluble compounds in cotton seed (Saxena, 1969) and glycosides in milkweed seeds (Bongers and Müermann, 1973) are also reported to act as factors of seed-preference and phagostimulation in cotton stainers and large milkweed bugs respectively. Moreover, it is known that other seed-coat factors (Eyles, 1964; Beck et al., 1958) specially those acting as "token stimuli" may also play an important role in host-preference. The changing preference among different stages of some of the species studied here, possibly implies some flexibility in feeding behaviour of the insect species being modified by inputs that include many features of food (i.e. colour, size, shape, texture, toughness, seed coat quality and presence of conspecific individuals etc.), but probably in the majority of the species the primary cues are of chemical nature (i.e. odour and taste) (Slansky and Rodriguez, 1987). Further, the change in seed-preference may be connected with the changing nutritional requirements of the insect species (Eyles, 1964) and dispersal and colonization of the new host plants by the advanced stages of some heteropteran species (Slansky and Panizzi, 1987). Such host-plant shifts had also been observed in coreid species in connection with tracking of high concentrated nutrient sources or fruits (Mitchell, 1980).

Although in the present study the lygaeid (S.hospes) and the pyrrhocorid (D.koenigii) do show similar trend of preference in relation to the basic nutrients and their ratio (CHO/protein), the absence of any such relation in the coreid species (C.bipunctatus) prevents a generalization. Nevertheless, in most cases of seed-sucking the relation of seed-preference and some of the dietary components of seeds can not be overlooked. It may be added that in a host-choice study from South India, the same coreid species (C.bipunctatus) was found to prefer seeds with high C/N - ratio and lipid level — possibly a departure from the normal trends (Chandrasekar, 1988). Moreover, learning can also be important in food-selection (Lee and Bernays, 1988) specially those adapted to local crops.

#### Postembryonic development period and nymphal mortality

The ultimate goal of nymphal stage is to produce an adult whose quality matches its genetically determined potential. Species in the same and in different guilds differ in the development and growth subcomponents of their life history strategies and in the tactics by which they attempt to achieve this goal (Slansky and Rodriguez, 1987).

The hypothesis that prolonged development is associated with poor nutrition, posits that there is

selection for body size, and that given a nutritional constraints it takes a long time to attain a large size (Karban, 1984). So, short development periods of nymphs clearly reflect better nutritional quality of seeds, as well as the higher utilization efficiency of the immature stages of the seed-suckers. The fast nymphal development could be related in all the three species belonging to three different families, to seeds having high protein, narrow CHO/protein ratio, low phenol and low soluble tannin (TAE) ; whereas low protein, high CHO/protein ratio, low quantity of free amino acids, high soluble and condensed tannins could be linked with prolonged nymphal development periods. (Figs. 12, 23 & 34, Figs. 4, 15 & 26). Almost similar relations between development rate and seed bio-chemistry are available for some more seed-feeders (Sanjayan and Ananthakrishnan 1987, Mukhopadhyay and Saha 1992a,b).

Further, some conclusive evidences that high nitrogen and low sugar levels of host seeds lead to faster nymphal development and growth are available from works of Chaplin and Chaplin (1981), Ananthakrishnan et al. (1982) and general remarks by Ananthakrishnan (1992). High lipid content of seeds could also be related to shorter nymphal development period in oil-seed feeding lygaeid, Elasmolmus sordidus (Mukhopadhaya and Saha 1992b). So, in a life cycle

strategy, prolonging nymphal development is possibly a means to increase overall food consumption while negotiating a suboptimal diet.

In the three seed-sucking species, an increased nymphal mortality is found usually connected with a low protein, high carbohydrate, high CHO/protein ratio, low free amino acids, generally matched with a high phenol, soluble and condensed tannins, alkaloid and low moisture content of the seeds. These components being found at enhanced levels (increasingly low or high) in seeds of B.ceiba, possibly precluded completion of postembryonic development and gradually resulted into 100% nymphal mortality (Figs. 12, 23 & 34, Figs. 5, 16 & 27). The higher levels of tannins and alkaloids may lessen availability of protein through nutrient - allelochemic interaction (Slansky, 1992) and specially through their binding property (Mc Neill and Southwood, 1978). Besides the role of these allelochemic factors specially tannins in feeding deterency and inhibition (Fraizer, 1986), their adverse effects on the activity of certain enzymes (Prakash, 1992) and their influence as gut epithelial and/or pharmacological toxins are also well established (Slansky, 1992; Karowe, 1989).

### III. Reproductive performance and longevity

Life time egg production of various seed-suckers ranges broadly, but such data have been seldom summarized within an ecological context that includes food characteristics (Slansky and Panizzi, 1987). The quality and the available amount of food to mated female affect the extent of egg production indirectly through neurohormonal interaction and directly by influencing the availability of energy and nutrients used in production of eggs (Johansson, 1958; Odhiambo and Arora, 1973; Slansky, 1980a,b).

In all the three species of seed suckers it was generally found that seeds with high protein, narrow CHO/protein ratio and high moisture supported more egg - laying (Figs. 12, 23 & 34, Figs. 6, 17 & 28). Such a relation has also been found to exist in other seed - feeding lygaeid species (Sanjayan and Ananthakrishnan, 1987, Mukhopadhyay and Saha, 1992a,b). Usually the bugs feeding on seeds with high phenol, soluble and/or condensed tannin and low moisture had reduced or no egg-production (e.g. D.koenigii on B.ceiba). The role of these allelochemicals in interfering with availability of nutrients both at ingestive, gut and postabsorptive levels are now known (Slansky, 1992, 1993; Fraizer, 1986; Brattsten, 1986),

moreover, low moisture may be a limiting factor for efficient food utilization even precluding egg laying, as has been observed in seed/fruit feeding pentatomid bug, Nezara viridula (Panizzi and Meneguim, 1989).

The reasons behind variation in male and female longevity of the concern species of bugs are intriguing and may only be generalized with caution in light of the nutritional qualities of their host seeds. Parameters regulating seed suckers longevity are several and poorly understood (Slansky and Panizzi, 1987). The authors have referred to some case histories where reduced longevity of adults feeding on a certain food was regulated by several causes including the toxic effect of allelochemicals, poor nutritional composition causing the insects to rapidly utilize stored reserves, and even superior nutritional quality enabling females to achieve a high egg output, thereby shortening their life and many such other factors (Panizzi and Slansky, 1985). Nonetheless, in the present study adult longevity seemed to get grossly affected only when the seed suckers were made to feed on some host seeds with major deficiencies (sensu lato). But such generalizations have to be confirmed with more information and studies.

#### IV. Mass budget and body weight

##### A. Consumption

Quantity of food consumed/ingested is influenced by a number of exogenous and endogenous factors. Among the host of factors that affect consumption, food quality (e.g. nitrogen, water, and energy content) is an important one (Muthukrishnan and Pandian, 1987). One of the chief acts of feeding behaviour, that determines a herbivore's exposure to phytochemicals, is its quantitative food consumption (C), and in particular, the body mass-relative consumption rate (RCR). Many factors affect a herbivore's feeding rate, including not only environmental conditions but also attributes of the food (especially its allelochemical and nutrient contents) and the animal (e.g. age, size, sex, reproductive state, and activity level) (Slansky, 1992).

For sake of intraspecific comparison within host ranges, most factors were kept the same excepting the host seeds. Consumption was found to be highest on seeds with low phenol, alkaloid and high moisture content. Some departure in female S.hospes was noted, which consumed more of C.gigantea seeds to S.melongena -- possibly an adaptation for obtaining more protein from the former seed (rich

in basic nutrients). Such shifts in host-seed consumption were not evident in immature and adult stage of D.koenigii and C.bipunctatus as they all through showed high consumption on protein-rich seeds of H.esculentus and P.orientale in their respective host ranges.

Relative consumption rate (RCR) was found to be high for all the three species on seeds having low phenol and alkaloid contents. Further, the high rate could be related to seeds with low protein and high carbohydrate. Exception to this was C.bipunctatus, which maintained a high RCR even when feeding on protein rich food of P.orientale, but this seed, all the same, had the higher soluble and condensed tannin content. Increase in the consumption rate along with the decrease of the food nitrogen level and quality for sake<sup>of</sup> compensation has been reported by Slansky and Feeny (1977), Krishnan (1984) and Farrar et al. (1989). A possible explanation for high RCR when feeding on apparently protein rich P.orientale may be that the actual nitrogen (Protein) available to the insect may not be as evident in the seed's dietary profile. It is known that during feeding (damage) of a food substance the reduction of the available protein may take place due to allelochemic-nutrient (tannin-protein) interactions. (Mc Neill and Southwood, 1978 and Feeny, 1969). Such an explanation, however, needs verification through further experimental findings.

## B. Production and growth by weight

Growth in animals involves conversion of extraneous matter in live tissue through the process of ingestion, digestion, absorption, assimilation, and synthesis. In addition to the energy cost of metabolism, these processes also require expenditure of energy. Total growth includes somatic growth, exuviae and gametes (chiefly eggs produced) in hemipterans. In them the maximum growth attained during the larval stage is maintained for sometimes after maturity with narrow fluctuations due to activities associated with reproduction (Muthukrishnan and Pandian, 1987).

An increased overall production and total growth (wt.) were evident in all stages of S.hospes and D.koenigii and females of C.bipunctatus on seeds having high protein, low CHO/protein ratio along with high aminoacid and moisture contents.

Variation in both basic nutrients and nonnutritional components (allelochemicals) in food affect the amount and rate of food eaten, digested, assimilated, and converted into tissue/growth (Slansky, 1982). The poorest growth in body weight of nymphs of Spilostethus pandurus on gingelly probably reflected the paucity of basic nutrients (except lipid) and total amino acids, whereas its performance was just the reverse on nutritionally rich milkweed

seed (Mukhopadhyay and Saha, 1992a). That nutritionally rich quality of seeds/fruits supported significantly higher weight gain by nymphs leading to the heaviest adults, has been well documented for Nazera viridula when its nymphs were fed on the most preferred seeds of Leonurus sibiricus (Panizzi and Meneguim, 1989).

In addition to life-style and feeding pattern, the vast differences in the overall growth rate between species of the same trophic level as well as those of other trophic levels can be accounted for partly by food quality (Scriber and Slansky, 1981). Factors such as nitrogen, water energy, mineral, and toxin contents of the food significantly influence the overall growth rate through feeding rate (Muthukrishnan and Pandian, 1987).

It is worth noting that the relative growth rate (RGR) in relation to the nutritional quality of the host seeds kept varying in different stages of the species under study. The IVth instar nymphs in general showed a higher RGR on seeds with elevated CHO/protein ratio or increased carbohydrate levels usually combined with a low phenol, condensed tannin, alkaloid and moisture (except C. bipunctatus, where RGR was higher despite elevated phenol and alkaloid levels). But RGR in Vth instars was generally

higher on seeds having a higher protein and low CHO/protein ratio along with a high free-amino acid level (except D.koenigii where a higher CHO/protein ratio induced higher RGR). Nonnutrient factors were not found to uniformly influence RGR in this stage, nevertheless, a low moisture content could be related to low RGR - values. RGR in males showed higher values on seeds having high CHO/protein, low phenol & alkaloid contents, contrastingly in females higher RGR was recorded on seeds having low CHO/protein ratio and rich protein as well as amino acid levels. A high moisture could also be related to high RGR values.

Such a variability of in relative growth rates from stage to stage and sex to sex in all the three species can not be readily explained. Their differential performance may be related to their variable adaptive strategy in meeting the vital requirement of the concerned stage, as such no generalized pattern of relative growth rate was evident.

Age, temperature, stage and food availability are the potential factors that influence overall growth rates of insects (Muthukrishnan and Pandian, 1987). Moreover, reduction in RCR (relative consumption rate) and RGR could be the result of an allelochemical with deterrent/antifeedant activity that lowered RCR, with a subsequent decline in RGR,

or alternatively the allelochemical may have pharmacologic activity that lowers RGR with a consequent reduction in RCR (Slansky, 1992). Unfortunately, our understanding of the complex interactions between these ratio and efficiencies are very limited (Slansky and Scriber, 1985). To add to the complexity, an allelochemical might have more than one mode of action against the herbivore. Thus, measures of quantitative food utilization must be interpreted cautiously (Slansky, 1992).

### C. Maintenance cost (R/P) and production index (P/A)

In seed-suckers, usually the short-lived forms, the predisposition to develop on or in vicinity of food sources normally saves them the energy of seeking food, specially in the nymphs. However, the cost of neutralization of toxic substances in food plants and dealing with the intractable substances considerably decreases the net energy gain through feeding (Muthukrishnan and Pandian, 1987). Besides the cost of detoxification or neutralization of toxins in food, the very act of feeding, digesting, absorbing and excreting excess or imbalanced nutrients cost substantial energy which is reflected through an increased respiration or the ratio (R/P), designated as 'maintenance cost'.

In the present study, maintenance cost (R/P) in general, was higher at all stages on seeds having an elevated level of tannin (soluble/condensed), at times matched with an increased phenolic level. Exception to this was Vth instar of S.hospes.

In the range of host seeds of a species the production index (P/A) was the highest, atleast in the advanced nymphal instar and the female, on nutritionally rich seeds having high protein and narrow CHO/protein ratio. A few departures were however evident. The production index (P/A) when expressed in percentage amounts to net growth efficiency. This efficiency may vary widely even within a feeding category. The physiological bases for such wide variations and high growth efficiencies deserve a critical evaluation. Food quality, especially nitrogen, water, and defense chemical contents of food plants in herbivores, energy content of food in foragers and the overall balance of nutrients in general, significantly influences growth efficiencies (Muthukrishnan and Pandian, 1987).

#### V. Future direction

The present study tries to give a preliminary idea on seed [sucker-host] seed relations in terms of nymphal

and adult performance on their acceptable host ranges. Some of the generalizations done based on the representative species of three seed-feeding hemipteran families may be a first hand attempt, atleast with the local populations of the pest species, nontheless is expected to be of great value in setting a direction. More elaborate study needs to be undertaken in future with more of representative species of the seed-feeding hemipteran families specially with development of some ideal artificial or semisynthetic diet for these locally adapted species. This will throw-up the opportunity of manipulation of their diet by addition and alteration of the basic as well as nonnutritional (allelochemicals) components in such chemically defined diets ; and thus help in better evaluation of dose-dependent performance of these hemipterans. Instead of venturing in the realm of speculation or making "educated guesses" while working with various seed-sucking species around the world, it would be ideal to go for designing a diet based on information on their host seed biochemistry. Some idea of which can be taken from the present study and studies held in other parts of the world. Expectedly such small findings, as are the ones in the present thesis, would help in developing a strong and useful future programme on host-plant resistance for such seed-sucking pests.

# **SUMMARY**

## 8. S U M M A R Y

1. Seeds with high protein, low carbohydrate and narrow carbohydrate/protein  $[(\text{CHO})/\text{protein}]$  ratio registered a higher preference by nymphs and adults of Spilostethus hospes and Dysdercus koenigii. No clear choice for any particular seed was evident in Cletus bipunctatus; moreover, its advanced nymphs showed a departure in preferring CHO-rich seeds.
2. Usually seeds with low soluble tannin (TAE) and high moisture were preferred.
3. Least preference was largely shown for seeds with high phenol, TAE, and low moisture. High condensed tannin and alkaloid affected preference variably and no generalization was possible.
4. Postembryonic development period was short on seeds with high protein and narrow CHO/protein ratio. Faster nymphal development took place on seeds with low quantities of phenol and TAE, while the other nonnutrient components appeared to be variably related to nymphal duration.

Conversely, prolonged nymphal duration or incomplete development took place mostly on seeds with low protein, high CHO/protein ratio, low amino acid level, specially when matched with high TAE and condensed tannin. Incomplete development of D.koenigii on Bombax ceiba was possibly due to low protein, carbohydrate, and high CHO/protein ratio, TAE and alkaloid values with low moisture of the seed.

5. Low protein, high CHO/protein ratio, and low amino acid level of seeds could be related to high mortality in nymphs. Additionally, very high phenol, TAE, condensed tannin, alkaloid and low moisture appeared to be responsible for total nymphal mortality on B.ceiba.
6. In all cases, high fecundity (total eggs laid/female) seemed to be influenced by high protein, low CHO/protein ratio and high moisture. A reasonably high phenol, TAE or condensed tannin and low moisture reduced fecundity. A very high CHO/protein ratio with low lipid and amino acid on one hand, and high phenol, TAE, condensed tannin, and alkaloid with low moisture of B.ceiba seeds possibly precluded egg laying.

7. Egg-laying rate seemed to be a strategy adopted by the concerned species apparently independent of the dietary composition of the seeds.
8. Hatchability was not significantly different on the host-seed range of a species, as such no influence of the dietary components was apparent.
9. Adult longevity did not seem to be much dependent on the nutritional quality of the seeds, nevertheless, short life span of D.koenigii on seed B.ceiba, appeared to be the adverse effect of the poor nutritional quality marked by very high CHO/protein ratio, lowest lipid, amino acid and moisture with very high phenol, TAE, condensed tannin and alkaloid.
10. Weight gain was maximum on seeds with low CHO/protein ratio, high amino acid, and moisture. The lowest weight gain of species, specially of D.koenigii on B.ceiba was due to the deficient dietary quality of the seed.
11. Consumption was found to be highest of seeds with low phenol, alkaloid, and high moisture content. Some variation in female S.hospes was noted, which consumed more of Calotropis gigantea seeds to S.melongena —

possibly an adaptation of the egg-laying mother for obtaining more protein from the former seed, rich in basic nutrients despite high phenol and condensed tannin levels. The advanced stages and both the sexes of D.koenigii and C.bipunctatus showed consistently a higher consumption on protein-rich seeds.

12. Relative consumption rate (RCR) was high on seeds having low phenol and alkaloid. RCR was high on seeds with high carbohydrate and low protein. However, the high RCR-value of C.bipunctatus<sup>nymphs</sup> on P.orientale was a departure, the latter being rich in protein but at the same time having the highest TAE and condensed tannin values.
13. All stages of S.hospes, D.koenigii and females of C.bipunctatus showed highest production (weight gain) on seeds with high protein and low CHO/protein ratio, specially when combined with high aminoacid and moisture.
14. Relative growth rate (RGR) :

\* Generally in IVth instar (RGR) was higher on seeds with high CHO/protein ratio or carbohydrate content

along with a low phenol, condensed tannin, alkaloid and moisture (except in C.bipunctatus on Chenopodium album where RGR is high despite higher phenol and alkaloid).

- \* RGR in Vth instar was higher in general on seeds having a high protein and low CHO/protein ratio and specially a very high aminoacid level (except in D.koenigii, where a higher CHO/protein ratio induced more RGR). Non-nutritional factors were not found to uniformly influence the RGR, however, a low moisture content of the seeds was related to low RGR.
- \* RGR in males showed higher values on seeds having high CHO/protein ratio, low phenol, and alkaloid levels.
- \* RGR in females was high on seeds rich in protein and low in CHO/protein ratio. A relatively high aminoacid and moisture were, in general, common factors related to higher RGR.

15. Production was the highest in all stages of S.hospes and D.koenigii and female of C.bipunctatus on seeds rich in protein and low in CHO/protein ratio. Some anomaly, however, was noted in nymphs and adult male

of C.bipunctatus where the highest production in IVth instar took place on carbohydrate rich seeds followed by Vth and adult male on a seed only rich in lipid and aminoacid (C.album).

16. Highest production index (P/A) for IVth & Vth nymphal instars of all the species showed consistent results on the same seeds but a variation was noted in males and females of D.koenigii and C.bipunctatus.
17. Maintenance cost (R/P) was higher in all the three species and stages on seeds with higher tannin content (soluble/condensed) also when at times matched with higher phenol level. However, some departure was notable in the Vth instar of S.hospes.

# **HIGHLIGHTS**

## 9. HIGH LIGHTS

### Salient features and findings of the study

- \* Only more conclusive findings based on the performance of three seed-feeders representing three heteropteran families on their host-seed ranges are given below.
- \* Usually host-seeds with high protein, low carbohydrate, narrow carbohydrate/protein ratio, low soluble tannin (TAE) and high moisture were preferred.
- \* Postembryonic development period was generally short on seeds with high protein, narrow carbohydrate /protein ratio, low phenol and soluble tannin.
- \* High mortality seemed to be related to host-seed with low protein, high carbohydrate/protein ratio, low amino-acid, high phenol, soluble tannin, condensed tannin, alkaloid and low moisture.
- \* High fecundity apparently was influenced by high protein, low carbohydrate/protein ratio and high moisture.

- \* High production in general was recorded on seeds with high protein, low carbohydrate/protein ratio, high amino acid and moisture.
- \* Maintenance cost (R/P) was recorded <sup>high</sup> on seeds with higher tannin content (soluble/condensed) combined with high phenol level.
- \* It could be understood that fair performance of the seed-feeders were commonly related to better values of seeds, rich in basic nutrients specially the protein level with a reasonably low levels of allelochemicals. However, some departures from the above bases for particular stage, sex and species proved the diversity in adaptive strategy that also exist.

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# **ANNEXURE**

11. A N N E X U R EA. List of papers published and in press, related to the present work.

- (i) Mukhopadhyay, A. and Saha, B. 1992a. Performance of the polyphagous pest, Spilostethus pardurus (Scopoli) (Heteroptera : Lygaeidae) in relation to the nutritional status of four host-seeds. Phytophaga, 4 (2) : 111 - 120.
- (ii) Mukhopadhyay, A. and Saha, B. 1992b. Nutritional value of four host seeds and their relationship with adult and nymphal performance of seed bug (Elasmolomus sordidus) (Heteroptera : Lygaeidae). Indian Journal of Agricultural Sciences, 62 (12) : 834 - 837.
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11. ANNEXURE

- B. Reprint - copies of published papers related to the present work.

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# PERFORMANCE OF THE POLYPHAGOUS PEST, *SPILOSTETHUS PANDURUS* (SCOPOLI)(HETEROPTERA : LYGAEIDAE) IN RELATION TO THE NUTRITIONAL STATUS OF FOUR HOST-SEEDS

A. MUKHOPADHYAY\* and B. SAHA

Entomology Laboratory, Zoology Department, North Bengal University, Siliguri 734 430, India

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## ABSTRACT

*Spilostethus pandurus* (Scopoli) was found to utilize mature seeds of *Calotropis gigantea*, *Solanum melongena*, *Sesamum indicum* and *Helianthus annuus* as food. A comparative study of various aspects of biology of this pest species, like seed-preference, hatchability, nymphal weight, development period, mortality, longevity and fecundity, that act as indices for nutritional values of the above seeds, were conducted under the same physical conditions. The basic nutrients, free aminoacids, and the phenol content of the seeds were biochemically analysed for a better understanding of the nutritional values of the seeds and their relations with the differential performance of the species. The study apparently revealed that variations of the basic nutrients, especially storage proteins of seeds, might be a major controlling factor of the performance of the species. Total free aminoacid content of the seeds might also be a supplementary nutritional factor which regulate the performance. Higher level of total phenol seemed to influence fecundity and fresh body weight unfavourably despite the presence of fair proportion of basic nutrients, as was the case with sunflower seeds. So, suboptimal performance could result from certain proportions and compositions of the nutrients and allelochemicals of the ingested seeds. Nonetheless, the dietary information available on the seeds has yet to be related more meaningfully to the nutritional ecology of seed-sucking bugs.

**Key words :** Performance, *Spilostethus pandurus*, host seeds.

## INTRODUCTION

Influence of seed-feeding on growth and reproduction of lygaeid bugs has been documented by Eyles (1964), Kugelberg (1973), Janzen (1978), Slansky (1980, 1982), Mukhopadhyay (1985), Sanjayan and Ananthkrishnan (1987) and many other workers. In India, the crop plants attacked by the polyphagous milkweed bugs, *Spilostethus pandurus* (Scopoli), belonging to the subfamily Lygaeinae, are *Gossypium herbaceum* L. (Kapas Cotton) (Maxwell-Lefroy, 1909), *Sorghum vulgare* Pers. (Sorghum) and *Capscium frutescens* L. (Chillies) (Fletcher, 1921), *Solanum melongena* L. (brinjal), *Hibiscus esculentus* L. (Lady's finger) and *Phaseolus mungo* L. (Black Gram) (Nair, 1975) and *Sesamun indicum* L. (Gingelly) (Thangavelu, 1979). The non-economic alternate host-plant is *Calotropis gigantea* R. Br. (Milkweed), on which some aspects of bioecology of the speices have been studied from India by Bhattacharjee (1959) and Mukhopadhyay (1983, 1985). *Helianthus annuus* L. (Sunflower) seed has been suggested to be a standard food for rearing most lygaeid bugs (Malipatil, 1979).

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\* Corresponding Author.

The effects of variation of the values of diets can be measured in terms of growth, development, reproductive performance, mortality, longevity, and morphological abnormalities (Singh, 1977). Seeds of four hosts, milkweed, brinjal, gingelly, and sunflower were chosen as food for *S. pandurus* in the present study.

Host preference and selection are based on the insects sensory system, which detects and decodes the cues of the host-plants (Deithier, 1982). Hence, an experiment was designed to understand the ability of *S. pandurus* to orient and exercise its degree of preference for four host-seed choices. Because growth of an insect is affected by variation in both nutrients and non-nutritional components (allelochemicals) in food (Slansky, 1980, 1982) and because little is known about how seed secondary compounds affect the bugs that feed on mature seeds (Janzen, 1978), an attempt was made to analyse the basic nutrients along with total free aminoacids and total phenol content of the host-seeds. Such a dietary profile might help in better understanding the performance of *S. pandurus* in relation to the nutritional status of the different host-seeds in question. Information on nutritional ecology of seed-suckers has direct applied value because of the significant pest status of many species (Slansky and Panizzi, 1987).

## MATERIALS AND METHODS

*S. pandurus* was reared in plastic containers (5.5 × 4 cm) at 30 ± 1°C, 80 ± 2% RH, and L:D 12 hours using four host-seeds, milkweed, brinjal, gingelly, and husk sunflower. Seeds and water in siphon were provided ad libitum. All tests were carried out with population of the species raised separately on the respective seeds.

Orientation response and food-preference tests were carried out, with a little modification, after Sanjayan and Ananthakrishnan (1987) in an 'X'- shaped glass apparatus with four separate categories: (I) early nymphs (2nd and 3rd instars), (II) advanced nymphs (4th and 5th instars), (III) males, and (IV) females. Biochemical analyses of the dietary components have mostly been done with locally available seeds. Extraction and estimation of storage proteins were done after Draper (1976) and Lowry *et al.*, (1951). The nutritive carbohydrates were extracted and assayed by using 80% ethanol, and starch after treating with HCl, according to Ananthakrishnan (1990) and Plummer (1979). Extraction of total lipid and its gravimetric estimation were done using the standard technique with petroleum ether (Ananthakrishnan, 1990). Total phenol for seeds could best be assayed by using methods suggested by Hori (1974). Free aminoacids were extracted and estimated after Draper (1976) and Plummer (1979). For fresh body weights a monopan electrical balance (0.01 mg sensitivity) was used. Observations were taken with 15 fresh replicates for each nymphal stage and 10 replicates for males and females on all four host-seeds. Adult weights were recorded weekly for 4 weeks (with at least 50% of the original number of specimens surviving).

## RESULTS

### *Seed preference by different stages (Table 1)*

Food-finding and seed-preference experiments indicated that, excepting the adult males, a preference for milkweed seeds was shown by the females, the early, and the advanced

Table 1  
Seed preference<sup>1</sup> of different stage and sexes of *S. pandurus* with percentage preference (Pr.)

Host-seed	Early nymphs (n = 20)		Advanced nymphs (n = 20)		Male (n = 20)		Female (n = 20)	
	Mean $\pm$ S.E.	Pr.	Mean $\pm$ S.E.	Pr.	Mean $\pm$ S.E.	Pr.	Mean $\pm$ S.E.	Pr.
Milkweed	6.2 $\pm$ 0.64 a	31.00	7.0 $\pm$ 0.65 a	35.00	5.1 $\pm$ 0.73 a	25.50	3.8 $\pm$ 0.24 a	19.00
Brinjal	3.3 $\pm$ 0.32 bc	16.50	2.3 $\pm$ 0.40 b	11.50	4.1 $\pm$ 0.54 a	20.50	2.6 $\pm$ 0.15 b	13.00
Gingelly	2.7 $\pm$ 0.43 b	13.50	2.6 $\pm$ 0.29 b	13.00	2.8 $\pm$ 0.44 a	14.00	2.7 $\pm$ 0.28 b	13.50
Sunflower	3.5 $\pm$ 0.29 bc	17.50	3.6 $\pm$ 0.60 bc	18.00	3.6 $\pm$ 0.55 a	18.00	3.1 $\pm$ 0.39 ab	15.50
Blank	4.3 $\pm$ 0.38 c	21.50	4.5 $\pm$ 0.32 c	22.50	4.4 $\pm$ 0.70 a	22.00	7.8 $\pm$ 0.28 c	39.00

<sup>1</sup> Means followed by the same lower case letter or alphabet in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

Table 2  
Post embryonic development period (Days, Mean  $\pm$  S.E.)<sup>1</sup> and nymphal mortality (%) of *S. pandurus* on four different host-seeds.

Host-seed	1st instar	2nd instar	3rd instar	4th instar	5th instar	Total nymphal development period	Total nymphal mortality (%)
Milkweed	3.04 $\pm$ 0.04 aA	3.00 $\pm$ 0.00 aA	2.24 $\pm$ 0.13 aB	3.52 $\pm$ 0.17 acC	4.48 $\pm$ 0.17 aD	16.24 $\pm$ 0.13 a	16.67
Brinjal	3.28 $\pm$ 0.15 aA	3.17 $\pm$ 0.12 aA	2.50 $\pm$ 0.12 abcB	4.12 $\pm$ 0.16 abc	6.06 $\pm$ 0.24 bD	19.06 $\pm$ 0.24 b	40.00
Gingelly	4.30 $\pm$ 0.52 bA	5.60 $\pm$ 0.34 bB	2.74 $\pm$ 0.15 acC	4.21 $\pm$ 0.19 bA	6.68 $\pm$ 0.34 cD	23.47 $\pm$ 0.74 c	36.67
Sunflower	3.00 $\pm$ 0.00 aA	2.21 $\pm$ 0.15 cB	3.07 $\pm$ 0.12 cAC	3.46 $\pm$ 0.19 cC	5.54 $\pm$ 0.18 bD	17.15 $\pm$ 0.16 d	13.33

<sup>1</sup> Means followed by the same lower case letter in each column and same upper case letter in each row are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

nymphs. Sunflower seeds were little preferred to the blank end (control) by all stages, except the females. Brinjal and gingelly seeds were hardly distinguished by the adults or the advanced nymphs.

*Nymphal development period and mortality* (Table 2)

The post embryonic development period was the shortest on milkweed seeds, closely followed by that on sunflower. On these two seeds the mortality percentage was also appreciably low. Nymphal development was lengthened on brinjal seeds with the highest percentage of mortality, which was slightly lower on gingelly seeds; but nymphal development took the longest on this seed.

*Reproductive performance and longevity* (Table 3)

No significant difference in adult longevity was evident on any of the four seeds, except the female on brinjal seed, where the mean length of life was relatively reduced. While the oviposition period and fecundity were by far best on milkweed seeds, these were insignificantly moderate on the other seeds. Percentage hatchability, however, was not affected significantly.

*Nymphal body weight* (Table 4)

In general the trend of increase in the fresh body weight of the nymphs was apparent on all four seeds. While there were quite appreciable change in the body weight noted in the first to second instar, a significant change also occurred in advanced instars. In all immature stages of *S. pandurus* a significantly higher weight gain was observed on milkweed seeds. The poorest weight gain was recorded for the instars growing on gingelly seeds.

*Adult body weight* (Table 5, 6)

The fresh body weights of adult males differed significantly on all seeds, except 1st day males reared on brinjal and sunflower seeds. In all males the body weights subsequent to the 1st day were lower on all seeds, at least until the 22nd day, when recovery of weights (gain) was recorded on milkweed and brinjal seeds (Table 5).

The trend for female body weight was variable. Steady gain over a month (except 15th day) was noted on milkweed and brinjal seeds. A reverse trend was noticed on gingelly and sunflower seeds, where weights decreased from or remained the same as the initial weight. The final weight gain at the end of the month was by far the highest on the milkweed seeds (Table 6).

*Biochemical analysis of some dietary components* (Table 7)

Storage seed protein (the sum total of albumin, globulin, glutelin, and prolamin) was in highest quantity in milkweed. Next in order was sunflower, then brinjal, and the poorest content was in gingelly. Total nutritive carbohydrate (the mono-, oligosaccharides, and starch) was highest in milkweed seeds, closely followed by brinjal, gingelly, and sunflower seeds. Oil seeds of gingelly had the most lipid, closely followed by sunflower seeds. Milkweed and brinjal seeds had low but significantly different lipid contents. Total phenol content of sunflower seed was maximum, followed by a significantly lower amount in milkweed. Brinjal and gingelly seeds had

Table 3  
Reproductive performance and longevity (Mean  $\pm$  S.E., N = 10)<sup>1</sup> of *S. pandurus* on four different host-seeds.

Host-seed	Oviposition period (days)	Fecundity (per pair)	% hatchability <sup>2</sup> (per batch)	Female longevity (days)	Male longevity (days)
Milkweed	29.30 $\pm$ 2.92 a	1616.40 $\pm$ 169.89 a	70.37 $\pm$ 2.55 a	38.00 $\pm$ 3.52 a	54.38 $\pm$ 6.22 a
Brinjal	11.40 $\pm$ 1.96 b	192.50 $\pm$ 35.85 b	70.44 $\pm$ 3.80 a	24.10 $\pm$ 3.60 b	49.80 $\pm$ 8.58 a
Gingelly	17.60 $\pm$ 2.09 b	143.00 $\pm$ 30.00 b	64.79 $\pm$ 4.45 a	44.20 $\pm$ 5.44 a	45.20 $\pm$ 1.66 a
Sunflower	14.40 $\pm$ 1.51 b	321.60 $\pm$ 76.12 b	71.54 $\pm$ 4.18 a	41.20 $\pm$ 1.97 a	44.80 $\pm$ 2.92 a

<sup>1</sup> Means followed by the same lower case letter in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

<sup>2</sup> Data transformed to arcsine for statistical analysis.

Table 4  
Change in fresh body weight (mg) by the nymph of *S. pandurus* on four different host-seeds (Mean  $\pm$  S.E., N = 15)<sup>1</sup>

Host-seed	1st instar	2nd instar	3rd instar	4th instar	5th instar
Milkweed	0.27 $\pm$ 0.00 aA	4.25 $\pm$ 0.23 aB	7.36 $\pm$ 0.16 aC	33.09 $\pm$ 1.27 aD	85.85 $\pm$ 3.49 aE
Brinjal	0.21 $\pm$ 0.00 bA	1.84 $\pm$ 0.11 bB	5.06 $\pm$ 0.55 bC	21.40 $\pm$ 1.20 bD	53.25 $\pm$ 0.62 bE
Gingelly	0.21 $\pm$ 0.00 cA	1.55 $\pm$ 0.18 bB	3.70 $\pm$ 0.45 bC	14.19 $\pm$ 1.06 cD	37.42 $\pm$ 0.95 cE
Sunflower	0.22 $\pm$ 0.00 bA	2.85 $\pm$ 1.10 cB	3.84 $\pm$ 0.26 bC	15.48 $\pm$ 1.00 cD	66.98 $\pm$ 3.99 dE

<sup>1</sup> Means followed by the same lower case letter in each column and same upper case letter in each row are not significantly different at 5% level using ANOVA and Significant difference between individual pair of means.

Table 5

Fresh body weight (mg) of adult male of *S. pandurus* of different ages (Means  $\pm$  S.E., N = 10)<sup>1</sup> fed on different host-seeds.

Host-seed	1st Day	8th Day	15th Day	22nd Day	29th Day
Milkweed	100.18 $\pm$ 2.24 a	95.54 $\pm$ 1.58 a	89.92 $\pm$ 1.64 a	96.66 $\pm$ 2.23 a	102.87 $\pm$ 3.64 a
Brinjal	78.07 $\pm$ 3.19 b	76.93 $\pm$ 2.88 b	76.97 $\pm$ 3.36 b	76.64 $\pm$ 4.14 b	85.82 $\pm$ 3.59 b
Gingelly	51.77 $\pm$ 2.36 c	40.13 $\pm$ 2.09 c	45.22 $\pm$ 4.35 c	44.64 $\pm$ 2.24 c	—
Sunflower	80.19 $\pm$ 3.43 b	68.28 $\pm$ 3.91 d	65.85 $\pm$ 3.42 d	61.39 $\pm$ 5.38 d	58.11 $\pm$ 5.36 c

<sup>1</sup> Means followed by the same lower case letter in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

Table 6

Fresh body weight (mg) of adult female of *S. pandurus* of different ages (Means  $\pm$  S.E., N = 10)<sup>1</sup> fed on different host-seeds.

Host-seed	1st Day	8th Day	15th Day	22nd Day	29th Day
Milkweed	94.30 $\pm$ 5.18 a	101.10 $\pm$ 2.83 a	96.38 $\pm$ 4.23 a	102.73 $\pm$ 5.71 a	107.30 $\pm$ 6.18 a
Brinjal	73.05 $\pm$ 1.63 bc	85.05 $\pm$ 2.96 b	80.96 $\pm$ 3.91 b	81.21 $\pm$ 3.83 b	89.49 $\pm$ 4.49 b
Gingelly	63.04 $\pm$ 3.01 c	40.88 $\pm$ 1.47 c	38.43 $\pm$ 1.46 c	40.57 $\pm$ 1.74 c	—
Sunflower	83.84 $\pm$ 3.76 ab	78.84 $\pm$ 3.86 b	78.59 $\pm$ 1.73 b	74.92 $\pm$ 0.88 b	72.21 $\pm$ 0.79 c

<sup>1</sup> Means followed by the same lower case letter in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

Table 7

Biochemical estimation (Means  $\pm$  S.E., mg/g, N = 5)<sup>1</sup> of different host-seeds of *S. pandurus*.

Host-seed	Total storage protein	Total nutritive carbohydrate	Total lipid	Total phenol	Free aminoacid
Milkweed	196.32 $\pm$ 1.07 a	159.47 $\pm$ 0.59 a	170.07 $\pm$ 2.95 a	13.71 $\pm$ 0.07 a	12.22 $\pm$ 0.11 a
Brinjal	128.28 $\pm$ 0.35 b	150.33 $\pm$ 3.05 b	144.62 $\pm$ 0.92 b	8.31 $\pm$ 0.10 b	5.19 $\pm$ 0.13 b
Gingelly	112.91 $\pm$ 0.59 c	141.58 $\pm$ 0.53 c	411.75 $\pm$ 0.95 c	7.94 $\pm$ 0.16 c	4.74 $\pm$ 0.33 b
Sunflower	159.95 $\pm$ 0.64 d	137.48 $\pm$ 0.46 d	316.12 $\pm$ 2.96 d	22.55 $\pm$ 0.09 d	31.10 $\pm$ 0.11 c

<sup>1</sup> Means followed by the same lower case letter in each column are not significantly different at 5% level using ANOVA and Duncan's multiple range test (1955).

a low phenolic level, about one third of that of sunflower. Free aminoacids were present in very large quantity in sunflower seeds. Milkweed seeds had a moderate but significantly higher amount than brinjal and gingelly seeds.

## DISCUSSION

In seed-preference behaviour, the extent to which seed quality influences host choice by seed-suckers is virtually unknown (Slansky and Panizzi, 1987). Chaplin (1980) found that qualitative differences among seeds from different species of milkweeds had some influence on host choice by *Oncopeltus*. However, the present study revealed that besides uniform predilection for the milkweed seeds, the choice or the nature of preference varied amongst stages and sexes. In some cases, the preference noted for two or more seeds was insignificant, a fact also reported for another seed-feeding lygaeid, *Elasmolomus sordidus* by Sanjayan and Ananthakrishnan (1987).

The short development period and the low mortality on milkweed and sunflower seeds clearly reflected the nutritional quality of both these seeds, as well as the utilization efficiency of the immature stages of the bug. The greater amount of storage protein, nutritive carbohydrate, and free aminoacids of the above seeds as compared to brinjal and gingelly seeds might be responsible for the better performance of the nymphs on the former seeds (Table 2, 7). In a similar observation on *Nezara viridula*, Panizzi and Meneguim (1989) reported low total nymphal mortality on *Brassica katber* and *Leonurus sibiricus* fruits, and short development time, particularly on the former food, indicating their better suitability for development.

Despite similar longevity of the adults on milkweed and sunflower seeds, the prolonged oviposition period and highest fecundity on milkweed seeds signified that these had an edge over sunflower seeds. It is known that glycosides of milkweeds are phagostimulatory to the seed-sucking milkweed specialist, *Oncopeltus fasciatus* (Bongers and Mürmann, 1973). Further, the higher phenolic content of the sunflower seeds might also be responsible for reproductive interference, since implication of

phenol in the ovarioles is certainly known (Banerjee and Haque, 1985). The poor performance of the females on gingelly and brinjal seeds might be due to the low nutritional quality of these seeds (Table 3, 7). Slansky and Panizzi (1987) in a similar observation on *O. fasciatus* found that delay in onset of oviposition, low egg production, and development periods were influenced by the poor quality of food and a consequent reduction in feeding rate.

Variation in both basic nutrients and non-nutritional components (allelochemicals) in food affect the amount and rate of food eaten, digested, assimilated, and converted into tissue/growth (Slansky, 1982). The poorest growth in body weight of nymphs on gingelly probably reflects the paucity of basic nutrients (except lipid) and total free aminoacids, whereas the performance was just the reverse on nutritionally rich milkweed seeds (Table 4, 7). That nutritional quality of the seed/fruit supported significantly higher weight gain by nymphs leading to the heaviest adults (freshly eclosed), had been well documented for *Nezara viridula*, when its nymphs were fed on the most preferred seeds of *Leonurus sibiricus* (Panizzi and Meneguim, 1989).

*Oncopeltus fasciatus* adults, when kept on reduced rations (seed wt./week), lost weight (Slansky, 1980). The same author also noted that recovery of reduced body weight could occur by a compensatory mechanism through enhanced food consumption (cumulative) after a certain period. Farrer *et al.* (1989) also concluded that insects feeding on foods of lower nutritional quality often show higher rates of consumption than similar insects feeding on more nutritional foods. Insects may therefore compensate for lower food quality by increasing consumption to obtain sufficient nutrition for development. Therefore, the recovery of body weight of *S. pandurus* males, noticed on the 22nd day on milkweed and brinjal seeds, may be a parallel situation.

From the limited knowledge of the nutritional requirements of seed-suckers and the allelochemicals that influence their pre feeding behaviour and post feeding performance, there seems to be great potential in developing resistant seed-crop varieties that differ in nutritive or allelochemical content, in physical/structural features, or in other ways. Unfortunately, much information on nutritional ecology of seed-sucker pest species necessary to develop improved means of manipulation and control is lacking (Slansky and Panizzi, 1987). The present work on *S. pandurus* might furnish some information useful for a new approach towards better management of this pest species.

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## CROP PROTECTION

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### Nutritional value of four host seeds and their relationship with adult and nymphal performance of seed bug (*Elasmolomus sordidus*) (Heteroptera : Lygaeidae)

A MUKHOPADHYAY<sup>1</sup> and B SAHA<sup>2</sup>

Centre for Life Sciences, North Bengal University, Darjeeling, West Bengal 734 430

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#### ABSTRACT

An experiment was conducted during 1989-91 to study the nutritional value of seeds of sesame (*Sesamum indicum* L.), groundnut (*Arachis hypogaea* L.), wheat (*Triticum aestivum* L. emend. Fiori & Paol.) and peepal (*Ficus religiosa* L.). Relationship between nutritional values of host seeds with performance of adults and nymphs of seed bug [*Elasmolomus sordidus* (Fabr.)] was also studied. Variation in the basic nutrients, specially storage protein and lipid, modulated some of its life processes like post-embryonic development period and fecundity. The influence of the total phenol content of the seeds on host preference and mortality was apparent.

Seed bug [*Elasmolomus sordidus* (Fabricius 1787)] is a serious post-harvest lygaeid pest of sesame (*Sesamum indicum* L.) (Nair 1975), groundnut (*Arachis hypogaea* L.) (Nair 1975) and wheat (*Triticum aestivum* L. emend. Fiori & Paol.) (Maxwell-Lefroy 1971). As a seed depreator, it is also well known from the habitat of fig litter including peepal (*Ficus religiosa* L.) (Mukhopadhyay 1989) and some other hosts (Chopra and Singal 1982).

The effect of variation in diet is measured in terms of growth, development, reproduction, mortality, longevity and morphological abnormalities (Singh 1977). Since sufficient information is not available from eastern India on the nutritional quality of these host seeds and their relationship with the various biological

criteria like seed preference, development and reproduction of *E. sordidus*, an investigation was conducted.

#### MATERIALS AND METHODS

*Elasmolomus sordidus* was reared in plastic vials on sesame, groundnut, wheat and peepal seeds. Sufficient food and water were provided. Observations were taken on 30 replications, on insects reared at 30°C, 80% relative humidity and in dark. The work was done during 1989-91.

Food preference was tested as per Sanjayan and Ananthkrishnan (1987) in an X-shaped glass apparatus in subdued light at 4 stages of the insect, viz early nymph, advanced nymph, male and female. The seeds of locally available varieties were biochemically analysed. Storage proteins were extracted and estimated as per the methods of Draper (1976) and Lowry *et al.* (1951) respectively. The nutritive carbohydrates (monosaccharides

<sup>1</sup>Senior Lecturer, <sup>2</sup>Research Fellow (Council of Scientific and Industrial Research), Department of Zoology

and oligosaccharides) were extracted by using 80% ethanol (Ananthkrishnan 1990), and starch was extracted after hydrolysing with HCl (Plummer 1979); and both these were assayed colorimetrically. Total lipid was extracted by petroleum ether and was gravimetrically estimated (Ananthkrishnan 1990). The total phenols for seeds were extracted and assayed (Hori 1974). Free amino acids were extracted (Draper 1976) and estimated (Plummer 1979).

RESULTS AND DISCUSSION

The adult males, females and early nymphs showed choice of seeds. But the advanced nymphs showed no clear choice (Table 1).

The post-embryonic development period of the pest differed significantly, except that on wheat with that of groundnut and sesame (Table 2). It indicates better adaptation of the local population to sesame seeds. However, sesame did not support long life of both the sexes. Longevity was the highest on wheat, followed by groundnut and peepal. When reared on wheat, the onset of egg-laying was delayed and oviposition period was protracted (Table 2). The average fecundity per pair was the maximum on sesame, followed by groundnut, wheat and peepal. These results indicate the nutritional potential of the 4 host seeds in general.

Table 1 Seed preference of different stages and sexes of seed bug in 4 host seeds

Host seed	Early nymphs		Advanced nymphs		Adult (male)		Adult (female)	
	$\bar{X} \pm SE$	Preference (%)	$\bar{X} \pm SE$	Preference (%)	$\bar{X} \pm SE$	Preference (%)	$\bar{X} \pm SE$	Preference (%)
Sesame	4.2 <sup>ab</sup> ± 0.5	21.0	3.9 <sup>a</sup> ± 0.7	19.5	5.5 <sup>a</sup> ± 0.6	27.5	6.2 <sup>a</sup> ± 0.8	31.0
Groundnut	4.1 <sup>ab</sup> ± 0.4	20.5	5.1 <sup>a</sup> ± 0.7	25.5	2.9 <sup>bc</sup> ± 0.2	14.5	4.4 <sup>ab</sup> ± 0.6	22.0
Wheat	3.9 <sup>a</sup> ± 0.5	19.5	3.7 <sup>a</sup> ± 0.3	19.0	5.3 <sup>a</sup> ± 0.9	26.5	5.3 <sup>ab</sup> ± 0.6	26.5
Peepal	5.5 <sup>b</sup> ± 0.4	27.5	4.0 <sup>a</sup> ± 0.7	20.0	4.8 <sup>ab</sup> ± 1.0	24.0	3.5 <sup>b</sup> ± 0.5	17.5
Control	2.3 <sup>c</sup> ± 0.5	11.5	3.2 <sup>a</sup> ± 0.4	16.0	1.5 <sup>c</sup> ± 0.3	7.5	0.6 <sup>c</sup> ± 0.3	3.0

Means followed by the same letter in each column are not significantly different at P = 0.05, using analysis of variance and Duncan's multiple range test

Table 2 Comparative performance (mean ± SE) of seed bug on 4 different host seeds

Host seed	Total nymphal period (days)	Oviposition period/pair	Fecundity/pair	Hatchability/batch (%)	Male longevity (days)	Female longevity (days)	Total nymphal mortality (%)
Sesame	20.6 <sup>a</sup> ± 0.1	20.1 <sup>a</sup> ± 2.2	456.1 <sup>a</sup> ± 48.1	47.8 <sup>a</sup> ± 2.1	33.9 <sup>a</sup> ± 2.2	31.6 <sup>a</sup> ± 3.0	40.0
Groundnut	22.9 <sup>b</sup> ± 1.0	21.8 <sup>a</sup> ± 2.3	439.7 <sup>a</sup> ± 43.4	52.5 <sup>a</sup> ± 3.0	35.2 <sup>ab</sup> ± 2.7	33.3 <sup>a</sup> ± 2.9	53.3
Wheat	21.9 <sup>ab</sup> ± 0.5	29.4 <sup>b</sup> ± 2.0	237.2 <sup>b</sup> ± 19.0	48.9 <sup>a</sup> ± 1.9	40.5 <sup>b</sup> ± 2.7	40.5 <sup>b</sup> ± 1.7	46.7
Peepal	26.8 <sup>c</sup> ± 0.8	22.2 <sup>a</sup> ± 0.8	82.0 <sup>c</sup> ± 5.5	48.6 <sup>a</sup> ± 2.9	32.1 <sup>a</sup> ± 1.8	28.5 <sup>a</sup> ± 0.8	60.0

Means followed by the same letter in each column are not significantly different at P = 0.05, using analysis of variance and Duncan's multiple range test

Biochemical analysis of the storage protein—comprising albumin, globulin, prolamin and glutelin—significantly differed in different seeds, with highest quantity in groundnut followed by sesame, wheat and peepal. Total nutritive carbohydrates, comprising monosaccharides, oligosaccharides and starch, were the highest in wheat, followed by significantly different quantities in groundnut, peepal and sesame. The seeds of sesame and groundnut had significantly higher lipid content than of peepal and wheat. Peepal seeds contained the highest amount of total phenols, which significantly varied from that of groundnut, wheat and sesame; the last having the lowest value. The content of free amino acids was significantly highest in groundnut, and lowest in sesame; whereas the values were intermediate for wheat and peepal (Table 3).

Variation in both basic nutrients and non-nutritional components (allelochemicals) in the food affects the amount and rate of food eaten, digested, assimilated and converted into tissue for growth (Slansky 1982). Slansky and Panizzi (1987) indicated that among dietary proteins albumins and globulins were of highest quality, glutelins intermediate and prolamin the poorest. Phenolics are extremely abundant plant allelochemicals, often associated with feeding deterrence or growth inhibition (Suresh 1988). Higher indices of host preference for sesame and wheat (having a low phenolic content) could reasonably be understood, supporting the observation of Sanjayan and Ananthakrishnan (1987). Adverse relation of the phenolic level with the post-embryonic developmental period and mortality (%) was apparent. The total developmental period of the nymphs increased with the increase in the phenolic level of the seeds, as also the death rate.

In our study, high protein diet (in groundnut) (Table 3) supported rapid development

Table 3 Biochemical estimation (mean  $\pm$  SE) of basic nutrients, phenol and free amino acids (mg/g) in seeds of different hosts of seed bug

Host seed	Albumin + globulin		Storage protein		Total	Nutritive carbohydrate		Total lipids	Total phenols	Free amino acid
	Prolamin	Glutelin	Prolamin	Glutelin		Mono- and oligo-saccharides	Starch			
Sesame	49.1 <sup>a</sup> $\pm$ 0.3	14.4 <sup>a</sup> $\pm$ 0.2	49.5 <sup>a</sup> $\pm$ 0.3	112.9 <sup>a</sup> $\pm$ 0.6	23.2 <sup>a</sup> $\pm$ 0.3	118.4 <sup>a</sup> $\pm$ 0.4	141.6 <sup>a</sup> $\pm$ 0.5	411.8 <sup>a</sup> $\pm$ 1.0	7.9 <sup>a</sup> $\pm$ 0.2	4.7 <sup>a</sup> $\pm$ 0.0
Groundnut	130.8 <sup>b</sup> $\pm$ 0.2	16.9 <sup>b</sup> $\pm$ 0.3	83.5 <sup>b</sup> $\pm$ 0.4	231.1 <sup>b</sup> $\pm$ 0.4	146.3 <sup>b</sup> $\pm$ 0.2	106.3 <sup>b</sup> $\pm$ 0.2	252.7 <sup>b</sup> $\pm$ 0.2	394.1 <sup>b</sup> $\pm$ 1.1	19.8 <sup>b</sup> $\pm$ 0.1	21.2 <sup>b</sup> $\pm$ 0.1
Wheat	43.5 <sup>c</sup> $\pm$ 0.4	25.6 <sup>c</sup> $\pm$ 0.4	37.1 <sup>c</sup> $\pm$ 0.2	106.3 <sup>c</sup> $\pm$ 0.6	38.2 <sup>c</sup> $\pm$ 0.4	550.7 <sup>c</sup> $\pm$ 2.5	589.0 <sup>c</sup> $\pm$ 2.3	12.2 <sup>b</sup> $\pm$ 0.7	3.7 <sup>c</sup> $\pm$ 0.1	6.8 <sup>c</sup> $\pm$ 0.1
Peepal	13.2 <sup>d</sup> $\pm$ 0.2	35.6 <sup>d</sup> $\pm$ 0.4	15.2 <sup>d</sup> $\pm$ 0.3	64.2 <sup>d</sup> $\pm$ 0.3	12.5 <sup>d</sup> $\pm$ 0.2	201.9 <sup>d</sup> $\pm$ 0.5	214.4 <sup>d</sup> $\pm$ 0.7	63.7 <sup>b</sup> $\pm$ 0.7	30.8 <sup>d</sup> $\pm$ 0.1	8.7 <sup>d</sup> $\pm$ 0.1

Means followed by the same letter in each column are not significantly different at  $P = 0.05$ , using analysis of variance and Duncan's multiple range test.

and high fecundity but also showed high mortality and reduced longevity. This is corroborated by the general view that superior nutritional composition allows the females to achieve a high egg output, thereby shortening their life (Slansky and Panizzi 1987). Low lipid content of seed diets did not appear to have much impact, as found in red cotton bug [*Dysdercus koenigii* (Fabricius)] (Saxena 1969). However, feeding on seed containing the highest amount of lipid (viz sesame) (Table 3) showed shortest post-embryonic development, highest fecundity and lowest mortality. It indicates that lipids possibly support vital life processes of *E. sordidus*. Slansky and Panizzi (1987) reported that the growth of seed bugs was not significantly affected by a wide range of concentrations of at least 10 essential amino acids (6–12 times or more). In a finding similar to that of the above, the highest concentration of free amino acid in groundnut and lowest in sesame (Table 3) seeds had no appreciable impact on the life process (Table 2) and seed preference of the bug.

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