STUDIES ON BRUCHID FAUNA INFESTING PULSE CROPS OF KARNATAKA WITH SPECIAL EMPHASIS ON THE BIOECOLOGY OF *Callosobruchus chinensis* (Linnaeus) (COLEOPTERA : BRUCHIDAE)

G. S. PRABHAKARA

Department of Agricultural Entomology
UNIVERSITY OF AGRICULTURAL SCIENCES
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G. S. PRABHAKARA

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BANGALORE

CERTIFICATE

This is to certify that the thesis entitled "STUDIES ON BRUCHID FAUNA INFESTING PULSE CROPS OF KARNATAKA WITH SPECIAL EMPHASIS ON THE BIOECOLOGY OF *Callosobruchus chinensis* (Linnaeus) (COLEOPTERA : BRUCHIDAE)" submitted by Mr.G.S.PRABHAKARA for the degree of MASTER OF SCIENCE (AGRICULTURE) in AGRICULTURAL ENTOMOLOGY of the University of Agricultural Sciences, Bangalore, is a record of research work done by him during the period of his study in this University, under my guidance and supervision, and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

7/5/79

(R.Balasubramanian)
Assistant Professor of Agricultural Entomology

Bangalore
February , 1979

APPROVED BY:

Chairman : (R.Balasubramanian) 7/5/79

Members : 1. (G.P.ChannaBasavanna) 7.5.79

2. (G. Shivashankar)

3. (K.Balakrishna Rao) 7.5.79

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INTRODUCTION

Pulses besides cereals constitute the most widely used components of Indian diet, as they constitute the only and the most abundant source of protein to the vegetarians. Pulses contain 20 to 30 per cent protein on dry basis which is nearly three times that of cereals. The proteins present in cereals and pulses differ in their amino-acid composition and are complementary to each other. Thus, the biological value of proteins in a mixed diet of cereals and pulses closely approaches that of the standard protein source in milk.

The world's total area under pulse crop is estimated at 53 million hectares with a production of 37 million tonnes. Though the area under pulses in India is 24 million hectares its production is only 12.44 million tonnes with an estimated value of Rs.700 million (Vevai, 1970). In Karnataka, the area under pulses is 12.77 lakh hectares with an estimated production of 5.61 lakh tonnes. Of this, red gram (*Cajanus cajan* Linn.) alone accounts for over 3.04 lakh hectares and production of 1.82 lakh tonnes, respectively[1].

In order to meet the growing demand of pulses, greater emphasis is being laid in recent years by both Central and the State governments on increased production of pulses by means of both extensive and intensive cultivation.

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1. Final Forecast Report issued by the Bureau of Economics and Statistics, Karnataka, for the year 1977-78.

In the Agricultural Universities and Agricultural Research Stations, all over the country, efforts are being concentrated on breeding programmes to get better genotype for both quality and higher yield coupled with pest and disease resistance, drought tolerance and response to better agronomic practices.

More than 150 species of insect pests are known to attack pulse crops both in fields and storage conditions in India. Of these, 25 species cause appreciably serious damage. Bruchids assume greater importance as pests as they damage the final produce in the field as well as in the stores.

A total of 117 species belonging to 11 genera of bruchid have, so far, been listed in India (Vazirani, 1975; Arora, 1977). Of these, the genus Callosobruchus includes three economically important species, namely, C. chinensis (Linnaeus), C. maculatus (Fabricius) and C. analis (Fabricius).

Considerable amount of work has been done on the taxonomy of bruchids (Mukerji and Chatterjee, 1951; Southgate et al., 1957; Arora, 1977). Studies on the biology under laboratory conditions are also not lacking (Kunhikannan, 1919; Haricharan Singh, 1962; Raina, 1970). Though it is widely accepted that the infestation of these species is carried from the field to the stores, no information is available on their biology and ecology under field conditions.

The use of life-tables showing changes in population during different developmental stages throughout the life cycle of an insect in the natural environment has been considered to be one of the most important approaches in understanding population dynamics (Harcourt, 1969).

Life-tables have been prepared for two dozen insect species infesting forest, orchard and agricultural crops (Beaver, 1966; Harcourt, 1969 and 1971; Harcourt and Guppy, 1975; Balraj Singh *et al.*, 1977; Jayarathnam, 1977).

With a view to obtain detailed information on the biology and ecology of *C. chinensis*, especially under field in South Indian conditions, detailed studies were undertaken during the period September 1976 through September 1977 on the following aspects:

a) Determination of bruchid fauna infesting various pulse crop seeds in the State of Karnataka.

b) Biology and ecology of *C. chinensis* under laboratory conditions.

c) Field biology and ecology of *C. chinensis* including life-table studies.

d) Testing of seeds of varieties of different pulse crops for their susceptibility to bruchids.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Economic Importance

Bruchids have been considered as major pests of stored pulse seeds than as pests in the field. Chondola et al. (1969) have placed the loss of cow pea due to Callosobruchus chinensis (Linneaus) at 16 to 20 per cent in stores. The loss during storage of pulses due to insect pests has been estimated at 5 per cent (Anonymous, 1970). Further the expert committee constituted by Government of India in 1967 has also put the post-harvest loss of pulses due to insect pest at 5 per cent in India (Girish and Krishnamurthy, 1972).

Fletcher (1918) reported the incidence of C. chinensis on cow pea in India. According to Bindra and Jakhmola (1967) pulse beetle attacked red gram only at harvest time and most of the damage to grain was done subsequently. The per cent pod attacked in the field varied from 1.2 to 10.2 averaging 5.15 and that of seed ranged from 0.4 to 4.8 per cent averaging 2.25. The loss in weight of the damaged grain varied from traces to 25.37 per cent. Studies carried out at International Crops Research Institute for the Semi-Arid Tropics, Hyderabad on pigeon pea, pod samples collected at different locations of Andhra Pradesh revealed on an average of 5 per cent attack of bruchids with incidence in one case being 28 per cent. The report also observed that the per cent seed damaged by bruchids varied from zero to 26.4 per cent with a mean of 3.49 (Anonymous, 1976). Damage by C. chinensis to red gram seeds in the field ranged from 16.4 to 40.7 per cent as reported by Gunathilagaraj et al. (1977) from Coimbatore.

Common Name

Bruchids have been referred to by several common names. In western countries, they are commonly referred as 'Bean weevil' (Larson and Fisher, 1938; Mitchell, 1975).

In India, 'Pulse beetle' is the most common name by which it has been called (Kunhikannan, 1919; Ayyar, 1940; Pruthi, 1969).

Bruchid Fauna of India

Vazirani (1975) in his check list, listed 88 species of bruchids of which 78 species are from India which include 13 cosmopolitan species. Arora (1977) in his 'Taxonomy of the Bruchidae (Coleoptera) of North-West India' described 48 species of which 29 were new. With this, the number of bruchid species recorded in India totalled 117.

Regarding bruchid species occurring in Karnataka, in the erstwhile Mysore State, Kunhikannan (1919) recorded four species which included C. chinensis (Linnaeus), C. analis (Fabricius), C. quadrimaculatus (Fabricius) and an unidentified species on pulses in stores. Usman and Puttarudriah (1955) listed seven species of which two species were on pulse crops namely, C. theobromae (Linnaeus) on Cajanus pods in the field and C. chinensis (L.) on Bengal gram, lab-lab and green gram, etc., throughout erstwhile Mysore State. With this, the total number of bruchids recorded in Karnataka rose to nine.

Taxonomy of Bruchids of Karnataka

Pic (1902) proposed *Callosobruchus* as a new sub-genus of *Bruchus*. Bridwell (1929) elevated it to generic status and designated *Bruchus scutellaris* (=*Curculio chinensis* Linnaeus 1758) as the type species.

The synonymy and the description of the *Callosobruchus chinensis*, *C. maculatus*, *C. analis* and *C. theobromae* are as follows:

1. *Callosobruchus chinensis* (Linnaeus)

Curculio chinensis Linnaeus, 1758, Systema naturae, ed. 10, 1:386.

Bruchus pectinicorus Linnaeus, 1767, Systema naturae, ed. 10, 1:605.

Bruchus rufus Degeer, 1775, Mem. Ins., 5:281.

Bruchus scutellaris Fabricius, 1792, Entomologia Systematica, 1:372.

Bruchus bistriatus Fabricius, 1801, Systema Eleutheratorum, 2:402.

Bruchus barbicornis Fabricius, 1801, Systema Eleutheratorum, 2:403.

Bruchus elegans Sturm, 1826, Cat. meiner Insecten, Samlung, 1826:103.

Bruchus chinensis Schonnerr, 1833, Genera at Species *Curculionidum*, 1:101.

Bruchus adustus Motschulsky, 1874, Bull. Soc. Imp. Nat. Moscou, 46:227 (1873).

Hosts:

Dolichos lab-lab (Medik), (Usman and Puttarudriah, 1955).

Glycine hispida (Haricharan Singh, 1962).

Cicer arietinum Linn. (Bengal gram), *Lens culinaris* Medik (Lentil), *Phaseolus aureus* Roxb. (Green gram), *P. aconitifolius* Jaq. (Moth bean),

Dolichos biflorus Linn. (Horse gram), *Cajanus cajan* (Linn.) (Red gram),
Vigna sinensis (Linn.) (Cow pea), *Pisum sativum* Linn. (Pea), *Cassia tora* L. (Panwar), *Acacia modesta* Wall., (Phalla) (Arora, 1977).

Sexual dimorphic characters:

Male - Antennae long and pectinate; a pair of tubercles present at the bases of 3rd and 4th stage of each elytron; length - 3.23 to 3.36 mm.

Female - Antennae short and sub-serrate; elytral tubercles absent; length - 3.43 to 3.56 mm. (Raina, 1970; Arora, 1977).

2. *Callosobruchus maculatus* (Fabricius)

Bruchus maculatus Fabricius, 1775, Systema Entomologica:65.

Bruchus quadrimaculatus Fabricius, 1792, Entomologia Systematica, 1:371.

Bruchus ornatus Bohemann, 1829, Nouv. Mem. Soc. Nat. Moscou, 1:103.

Bruchus vicinus Gyllenhal, in Schonherr, 1833, Genera at Species Curcilionidum, 1:36.

Bruchus ambiguus Gyllenhal, in Schonherr, 1833, Genera et Species Curcilionidum, 1:11.

Hosts:

Phaseolus aureus Roxb. (Green gram), *P. aconitifolius* Jaq. (Moth bean), *P. mungo* Linn. (Black gram), *Vigna sinensis* (Linn) (cow pea), *Cajanus cajan* (Linn.) (Red gram), *Cicer arietinum* Linn.

(Bengal gram), *Pisum sativum* Linn. (Pea), (Arora, 1977).

Sexual dimorphic characters:

Male - Antennae long and deeply serrate; elytra without distinct C-shaped areas of white pubescence; pygidium uniformly covered with golden setae; length - 3.29 to 4.95 mm.

Female - Antennae short and sub-serrate; white pubescence on the elytra forming two distinct C-shaped areas with their bases facing each other; pygidium with a pair of black postero-lateral spots; length 4.01 to 4.81 mm.
(Raina, 1970; Arora, 1977).

3. *Callosobruchus analis* (Fabricius)

Bruchus analis Fabricius, 1781, Species Insectorum, 1:75.

Bruchus jekeli Allibart, 1847, Rev. Zoologique, 1847:15.

Bruchus glaber Allibart, 1847, Rev. Zoologique, 1847:16

Hosts:

Phaseolus aureus Roxb. (Green gram), *P. aconitifolius* Jaq. (Moth bean), *P. mungo* Linn. (Black gram), *Vigna sinensis* (Linn.) (Cowpea), *Cicer arietinum* Linn. (Bengal gram), *Glycine max* Merr. (Soy bean), *Cajanus cajan* (Linn.) (Red gram), (Arora, 1977).

Sexual dimorphic characters:

Male - Each elytron with a pair of black naked spots separated by a patch of dull white setae; pygidium vertical. Antennae slightly thick; length - 3.64 to 3.96 mm.

Female - Each elytron with a pair of dark black spots separated by a patch of shining white setae; pygidium oblique. Antennae slightly thin; length - 3.22 to 3.89 mm. (Raina, 1970; Arora, 1977).

4. Callosobruchus theobromae (L.)

Bruchus theobromae Linnaeus, 1767, Systema naturae, ed. 12, 1:605

Hosts:

Cajanus (Linn.) (Usman and Puttarudriah, 1955)., Theobromae feminibus, and Cajanus indicus (Vazirani, 1975), Glycine max Merr (Arora, 1977).

Sexual dimorphic characters:

Male - Antennae thick, long and serrate; pygidium vertical and hardly visible in the dorsal view; length - 4.02 to 5.01 mm.

Female - Antennae narrow, slightly shorter and sub-serrate; pygidium sub-vertical and visible dorsally; length - 3.89 to 5.08 mm (Arora, 1977).

Life History of C. chinensis

Eggs:

Oval, plano convex and transparent at the time they are laid (Kunhikannan, 1919; Raina, 1970). The former has specified the length of the egg to be 0.3 mm and width to be half of that of length. Howe and Currie (1964) reported an incubation period of 4.2 days at 30°C and 70 per cent relative humidity on cowpea whereas under similar conditions, Raina (1970) recorded 3.5 days on green gram.

According to Rajak and Pandey (1965) incubation period lasted for 3 to 18 days on cow pea under laboratory conditions.

During the cold months in the field the incubation period varied from 10 to 21 days on cow pea in Africa (Skaife, 1918). Howe and Currie (1964) reported that none of the eggs hatched at 40°C. The optimum condition for rapid development was 30°C and 70 per cent relative humidity. The incubation period increased at both lower and higher humidity as well as lower and higher temperature.

Larva:

Riley (1892) noticed H-shaped pronotal induration of chitin in the first larval instar of Mylabris obtectus Say, and Bruchus fabae Riley, as early as 1891. Chittenden (1898) was the next to describe the thoracic plates in two more species namely M. chinensis and M. quadrimaculatus, but did not study their function. While describing prothoracic plates in eight different species of bruchids Kunhikannan (1923) elucidated in detail the functions of these plates. According to him these plates with chitinous spines helped the larva in the process of hatching to hold on to the egg shell for getting proper hold of the seed surface by its mandibles and to cut through the seed coat. According to Van Emden (1946) the first instar larvae bear a large spine on either side of the first abdominal segment and two groups of small spines dorsally on the tergal plate of the pronotum.

According to Kunhikannan (1919) first instar larvae measured 0.5 mm long.

Kunhikannan (1923) reported that the legs of first and subsequent larval stages, were atrophied, and as such gripping the surface of the seed with legs was not possible. He further stated that the frass produced by the larvae filled the egg shell and gave the empty shell a white appearance which was an indication of successful penetration of the larvae into the seed.

According to Howe and Currie (1964) C. chinensis underwent four larval instars with a mean duration of 2.9, 2.5, 2.5 and 4.2 days at 30°C and 70 per cent relative humidity on cow pea. In a study conducted at Delhi, Rajak and Pandey (1965) observed an average larval period of 29 days with a mean duration of four instars being 2.4, 3.5, 6.4 and 16.7 days respectively on cow pea except in winter. However, Raina (1970) found that the larvae underwent four moults before pupation. Under field condition, in Africa, Skaife (1918) observed the larval duration lasting 4 to 5 months during cold season but about five weeks in summer.

Pupa:

The mean pupal duration was over 2.7 days (at 30°c and 70 per cent relative humidity) (Howe and Currie, 1964). Rajak and

Pandey (1965) observed a pupal period of 6 to 21 days. Raina (1970) observed that before pupation the final instar larvae chewed a circular hole near the seed coat until only a thin layer of testa was left intact which gave an appearance of a 'window' or dark spot. According to him, this was an indication as to pupation, which was noticed in most of the cases. At this stage, the final instar larvae laid itself with its mandibles facing the window and underwent pre-pupal and pupal development (Howe and Currie, 1964; Raina, 1970).

Total developmental period:

The total larval and pupal developmental period of C. chinensis on different host seeds were 18.9, 19.2, 26.4, 21.5, 22.9, 22.9, 38.3, 24.4 and 35.2 days on labia (Phaseolus calcaratus), beans (Dolichos lab-lab), moong (P. mungo), moth bean (P. aconitifolus), kabli gram (Cicer arietinum), desi gram (Cicer arietinum), mash (P. radiatus), lentil (Lens esculenta) and soy bean (Glycine hispida) respectively at room temperature. Further the insect failed to develop on peas (Pisum sativum), cow pea (Vigna catjang) and guar (Cyamopsis psoralioides) (Haricharan Singh, 1962). According to Howe and Currie (1964), the optimum temperature and relative humidity for the rapid development of larval and pupal stages of C. chinensis were 30°C and 70 per cent relative humidity and none could develop completely at 37.5°C.

Rajak and Pondey (1965) stated that the total developmental period of C. chinensis differed from season to season with a minimum of

17 days and maximum of 114 days on cow pea. It lasted from 21 to 27 days with an average of 22.3 days on mung (Raina, 1970).

Howe and Currie (1964) and Simba and Utida (1967) considered a temperature of 17°C as minimal for the development of *C. chinensis*. However, Utida (1971) was of the opinion that the threshold of development was 17 to 18°C for *C. maculatus* and 12 to 13°C for *C. chinensis*.

The pre-adult developmental period of *C. maculatus* was negatively correlated with temperature and was also affected to a lesser degree by humidity. However, lower humidity prolonged the developmental period (Booker, 1967).

Adult emergence:

Schalk and Russoulian (1973) observed 22 per cent of emergence of F_1 progeny of *C. maculatus* on cow pea pods. Sangappa and Balaraju (1977) observed 22.8 per cent and 10.3 per cent emergence of *C. chinensis* from eggs laid on green and yellow pods of red gram respectively. Gunathilagaraj *et al.* (1977) observed an emergence of 47 adults from 79 eggs laid (59.49 per cent) on green pods and 31 adults from 61 eggs (51.66 per cent) laid on mature pods of red gram.

Sex ratio:

Males were more numerous than females according to Haricharan Singh (1965), Teotia and Singh (1966) observed that the ratio of females to males was generally higher on the more nutritious seeds.

The proportion of *C. analis* females was found to vary inversely with the temperature as opposed to which males outnumbered females under all conditions (Adarsh and Sohi, 1969). Raina (1970) found that males and females occurred in equal numbers with males having a slight majority (6 : 5).

Mating:

Although one mating was sufficient to ensure egg laying, repeated matings were observed (Haricharan Singh, 1965; Raina, 1970). Raina (1970) observed that adults moved within the seed for some time and were sexually mature when they emerged. The adult mated within an hour of its emergence and it lasted for 5 to 8 min. According to Pajani and Mohindergill (1974) the adults hid themselves under seed but copulated with equal efficiency both in darkness and light.

Adult feeding:

De Luca (1966) reported that the adult species of *Callosobruchus* do not require food for survival or reproduction, whereas, Pajani and Mohingergill (1974) observed the adult bruchids to consume the pollen of pea flowers.

Pre-oviposition period:

Howe and Currie (1964) observed very short pre-oviposition period after emergence. According to Raina (1970) mating and oviposition followed emergence.

Oviposition:

Utida (1943) reported an initial oviposition of one egg on each available seed and that further oviposition was at random. However, Raina (1970) observed that usually one to three eggs were laid per seed although as many as seven eggs were also found on a single seed while there were still a few seeds without eggs.

C. chinensis inhibited a second oviposition through a chemical marker (Zaazou, 1953; Oshima et al., 1973). But according to Saleh (1954), a particular smell given off from the infested cow pea seeds acted as a stimulant for oviposition in C. maculatus.

Colour (Booker, 1967) and light (Pajani and Mohindergill, 1974) had no influence on egg laying.

Fletcher (1918) recorded the field infestation of bruchid on cow pea pods. Bridwell (1918) gave an account of field biology of C. chinensis. It was observed to lay eggs either on the unbroken red gram pod or if the pod had burst open, upon the bean. Adults developing from these eggs mated and oviposited before cutting their way out of the pod. On cowpea, it preferred dry and ripe pod (Skaife, 1918). According to Kunhikannan (1919) the beetles got at the exposed seeds in red gram pods at the time of harvest and laid eggs on them. Infestation also took place during the interval between harvest and storage or in the store itself. pPrevitt (1961) and Casewell (1961) observed that in the field oviposition by C. maculatus did not commence until cow pea pods were fully formed and appeared light coloured. Raina (1971) recorded C. chinensis and C. *maculatus* as field pests of cow pea (*Vigna unguiculata*), mung (*Phaseolus aureus*), urid (*P. mungo*), chick pea (*Cicer aritinum*) and pigeon pea (*Cajanus cajan*) and C. *theobromae* on pigeon pea. He further reported that C. *chinensis* and C. *maculatus* laid eggs on half shattered pods of redgram in which a few seeds lay exposed. Further, he stated that females under captivity laid eggs on the whole pods of cow pea, mung, urid and red gram. There was 95 per cent larval mortality and that a few of the adults developed, could not chew their way out of the pod and consequently died inside.

According to Schalk and Russolion (1973), when adults of C. *maculatus* were given a free choice for oviposition on cow pea, developing pods were preferred over mature pods when both sets of pods were atleast 8 cm long. Sangappa and Balaraju (1977) observed highest number of eggs on green red gram pods followed by yellow pods, dry and tender pods in that order. Experiments conducted by Gunathilagaraj *et al*. (1977) at Coimbatore revealed that C. *chinensis* preferred developing and mature pods of red gram for oviposition which allowed the emergence of 31 adults from 61 eggs laid on mature pods and 47 adults from 79 eggs laid on green pods.

Fecundity:

Takasugi (1924) reported a fecundity of 70 to 80 eggs. The number of eggs laid by a female C. *chinensis* ranged from 20 to 64 with an average of 45 eggs at 30°C and 70 per cent relative humidity and oviposition rate reached a maximum after 2 to 3 days of emergence after which it fell quickly at high temperature and more slowly at low temperature (Howe and Currie, 1964). Rajak and Pandey (1965) recorded 50 to 103 eggs. According to Raina (1970), a female laid on an average 78 eggs, ranging from 63 to 90 over a period of eight days. He further reported that the maximum daily egg lay occurred in the first 24 hours and the number gradually dropped till the last day of oviposition.

Adult longevity:

A longevity of 4.2 to 7.3 days in April to October and 12.3 days in November in respect of male and 5.1 to 9.5 and 15.6 days in the same months, respectively, in respect of females, was reported by Haricharan Singh (1965). Haricharan Singh (1965) and Raina (1970) reported that unmated females lived longer than mated females. The latter did not observe much difference in the life span of the two sexes. However, he found that males lived for 6 to 11 days averaging 7.6 days, while females lived for 5 to 10 days with an average of 7.4 days.

Hibernation:

There is only one report pertaining to hibernation by Rajak and Pandey (1965) who observed that larvae of C. chinensis hibernated during coldest months of the year (November to February).

Number of generations:

Haricharan Singh (1965) reported eight overlapping generations of C. chinensis in a year at Delhi on cow pea. Laboratory studies carried out at Hyderabad indicated that there could be 11 generations on red gram during a period of ten months at room temperature (Anonymous, 1976).

Natural enemies:

Parasites which have been recorded and reared on *C. chinensis* and *C. maculatus* from different countries are listed hereunder:

Name of the parasite	Country	Reported by
Host: *Callosobruchus chinensis* (Linnaeus)		
Insecta		
Order: Hymenoptera		
Family : Pteromalidae		
1. *Bruchobius colemani* Crwf.	India	Crawford (1913)
2. *Bruchobius vagabundus* Timb.	Hawaii India	Timberlake (1926) Usman and Puttarudriah (1955)
3. *Aplastomorpha calandrae* How.	Malaya	Carbett and Miller (1933)
4. *Pteromalus* sp	Formosa	Takahashi (1937)
Family : Trichogrammatidae		
5. *Uscana semifumipennis* Gir.	Hawaii	Bridwell (1918)
6. *Uscana mukerjii* (Mani)	India	Lal *et al*. (1975)
Family : Eupelmidae		
7. *Bruchocida orientalis* Crwf.	India	Crawford (1913)
Acarina		
Order : Prostigmata		
8. *Pyemotes ventricosus* Newp.	S. Africa India	Skaife (1919) Kunhikannan (1919)
Host: *Callosobruchus maculatus* (Fabricius)		
Insecta		
Order : Hymenoptera		
Family : Pteromalidae		
1. *Bruchobius laticeps* Ashm.	U.S.A.	Crawford (1913)

2.	*Chaetospila elegans* Westw.	Hawaii	Bridwell (1919)
3.	*Aplastomorpha calandrae* How.	U.S.A.	Cotton (1923)
4.	*Bruchobius vagabundus* Timb.	Hawaii	Timberlake (1926)
Family : Trichogrammatidae			
5.	*Uscana semifumipennis* Gir.	U.S.A.	Paddock and Reenhard (1919)
6.	*Chaetostricha mukerjii* Mani.	India	Mani (1935)
7.	*Uscana* sp	India	Arora (1966)
Acarina			
Order : Prostigmata			
8.	*Pyemotes ventricosus* Newp.	U.S.A.	Weiss (1915)

Ecology studies

Life-table studies:

Though life-table studies under laboratory conditions for many species of stored product including *Callosobruchus* have been made (Atwal *et al*., 1968) such studies under field conditions on Bruchidae are not reported except for a study of Mitchell (Personal communication) on *Mimosestes amicus* (Horn) infesting pods of *Circidium floridum* Benthi (Fam - Fabaceae).

Testing of Seeds of Different Pulse Crop Varieties for Their Relative Susceptibility to the Attack of Bruchids

Literature on the screening of seeds of varieties of different pulse crops for their relative susceptibility to the attack of bruchid is plenty both from India and outside as well.

Srivastava and Bhatia (1958) observed that in sword bean, hyacinth gram, kidney bean and soy bean, the first instar larvae of *C. chinensis* entered the seed to a pinpoint, but were all found dead. Lin (1964) reported that red bean and green bean were found to be heavily infested by *C. chinensis* while soy bean, green soy bean and ground nut were apparently uninfested. Of the Japanese and Israeli strains of *C. chinensis* which were tried to be raised on different varieties of soy beans by Applebaum *et al.* (1968), Japanese strain failed to develop in any of the varieties but Israily strains showed partial larval development although no larvae reached pupation. Chopra and Khurab (1970) observed that cow pea and peas were fairly resistant to *C. analis*, whereas mung, moth gram and urid were susceptible. Studies conducted at Indian Agricultural Research Institute on three varieties each of different pulses namely, green gram, black gram, pea, lathyrus and bengal gram indicated that Bengal gram variety BG-109-1 was highly resistant and it was concluded that large and smooth seeds were preferred for egg laying although it was not necessary that such seeds were equally more suited for completing the development. It was also observed that for completing the life cycle, minimum time was taken in green gram and cow pea whereas the longest duration was in the case of peas and lentil (Anonymous, 1971). According to Shivashankar *et al.* (1972) out of three black gram varieties studied, Singhkhed (KH_3) showed a high degree of resistance to *C. chinensis*.

Gokhale (1973) observed that out of 13 species of pulse seeds, moth bean proved to be of maximum food value to *C. maculatus* followed by green gram, red gram, cow pea, Bengal gram, chick pea, black gram, pea and hyacinth bean in decreasing order and that the insect completely failed to develop on soy bean, lima bean, French bean and lentil. Growth index of 0.091 (Bengal gram), 0.081 (pea), 0.079 (green gram), 0.075 (red gram) and 0.05 on soy bean for *C. maculatus* were reported by Girish *et al.* (1974). They further observed that though soy bean, Bengal gram and peas were preferred for oviposition to other pulse seeds, however, the development of *C. maculatus* was not better in these seeds.

MATERIALS AND METHODS

CHAPTER III

MATERIAL AND METHODS

Bruchid Fauna Infesting Pulse Crops and Their Distribution in Karnataka

Samples of different pulse seeds namely, red gram (*Cajanus cajan* Linn), black gram [*Vigna mungo* (L) Hepper. (*Phaseolus mungo* Linn.)] , green gram [*V. radiata* (L.) Wilczek (*P. aureus* Roxb.)], cow pea [*V. unguiculata* (L.) Walp. Sub. sp *Cylindrica* (L.) var. *Eseltine*, (*Vigna sinensis* Savi.)], horse gram [*V. unguiculata* (L.) Walp. Sub. sp *Unguiculata*, (*Dolichos biflorus* Linn.)] , Bengal gram (*Cicer arietinum* Linn.), field bean (*Lab-lab niger* Medikus), and soy bean (*Glycine max* Merr.) were collected from the districts of Bangalore, Bellary, Bidar, Chikmagalur, Chitradurga, Gulbarga, Hassan, Kolar, Mandya, Raichur and Tumkur. The samples collected from the threshing yard(s)/the standing crop(s) nearing harvest as well as from stores were appropriately labelled. Immediately after reaching the headquarters, hundred seeds were collected at random from each of the samples and kept in specimen tubes (6" x 1"). The mouths of the vials were properly stoppered with cotton wads. The number of adults emerging was recorded every day till the emergence completely ceased. The percentage of the infested seeds that was carried from the field to the stores through harvest was worked out. The species of bruchids infesting pulse seeds and the extent of infestation by each species were established.

Seasonal Incidence

The seasonal incidence of the bruchid species namely

Callosobruchus chinensis (Linnaeus), and *C. theobromae* (Linnaeus) on red gram were studied. The adult bruchids were collected by sweeping with hand net every week during September 1976 to July 1977. The number of sweepings consisted of three sets of sweepings in three locations, each set comprising 20 sweepings (total of 60 sweepings) per plot of 10' x 10'. Number of bruchids per 20 sweepings of one set was recorded.

For the seasonal incidence studies on standing crop of red gram which was in flowering stage during September 1976 to January 1977 were made use of. Inflorescence were obtained during the remaining period of February 1977 to July 1977 by growing a short duration, photoinsensitive variety (Prabhat) of red gram at monthly intervals.

Life History Studies of *C. chinensis*

Stock culture of *C. chinensis* raised from a single pair on red gram seeds was maintained throughout the study in plastic jars covered with muslin cloth held in place by a rubber band.

The life history was studied for six generations under laboratory conditions on six hosts namely, red gram (variety S_5), green gram (local), cow pea (local), black gram (KH_3), soy bean (Hardee) and field bean (Hebbal Avare-3) during the period January to June 1977. Red gram was used as the main host from February to June 1977 while seeds of other pulse crops were used for studying the life cycle for one generation only. Green gram and cow pea were used as hosts in the first generation. Subsequently, red gram was used consistently as hosts for the remaining period of study, with black gram (second and third generation), field bean (fourth generation), soy bean (fifth generation) as additional hosts and red gram only for the sixth generation. The study on each host was replicated four times.

One pair of newly emerged _C. chinensis_ was released into each of the four small petridishes (2" x 1"). Every day 40 seeds were enclosed in each of the four petridish for egg laying. Every morning the number of eggs laid on seeds were recorded and such seeds with eggs were removed and kept separately in small glass vials 1" x 6". Healthy, sound seeds, free of eggs equal in numbers to those were put back into the petridishes so as to maintain the number of seeds at 40. The fecundity, incubation period, larval, pupal period were recorded. For the determination of the number of larval instars and their duration, pre- and pupal period in red gram seeds the following method was adopted: Seeds with eggs laid on same day were taken. Only one egg was allowed to remain on each seed. At the time of experiment, there were totally 91 eggs in the first generation (March 1977), 129 in the second generation (April 1977) and 103 in the third generation (July 1977). Of these seeds only such seeds wherein egg was observed to hatch and the resulting grub bore into the seed successfully on the same day were pooled and used for further studies. Each day three seeds were dissected carefully and the stage or instar of the larva present inside the seed was fixed based on the number of castings of head capsules present.

The process was continued till dissection showed only pupal stages. Later emergence of adults were observed from the same stock and pupal period was determined.

Several other methods were tried, in vain to establish the number of instars and their duration. They were: (i) releasing different instars of the grub in flour of red gram seed, (ii) cutting the red gram seed into two halves, making a small scoop, releasing the grub in the grove and tying the two halves together, and (iii) seeds so scooped after releasing the grub were glued to the bottom of petridish so that the activity of the larvae could be observed.

The feeding behaviour of adult, mating and duration of mating, pre-oviposition period, oviposition behaviour, fecundity were determined.

The field biology of C. chinensis was studied on potted red gram plants in glass house. The infloresecence with green to mature pods were caged by using cylindrical plastic tubes of 3" diameter. The open end at the bottom was stoppered with synthetic pith such that it held the infloresecence in position as well as prevented the adult from escaping. The upper open end was covered with thin muslin cloth (Fig.1) for aeration. A pair of newly emerged C. chinensis was enclosed in each cage. Insects were removed the next day and the number of eggs laid was recorded. Incubation period and total larval-pupal developmental period as well as the fecundity of adult female under field conditions were determined.

Fig.1 Cylindrical plastic tubes used to cage green to mature pods under glass house conditions

Fig.2a Cloth cages with polythene windows used for enclosing C. chinensis on red gram plants

Fig.2b Close-up of the cloth cage as shown in 2a

Fig.1

Fig.2a

Fig.2b

Similarly, in red gram fields cloth cages with polythene windows fitted on to a frame made out of G.I. wire were used to enclose the red gram plants (Fig.2a, 2b). Into each cage a known number of newly emerged pairs of C. chinensis were introduced for the purpose of egg laying. Next day the adults were removed and the number of eggs laid on different stages of the pods was recorded. Individual pods were numbered. Observations on the hatching and boring into the pods of redgram were made.

When completely dry (nearing harvest), the plants were removed. Later the pods were collected and shelled individually. The seeds were glued on to the paper strip in the same order as they were found inside the pod. These were enclosed in small round plastic boxes of (2" x 2") (Fig.3). The observations on the emergence and number of adults emerging were also made regularly. Based on the above data the incubation period and total developmental period and sex ratio were determined.

Studies on Comparative Development of *C. chinensis* and *C. maculatus*

Day old females and males were enclosed with seeds of Bengal gram (var.Annigeri), black gram (var.KH_3), cow pea (var. local), field bean (var. local), field bean (var. Hebbal Avare-3), horse gram (var. local), red gram (var. S_5) and soybbean (var. Hardee) for the purpose of egg laying in small petridish, only one egg on each seed was retained. The development of *C. chinensis* and *C. maculatus* was studied and compared in each of the above eight pulse seeds.

Fig.3 Seeds glued on to paper strip and enclosed in small round plastic box for emergence of adult *C. chinensis*

Fig.4a Device used to study the effect of light on oviposition trend of *C. chinensis*

Fig.4b Devise used to study the effect of light on oviposition trend of *C. chinensis*

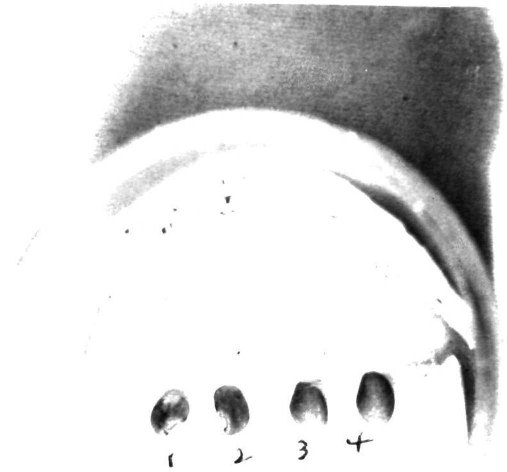


Fig.3

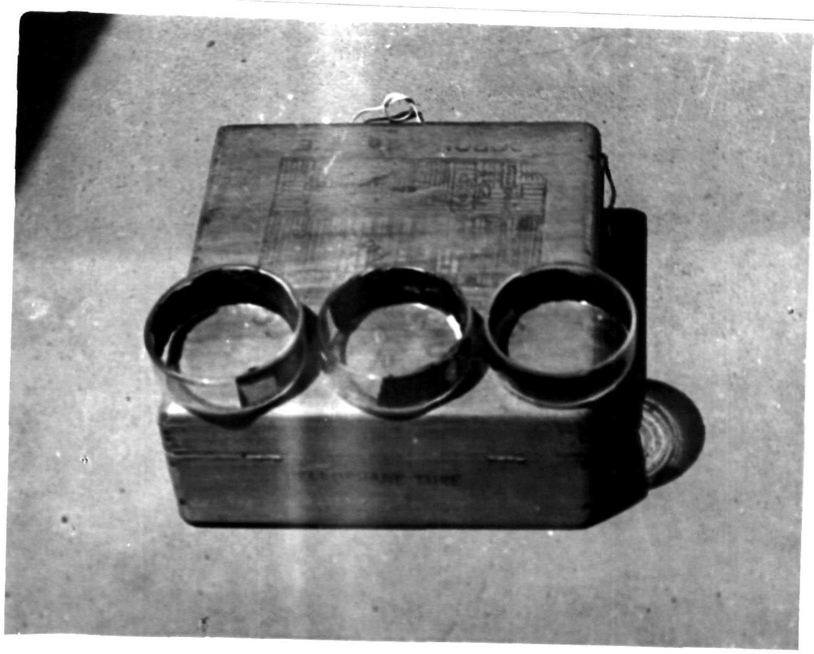


Fig.4a

Fig.4b

Ecology

Effect of light on the oviposition trend:

The object of this experiment was to find out whether light had any positive or negative influence on egg deposition. For this 60 red gram seeds were taken in three separate groups of 20 seeds each. Each group of 20 seeds were arranged in 3 to 4 alternate rows and glued to a common black paper strip with space in between. Three types of lighting (namely, directly above the seeds and lighting the sides of the seeds) were allowed on the seeds by appropriately blackening the bottom and side surfaces of petridish and placing the latter inversely over respective groups. The extreme two groups of seeds were covered with petridishes the bottom of which was completely blackened with a black paper. Further, three quarter of the side was darkened with one quarter remaining open through which the light could enter (Fig.4a). The dishes were placed inversely over the seeds. The open sides of the dishes were kept opposed facing the light source. The middle group of 20 seeds was inversely covered with petridish whose sides were only completely blackened and the bottom kept open for the entry of light. A 3-volt bulb constituted the light source. This was placed over the middle petridish (Fig.4b). A pair of C. chinensis each were released on to the three groups of seeds and the entire lot was kept enclosed in a wooden box, whose inside surface was also darkened. It was under observation for a duration of six hours, at the end of which the number of eggs laid on the shaded and lighted surface of the seeds was recorded. The experiment was repeated three times. Another experiment was also conducted in total darkness (with the light source removed). The number of eggs laid was recorded.

Influence of temperature and relative humidity on certain biological parameters of C. chinensis:

Three biological parameters namely, percentage of hatching speed of development and sex ratio of C. chinensis under the influence of four temperature levels of 10, 20, 30 and 40°C, each of them at relative humidity of 33, 55 and 80 per cent were studied. Temperature cabinets were used to maintain the desired temperature levels. Saturated solutions of salts namely, magnesium chloride, glucose and anhydrous ammonium sulphate were used in desiccators (6" diameter) to obtain 30, 55 and 80 per cent (±1 per cent) relative humidity respectively (Winston and Bates, 1960) under all temperature levels. The seeds with one egg each laid on the same day per treatment were taken in petridish (2" x 1") and kept in desiccators. The experiment was replicated twice. Per cent hatching, total developmental period of male and female, and sex ratio were recorded. Another experiment to study the effect of temperature at 10°C and 40°C on the larva of C. chinensis was conducted concurrently. Seed containing hatched larva from the material used for the other experiment were subjected to above temperature levels. At the end of the experiment the seeds were split open and condition of the larva was noted.

Thermal constant of C. chinensis:

C. chinensis was reared at constant temperatures of 30 and 25°C and at constant relative humidity of 75 per cent and their total developmental period was recorded. Using the above data the temperature threshold of development of *C. chinensis* was determined as per the method described by Atwal and Bains (1974). The value of thermal constant was computed thus the total developmental period of *C. chinensis* at ambient temperature and 75 per cent relative humidity was studied during the period 7th July to 5th August 1977. The prevailing temperature during the period of study was recorded. From this, effective temperature for each day of development was computed and their summation (product of effective temperatures) gave the thermal constant.

Life-table Studies of *C. chinensis*:

A preliminary life-table of *C. chinensis* on red gram was studied during the period May/June/July 1977. As in the case of field biology studies, a number of newly emerged pairs of *C. chinensis* were enclosed for the purpose of egg laying on red gram plants in reproductive phase by using cloth cages (described earlier). Next day the beetles were removed and the number of eggs laid on different stages of the pod were recorded. The reproductive parts of red gram were categorized into eight groups namely, flower buds (upto 5.25th day), flowers (from 5.25th day to 6.25th day with a mean duration of one day), very tender pods (from 6.25th day to 15.25th day with a mean duration of 9.00 days, the seed not well developed inside), tender pods (from 15.25th to 20.25th day with a mean duration of 5 days, seeds developed inside), green pod (from

20.25th day to 26.75th day with a mean duration of 6.5 days, the pods being dark green and the pod coat appressed to the seed within), mature green pod (from 26.75th day to 35.25th day with a mean duration of 8.5 days, the pod coat shining light green in colour and appressed to the seed inside), yellow pods (from 35.25th day to 42.75th day, with a mean duration of 7.5 days, the pod coat yellow shining and appressed to seed inside), and dry pods (from 42.75th to 61.75th day with a mean duration of 19 days, the pod coat being completely dry, with gap between pod coat and the seed inside). The individual pods were numbered. Observations on hatching and boring into the pod of red gram, the number of first instar larvae that bored into the pod coat but could not reach the seed, date of emergence of adult and number of emerging adults were made. When no further adult emergence was seen, the seeds were carefully dissected for recording the number of dead larvae, pupae and adults inside the seed. The column headings proposed by Morris and Miller (1954) and Harcourt (1969) were used in the preparation of life-table.

x = age interval, egg, grub, pupa and adult.

lx = number alive at the beginning of the stage noted in the 'x' column.

dx = number dying within the age interval mentioned in the 'x' column.

dxf = mortality factor responsible for 'dx'.

100qx = percentage of mortality.

Sx = survival rate within the stage stated in 'x' column.

The contribution of successive developmental stages to the overall population trend and the key factors influencing the build up of the bruchid population were determined by following the method of Varley and Gradwell (1963, 1965).

<u>Testing Seeds of Different Pulse Crop Varieties for Their Relative Susceptibility to the Attack of Bruchids</u>

a) <u>Natural infestation</u>:

The studies on the relative susceptibility of varieties of different pulse crops namely, red gram (17), green gram (12), black gram (9), cow pea (10) and soy bean (4) were carried out during the months of April to July 1977. Test samples consisted of 50 g of seeds from each variety under each crop taken in wax coated ice cream cups. These uncovered cups were kept in specially made cupboard with wire mesh doors (Fig.5a, 5b and 5c) to prevent rodents from entering and causing damage. The experiment was replicated thrice.

b) <u>Forced infestation</u>:

The number of varieties of seeds and number of crops remained the same as in the earlier experiment except in case of green gram, cow pea and soy bean where the number of varieties was reduced by 2, 1 and 1 respectively because of non-availability. Red gram had one more variety added to the earlier lot. It was ensured that the seeds that were selected for testing were free from infestation. Three pairs of newly emerged <u>C. chinensis</u> were enclosed per cup, the mouth of which was covered with muslin cloth (Fig.6).

Fig.5a Testing for the relative susceptibility of different pulse seeds contained in paper cups to bruchid attack (allowed for natural infestation)

Fig.5b Testing for the relative susceptibility of different pulse seeds contained in paper cups to bruchid attack (allowed for natural infestation)

Fig.5c Close-up of 5a, 5b

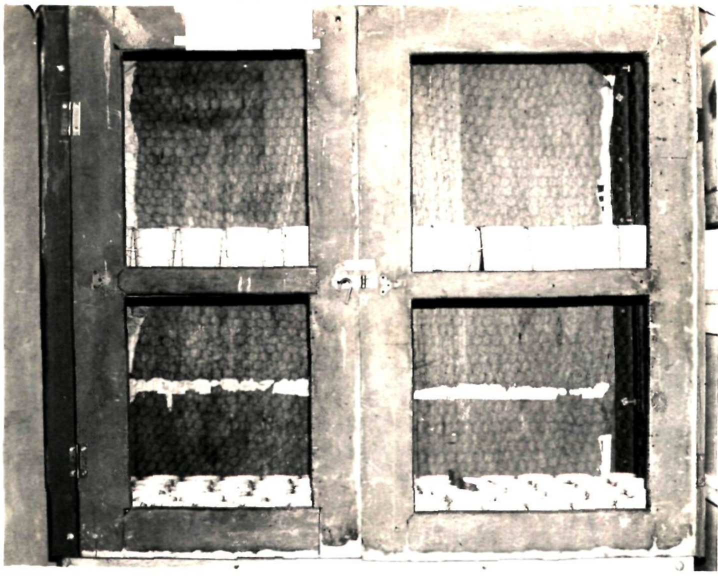


Fig.5a

Fig.5b

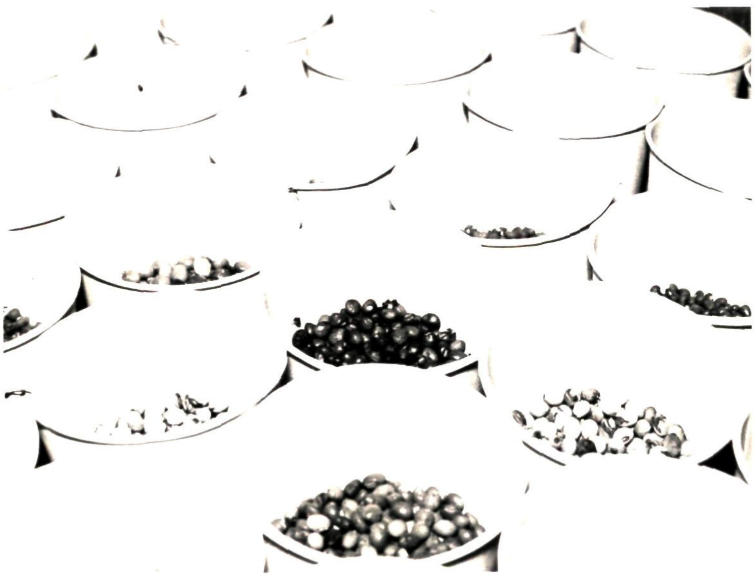


Fig.5c

Fig.6 Screening of different pulse crop varieties for susceptibility to the attack of *C. chinensis* beetles under artificial infestation

Fig.6

Observations on the following five parameters (i) number of eggs laid, (ii) percentage of infestation based on the number of seeds showing emergence holes, (iii) per cent weight loss in seeds, (iv) number of dead adults, and (v) per cent seed showing bruchid parasitization based on parasite emergence hole were made.

EXPERIMENTAL RESULTS

CHAPTER IV

EXPERIMENTAL RESULTS

Results of the investigations on the bruchid fauna, field infestation, seasonal incidence of pulse beetles in Karnataka, as well as on the biology, ecology and relative susceptibility of seeds of 52 varieties of five pulse crops, carried out during the period September 1976 through September 1977 are presented in the following pages.

Bruchid Fauna Infesting Pulse Crops and Their Distribution in Karnataka

The data pertaining to the survey for bruchid incidence in 10 districts of the State (six in southern region and four in northern region) are furnished in Table I and II. The survey brought to light the existence of five species of bruchid namely, *Callosobruchus chinensis* (Linnaeus), *C. theobromae* (Linnaeus), *C. maculatus* (Fabricius), *C. analis* (Fabricius), and an unidentified species. These were found associated with the following seven pulse crops, red gram (*Cajenus cajan* Linn.), green gram [*Vigna radiata* (L) Wilczek (*Phaseolus aureus* Roxb.)], cow pea[*V. unguiculata* (L.) Walp. Sub. sp. *Cylindrica* (L.) var. *Eseltine* (*V. sinensis* Linn.)], horse gram [*V. unguiculata* (L.) Walp. Sub. sp. *Unguiculata* (*Dolichos biflorus* Linn.)], field bean (*Lab-lab niger* Medikus), black gram [*V. mungo* (L.) Hepper, (*P. mungo* Linn.)] and soy bean (*Glycine max* Merr.) under cultivation in ten districts of the State surveyed.

Of the five species of bruchid, *C. chinensis* was widely

Table I. Field infestation by bruchids as recorded from field collected samples during November 1976 through February 1977 from different pulse growing areas of the State

District/ Place	Red gram		Green gram		Black gram		Horse gram		Cow pea		Field bean		Soy bean	
	Mean No. of bruchids for 100 seeds	Mean % of infestation	Mean No. of bruchids for 100 seeds	Mean % of infestation	Mean No. of bruchids for 100 seeds	Mean % of infestation	Mean No. of bruchids for 100 seeds	Mean % of infestation	Mean No. of bruchids for 100 seeds	Mean % of infestation	Mean No. of bruchids for 100 seeds	Mean % of infestation	Mean No. of bruchids for 100 seeds	Mean % of infestation
Bangalore:														
GKVK/Hebbal	0.55	0.55	1.26	1.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ramanagar	2.00	2.00	-	-	-	-	0.00	0.00	-	-	0.00	0.00	-	-
Nelamangala	1.75	1.75	-	-	-	-	-	-	0.00	0.00	0.00	0.00	-	-
Bellary:														
Bylour	0.33	0.33	-	-	-	-	-	-	-	-	-	-	-	-
Bidar:														
Humnabad	1.66	1.33	-	-	-	-	-	-	-	-	-	-	-	-
Chikmagalur:														
Kuntathimanahalli	0.00	0.00	-	-	-	-	-	-	1.00	1.00	-	-	-	-
Gulbarga:														
U.A.S. Farm	1.20	1.00	-	-	-	-	-	-	-	-	-	-	-	-
Hassan:														
Gollahalli	1.00	1.00	-	-	-	-	0.50	0.50	-	-	0.00	0.00	-	-
Yelvarae	2.00	1.66	-	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sadarhalli	-	-	-	-	-	-	0.00	0.00	0.00	0.00	3.00	1.00	-	-
Kolar:														
Robertsonpet	0.83	0.83	-	-	-	-	-	-	-	-	-	-	-	-
Mandya:														
V.C. Farm	-	-	-	-	-	-	-	-	0.50	0.50	-	-	-	-
Somanahalli	-	-	-	-	-	-	-	-	0.33	0.33	-	-	-	-
Raichur:														
R.R.S.	0.83	0.70	-	-	-	-	-	-	-	-	-	-	-	-
Tumkur:														
Gollahalli	5.00	3.33	-	-	-	-	-	-	-	-	2.00	2.00	-	-
Mean	1.04	0.90	1.26	1.26	0.00	0.00	0.05	0.05	0.18	0.18	0.55	0.33	0.00	0.00

Table II. Extent of field infestation of samples by different bruchids

District	Red gram				Green gram				Black gram			
	No. of samples	% infested samples by			No. of samples	% infested samples by			No. of samples	% infested samples by		
		bruchids	*C. c.*	*C. th.*		bruchids	*C. c.*	*C. th.*		bruchids	*C. c.*	*C. th.*
Bangalore	23	52.17	39.13	17.39	19	68.42	68.42	-	15	0.00	0.00	0.00
Bellary	3	33.33	33.33	-	-	-	-	-	-	-	-	-
Bidar	3	33.33	33.33	-	-	-	-	-	-	-	-	-
Chikmagalur	1	100.00	100.00	-	-	-	-	-	-	-	-	-
Gulbarga	5	100.00	60.00	40.00	-	-	-	-	-	-	-	-
Hassan	4	80.00	80.00	-	-	-	-	-	-	-	-	-
Kolar	6	66.66	50.00	16.66	-	-	-	-	-	-	-	-
Mandya	-	-	-	-	-	-	-	-	-	-	-	-
Raichur	37	35.13	21.89	16.21	-	-	-	-	-	-	-	-
Tumkur	3	66.66	66.66	-	-	-	-	-	-	-	-	-
Mean	85	49.41	34.11	17.64	19	68.42	68.42	-	15	0.00	0.00	0.00

C. c. = *Callosobruchus chinensis*

C. th. = *Callosobruchus theobromae*

Table II (Contd)

District	Horse gram				Cow pea				Field bean				Soy bean			
	No.of samples	% infested samples by			No.of samples	% infested samples by			No.of samples	% infested samples by			No.of samples	% infested samples by		
		bruchids	*C. c.*	*C. m.*		bruchids	*C. c.*	*C. m.*		bruchids	*C. c.*	*C. m.*		bruchids	*C. c.*	*C. m.*
Bangalore	9	0.00	0.00	0.00	3	0.00	0.00	0.00	5	0.00	0.00	0.00	6	0.00	0.00	0.00
Bellary	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bidar	-	-	-	-	--	-	-	-	-	-	-	-	-	-	-	-
Chikmagalur	-	-	-	-	1	100.00	100.00	0.00	-	-	-	-	-	-	-	-
Gulbarga	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hassan	9	11.11	11.11	0.00	5	0.00	0.00	0.00	3	33.33	33.33	0.00	7	0.00	0.00	0.00
Kolar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mandya	-	-	-	-	5	40.00	-	40.00	-	-	-	-	-	-	-	-
Raichur	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tumkur	-	-	-	-	2	0.00	0.00	0.00	1	100.00	-	100.00	-	-	-	-
Mean	18	5.55	5.55	0.00	16	18.75	6.25	12.50	9	22.22	11.11	11.11	13	0.00	0.00	0.00

C. c. = *Callosobruchus chinensis*

C. m. = *Callosobruchus maculatus*

distributed in nine districts. It was the dominant species in that it occurred in five out of seven crops, which included green gram (68.42 per cent of mean number of samples infested), red gram (34.11 per cent), field bean (11.11 per cent), cow pea (6.25 per cent) and horse gram (5.75 per cent) from nine districts of the State surveyed.

C. theobromae occupied the next position in the field infestation. It was observed to occur only on one crop - red gram (17.64 per cent) out of seven crops studied from four districts. The adult beetles were also collected in field wsweepings on red gram inflorescence in the districts of Bangalore, Raichur, Tumkur and Kolar.

C. maculatus was the third, and was recorded from cow pea (12.5 per cent) and field bean (11.11 per cent).

An unidentified bruchid was the fourth species encountered in the field. The adult beetles were collected in hand net sweepings over ground nut (*Arachis hypogaea*) (Raichur) and red gram (Raichur and Gulbarga). Incidence was more on ground nut than on red gram.

C. analis - None of the field samples collected from the standing crops as well as from threshing yards were infested by *C. analis*. Only the samples from stored green gram seed showed infestation by *C. analis*.

Field infestation:

Field infestation of bruchid (Table I) was maximun on green gram (1.26 per cent) followed by red gram (0.90 per cent), field bean (0.33 per cent), cow pea (0.18 per cent) and horse gram (0.05 per cent). On black gram and soy bean infestation was nil (zero per cent). The district-wise data pertaining to percentage of samples infested by different bruchid species are shown in Table II. The data on the percentage of samples of seven crops infested by bruchids showed that green gram samples carried maximum infestation (68.42 per cent), followed by red gram (49.41 per cent), field bean (22.22 per cent), cow pea (18.75 per cent) and horse gram (5.55 per cent), black gram and soy bean samples recorded no bruchid infestation.

In case of green gram, the infestation was caused only by *C. chinensis*. *C. chinensis* (34.11 per cent) and *C. theobromae* (17.64 per cent) shared the infestation in case of red gram samples. *C. chinensis* and *C. maculatus* infested samples constituted 11.11 and 11.11 per cent, respectively in field bean and 6.25 and 12.50 per cent, respectively in cow pea.

Taxonomy

Callosobruchus chinensis (Linnaeus): (Fig.7a, 7b)

Head medium sized, brown, posterior end broader; frons covered with setae, eyes bulbous and strongly emarginate. Antennae dark brown, 11 segmented, deeply pectinate in male and serrate in female.

Pronotum sub-conical, dark brown possess light brown setae,

Fig.7a *C. chinensis* (adult female)

Fig.7b *C. chinensis* (adult male)

Fig.8 *C. maculatus* (adult female)

Fig.7a

Fig.7b

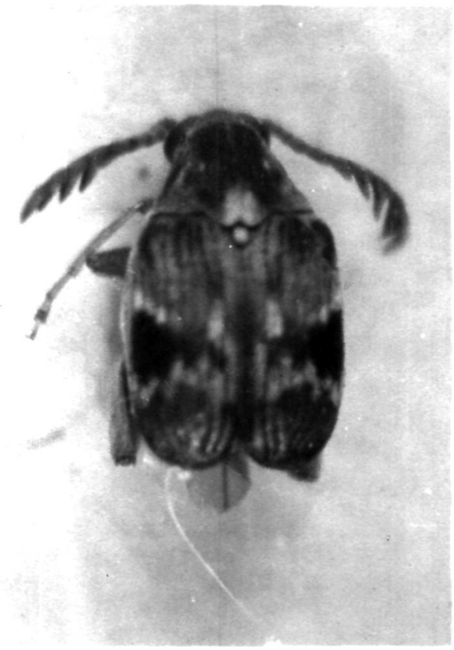


Fig.8

two median prominant callosities at the posterior region covered with white setae.

Scutellum square, with white setae. Elytra elongate, quadrangular rounded at apical margin, length twice the breadth, with reddish brown background intercepted by black space. Anterior half covered with reddish yellow seate, posterior portion with black setae, in between is a transverse bond of white setae, striae 10, pair of tubercles at the base of 3rd and 4th striae in male. Legs light to dark brown, hind femora bicarinate on interior margin, each carina with an apical spine, outer spine large and blunt inner spine narrow and pointed. Hind tibia produced into long pointed spiny projection at its apical end on the internal margin, a small spine at the apical outer end, between these two are two tiny spines on either side. Pygidium, in female oblique brown with a median row of white setae. Dull white and vertical in male.

Size - small:

Male - Length 3.32 to 3.40 mm (mean of 3.36 mm)
Breadth 1.88 to 1.92 mm (mean of 1.90 mm)

Female - Length 3.44 to 3.52 mm (mean of 3.48 mm)
Breadth 1.96 to 2.14 mm (mean of 2.10 mm)

Callosobruchus maculatus (Fabricius): (Fig.9)

Head big black covered with white setae, dense on frons. Eyes emarginate, antennae 11 segmented, serrate, longer in male and shorter in female.

Pronotum sub-conical, black with golden coloured setae which get denser towards posterior median callosites.

Scutellum quadrangular, possessing white setae. Elytra elongate, longer than breadth, ground colour black, dark brown to white setae arranged in a semicircle encircling the black area on each elytra seen prominently in female, faint in male whose elytra is testaceous with gold coloured setae. Seriae 10, legs dark brown with hind legs black. Hind femur bicarinate below, inner carina possess a narrow pointed tooth, while the outer carina bears a blunt tooth. Tibia at its inner apical end spine like, outer apical end blunt. Pygidium light brown (testaceous in male) becoming dark at its posterior lateral margin bears white setae, oblique in female and vertical in male.

Size - large:

Male	-	Length 3.32 to 3.40 mm (mean of 3.36 mm)
		Breadth 1.89 to 1.92 mm (mean of 1.90 mm)
Female	-	Length 3.44 to 3.52 mm (mean of 3.48 mm)
		Breadth 1.96 to 2.14 mm (mean of 2.10 mm)

<u>Callosobruchus</u> <u>analis</u> (Fabricius): (Fig.9)

Head small, dark brown, white setae on frons. Eyes emarginate separated by median longitudinal ridge. Antennae 11 segmented, testaceous and sub-serrate.

Pronotum sub-conical, dark brown with sparce short gold coloured

Fig.9 C. *analis* (adult)

Fig.10 C. *theobromae* (adult)

Fig.11 Unidentified bruchid (adult)

Fig.9

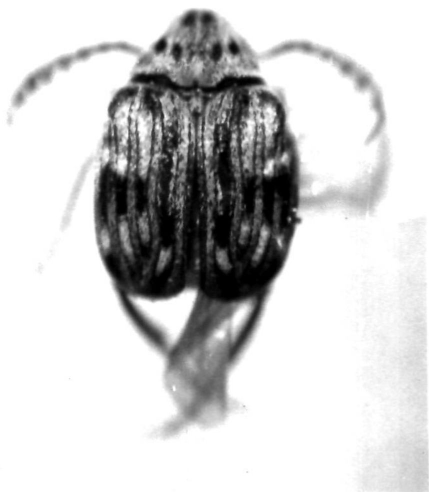


Fig.10

Fig.11

setae, posterior margin with a pair of median callosites possessing dense white setae.

Scutellum quadrangular with dense white setae, light brown. Elytra with black spot separated by a band of white setae, about twice longer than breadth. Striae 10 with striae 4 and 5 being short. Hind legs dark brown, the rest testaceous, femur bicarinate, each with sub-apical spines, inner spine short and pointed, outer spine longer and blunt. Tibia flattened, inner apical and drawn into a prominant process, outer apical end with a short spine, in between the two are present two short spines on either side. Pygidium black, oblique with median band of white setae, light brown and vertical in female.

Size - Medium:

Male	-	Length 3.01 to 3.42 mm (mean of 3.19 mm)
		Breadth 1.50 to 1.76 mm (mean of 1.64 mm)
Female	-	Length 3.32 to 3.62 mm (mean of 3.84 mm)
		Breadth 1.80 to 1.89 mm (mean of 1.84 mm)

__*Callosobruchus theobromae*__ (Linnaeus): (Fig.10)

Head medium, brown, sub-conical, possessing gold coloured setae. Longitudinal ridge between two eyes, eyes large emarginate covering most of the head region. Antennae testaceous, 11 segmented, thick long and serrate in male; short, narrow and sub-serrate in female.

Pronotum sub-conical, brown coloured with golden setae. Posterior margin possessing a pair of median callosites with dense golden coloured setae.

Scutellum quadrangular, longer than breadth bears white setae, elytra brown with black and white patches, striae 10 with a tubercle at base of 3 and 4 striae. Leg brown testaceous, hind femur bicarinate distally, inner carina apically possessing narrow pointed tooth, outer carina with short blunt process. Hind tibia drawn into a small process internally at its apex.

Pygidium brown uniformly covered with dense golden coloured setae, oblique in female and vertical in males.

Size - medium:

Male - Length 2.76 to 3.00 mm (mean of 2.90 mm)
Breadth 1.64 to 1.76 mm (mean of 1.71 mm)

Female - Length 3.23 to 3.44 mm (mean of 3.29 mm)
Breadth 1.72 to 1.97 mm (mean of 1.95 mm)

<u>Bruchus</u> sp. <u>(unidentified species)</u>: (Fig.11)

Head big, black frons carinate with white setae; eyes emarginate. Antennae 11 segmented, serrate, first five segments yellowish, segment 6 to 11 black. Pronotum, sub-conical, black sparsely covered with dull white setae. Posterior margin with two median callosites.

Scutellum quadrangular possess white setae. Elytra twice longer than breadth, black with dense small dull white setae, posterior end rounded, striae 10, striae 4, 5 and 6 shorter.

First and second pair of legs brown, hind legs black with white setae, hind femur slightly bicarinate distally, tibia flattened produced into apical inner spine. Pygidium, oblique, black covered with white setae. Size -

Size - very small: Length - 1.48 to 1.80 mm (mean of 1.65 mm),
Breadth - 0.88 to 1.00 mm (mean of 0.94 mm)

The bruchids encountered on pulse crops in Karnataka can be distinguished by using the following key:

1. Hind femur without a tooth on its outer side. General colour black with whitish pubescence. Small (length 1.48 to 1.80 mm; breadth 0.88 to 1.00 mm)
...............................*Bruchus* sp.

- Hind femur with a prominent tooth on its outer side. General colour variable, large beetles 2

2. Males with a tubercle on elytra at the base of 3rd and 4th striae 3

- Males without tubercles on the elytra 4

3. Antennae strongly dimorphic in sexes. Serrate in female and pectinate in male. Eyes strongly bulging
..........................*Callosobruchus chinensis*

- Antennae serrate in males and sub-serrate in female. Eyes moderately bulging. Ground colour of body pale yellow, black spots on elytra indistinctly separated from dull white setae around them. Pygidium with unicolourous setae.
...............................*C. theobromae*

4. A large acute tooth on inner carina of ventral edge of hind femur present. Colouration strongly sexually dimorphic. Lateral black spots on elytra bounded by white setae internally; anteriorly and posteriorly. White setae together forming in female 'C' shaped areas on each elytra. Pygidial median white setae present only in female .... *C. maculatus*

Tooth on inner carina of ventral edge of hind femur either small or absent. Male and females more or less similar lateral black spots on each elytron separated by a band of white setae. Pygidial median band of white setae present in both sexes.................. *C. analis*

Seasonal Incidence

The study which was confined to two species of bruchids namely *C. chinensis* and *C. theobromae*, on red gram was conducted at the Main Research Station (MRS), Hebbal during the main cropping season of September 1976 to January 1977 and from February to July 1977.

The data pertaining to the seasonal incidence studies are furnished in Table III. Throughout the period of study, *C. theobromae* had higher field incidence over *C. chinensis*. The lowest incidence of *C. theobromae* (0.83) was observed during the month of June 1977 and that of *C. chinensis* (0.00) in the month of September 1976. The highest incidence of *C. theobromae* (9.00) and *C. chinensis* (8.00) was recorded during January 1977.

Table III. Mean number of bruchids recorded on red gram during September 1976 through July 1977

Year	Month	Mean number of *Callosobruchus chinensis*	Mean number of *Callosobruchus theobromae*	Mean number of bruchids	Mean temperature (°C)	Mean relative humidity (per cent)
1976	September	0.00	1.50	1.50	24.63	76.20
1976	October	2.80	5.00	7.80	25.08	74.19
1976	November	3.25	3.75	7.00	23.08	79.50
1976	December	6.00	7.50	13.50	22.64	74.80
1977	January	8.00	9.00	17.00	22.89	63.10
1977	February	0.83	1.17	2.00	24.55	70.39
1977	March	2.00	1.17	3.17	27.20	56.65
1977	April	0.50	1.00	1.50	28.56	68.34
1977	May	-	-	-	-	-
1977	June	2.82	0.83	3.65	26.45	82.06
1977	July	1.12	3.90	5.02	24.66	79.36

- = Information not available

Mean combined incidence of *C. theobromae* and *C. chinensis* was observed to be low (1.50) during both September 1976 and April 1977. The combined bruchid incidence which was low during September 1976 (1.50) which incidentally was the period of commencement of flowering of the main crop rose during October 1976 (7.90) with a slight setback during November 1976 (7.00) followed by further increase during December 1976 (13.50) with the peak incidence in the month of January 1977 (17.00) which was incidentally the period of harvest. A similar trend was observed in respect of *C. theobromae* during the above period. However, *C. chinensis* deviated from the above trend in that the increasing incidence was gradual without any setback from September 1976 to January 1977.

The incidence during the remaining period from February to July 1977, fluctuated recording two small peaks in March 1977 (3.17) and July 1977 (5.02) in the case of combined bruchid incidence. However, a decreasing incidence of *C. theobromae* was seen during February 1977 to June 1977 (1.17 to 0.83) with a sudden rise during July 1977 (3.90) while *C. chinensis* exhibited a trend similar to that of combined incidence with two smaller peaks during March and June 1977 (2.00 and 2.82 respectively).

Studies revealed that the occurrence of *C. chinensis* and *C. theobromae* was negatively correlated to the temperature (-0.672 and -0.754 respectively) indicating that with the rise in temperature the incidence of both species of bruchids decreased and vice-versa. The correlation between relative humidity and bruchid incidence was not significant.

Life History of *C. chinensis*

The data on the developmental period of different stages of *C. chinensis* in red gram are provided in Table IV.

Egg:

The egg was ovoid, smooth, drawn almost to a point at the narrow end. Immediately before extrusion, the egg was in semisolid state. After deposition on the seed, the egg shell adjusted itself to the curvature of the seed with the result that the egg lost its convexity on the side which was in contact with the seed surface and became flat. Thus the egg assumed oval and plano-convex shape. Freshly laid egg was transparent and covered by a secretion with which it was glued on to the seed surface. The mother beetle after depositing the egg stayed covering the egg for 1 to 2 minutes till the secretion dried and the egg was fastened to the seed. The egg had a mean length of 0.56 mm (0.52 to 0.60 mm) and a mean breadth of 0.34 mm (0.30 to 0.36 mm).

Incubation:

The mean incubation period (Table IV), (from the day of egg laying to complete hatching and boring) under laboratory conditions ranged from 6.67 days on red gram during April to 9.17 days on green gram during January 1977. Eggs laid on the same host on different days of oviposition (Table IV) showed very little difference in the incubation period. However, mean incubation period differed markedly between eggs laid on different crops. Incubation period of eggs laid on green gram was 9.17 days and on red gram 6.67 to 7.53 days.

Table IV. <u>Incubation period of eggs of *C. chinensis* as recorded during different months under laboratory conditions</u>

(in days)

Day of oviposition	January 1977 Green gram	March 1977 Red gram	April 1977 Red gram	May 1977 Red gram
1st day	8.54	6.64	6.55	7.32
2nd day	7.72	7.08	6.67	7.74
3rd day	7.97	7.04	6.77	7.82
4th day	8.06	7.00	6.70	7.76
5th day	8.71	7.38	-	7.60
6th day	8.00	7.00	-	7.50
7th day	-	-	-	7.00
Gross mean	8.17	7.02	6.67	7.53
Mean temperature (°C)	22.89	27.20	28.56	27.98
Mean relative humidity (per cent)	63.10	56.65	68.34	78.80

In the field, the incubation period (Table V) ranged from 6.19 days (March 1977) to 6.48 days (April 1977) on red gram pods. Under glass house conditions with a mean temperature of 33.07°C and relative humidity of 71.77 per cent, the mean incubation period was found to be 7.95 days.

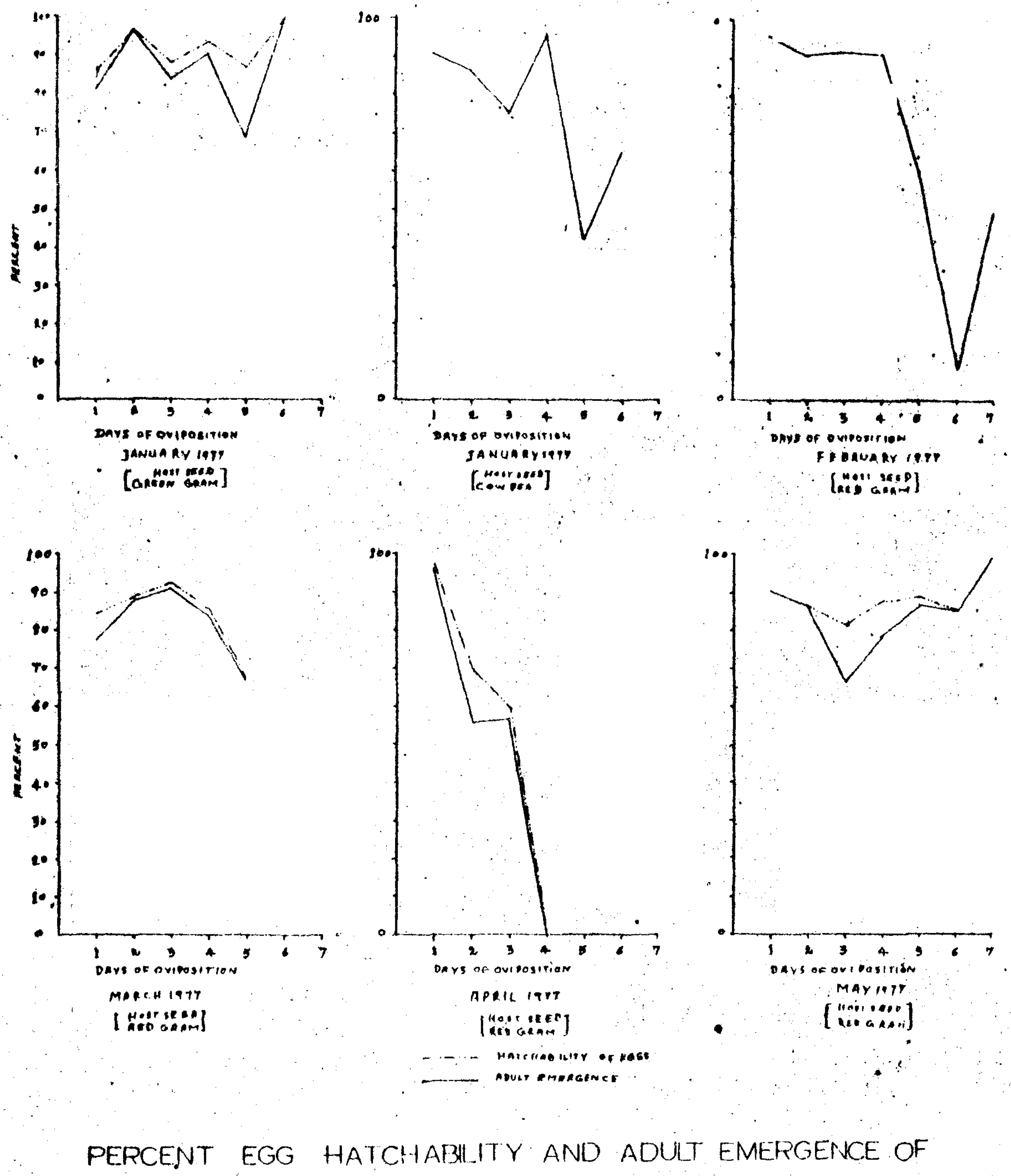
Hatchability:

The hatchability of eggs laid on different days of oviposition under laboratory were found to fluctuate without indicating any definite trend (Fig.12). The per cent hatching which was observed to be 86.67 (green gram) and 90.24 (red gram) for the egg laid on the first day of oviposition in January and May 1977 respectively registered an increase towards the last day of oviposition to 100 per cent. The trend was found reversed during March and April 1977 when per cent hatching of egg laid on red gram registered a decline from 85.00 and 97.67 (first day of oviposition) to 65.67 and 0.00 (last day of oviposition) per cent, respectively.

The contents of the one to two day old egg became granular and opaque except at the broader end. In the three day old eggs, the peristaltic movement of the developing larva with its ventral surface facing the seed was observed.

The larva emerged using its curved prothoracic plate as a fulcrum which helped to obtain grip against the broader end of the chorion. The scratching caused by the prothoracic plate was observed. It then bored into the seed through the egg shell. As the hatching and boring of larva progressed, the egg turned cream

FIG. 12.



PERCENT EGG HATCHABILITY AND ADULT EMERGENCE OF

C. CHINENSIS

Table V. Developmental period of *C. chinensis* in red gram under field conditions during January 1977 to August 1977

Particulars	Date of egg laying			
	27.1.77 (Glass house)	16.3.77 (Field)	19.4.77 (Field)	31.5.77 (Field)
Total number of eggs	64	285	45	327
Mean incubation period (days)	7.95	6.19	6.49	6.45
Mean total larval and pupal period (days)	53.55	30.81	29.52	25.07
Mean developmental period from egg to adult (days)	61.50	37.00	35.00	31.52
Number of adults:				
Male	2	15	1	54
Female	-	2	-	18
Adult emergence (per cent)	3.12	5.96	2.22	22.02
Mean temperature (°C)	33.07	27.87	26.70	24.29
Mean relative humidity (per cent)	71.77	96.22	49.60	94.42

coloured due to the accumulation of frass inside the egg shell.

Larva:

I instar: The hatched larva was a thick set grub, pale yellowish and opaque with clear annulations. The head was brown and clearly visible. The thoracic legs were represented by conical stumps. It possessed a pair of pro-thoracic plates. The emerging larva bored vertically into the seed for a short distance and soon after the first moult took a turn. Duration of first instar (Table VI) was 2 to 3, 1 to 3 and 1 to 4 days during March, April and July 1977, respectively. The length was 0.48 to 0.55 mm (mean 0.51 mm) while the breadth was 0.31 to 0.33 mm (mean 0.32 mm).

II instar: The larva resembled the first instar larva except for the size and absence of prothoracic plates. The head was not distinct but represented by the presence of mouth parts. The body was stout, curved with the thoracic region enlarged than the posterior end. The larva changed its path of boring from the vertical to horizontal path to avoid getting deeper into the seed. The duration was 2-3 days (March 1977), 3-4 days (April 1977), and 1-4 days (July 1977). The stage of the grub was determined by the presence of the head capsule sandwitched between the faecal pellets of the preceding and the present instars. The length was 0.76 to 0.84 mm (mean 0.80 mm) while the breadth was 0.56 to 0.60 mm (mean 0.57 mm).

III instar: The third instar larva did not differ much from the second instar except for the size. It took 2 to 4, 2, and 2 to 3

Table VI. Duration of different instars of C. chinensis under laboratory conditions on red gram

Stage of the insect	Day of commencement and completion from the date of egg laying	Duration (range)
Egg laying - 13th March 1977		
Incubation	7th day	7
I instar	8th day	2-4
II instar	9th - 11th day	2-3
III instar	12th - 14th day	2-4
IV instar	14th - 19th day	2-3
Pre-pupa	17th - 20th day	1-2
Pupa	19th - 29th day	2-9
Adult	22nd - 30th day	5-9
Egg laying - 7th April 1977		
Incubation	6th day	6
I instar	7th day	1-3
II instar	7th - 9th day	3-4
III instar	10th - 13th day	2
IV instar	12th - 15th day	2-3
Pre-pupa	15th - 17th day	1-2
Pupa	16th - 27th day	7
Adult	23rd - 28th day	6
Adult entered pupal stage on 19th April		
Egg laying - 7th July 1977		
Incubation	7th day	7
I instar	8th - 11th day	1-4
II instar	10th - 12th day	2-1
III instar	12th - 15th day	2-3
IV instar	16th - 20th day	4-5
Pre-pupa	20th - 22nd day	4-2
Pupa	22nd - 31st day	2-9
Adult	28th - 32nd day	6

days in March, April and July 1977, respectively, to complete its development. The presence of castings of head capsules of first and second moult (Fig.13) sandwitched by faecal pellets clearly established the stages of the grub. The length was 1.00 to 1.40 mm (mean 1.21 mm) while the breadth was 0.68 to 0.96 mm (mean 0.90 mm).

IV instar: Here too, except for the size, the fourth instar resembled the third instar larva in its morphology. The larval development lasted for 2 to 3, and 4 to 5 days in April and May, and July 1977 respectively. The stage of the grub was recognized by the presence of three castings of head capsules respectively of the first, second and third instars which were sandwitched between the faecal pellets of preceding and succeeding instars. The tunnelling caused by the feeding of the grub extended upto the seedcoat where the grub fed leaving a thin layer of testa appearing like a circular spot (window). Towards the end, the grub prepared an oval pupal chamber by compressing the faecal matter against the wall of the tunnel. Facing the circular spot (window) on the seed coat, the larva became inactive without feeding. The length was 1.84 to 3.40 mm (Mean 2.53 mm) and the breadth was 1.20 to 2.20 mm (mean 1.70 mm).

Prepupa:

The pre-pupa (Fig.14a, 14b) was quiescent. The body divisions were distinct. The abdominal portion was broader than the thoracic portion in comparison to larval stages. The stage occupied a period

Fig.13 *C. chinensis* larva showing castings of head capsules of first (a) and second (b) mouth sandwitched by faecal pallets and the mouth part of third instar grub (c)

Fig.14a Red gram seed cut open to show the pre-pupal stage of *C. chinensis* in its chamber - lateral view

Fig.14b Red gram seed cut open to show the pre-pupal stage of *C. chinensis* in its chamber - ventral view

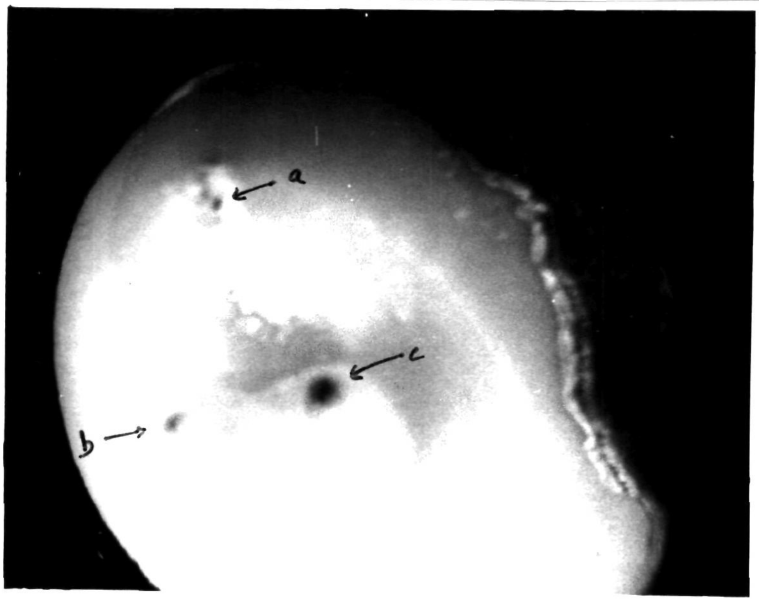


Fig.13

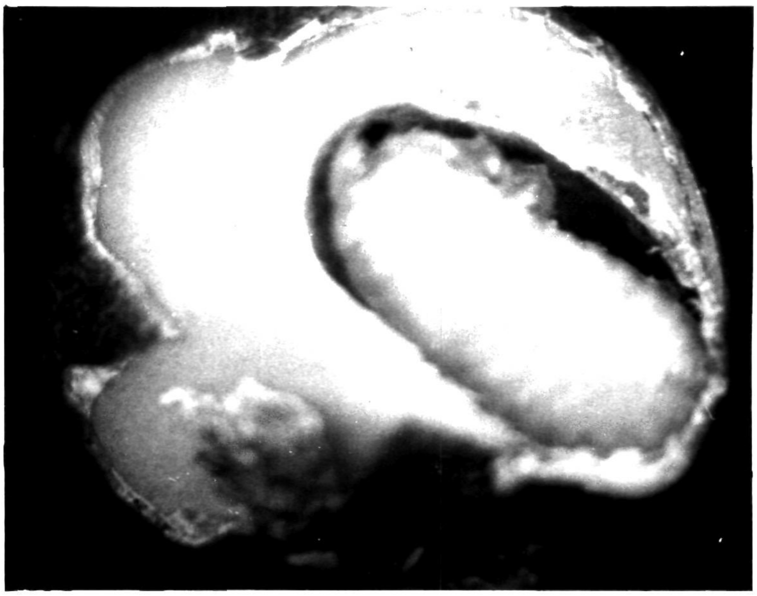


Fig.14a

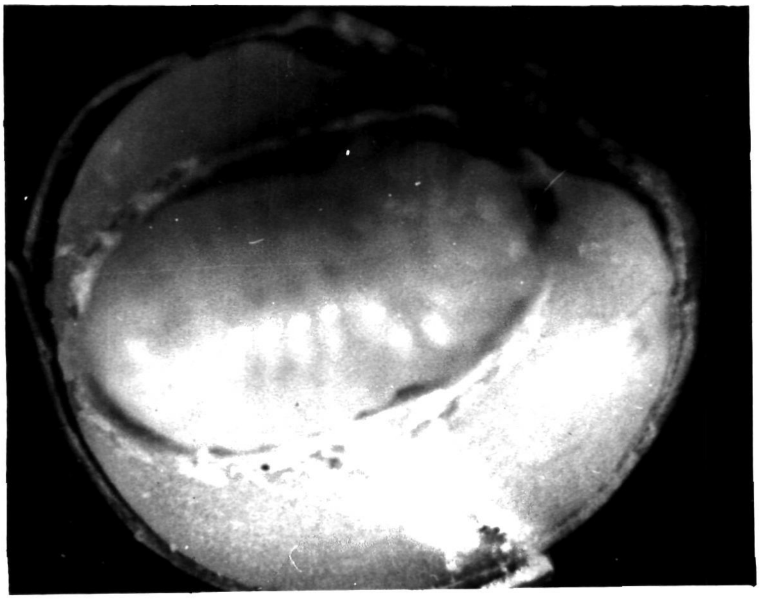


Fig.14b

of 1 to 2 days (April and May 1977) to 2 to 4 days (July 1977). The pre-pupa moulted into an exarate pupa. The length was 3.81 to 4.03 mm (mean 3.99 mm) and the breadth was 1.95 to 2.14 mm (mean 2.03 mm).

Pupa:

The pupa was light cream in colour. Though the appendages were free they were held close to the body (Fig.15a, 15b). The pupal stage occupied more than two days extending upto nine days. As the pupa aged, its colour changed from cream to dark brown, with the result the colour of the window also changed from light colour to dark. The colour change in the window was noticed only in certain seeds like green gram and horse gram and vaguely in case of red gram. The adult emerged by cutting all along the periphery of the window and pushing the circular lid outside. The length was 2.81 to 3.80 mm (mean 3.17 mm) and the breadth was 1.79 to 2.10 mm (mean 1.83 mm).

Under field conditions the adult was observed to emerge through the seed coat also by cutting a circular lid which remained attached to the pod coat at a point (Fig.16).

Total larval-pupal period:

The data pertaining to larval-pupal period are presented in Table VII. The mean larval-pupal developmental period (Table VII) as studied under laboratory conditions during January to June 1977 was shortest during April 1977 (17.95 days on red gram) and longest during January 1977 (23.67 days on green gram).

Fig.15a Red gram seed cut open to show the pupal stage of *C. chinensis* in pupal chamber - lateral view

Fig.15b Red gram seed cut open to show the pupal stage of *C. chinensis* in pupal chamber - ventral view

Fig.16 Red gram pods showing emergence holes of adult *C. chinensis* under field conditions

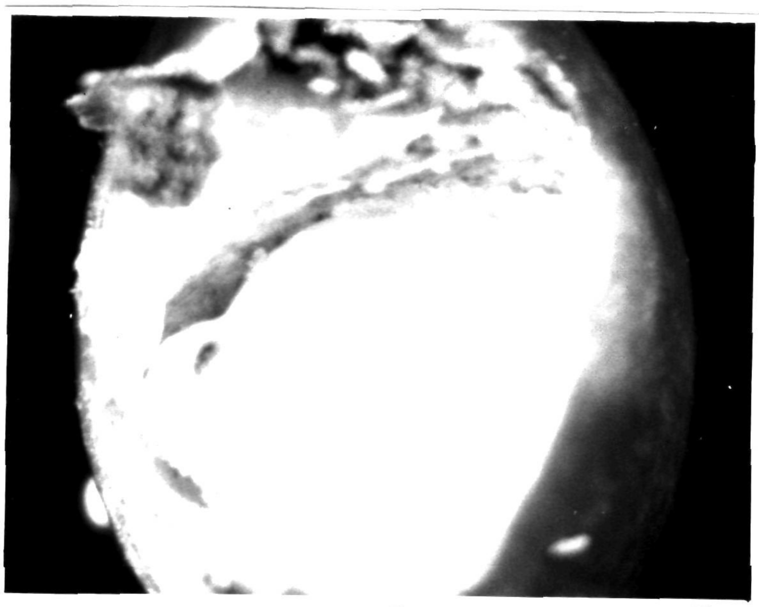


Fig.15a

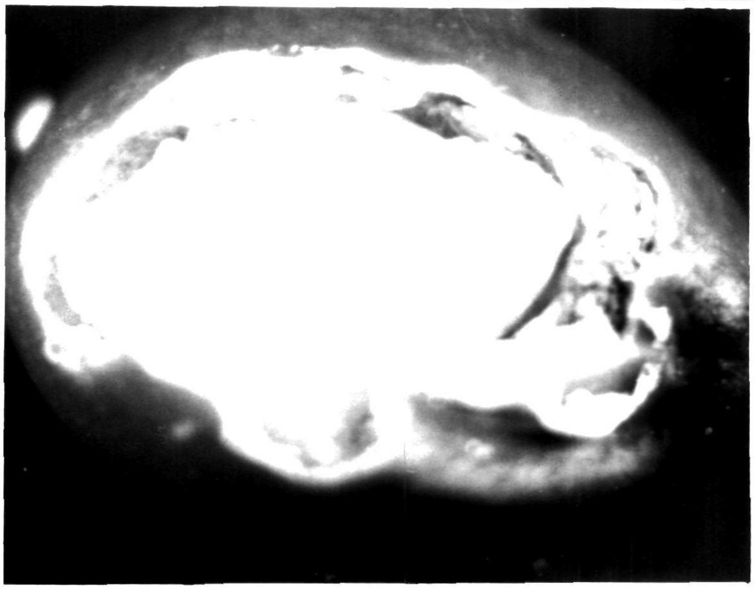


Fig.15b

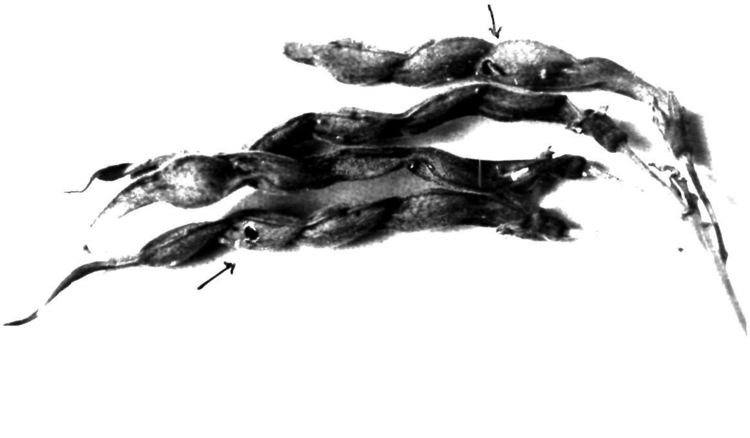


Fig.16

Table VII. Mean total larval and pupal period of *C. chinensis* as observed during different months under laboratory conditions

(in days)

Days of egg laying	January 1977 Green gram	March 1977 Red gram	April 1977 Red gram	May 1977 Red gram
1st day	23.77	19.33	17.78	17.56
2nd day	24.45	19.00	17.30	17.16
3rd day	23.82	18.73	18.81	17.31
4th day	24.00	19.93	-	17.64
5th day	24.02	18.38	-	19.24
6th day	22.00	-	-	19.50
7th day	-	-	-	19.00
Gross mean	23.67	19.18	17.95	18.20
Mean temperature (°C)	22.89	27.20	28.56	27.89
Mean relative humidity (per cent)	63.10	56.65	68.34	74.80

Under field conditions (Table V) mean larval-pupal period on red gram was observed to be short during June-July 1977 (25.07 days) and long during March-April 1977 (30.81 days).

Total developmental period:

The total developmental period from egg to adult was at its minimum during April 1977 when it recorded 24.62 mean number of days on red gram and was prolonged during June 1977 when it registered 29.75 mean number of days on the same host (Table VIII). The mean total developmental period on green gram and cow pea during January 1977 were 31.84 and 32.36 days respectively. In black gram (var. KH_3) (Fig.17) and field bean (var. Hebbal avare-3) (Fig.18) no larval development was observed since the grub fed very little and died on the day of hatching itself. In the case of soy bean (var. Hardee) the first instar larva lived upto six days. There was considerable amount of feeding (Fig.19). Nevertheless, it did not undergo the first moult and died prematuredly.

The study indicated a negative correlation between temperature and total developmental period ($r = -0.956$) significant at 2 per cent level. The correlation between relative humidity and total biology was not significant.

In the field (Table V) the shortest mean total developmental period of 31.52 days was observed during May/June 1977 and the longest period of 37.00 days during March/April 1977. Under glass house conditions (Table V) which had a mean temperature of 33.07°C and relative humidity of 71.77 per cent, the period was extended to its maximum of 61.50 days.

Fig.17 Black gram (var. KH_3) seed (cut open) showing dead first instar grub and depth of larval boring

Fig.18 Field bean (var. Hebbal Avare-3) seed (cut open) showing the dead first instar grub and depth of larval boring

Fig.19 Soy bean (var. Hardee) seed (cut open) showing the depth of larval boring

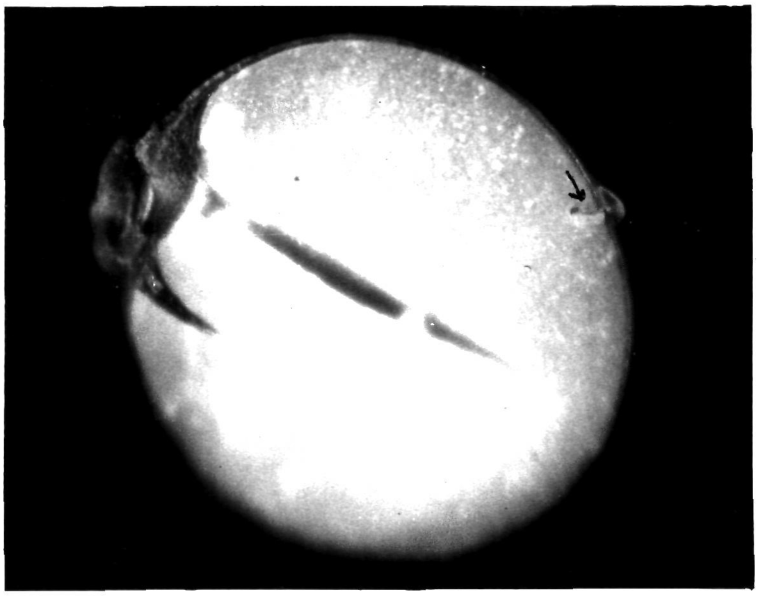


Fig.17

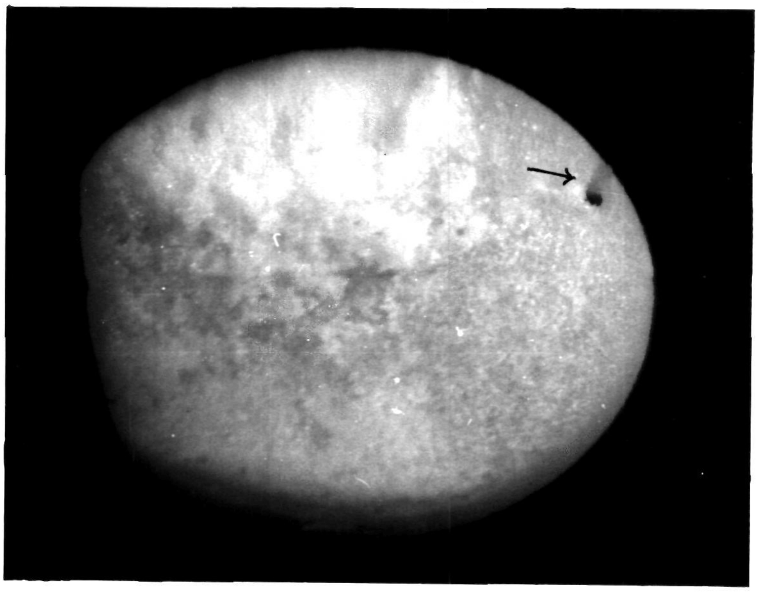


Fig.18

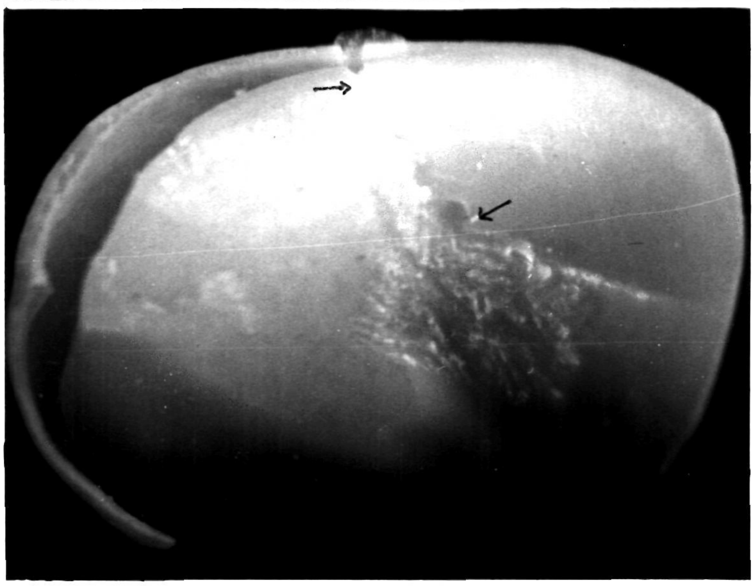


Fig.19

Table VIII. <u>Mean total life cycle of C. chinensis as determined during January to June 1977 on different pulse crops</u>

(in days)

Days of egg laying	January 77		February 77		March 77		April 77		May 77		June 77
	Green gram	Cow pea	Red gram	Black gram* (KH3)	Red gram	Black gram* (KH3)	Red gram	Field bean* (Hebbal avare-3)	Red gram	Soy bean (Hardee*)	Red gram
1st day	32.31	32.75	28.16	-	25.97	-	24.33	-	24.88	-	28-32
2nd day	32.17	32.94	27.71	-	26.08	-	23.97	-	24.90	-	-
3rd day	31.79	31.50	27.50	-	25.77	-	25.58	-	25.13	-	-
4th day	32.06	31.50	28.38	-	26.93	-	-	-	25.40	-	-
5th day	32.73	33.00	28.00	-	26.25	-	-	-	26.94	-	-
6th day	30.00	32.50	31.00	-	-	-	-	-	27.00	-	-
7th day	-	-	-	-	-	-	-	-	26.00	-	-
Gross mean	31.84	32.36	28.45	-	26.20	-	24.62	-	25.73	-	29.75
Mean temperature (°C)	23.52		26.13		27.93		28.08		27.91		24.29
Mean relative humidity (per cent)	67.57		59.12		64.04		69.21		74.03		80.19

<u>Note</u>: Mean temperature and mean relative humidity from the date of egg laying to completion of adult emergence

*Though egg laying was observed no adult emergence was recorded

Studies on the influence of the stage of the pod on total developmental period (Table IX) revealed that green pod favoured rapid development (27.50 mean number of days) as compared to yellow pods which stretched the period of development (34.50 mean number of days).

Adult emergence:

The adults did not have any difficulty in emerging out of the seed through the window which was made by the last instar grub. It was observed to make a circular cut along the peripheral margin of the window and then pushed the circular lid out. Adult emerged out through the opening.

Even the pupa exposed from the dissected seed, was observed to complete its development giving rise to adult successfully. The failure to complete, as seen in certain cases, was due to the mite infestation. The mean percentage of eggs successfully developing into adult varied in different host seeds (Fig.12). It ranged from 81.67 per cent (eggs laid on the first day) to 100.00 per cent (last day of egg laying) with a mean of 96.79 per cent in green gram during January 1977, 90.71 per cent (first day) to 66.67 per cent (last day) with a mean of 82.03 per cent in cow pea during January 1977; and 95.65 per cent (first day) during February 1977 to zero per cent (last day of oviposition) during March 1977 on red gram.

A general trend of decrease in the percentage of eggs developing into adult from the first day of oviposition towards the last day of oviposition was observed. However, increasing trend was

Table IX. Mean developmental period of different stages of *C. chinensis* as influenced by different stages of red gram pods in the field (in days) during June-July 1977

Stages of the pod	No. of eggs laid	Incubation period	Larval and pupal period	Total duration from egg to adult	% adult emergence
Tender	8	6.41	-	-	-
Green pod	42	6.33	21.17	27.50	23.31
Mature green pod	224	6.70	26.05	32.75	26.79
Yellow	31	6.50	28.00	34.50	6.45
Dry	22	-	-	-	-

also observed on green gram (January 1977) and red gram (May 1977).

Under field conditions, adult, after emerging out of the seed found itself in the space between the seed and pod coat in which the beetle made a circular cut and emerged, the emergent holes, being seen in the red gram pods (Fig.16). The percentage of eggs successfully developing into adults in the seeds of red gram pods varied from 2.22 to 22.02 (Table V). Among the eggs laid on different stages of red gram pods (Table IX), there was no adult emergence in the case of eggs laid on tender and dry pods. Eggs laid on green pods, mature pods and yellow pods respectively accounted for 23.31, 26.79 and 6.45 per cent adult emergence.

Mating and oviposition on the seeds inside the pod by the bruchids after their emergence from the seed and before their exit out of the pod, was not encountered during the course of the study.

<u>Sex ratio</u>:

The ratio of male to female under laboratory was observed to be equal during January/February, April/May and May/June 1977. The males were slightly prepondent over females during February/March (67 : 60.2) and March/April (47.5 : 36).

In the field, the male dominated over female (Table V) with a ratio of 2 : 0,7.5 : 1, 1 : 0 and 3 : 1 as recorded during January/February/March (glass house condition), March/April, April/May, and May/June/July 1977 months, respectively.

Adult feeding:

Study by confining adults on opened flowers of red gram showed no symptom of feeding.

Pre-mating period:

The mean pre-mating period was 45 min and 45 seconds with a range of 3 to 95 minutes.

Mating:

The emerging males were more active compared to female. After emergence, the male chased the female and made a number of attempts to mate. The females, all the while, avoided by pushing away the probing aedagus with its hind legs. After number of attempts, the male succeeded in mating with the females. In the process, the male climbed over the back of the female and established union. After a lapse of few seconds after establishment of the union, the males climbed down. Immediately the females tried to break the union by pushing away the aedagus with its hind legs in vain. The mating lasted for a mean period of 2 minutes and 32 seconds (2 minutes and 10 seconds to 3 minutes and 15 seconds). Repeated matings were observed among both sexes. Mating was observed both under lighted and dark conditions.

Pre-oviposition period:

The present study revealed a mean pre-oviposition period (between first mating and deposition of first egg) was 72 minutes and 12 seconds (19 minutes and 45 seconds to 129 minutes and 30 seconds).

Oviposition:

a) Egg laying trend: Though single egg per seed was common, deposition of more than one egg per seed was not uncommon as revealed in the present study wherein as many as three eggs per seed were recorded, inspite of the presence of seeds with out eggs. The trend seen under laboratory conditions was confirmed under field conditions too wherein the egg laying at single egg per pod to as many as six eggs confined to a small area per pod, the latter being 1 to 5 seeded (Fig.20a, 20b, 20c).

b) Egg laying trend as influenced by the stage of pod: The studies revealed (Table X) that maximum number of eggs (463) were found laid on mature green pods of red gram indicating that it was the most preferred stage of the pod for oviposition. This was followed by yellow pods (118 eggs) and green pod (105 eggs). Dry and tender pods proved to be less attractive to egg laying as revealed by 25 and 10 eggs laid on them respectively. Buds, flowers and very tender pods were never preferred for oviposition.

Fecundity:

The lowest mean fecundity of 42.62 egg was recorded during January 1977 and highest (83.00 eggs) during February 1977 under laboratory conditions (Fig.21).

Maximum mean daily egg laying was observed during the second day (23.07) followed by the first day (18.15) and the number of eggs laid gradually decreased till the last day of oviposition. Mean

Fig.20a Eggs of *C. chinensis* laid on red gram pods - dispersed

Fig.20b Eggs of *C. chinensis* laid on red gram pods - many eggs confined to a small area

Fig.20c Eggs of *C. chinensis* laid on red gram pods - hatched eggs

Fig.20a

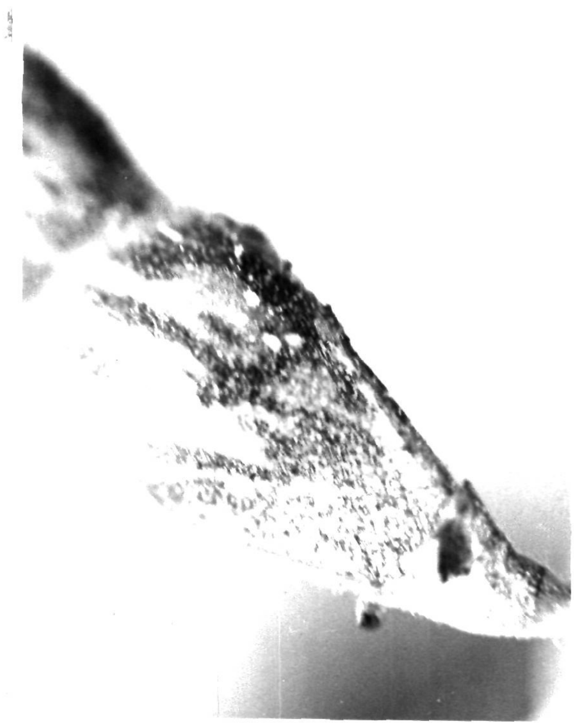
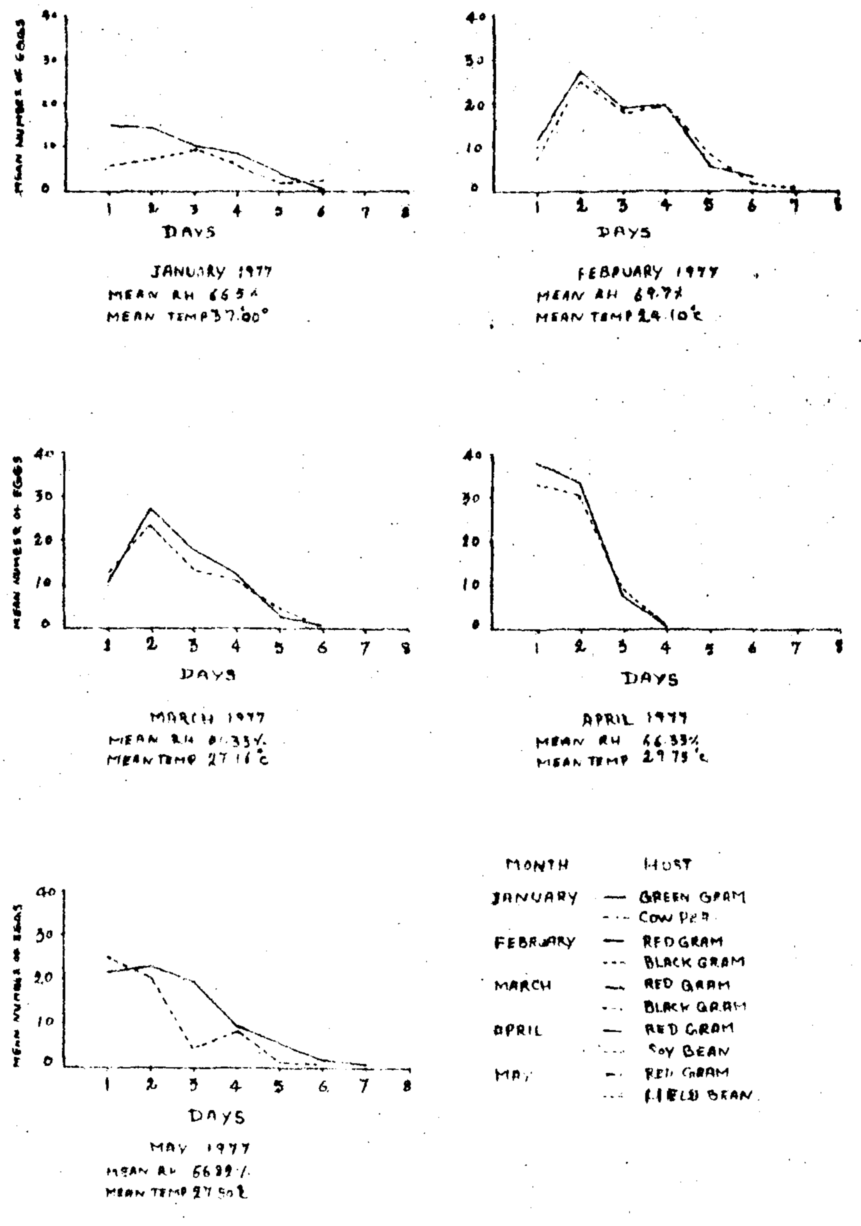


Fig.20b

Fig.20c

FIG. 21



PER DAY AND TOTAL FECUNDITY OF C. CHINENSIS AS RECORDED DURING DIFFERENT MONTHS

Table X. Ovipositional preference for different stages of red gram pods by C. chinensis

Stage of pod / Date of egg laying	Glass house 27.1.77	Field 16.3.77	Field 19.4.77	Field 31.5.77	Total No. of eggs laid
Tender pod	-	-	2	8	10
Green pod	16	44	3	42	105
Mature green pod	48	161	30	224	463
Yellow pod	-	79	8	31	118
Dry pod	-	1	2	22	25
Total	64	285	45	327	721

duration of egg laying ranged from 4 days in April to 7 days in February and May 1977.

The temperature and relative humidity prevailing during the experiment did not show significant correlation with the fecundity. Under field conditions, the fecundity was observed to range from 48 to 56 eggs per female with a mean of 52 eggs.

Adult longevity:

Longevity as observed under laboratory conditions (Fig.22) ranged from 5.00 to 9.00 days, with a mean of 7.27 days (males) and from 6.00 to 9.50 days with a mean of 7.30 days (females).

Hibernation:

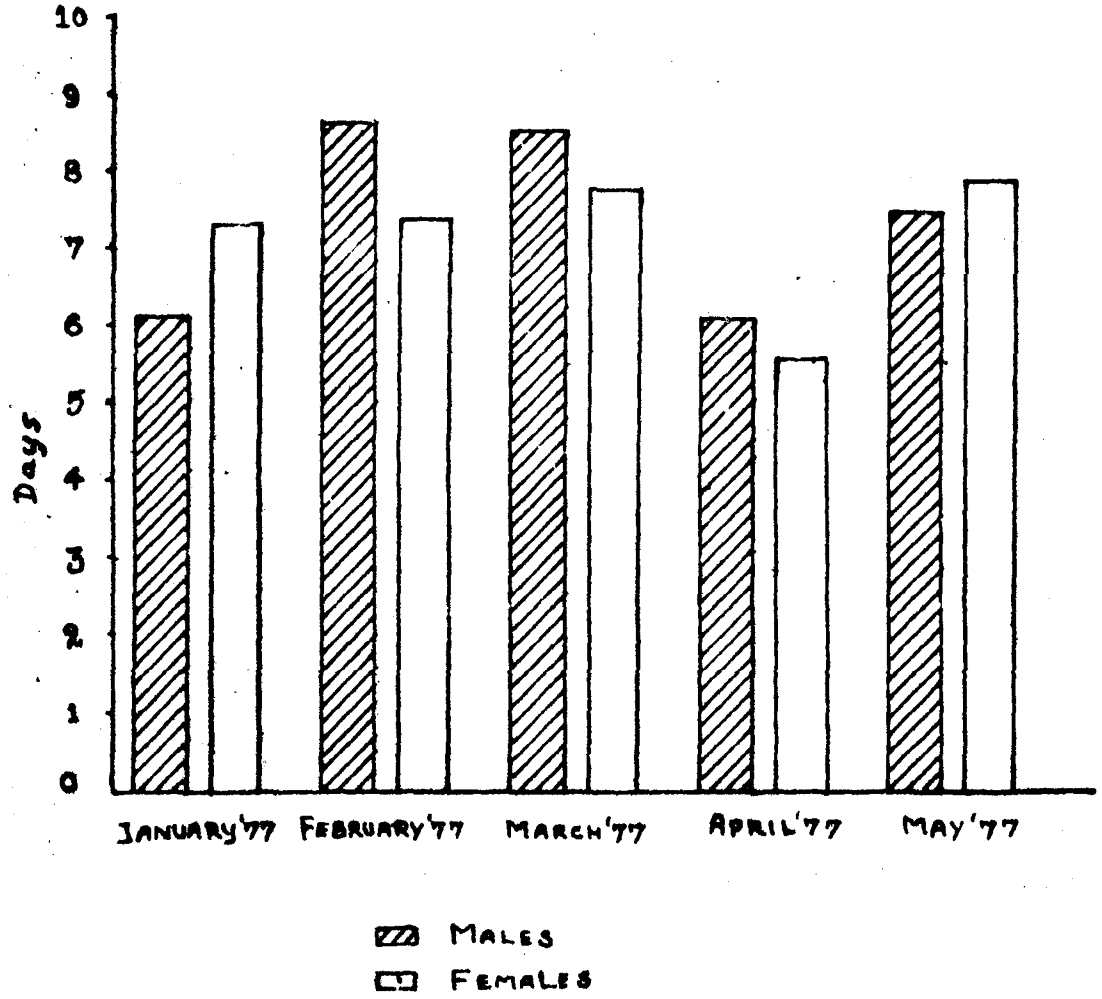
Larvae of *C. chinensis* were not observed to hibernate during the present investigation.

Natural enemies:

Three parasites which included two hymenopterous and one mite parasite were recorded on bruchids infesting pulse grains in the course of the present investigation.

Pyemotes ventricosus Newp. (Acari : Prostigmata - Pyemotidae) was found to be associated with the adult bruchids. The larvae, whenever found exposed, by lying outside the seed, were severely attacked by these mites (Fig.23a). The attack was confined to the inter-segmental regions (Fig.23b, 23c, 23) wherein they pierced their rostrum and sucked the body fluid. The infested larvae lost their shine on the body, shrivelled and died. As the feeding by

FIG. 22



MEAN LONGIVITY OF MALE AND FEMALE

C. CHINENSIS

Fig.23a Larval of _C. chinensis_ (when found exposed) attacked by _Pyemotes ventricosus_ a parasitic mite

Fig.23b Attack of female _P. ventricosus_ being confined to intersegmental regions of the larva of _C. chinensis_

Fig.23c Close-up of 23b

Fig.23a

Fig.23b

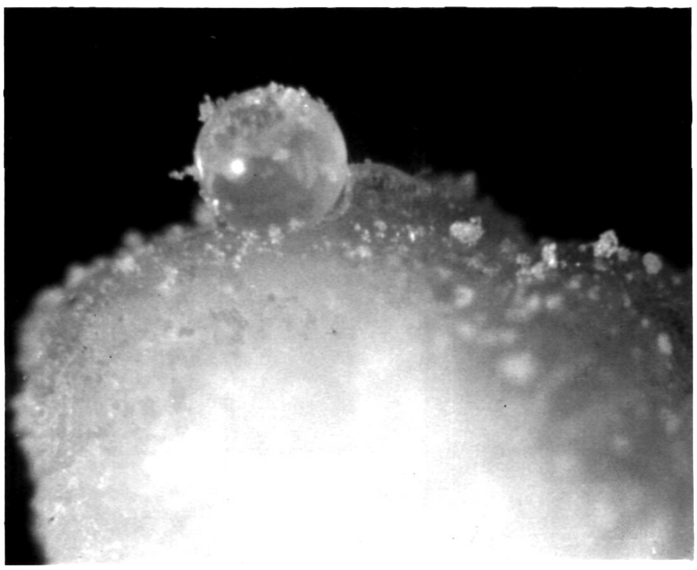


Fig.23c

female parasite mite progressed, its abdomen got enlarged giving an appearance of root-knot nematode (Fig.23d). Mites were always observed outside the seed and never inside.

Dinarmus vagabundus (Timberlake) (Hymenoptera : Pteromalidae) was a larval parasite of considerable importance under laboratory conditions. The female oviposited by drilling (Fig.24) into the seed with the help of its ovipositor. The eggs were deposited inside the host body. The adult parasite after emerging from the host, came out of the seed through tiny holes. Seeds with tiny holes were indicative of the parasitisation of bruchid larva inside the seed. On such seeds, the holes caused by emerging adult bruchid were not seen. Four to six adult parasites were observed to emerge from a single parasitized bruchid larva and these emerged out of the seed through a single hole. It was also observed that the number of tiny holes on seeds corresponded to the number of bruchid larvae parasitized.

Eupelmid parasite: Two eupelmid adult parasites were observed while dissecting the seeds contained in red gram pods brought from field (Fig.22). Later incidence of this parasite was not noted. The parasitized bruchid larva in the dissected seed was found shrivelled and dead.

Studies on the Comparative Development of *C. chinensis* and *C. maculatus*

Studies on the comparative development of *C. chinensis* and *C. maculatus* in Bengal gram (var. Annigeri), black gram (var. KH_3),

Fig.23d *P. ventricosus* (gravid female)

Fig.24 *Dinarmus vagabundus* (female) ovipositing by drilling on infested red gram seed

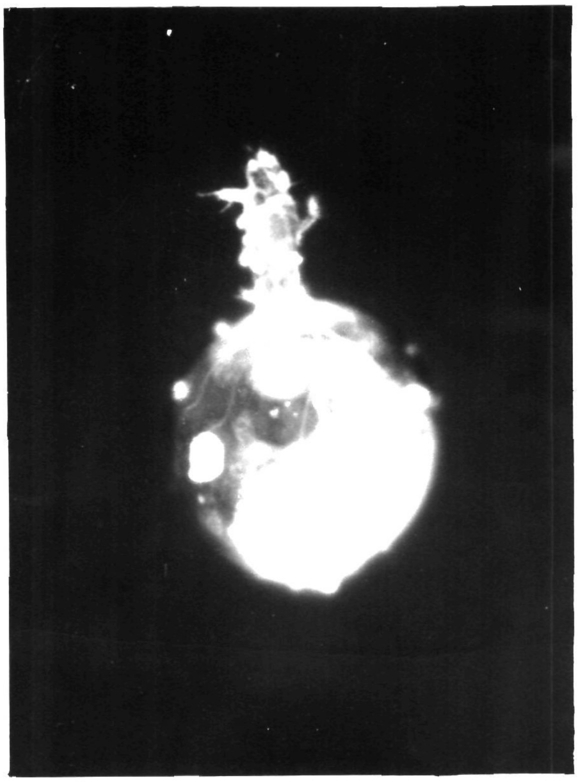


Fig.23d

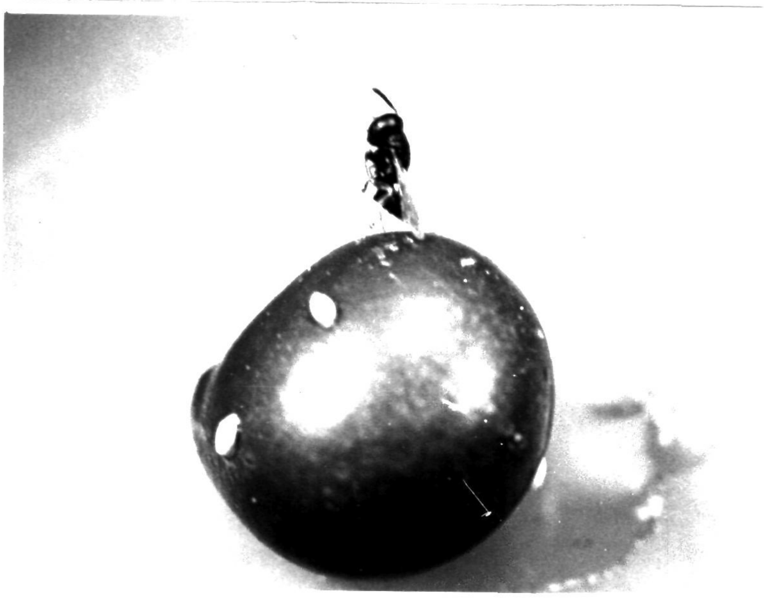


Fig.24

cow pea (var. local), field bean (var. local), field bean (var. Hebbal Arvae-3), horse gram (var. local), red gram (var. S_8) and soy bean (var. Hardee) seeds revealed that C. chinensis could complete its development in five (Bengal gram, horse gram, field bean (var. local), cow pea and red gram) out of eight pulse seeds. (Table XI). The mean total developmental period of C. chinensis ranged from a minimum of 28.74 days (cow pea) to a maximum of 34.00 days (field bean). The first instar larva was found dead on the first day of hatching and boring into the seed in the case of black gram (var. KH_3) and field bean (var. Hebbal Avare-3) while the duration of first instar was prolonged upto six days and was observed to die before moulting in seeds of soy bean (var. Hardee). On the contrary C. maculatus was observed to develop in seven out of eight species of pulse seeds, and completed its entire development in a minimum period of 32 days (cow pea) and a maximum period of 58.22 days field bean (var. Hebbal Avare-3). On horse gram, C. maculatus failed to lay eggs. Both the species were able to complete their development in respect of Bengal gram, field bean (var. local), cow pea and red gram.

Ecology Studies

Effect of light on the oviposition trend of C. chinensis

The study revealed that the adults were attracted to light. But females preferred to lay eggs on the darker or the shaded surface of the seed. In the experiment, 84.86 per cent of eggs were found laid on the darker surface of the seed while lighted surface recorded

Table XI. Comparative development of *C. chinensis* and *C. maculatus* on eight hosts (pulse) seeds

Host	Mean number of days	
	C. chinensis	*C. maculatus*
Bengal gram (var. Annigeri)	31.45	38.00
Black gram (var. KH_3)	Egg laying, hatching were observed without any further development	34.76
Cow pea (var. Local)	28.74	32.00
Field bean (var. Hebbal avare-3)	Egg laying, hatching were observed without any further development	58.22
Field bean (var. Local)	34.00	45.00
Horse gram (var. Local)	31.52	Egg laying not observed
Red gram (var. S_5)	31.90	36.00
Soy bean (var. Hardee)	Egg laying, hatching were observed without any further development	57.22

15.13 per cent eggs (Table XII). When seeds and beetles of both sexes were enclosed under complete darkness egg laying was seen all over the surface of the seed without any discrimination.

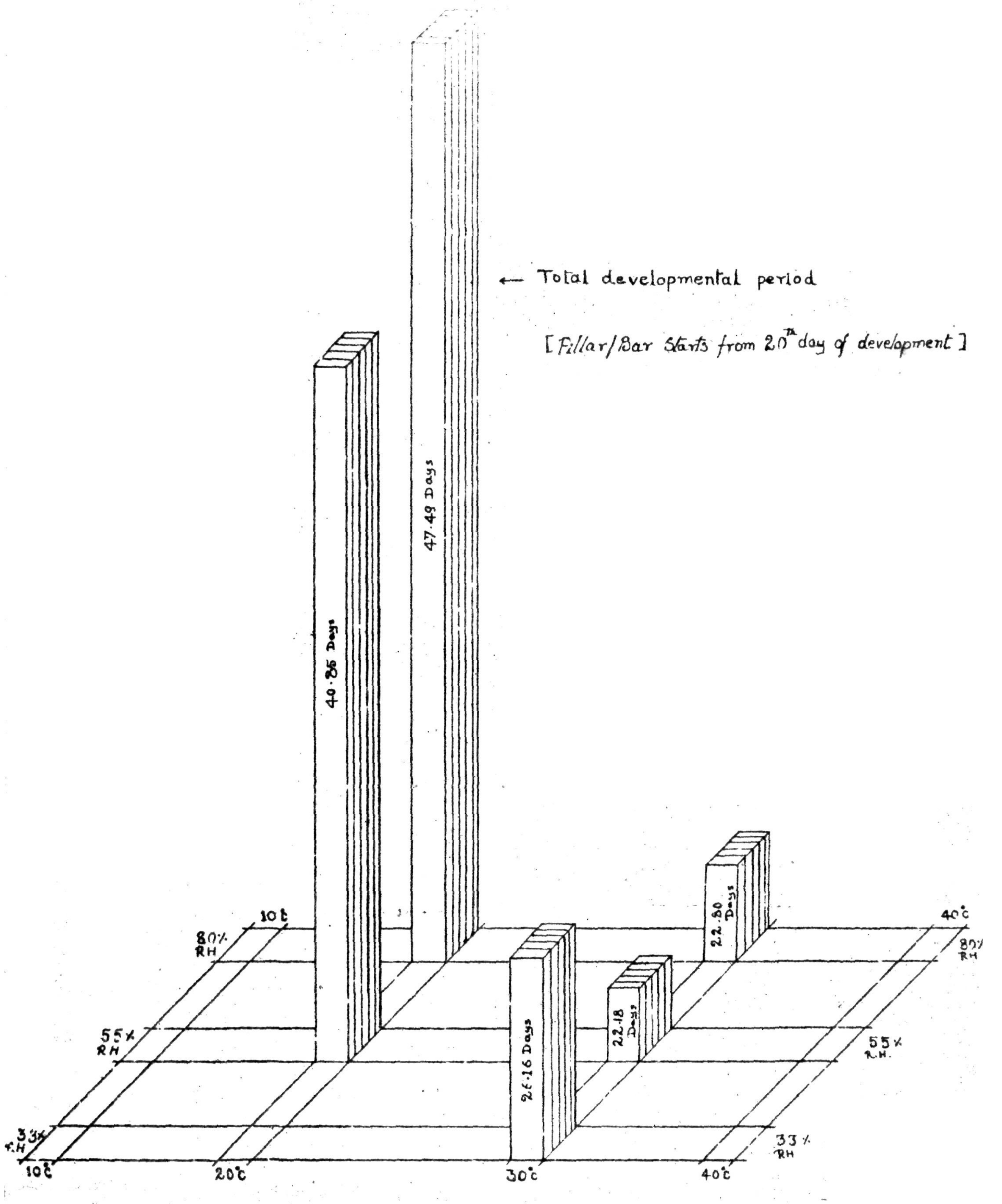
Influence of temperature and relative humidity on certain biological parameters of *C. chinensis*:

The development of *C. chinensis* was studied at constant temperature of 10, 20, 30 and 40°C each at 33 (± 1 per cent), 55 (± 1 per cent) and 80 (± 1 per cent) per cent relative humidities. Results of the experiment are given in Fig.25.

No embryonic development was observed at 10°C even after a lapse of 15 days from the date of egg laying under all three humidity levels. A few of the eggs from the same batch along with the seeds which bore them, when kept at ambient temperature, showed embryonic development.

No hatching of eggs was observed at 20°C and 33 per cent relative humidity. Under other two humidity levels of 55 and 80 per cent hatching was observed to the extent of 65 and 30 per cent respectively(Table XIIIa). The mean developmental period of male (Table XIIIb) was 41.9 and 47.0 days and that of female was 39.5 and 48.25 days at 55 and 80 per cent relative humidity, respectively. The mean total developmental period (both sexes) ranged from 40.85 days at 55 per cent relative humidity to 47.49 days at 80 per cent relative humidity (Fig.25). The sex ratio of male to female was 2 : 1.25 (55 per cent relative humidity) and 1 : 1 (80 per cent relative humidity) (Table XIIIc).

FIG 25



EFFECT OF DIFFERENT TEMPERATURE AND HUMIDITY LEVELS ON THE TOTAL DEVELOPMENTAL PERIOD OF C. CHINENSIS IN RED GRAM SEEDS

Table XII. Effect of light on the oviposition trend of *C. chinensis*

Lighting	Per cent of egg laid on: Darker surface	Per cent of egg laid on: Lighted surface
a) Left side of the light	85.30	14.70
b) Centre right below the light	89.29	10.71
c) Right side of the light	80.00	20.00
Mean	84.86	15.13

Table XIIIa. Per cent hatchability and survival of *C. chinensis* as influenced by different levels of temperature and relative humidity

Relative humidity (per cent)	Temperature (°C) 10	20	30	40
33	0.00	0.00	60.00	0.00
55	0.00	65.00	70.00	0.00
80	0.00	30.00	50.00	0.00

Table XIIIb. Mean developmental period of *C. chinensis* as influenced by different levels of temperature and relative humidity

(in days)

Relative humidity (per cent)	Temperature (°C) 10		20		30		40	
	Male	Female	Male	Female	Male	Female	Male	Female
33	-	-	-	-	26.5	26.75	-	-
55	-	-	41.9	39.5	21.8	23.16	-	-
80	-	-	47.0	49.25	22.5	23.25	--	-

Table XIIIc. Sex-ratio of male to female of *C. chinensis* as influenced by different levels of temperature and relative humidity

Relative humidity (per cent)	Temperature (°C) 10	20	30	40
33	-	-	1:1	-
55	-	2:1.25	2.5:1.0	-
80	-	1:1	1:1	-

Insect developed normally at all levels of relative humidity at 30°C. The percentage of hatching was 60, 70 and 50 at humidity levels of 33, 55 and 90 per cent respectively (Table XIIIa). The mean developmental periods of male and female at 33, 55 and 90 per cent relative humidity were 26.5 and 26.75, 21.8 and 23.16 and 22.5 and 23.25 days, respectively (Table XIIIb). The mean total developmental period (both sexes) lasted for 26.16, 22.19 and 22.90 days at relative humidity of 33, 55 and 90 per cent, respectively. Temperature of 30°C and relative humidity of 55 per cent which recorded the minimum developmental period of 22.19 days were the most optimum, followed by 30°C and 90 per cent relative humidity (22.90). Sex ratio of male to female was equal at relative humidity of 33 and 90 per cent whereas it was 2.5 : 1 at 55 per cent relative humidity (Table XIIIc).

At 40°C the eggs turned to transparent yellow with a depression on the top broader end at all humidity levels. Most of the eggs were found partially detached from the seed surface at relative humidity of 30 and 55 per cent. No embryonic development was observed at all levels of humidity at 40°C and also eggs from the same batch when exposed to ambient temperature.

The experiment conducted concurrently to study the effect of 10°C and 40°C each with three levels of 33, 55 and 90 per cent relative humidity on the larval stages revealed that larvae could not survive and died under both these temperatures.

Thermal constant of *C. chinensis*:

The mean developmental period from egg to adult was 25.16, 28.94 and 29.71 days at temperature of 30°C, 25°C and at room temperature respectively. The temperature threshold of development for *C. chinensis* was computed based on the above data and the method cited elsewhere. It was 8.28°C. The effective temperature of development for all the days required to complete the development of *C. chinensis* at ambient temperature (29.71 days) were calculated and summed up to give the thermal constant of 481.10 degree days. Under field conditions, the thermal constant was 622.62 degree days. With 6190.75 degree days under laboratory conditions and 5690 degree days under field conditions available during the period of study (September 1976 to August 1977, both inclusive) *C. chinensis* was found theoretically to complete 12.86 and 9.38 generations (Table XIV) in laboratory and field conditions respectively.

Life-table studies of *C. chinensis*:

Life-table studies of *C. chinensis* were carried out during May to July 1977 with the objective of identifying the key mortality factors responsible for causing fluctuations in the bruchid population under field condition. The mortality of the insect at various stages of its development was due to the following factors:

i) Embryonic failure of egg possibly due to sterility/ high temperature.

ii) The first instar larvae emerging outside the egg through unusual exit, perhaps due to defective (weak) chorion at the broader end of the egg.

Table XIV. Determination of number of generations of *C. chinensis* based on its thermal constant and degree days available in one year

Year	Month	Degree days: Under laboratory conditions	Degree days: Under field conditions (M.S. Hebbal)
1976	September	490.60	472.00
1976	October	522.82	478.67
1976	November	446.10	417.70
1976	December	445.10	396.77
1977	January	450.57	370.07
1977	February	461.66	405.41
1977	March	596.07	546.72
1977	April	602.35	584.30
1977	May	625.27	564.12
1977	June	548.37	496.35
1977	July	508.32	485.77
1977	August	503.52	492.12
Total degree days		6190.75	5690.00
Number of generations (*C. chinensis* took 481.10 degree days per generation under laboratory conditions and 622.62 degree days under field conditions)		12.86	9.38

iii) First instar larvae failing to reach and enter into the seed after boring into the pod due to the gap between pod coat and seed (Fig.26).

iv) Death of succeeding larval instars, pre-pupal and pupal stages due to unknown reasons which includes parasites (only two unidentified eupelmid parasite emerged from the seeds) and physiological reasons.

v) Death of adult due to trapping inside the seed as a result of its failure to emerge through the window because of its relative narrower size.

The life-table and the budget showing the key factors influencing the build up of C. chinensis population are in Table XVa and XVb.

Mortality of eggs owing to sterility accounted for 25.24 per cent. More than 56 per cent of larvae died in the first instar due to emerging outside through unusual exit because of defective (weak) chorion and failing to reach into the seed because of the presence of gap between the pod coat and the seed.

The generation survival was 0.11. The trend index of 2.23 was positive indicating that the mortality factors operating during the period of study were not effective in causing decline in the bruchid population.

Fig.26 Red gram pod showing gap between the pod coat and seed and the dead first instar larva

Fig.26

Table XVa. Life table of *C. chinensis* in red gram pods during July through August 1977

x	lx	dxf	dx	100qx	Sx
Egg (N_1)	327	Embryonic failure possibly due to sterility/ high temperature	76	23.24	0.77
Larvae:					
I instar					
i)	251	Emerging outside through unusual exit due to defective chorion	36	14.34	0.86
ii)	215	Not reaching the seed within pod due to gap	106	49.30	0.51
			142	56.57	0.43
II, III and IV instar	109	Unknown cause	30	27.52	0.72
Pupae	79	Unknown cause	6	7.59	0.92
Adults:					
i)	73	Trapped inside the seed	1	1.36	0.98
ii)	72	Sex (18 female)	36	50.00	0.50
Females X 2 (N_3)	36	-	-	-	1.00
Normal femalesX2	36	Adult mortality	-	-	1.00
		Total	291	88.99	

Expected eggs $(\frac{36}{2} \times 52)$ = 936

Number of dead/sterile = 207

Viable eggs (N_2) = 729

Trend index (I) $= \frac{N_2}{N_1} = \frac{729}{327} = 2.23$

Generation survival (SG) $= \frac{N_3}{N_1} = 0.11$

Table XVb. Budget of *C. chinensis* when eggs are laid on the red gram pods during July through August 1977

Age interval	Number	Log number	Ks
Eggs	327	2.5145	-
After mortality due to embryonic failure possibly due to sterility/ high temperature	251	2.3997	0.1149
I instar larvae			
After mortality due to emerging outside through unusual exit due to defective chorion	215	2.3324	0.0673
After mortality due to not reaching the seed within pod due to gap	109	2.0374	0.2950
II to IV instar larvae			
After mortality due to unknown cause	79	1.8976	0.1398
Pupae			
After mortality due to unknown cause	73	1.8633	0.0343
Adults			
After mortality due to trapping inside the seed	72	1.8573	0.0060
Reproductive females	18	1.2553	0.6020

K = 1.2592

Influence of stage of the pod on generation survival:

Tender pod: The trend index and generation survival were zero (Table XVIa and XVIb). The key mortality factor was the first instar larvae failing to reach and enter into the seed after boring into the pod which accounted for 100 per cent death.

Green pod: Showed a positive trend index of 2.85 and generation survival of 0.14 (Table XVIIa and XVIIb). Key mortality factors were the failure of the first instar larvae to reach and enter the seed after boring into the pod (51.72 per cent) and the predominance of males (40 per cent) in the emerging populations of adults.

Mature green pod: The trend index was positive (2.67) and the generation survival was 0.133 (Table XVIIIa and XVIIIb). Here, the key mortality factors were as in the case of green pods, the failure of the first instar larvae to reach and enter into the seed (41.14 per cent) and later the pre-ponderance of males (50 per cent) in the emerging adult population.

Yellow pod: The trend index and generation survival were observed to be zero (Table XIXa and XIXb). The key mortality factors were the failure of the first instar larvae to reach and enter into the seed which accounted for 87.50 per cent and the predominance of male in the adult population which accounted for 100 per cent death.

Dry pods: Here too, the trend index as well as generation

Table XVIa. Life table of *C. chinensis* when eggs are laid on tender red gram pods during July through August 1977

x	lx	dxf	dx	100 qx	Sx
Egg (E_1)	8	Embryonic failure possibly due to sterility/high temperature	2	25.00	0.75
Larvae					
I Instar					
i)	6	Emerging outside through unusual exit due to defective chorion	0	0.00	1.00
ii)	6	Not reaching the seed within pod due to gap	6	100.00	0.00
		Total	8	100.00	

Trend Index = 0.00 Generation survival (SG)=0.00

Table XVIb. Budget of *C. chinensis* when eggs are laid on tender red gram pods during July through August 1977

Age interval	Number	Log number	Ks
Eggs	8	0.9031	-
After mortality due to embryonic failure possibly due to sterility/high temperature	6	0.7782	0.1249
I Instar larvae			
After mortality due to emerging outside through unusual exit due to defective chorion	6	0.7782	0.0000
After mortality due to not reaching the seed within pod due to gap	0	0.0000	0.7782

K = 0.9031

Table XVIIa. Life table of C. chinensis when eggs are laid on green red gram pods during July through August 1977

x	lx	dxf	dx	100qx	Sx
Eggs (N_1)	42	Embryonic failure possibly due to sterility/high temperature	8	19.05	0.80
Larvae					
I instar					
i)	34	Emerging outside through unusual exit due to defective chorion	5	14.71	0.85
ii)	29	Not reaching the seed within pod due to gap	15	51.72	0.48
			20	58.82	0.41
II, III and IV instars	14	Unknown cause	3	21.43	0.78
Pupae	11	Unknown cause	1	9.09	0.90
Adults					
i)	10	Trapped inside the seed	0	0.00	1.00
ii)	10	Sex (3 females)	4	40.00	0.60
FemalesX2 (N_3)	6	-	0	0.00	1.00
Normal females X2	6	Adult mortality	0	0.00	1.00
		Total	36	85.71	

Expected eggs $(\frac{6}{2} \times 52)$ = 156

Number of dead/sterile = 36

Viable eggs (N_2) = 120

Trend index (I) $= \frac{N_2}{N_1} = \frac{120}{42} = 2.85$

General survival (SG) $= \frac{N_3}{N_1} = 0.14$

Table XVIIb. Budget of *C. chinensis* when eggs are laid on green red gram pods during July through August 1977

Age interval	Number	Log Number	Ks
Eggs	42	1.6232	-
After mortality due to embryonic failure possibly due to sterility/ high temperature	34	1.5315	0.0917
I Instar larvae			
After mortality due to emerging outside through unusual exit due to defective chorion	29	1.4624	0.0691
After mortality due to not reaching the seed within the pod due to gap	14	1.1461	0.3163
II, III and IV instar larvae			
After mortality due to unknown cause	11	1.0414	0.1047
Pupae			
After mortality due to unknown cause	10	1.0000	0.0414
Adults			
After mortality due to trapping inside the seed	10	1.0000	0.0000
Reproducing females	3	0.4771	0.5229

K = 1.1461

Table XVIIIa. Life table of *C. chinensis* when eggs are laid on mature green pods of red gram pods during July through August 1977

x	lx	dxf	dx	100 qx	Sx
Eggs (N_1)	224	Embryonic failure possibly due to sterility/high temperature	43	19.20	0.80
Larvae					
I instar					
i)	181	Emerging outside through unusual exit due to defective chorion	23	12.71	0.87
ii)	158	Not reaching the seed within pod due to gap	65	41.14	0.58
			88	48.60	0.51
II, III and IV instar	93	Unknown cause	27	29.03	0.70
Pupae	66	Unknown cause	5	7.58	0.92
Adults					
i)	61	Trapped inside the seed	1	1.64	0.98
ii)	60	Sex (15 females)	30	50.00	0.50
Females X 2(N_3)	30	-	0	0.00	1.00
Normal females X 2	30	Adult mortality	0	0.00	1.00
		Total	194	86.60	

Expected eggs $(\frac{30}{2} \times 52)$ = 780

Number of dead/sterile = 170

Viable eggs (N_2) = 610

Trend index (I) = $\frac{N_2}{N_1}$ = 2.67

Generation survival (SG) = $\frac{N_3}{N_1}$ = 0.133

Table XVIIIb. Budget of C. chinensis when eggs are laid on mature green red gram pods during July through August 1977

Age interval	Number	Log number	Ks
Eggs	224	2.3502	-
After mortality due to embryonic failure possibly due to sterility/high temperature	181	2.2577	0.0925
I instar larvae			
After mortality due to emerging outside through unusual exit due to defective chorion	158	2.1987	0.0590
After mortality due to not reaching the seed within the pod due to gap	93	1.9685	0.2302
II, III and IV instar larvae			
After mortality due to unknown cause	66	1.8195	0.1490
Pupae			
After mortality due to unknown cause	61	1.7853	0.0342
Adult			
After mortality due to trapping inside the seed	60	1.7782	0.0071
Reproducing females	15	1.1761	0.6021

K = 1.1741

Table XIXa. Life table of C. chinensis when eggs are laid on yellow red gram pods during July through August 1977

x	lx	dxf	dx	100 qx	Sx
Eggs (N_1)	31	Embryonic failure possibly due to sterility/high temperature	13	41.94	0.58
Larvae					
I instar					
i)	18	Emerging outside through unusual exit due to defective chorion	2	11.11	0.88
ii)	16	Not reaching the seed within pod due to gap	14	87.50	0.12
			16	88.88	0.11
II, III and IV instars	2	Unknown cause	0	0.00	1.00
Pupae	2	Unknown cause	0	0.00	1.00
Adults					
i)	2	Trapped inside the seed	0	0.00	1.00
ii)	2	Sex (No females)	2	100.00	0.00
Females X 2 (N_3)	0	-	0	0.00	0.00
		Total	31	100.00	

Trend Index = 0.00 Generation survival (SG) = 0.00

Table XIXb. Budget of *C. chinensis* when eggs are laid on yellow red gram pods during July through August 1977

Age interval	Number	Log number	Ks
Eggs	31	1.4914	-
After mortality due to embryonic failure possibly due to sterility/ high temperature	18	1.2553	0.2361
Larvae			
I instar			
After mortality due to emerging outside through unusual exit due to defective chorion	16	1.2041	0.0512
After mortality due to not reaching the seed within the pod due to gap	2	0.3010	0.9031
II, III and IV instar larvae			
After mortality due to unknown cause	2	0.3010	0.0000
Pupae			
After mortality due to unknown cause	2	0.3010	0.0000
Adult			
After mortality due to trapping inside the seed	2	0.3010	0.0000
Reproducing females	0	0.0000	0.3010

K = 1.4914

survival were noted to be zero (Table XXa and XXb). Mortality factors were mainly caused by the larva emerging through annual exit due to defective (weak) chorion (50 per cent) and the first instar larva failing to reach and enter into the seed (100 per cent).

Testing of Seeds of Different Pulse Crop Varieties for Their Relative Susceptibility to the Attack of Bruchids

Seeds of several varieties (red gram 17 and 18, green gram 12 and 10, cow pea 10 and 9, black gram 9 and 9 and soy bean 4 and 3 varieties under natural and forced infestation respectively) of pulse crops were screened for their relative susceptibility to the attack of bruchids under natural infestation and to the attack of *C. chinensis* under forced infestation conditions.

Under natural infestation:

The data pertaining to relative performance under different parameters of 52 varieties belonging to five pulse crops when tested under natural infestation conditions is furnished in Table XXIa.

Number of eggs laid: In the initial stage there was no marked variation in the number of eggs laid on different varieties of pulse seeds (Table XXIb.1, 2). During second and third months mean number of eggs laid markedly differed between different pulse crop seeds.

Seeds of black gram and green gram recorded the lowest mean number of eggs of 22.07 and 31.55, respectively during second month

Table XXa. Life table of *C. chinensis* when eggs are laid on dry red gram pods during July through August 1977

x	lx	dxf	dx	100 qx	Sx
Eggs (N_1)	22	Embryonic failure possibly due to sterility/high temperature	10	45.45	0.54
Larvae					
I instar					
i)	12	Emerging outside through unusual exit due to defective chorion	6	50.00	0.50
ii)	6	Not reaching the seed within pod due to gap	6	100.00	0.00
		Total	22	100.00	

Trend index = 0.00 Generation survival = 0.00

Table XXb. Budget of *C. chinensis* when eggs are laid on dry red gram pods during July through August 1977

Age interval	Number	Log number	Ks
Eggs	22	1.3424	-
After mortality due to embryonic failure possibly due to sterility/ high temperature	12	1.0792	0.2632
I instar larvae			
After mortality due to emerging outside through unusual exit due to defective chorion	6	0.7782	0.3010
After mortality due to not reaching the seed within pod due to gap	0	0.0000	0.7782

K = 1.3424

Table XXIa. Differential response of pulse varieties to the attack of bruchid (under natural infestation). Mean values during third month

	Variety	No. of eggs for 100 seeds	Per cent infestation	Per cent weight loss	No. of dead adult (cumulative)	Per cent parasitized
Blackgram:	1. JLVS.L	36.00-	1.33	0.40	12.00	2.66
	2. K-10	42.66	5.33	1.40	11.33	1.33
	3. V.Panth U-30	46.66	2.67	0.27	12.33	0.00-
	4. V.Panth U-26	61.33	4.00	0.53	9.66	5.33+
	5. Vig.52	68.00	1.33	0.07	18.33	4.00
	6. KH_3	101.33	0.00-	0.00-	8.33	0.00-
	7. Local	125.33	12.00+	5.47+	14.66	4.00
	8. V.Panth U-19	142.66	1.33	1.07-	21.33	0.00-
	9. PLS-364	181.33+	8.00	2.67	12.66	0.00-
	Mean	89.48	5.99	1.32	13.40	1.92
Green gram:	1. ML-5	48.00-	5.33-	6.80	11.33	9.33
	2. S-9	50.66	9.33	5.93	10.33-	9.33
	3. PS 2/1	53.33	6.66	5.46-	14.33	4.00
	4. PIMS-4	56.00	14.66	9.80	23.00+	4.00
	5. ML-4	84.00	14.66	8.93	13.33	1.33
	6. PIMS-3	90.66	13.33	15.86	17.33	14.66
	7. ML-12	105.33	5.33-	11.40	18.33	12.00
	8. PIMS-1	113.33	17.33	11.60	17.66	12.00
	9. PS-7	125.33	21.33	7.80	15.33	8.00
	10. ML-33	125.33	16.00	16.86+	16.66	9.33
	11. ML-24	140.00	20.00	11.66	20.33	10.00
	12. PIMS-2	157.33	25.33	11.00	21.66	29.33
	Mean	95.77	14.11	10.26	16.63	10.29
Cow pea:	1. P-1473	145.33	10.67	3.67	16.00	24.00
	2. CG-7	174.00	26.67	6.13	11.67-	18.66
	3. CG-5	175.33	20.00	2.27-	12.00	11.33
	4. Mani Purple	176.33	24.00	2.67	14.33	13.33
	5. No.779	192.00	14.67	5.20	13.67	14.66
	6. Pusa-2	197.33	12.00	8.93+	13.00	9.33
	7. Pusa-3	197.33	5.33	7.20	17.00	17.33
	8. Pusa-4	202.66	13.33	6.53	11.60	25.33
	9. CG-45	214.66	29.33+	8.66	27.33+	41.33+
	10. Pusa-1	226.66	21.33	5.73	14.33	29.33
	Mean	190.20	17.73	5.69	15.09	20.46
Red gram:	1. 4-64	90.66-	16.00	7.60-	12.66-	13.33
	2. S-73-20	108.66	34.66	12.40	38.66	12.00
	3. T-21	128.66	14.66-	9.73	20.00	16.00
	4. No.159	138.66	18.66	13.06	20.00	10.66-
	5. 4-84	161.33	36.00	15.53	34.11	22.66
	6. BS-1	181.33	35.33	15.33	31.66	24.00
	7. DL-74-1	194.66	21.33	9.46	16.66	16.00
	8. S-8	196.00	35.33	14.66	37.00	20.00
	9. MPA-1	196.00	37.33	14.46	41.33+	19.33
	10. 4-54	201.33	36.00	14.93	39.33	21.33
	11. JA-9-19	229.33	34.66	13.06	35.33	21.33
	12. CO-1	238.66	42.66	17.86+	31.33	40.00+
	13. HY-5	242.66	14.66-	12.66	21.66	38.66
	14. HY-4	250.66	52.00	14.13	37.00	26.66
	15. No.53	258.66	53.33+	14.60	28.33	37.33
	16. HY-1	260.00	16.00	11.60	24.33	38.00
	17. Local	270.66+	36.00	14.40	33.66	29.66
	Mean	196.94	31.84	13.26	29.61	21.64
Soy bean:	1. Black Kulthi	164.00-	00.00-	0.00	18.00	0.00
	2. Hebbal soya	234.66	0.00-	0.00	26.33+	0.00
	3. Hill	258.66	1.33	0.00	17.33-	0.00
	4. Hardee	294.66+	21.33+	0.00	36.33+	0.00
	Mean	238.00	5.66	0.00	21.99	0.00

\- = Lowest incidence
\+ = Highest incidence

Table XXIb. Number of eggs laid by bruchids on seeds of different pulse crop varieties (under natural infestation)

Pulse crop	No. of varieties	Initial	First month	Second month	Third month
			(Mean number/100 seeds)		
Red gram	17	0.13	16.35	101.74	156.94*
Green gram	12	1.07	16.54	31.57**	55.77
Black gram	5	0.14	8.88	22.07	85.45
Cow pea	10	0.00	10.50	53.00	150.20
Soy bean	4	0.05	1.51	134.16	255.00

*Significant at 5% level   **Significant at 1% level

Table XXIb.1. Mean number of eggs laid by bruchids on seeds of red gram (third month)

Sl. No.	Variety	Mean value	
1.	4-64	50.66	a
2.	[illegible]	108.66	ab
3.	T-21	125.66	abc
4.	No.155	138.66	abcd
5.	4-84	161.33	abcde
6.	[illegible]	181.33	abcdef
7.	[illegible]	194.66	bcdef
8.	[illegible]	196.00	bcdef
9.	[illegible]	196.00	bcdef
10.	4-54	201.33	bcdef
11.	[illegible]	225.33	cdef
12.	[illegible]	238.66	def
13.	[illegible]	242.66	ef
14.	[illegible]	250.66	ef
15.	No.53	255.66	ef
16.	[illegible]	260.00	ef
17.	Local	270.00	f

C.D. at 5% = 101.65

Table XXIb.2. Mean number of eggs laid by bruchids on seeds of green gram (second month)

Sl. No.	Variety	Mean value	
1.	ML-4	19.66	a
2.	ML-5	19.66	a
3.	ML-12	22.66	a
4.	[illegible]	24.00	a
5.	PIMs-1	25.33	ab
6.	PS 2/1	26.66	ab
7.	PIMs-3	29.00	abc
8.	ML-33	30.66	abc
9.	PIMs-4	33.33	abc
10.	PIMs-2	42.66	bc
11.	PS-7	45.33	cd
12.	ML-24	62.66	a

C.D. at 5% = 18.19

Treatments with same alphabets are not significantly different from each other

and 89.48 and 95.77 respectively during third month as compared to seeds of soy bean, red gram and cow pea varieties which accounted for higher mean number of eggs (134.16, 101.74 and 93.00 during second month, and 239.00, 196.94 and 190.20 during the third month, respectively).

Number of eggs laid varied significantly between the varieties of red gram (during third month) and green gram (during second month). In red gram, seeds of five varieties namely, 4-64, H-73-10, T-21, No.159 and 4-84 were the least preferred for egg laying. In case of green gram seeds of four genotypes namely, ML-4, ML-5, ML-12 and S-9 proved to be resistant to egg laying in that they carried the least number of eggs.

Similarly, seeds of local variety under red gram and ML-24 variety under green gram were the most susceptible to egg laying. Cow pea and soy bean varieties did not show any significant difference between them.

Variety P.1473 (cow pea) with 145.33 eggs and black kulthi (soy bean) with 146 eggs recorded the lowest mean number of eggs respectively as opposed to variety Pusa-1 (cow pea) with 226.66 and Hardee (soy bean) with 294.66 which recorded the highest mean number of eggs respectively.

<u>Infestation</u>: Soy bean varieties were least susceptible to the attack by bruchids as revealed by mean infestation of 5.66 per cent during the third month followed by black gram varieties (5.99 per cent) (Table XXIe). Green gram varieties and cow pea varieties

Table XXIc. Mean per cent infestation of seeds of different pulse crop varieties by bruchids (under natural conditions)

Pulse crop	No. of varieties	Initial	First month	Second month	Third month
Red gram	17	2.00	4.00	13.66	31.94
Green gram	12	2.00	2.94	3.66	14.11
Black gram	9	0.59	1.77	2.07	5.99
Cow pea	10	1.26	1.93	7.93	17.79
Soy bean	4	1.00	1.50	2.66	5.66

occupied next positions in that order by recording 14.11 and 17.79 per cent, respectively. Red gram varieties were the most susceptible with a mean infestation of 31.84 per cent.

With regard to the performance of varieties of different pulse crops, the difference observed between varieties of all the five pulse crops was not significant. Varieties Black kulthi and Hebbal soya in case of soy bean with mean infestation of zero, KH_3 in case of black gram with zero infestation, ML-12 and ML-5 in case of green gram and Pusa-3 in case of cow pea with 5.33 per cent infestation and T-21 and HY-5 in case of red gram with 14.66 per cent infestation were the least susceptible varieties under the respective crops. Similarly, Hardee with 21.33 (soy bean) local with 12 (black gram), PIMs-2 with 25.33 (green gram), CG-45 with 29.33 (cow pea) and No.55 with 53.33 per cent (red gram) were the most susceptible varieties under the respective crops.

The rate at which the seeds were infested, differed among the pulse crop seeds. Red gram and cow pea were attacked at a faster rate (4.00, 18.16 and 31.84 per cent and 1.93, 7.93 and 17.79 per cent, respectively, during first, second and third months) as compared to green gram, black gram and soy bean.

<u>Weight loss</u>: The minimum loss of weight was recorded in the case of soy bean (zero per cent) followed by black gram (1.32 per cent) and cow pea (5.69 per cent) as against the maximum weight loss of 13.26 per cent registered by red gram which was followed by green gram (10.26 per cent) (Table XXId).

Table XXId. Mean per cent of weight loss in seeds of different pulse crop varieties caused by bruchids (under natural infestation)

Pulse crop	No. of varieties	Initial	First month	Second month	Third month
Red gram	14	-	0.07	5.25	13.26
Green gram	12	-	0.00	0.80	10.26
Black gram	9	-	0.00	0.32	1.32
Cow pea	10	-	0.04	1.68	5.69
Soy bean	4	-	0.00	0.00	0.00

The difference observed between varieties of various pulse crops was not statistically significant. Soy bean varieties did not show any loss in weight of seeds. Among varieties of black gram KH_3 recorded the minimum loss of weight (zero per cent) as compared to that of local which accounted for a maximum loss of 5.47 per cent by weight.

In cow pea the minimum loss in weight (2.27 per cent) was recorded by variety CG-5 and the maximum by variety Pusa-2 (9.93 per cent). Variety PS 2/1 (5.46 per cent) and ML-33 (16.96 per cent) in case of green gram and varieties 4-64 (7.60 per cent) and CO-1 (17.96)per cent in case of red gram accounted for the minimum and maximum per cent loss in weight respectively.

Dead adult: The maximum mean number of dead adults on a cumulative basis (at the end of third month) was observed in the case of redgram seeds (29.61), soy bean with 21.99 mean number of dead adult followed next (Table XXIe). Green gram and cow pea recorded 16.63 and 15.09 mean number of dead adults, respectively. The minimum number of dead adults was registered by black gram (13.40).

The difference between the varieties of black gram, cow pea and soy bean was not significant. However, significant difference was observed between the varieties of red gram (during second, third months and based on cumulative total). Varieties KH_3 (9.33) and Panth U-19 (21.33) of black gram, CG-7 (11.67) and CG-45 (27.33) of cow pea, S-9 (10.33) and PIMS-4 (23.00) of green gram, Hill (17.33)

Table XXIe. Mean number of dead bruchid adults recorded in seeds of different pulse crop varieties (under natural infestation)

Pulse crop	No. of varieties	First month	Second month	Third month	Cumulative
Red gram	17	1.68	7.37*	22.13**	29.61**
Green gram	12	1.36	5.33**	10.50	16.63
Black gram	9	0.77	2.66	9.96	13.40
Cow pea	10	0.66	2.90	10.70	15.09
Soy bean	4	0.08	5.25	16.66	21.99

*Significant at 5% level

**Significant at 1% level

Table XXIe.1. Mean number of dead bruchid adults in seeds of red gram (second month)			Table IIXe.2. Mean number of dead bruchid adults in seeds of red gram (third month)			Table XXIe.3. Mean number of dead bruchid adults in seeds of red gram (cumulative)			Table XXIe.4. Mean number of dead bruchid adults in seeds of green gram (second month)		
Variety	Mean value		Variety	Mean value		Variety	Mean value		Variety	Mean value	
DL-74-1	1.66	a	4-64	10.33	a	4-64	12.66	a	S-9	2.00	a
T-21	2.33	a	No.159	13.33	a	DL-74-1	16.66	ab	PS-7	3.00	a
4-64	3.33	ab	DL-74-1	14.00	a	T-21	20.00	abc	ML-5	3.00	a
HY-5	5.66	abc	HY-1	15.33	ab	No.159	20.00	abc	ML-4	3.33	a
Bs-1	5.66	abc	T-21	16.33	ab	HY-5	21.66	abcd	PS 2/1	3.66	a
No.159	5.66	abc	No.53	21.00	bc	HY-1	24.33	abcde	ML-33	3.66	a
No.53	6.00	abc	H-73-20	21.33	bc	No.53	28.33	bcdef	PIMS-1	3.66	a
4-54	6.33	abc	CO-1	21.33	bc	CO-1	31.33	cdef	PIMS-3	4.66	a
HY-1	6.33	abc	4-84	22.00	bc	Bs-1	31.66	cdef	PIMS-2	4.66	a
MPA-1	7.00	abc	HY-5	22.00	bc	Local	33.66	cdef	ML-12	5.00	a
Local	7.00	abc	JA-9-19	23.33	c	4-84	34.33	cdef	ML-24	8.00	ab
HY-4	8.00	abcd	S-8	24.33	c	JA-9-19	35.33	def	PIMS-4	12.66	b
4-84	9.66	bcd	HY-4	25.33	cd	S-8	37.00	ef			
S-8	9.66	bcd	Local	25.33	cd	HY-4	37.00	ef			
CO-1	9.66	bcd	Bs-1	25.33	cd	H-73-20	3[illegible].66	ef			
JA-9-19	10.33	cd	MPA-1	26.66	cd	4-54	39.33	f			
H-73-20	14.33	d	4-54	31.66	d	MPA-1	41.33	f			
C.D. at 5% = 6.60			C.D. at 5% = 6.90			C.D. at 5% = 14.63			C.D. at 5% = 3.30		

Treatments with same alphabets are not significantly different from each other

and Hebbal Soya (26.33) of soy bean and 4-64 (12.66) and MPA-1 (41.33) of red gram recorded the lowest and highest mean number of dead adults, respectively.

Parasite attack: Studies on the percentage of seeds showing parasite emergence (D. vagabundus) holes in different varieties of five pulse crops revealed a positive relationship between the former and the extent of infestation. Soy bean and black gram recorded the lowest incidence of parasitization (zero and 1.92 per cent, respectively), green gram by registering 10.29 per cent incidence followed next (Table XXIf).

The highest level of parasitization was observed in case of cow pea (20.46 per cent) followed by red gram (21.64 per cent). None of the varieties under all the five pulse crops showed significant difference between them.

Of the black gram varieties, V.Panth U-30, KH_3, V.Panth U-19 and PLS-364 registered the minimum parasitization (zero per cent) as opposed to the maximum parasitisation observed in the case of V.Panth U-26 (5.32 per cent). ML-4 in the case of green gram, Pusa-2 in the case of cow pea and No.159 in the case of red gram recorded the lowest per cent of seeds showing parasite emergence holes of 1.33, 9.33 and 10.66 respectively, while varieties PIMS-2 (29.33 per cent), CG-45 (41.33 per cent) and CO-1 (40.00 per cent) recorded the highest parasitisation in the above crop seeds, respectively.

Table XXIf. Mean per cent parasitisation of bruchids in different varieties of pulse crop varieties (under natural infestation)

Pulse crop	No. of varieties	Ini-tial	First month	Second month	Third month
Red gram	17	-	-	17.72	21.64
Green gram	12	-	-	2.99	10.29
Black gram	9	-	-	0.00	1.92
Cow pea	10	-	-	14.53	20.46
Soy bean	4	-	-	0.00	0.00

Under artificial infestation:

The data pertaining to relative performance under different parameters of 49 varieties belonging to five pulse crops when tested under artificial infestation conditions, is furnished in Table XXIIa. Under this experiment, the seeds were tested for their relative susceptibility to the attack of only one species of bruchid namely, *C. chinensis*.

Egg laying: The mean number of eggs of *C. chinensis* recorded varied among different pulses (Table XXIIb). In the first month the mean number of eggs laid was lowest in case of black gram (2.03) followed by soy bean (8.11), green gram (32.20), red gram (79.35) and cow pea (105.77). Similar trend was observed during the second month. However, during the third month soy bean recorded the lowest (8.11) followed by black gram (34.94), green gram (157), red gram (290.72), and the highest mean number of 302.96 eggs by cow pea. There was no significant difference among the varieties of soy bean, black gram and green gram. However, varieties Hebbal Soya (5.00), V.Panth. U-26 (3.50) and PIMS-3 (3.00) respectively were found to be less attractive, for egg laying. Similarly, varieties Hill (soy bean), JLVS-2 (black gram) and ML-4 (green gram) recorded the highest mean number of eggs of 14.33, 102.00 and 440.00 respectively. The difference noted between the varieties of red gram and cowpea was observed to be significant during all the three months of study. In the first month variety HY-1 (26.00) and during both second and third months, variety BR-172 (159.33 and 193.66) of red gram

- = Lowest incidence

+ = Highest incidence

Table XXIIb. Mean number of eggs laid per 25 seeds by *C. chinensis* on seeds of different pulse crop varieties (under artificial infestation)

Pulse crop	No. of varieties	First month	Second month	Third month
Red gram	18	79.35**	267.55**	290.72**
Green gram	10	32.30	120.05	157.00
Black gram	9	2.03	8.02	34.94
Cow pea	9	105.77**	282.44**	302.96**
Soy bean	3	8.11	8.11	8.11

Table XXIIb.1. Mean number of eggs laid per 5 seeds by C. [illegible] on [illegible] varieties (first month)

Variety	Mean value	
MY-1	26.00	a
4-64	29.00	a
Bu-1	33.66	a
MY-4	41.33	ab
J-9	41.66	ab
4-45	46.33	ab
DL-74-1	53.33	abc
MPA-1	62.33	abcd
Local	63.33	abcd
4-94	67.66	abcd
KH-10	83.00	bcde
CO-1	87.33	bcde
RH-172	89.66	bcde
No.155	95.00	cde
MY-5	102.66	de
T-21	127.00	e
No.53	177.00	f
JA-9-15	157.00	f
C.D. at 5%	47.4[illegible]	

Table XXIIb.2. Mean number of eggs laid per 5 seeds by C. [illegible] on [illegible] varieties (second month)

Variety	Mean value	
RH-172	[illegible]	a
Local	[illegible]	ab
J-9	[illegible]	abc
No.[illegible]	[illegible]	abcd
4-[illegible]4	[illegible]	abcd
KH-10	[illegible]	abcd
CO-1	[illegible]	abcde
4-94	[illegible]	abcdef
JA-9-15	[illegible]	abcdef
4-64	276.33	bcdef
MY-1	294.66	cdef
MY-4	[illegible]	def
Bu-1	[illegible]	def
No.155	311.33	def
MY-5	335.66	ef
MPA-1	335.66	ef
T-21	344.66	f
DL-74-1	41[illegible]	f
C.D. at 5%	114.7[illegible]	

Table XXIIb.3. Mean number of eggs laid per 5 seeds by C. [illegible] on [illegible] varieties (third month)

Variety	Mean value	
[illegible]	[illegible]	a
[illegible]	[illegible]	ab
[illegible]	[illegible]	ab
[illegible]	[illegible]	abc
[illegible]	[illegible]	abcd
[illegible]	[illegible]	abcd
[illegible]	[illegible]	abcde
[illegible]	[illegible]	abcde
[illegible]	[illegible]	abcde
[illegible]	[illegible]	bcde
[illegible]	[illegible]	bcde
[illegible]	[illegible]	bcde
No.155	[illegible]	bcdef
[illegible]	[illegible]	cdef
[illegible]	[illegible]	def
MPA-1	[illegible]	ef
[illegible]	[illegible]	ef
DL-74-1	[illegible]	[illegible]
C.D. at 5%	[illegible]	

Table XXIIb.4. Mean number of eggs laid per 5 seeds by C. chinensis on soy bean varieties (first month)

Variety	Mean value	
No.775	30.33	a
Pusa-7	47.00	ab
CO-[illegible]	50.66	abc
CO-7	72.66	bc
Pusa-3	101.00	cd
Kalm Purple	1[illegible]1.00	de
Pusa-4	1[illegible]4.00	de
[illegible]-1473	174.66	e
Pusa-1	180.66	e
C.D. at 5%	55.28	

Table XXIIb.5. Mean number of eggs laid per 5 seeds by C. chinensis on soy bean varieties (second month)

Variety	Mean value	
No.775	[illegible]5.66	a
CO-[illegible]	216.66	a
Pusa-1	[illegible]	ab
Pusa-3	[illegible]4.00	abc
Kalm Purple	[illegible]	abc
[illegible]-1473	[illegible]	bc
CO-7	[illegible]	bc
Pusa-7	[illegible]	bc
Pusa-4	[illegible].66	c
C.D. at 5%	99.22	

Table XXIIb.6. Mean number of eggs laid per 5 seeds by C. chinensis on [illegible] varieties (third month)

Variety	Mean value	
[illegible]	[illegible]	a
[illegible]	[illegible]	a
[illegible]	[illegible]	a
[illegible]	[illegible]	a
[illegible]	[illegible]	a
[illegible]	[illegible]	a
[illegible]	[illegible]	a
[illegible]	[illegible]	a
[illegible]	[illegible]	a
C.D. at 5%	[illegible]	

Treatments with same alphabets are not significantly different from each other

recorded the lowest mean number of eggs. Similarly, variety JA-9-19 recorded the highest mean number of eggs (197) during the first month while variety DL-74-1 replaced the former during second (415.00 mean number of eggs) and third month (419.00 mean number of eggs).

In the case of cow pea, variety No.779 continuously registered the lowest mean number of eggs of 20.33, 79.66 and 96.66 during first, second and third months, respectively. Pusa-1 recorded the highest mean number of eggs (180.66) during first month whereas variety Pusa-4 recorded the highest of 372.66 and 379.33 eggs during second and third months, respectively.

Infestation: Soy bean recorded the lowest infestation of zero per cent followed by black gram (9.90 per cent), cow pea (66.66 per cent), green gram (68.00 per cent) and red gram (69.81 per cent) (Table XXIIe.1 to 5).

All the three varieties of soy bean recorded zero per cent infestation. The difference observed between varieties of black gram was found to be insignificant. However, varieties V.Panth U-26, V.Panth U-30, K-10, KH_3 and Vig.152 showed zero infestation as against the variety JLVS-2 which showed the highest infestation (29.33 per cent).

Varieties of cow pea showed significant difference between them during all the three months of the study. In the first month, varieties CG-5 and Pusa-1 recorded the lowest (8.00) and highest (61.33) per cent infestation respectively and during subsequent

Table XXIIc. Mean per cent infestation in different pulse crop varieties by *C. chinensis* (under artificial infestation)

Pulse crop	No. of varieties	First month	Second month	Third month
Red gram	18	17.13*	64.68*	69.81
Green gram	10	7.60	44.50	69.00
Black gram	9	0.15	1.77	9.90
Cow pea	9	31.63*	64.63**	66.66**
Soy bean	3	0.00	0.00	0.00

*Significant at 5% level

**Significant at 1% level

Table XXIIc.1. Mean per cent infestation in red gram varieties by *C. chinensis* (first month)

Variety	Mean value	
HY-1	6.66	a
BS-1	6.66	a
DL-74-1	8.00	ab
4-64	10.66	abc
S-8	10.66	abc
Local	12.00	abcd
4-54	13.33	abcd
HY-4	13.33	abcd
BR-172	13.33	abcd
MPA-1	13.33	abcd
4-84	19.00	abcd
JA-9-19	20.00	abcd
CO-1	22.66	bcde
No.159	24.00	cde
No.53	25.33	cde
T-21	26.66	de
KH-10	26.66	de
HY-5	36.00	e
C.D. at 5%	15.14	

Table XXIIc.2. Mean per cent infestation in red gram varieties by *C. chinensis* (second month)

Variety	Mean value	
4-64	34.66	a
Local	43.66	ab
CO-1	45.33	ab
JA-9-19	52.66	abc
HY-4	53.00	abc
BR-172	57.00	abc
S-8	59.00	abcd
No.159	60.00	abcd
4-54	65.33	bcde
KH-10	67.33	bcde
4-84	70.33	bcde
HY-5	71.33	bcde
MPA-1	71.66	bcde
HY-4	77.00	cde
No.53	77.66	cde
T-21	80.33	cde
DL-74-1	87.00	de
BS-1	91.00	e
C.D. at 5%	28.90	

Table XXIIc.3. Mean per cent infestation in cow pea varieties by *C. chinensis* (first month)

Variety	Mean value	
CO-5	8.00	a
No.779	8.66	a
Pusa-2	14.66	a
Pusa-4	33.33	ab
CO-7	33.66	ab
P-1473	34.66	ab
Mani purple	45.33	ab
Pusa-3	45.33	ab
Pusa-1	61.33	b
C.D. at 5%	31.63	

Table XXIIc.4. Mean per cent infestation in cow pea varieties by *C. chinensis* (third month)

Variety	Mean value	
No.779	25.33	a
Mani purple	43.66	ab
CO-5	45.33	abc
P-1473	58.66	bcd
Pusa-2	72.00	bcde
Pusa-3	76.66	cde
CO-7	81.00	de
Pusa-1	88.33	de
Pusa-4	90.66	e
C.D. at 5%	31.50	

Table XXIIc.5. Mean per cent infestation in cow pea varieties by *C. chinensis* (second month)

Variety	Mean value	
No.779	25.33	a
Mani purple	45.00	ab
CO-5	58.66	bc
P-1473	55.33	bc
Pusa-2	74.33	bcd
Pusa-3	76.66	cd
CO-7	81.33	cd
Pusa-1	88.66	cd
Pusa-4	90.66	d
C.D. at 5%	30.32	

Treatments with same alphabets are not significantly different from each other

months variety No.779 recorded the lowest (25.33) and variety Pusa-4 recorded the highest (90.66) per cent infestation.

The difference noticed among the varieties of green gram was not significant. Variety ML-33 recorded the lowest infestation (38.00 per cent) and ML-4 the highest (100 per cent).

Varieties of red gram differed significantly during first and second months with the difference during third month being insignificant. The lowest infestation of 6.66 per cent was recorded by variety HY-1 and BS-1 (first month) and it was replaced by variety 4-64 with 34.66 and 48.66 per cent infestation (second and third month). Similarly, highest infestation (36.00 per cent) was recorded by HY-5 during first month and by BS-1 (91.00 and 93.66 per cent during second and third months, respectively).

<u>Weight loss</u>: There was no loss in weight (zero per cent) observed in the case of soy bean and black gram recorded loss in weight of 4.79 per cent. Cow pea (36.75 per cent) and green gram (37.61 per cent) accounted for an increased loss with red gram accounting for the maximum loss of 41.46 per cent (Table XXIId.1 to 5).

Varieties of black gram and green gram did not differ significantly between themselves, while varieties V.Panth U-26, V.Path U-30, K-10, KH_3 and Vig.152 in the case of black gram and ML-33 in the case of green gram recorded the minimum loss in weight (zero per cent and 11.00 per cent, respectively). Variety JLVS-2 in the case of black gram and ML-4 in the case of green gram recorded

Table XXIId. Mean per cent weight loss in seeds of different pulse crop varieties caused by *C. chinensis* (under artificial infestation)

Pulse crop	No. of varieties	First month	Second month	Third month
Red gram	19	11.80**	37.67	41.46**
Green gram	10	3.39	31.37	37.61
Black gram	9	0.00	0.12	4.79
Cow pea	9	15.07**	34.22**	36.75**
Soy bean	3	0.00	0.00	0.00

* Significant at 5% level

** Significant at 1% level

Table XXIId.1. Mean per cent weight loss caused by *C. chinensis*, in red gram varieties (first month)

Variety	Mean value	
BR-172	0.20	a
Local	0.53	a
No.53	0.60	a
HY-4	0.60	a
JA-9-19	2.53	a
HY-1	4.00	a
BS-1	5.00	ab
S-8	6.06	abc
4-64	6.06	abc
DL-74-1	13.66	bcd
4-54	14.56	cde
MPA-1	20.26	def
4-84	17.66	def
No.159	21.66	defg
KH-10	22.40	defg
CO-1	22.73	efg
HY-5	24.93	fg
T-21	28.93	g
C.D. at 5%	8.76	

Table XXIId.2. Mean per cent of weight loss in red gram varieties caused by *C. chinensis* (third month)

Variety	Mean value	
HY-4	26.66	a
HY-1	37.46	a
4-64	37.73	a
S-8	38.80	ab
BS-1	39.26	ab
Local	39.33	ab
No.159	40.80	abc
DL-74-1	41.40	abc
No.53	41.46	abc
4-84	41.73	abc
CO-1	42.06	abc
MPA-1	42.73	abc
BR-172	42.13	abc
KH-10	45.46	abc
4-54	45.63	abc
HY-5	45.66	abc
T-21	47.86	b
JA-9-19	50.06	c
C.D. at 5%	9.46	

Table XXIId.3. Mean per cent of weight loss in cow pea varieties caused by *C. chinensis* (first month)

Variety	Mean value	
CG-5	0.80	a
Pusa-2	0.93	a
No.779	1.20	a
Mani purple	6.50	ab
P-1473	16.73	bc
CG-7	19.80	c
Pusa-3	27.00	cd
Pusa-1	29.40	cd
Pusa-4	33.26	d
C.D. at 5%	12.67	

Table XXIIe.4. Mean per cent of weight loss in cow pea varieties caused by *C. chinensis* (second month)

Variety	Mean value	
No.779	10.40	a
Mani Purple	12.86	a
Pusa-2	27.13	b
P-1473	27.40	b
CG-5	30.00	b
CG-7	45.26	c
Pusa-3	48.33	c
Pusa-1	50.80	c
Pusa-4	55.00	c
C.D. at 5%	12.31	

Table XXIIe.5. Mean per cent of weight loss in cow pea varieties caused by *C. chinensis* (third month)

Variety	Mean value	
No.779	13.06	a
Mani Purple	17.00	ab
P-1473	28.33	bc
Pusa-2	31.66	c
CG-5	35.86	cd
Pusa-1	48.60	de
CG-7	49.80	de
Pusa-3	50.60	e
Pusa-4	55.53	e
C.D. at 5%	14.28	

Treatments with same alphabets are not significantly different from each other

the maximum loss in weight (25.00 and 57.40 per cent, respectively).

Difference between the varieties of cow pea was significant throughout the experimental period. In the first month, CG-5 recorded the minimum loss (0.90 per cent) and Pusa-4 the maximum (33.26 per cent), whereas in the second and third months No.779 accounted for minimum loss in weight of 10.40 per cent and 13.06 per cent respectively, while Pusa-4 recorded the maximum per cent of loss in weight of 55.00 and 55.53 in respective months.

Varieties of red gram showed significant difference between them during first and third months. Varieties BR-172 (first month) and HY-4 (third month) recorded the lowest weight loss of 0.20 per cent and 26.66 per cent, respectively. Variety T-21 with 29.93 per cent and variety JA-9-19 with 50.06 per cent recorded the maximum loss in weight during first and third months, respectively.

Dead adults: Mean number of dead adults based on cumulative data recorded was the lowest in soy bean (6.00) followed by black gram (51.01). Green gram (377.25) and cow pea (440.81) recorded greater incidence of dead adults. Red gram (463.24) recorded the highest number (Table XXIIe.1 to 7).

While the difference between different varieties was not significant in case of black gram and green gram, it was significant in cow pea and red gram varieties.

Varieties V.Panth U-26, V.Panth U-30, K-10, KH_3 and Vig.152

Table XXIIe. Mean number of dead adults of C. chinensis in different pulse crop varieties (under artificial infestation)

Pulse crop	No. of varieties	First month	Second month	Third month	Cumulative total
Red gram	18	91.77**	364.90**	24.07**	463.24**
Green gram	10	45.15	259.50	72.60	377.25
Black gram	9	6.00	5.98	40.37	51.01
Cow pea	9	8.00**	335.29**	17.29	440.81**
Soy bean	3	6.00	0.00	0.00	6.00

*Significant at 5% level

**Significant at 1% level

Table XXIIe.1.
Mean number of dead adults of *C. chinensis* in red gram varieties (first month)

Variety	Mean value
HY-1	39.33 a
4-54	41.66 ab
Local	49.33 ab
HY-4	50.33 ab
BS-1	52.00 ab
4-64	54.00 ab
S-8	65.00 abc
DL-74-1	67.00 abc
No.159	82.00 abcd
4-84	83.33 abcd
CO-1	83.66 bcd
BR-172	98.33 cde
HY-5	105.00 cde
KH-10	106.66 cde
MPA-1	107.00 cde
No.53	121.66 de
JA-9-19	124.66 de
T-21	139.00 e

C.D. at 5% 44.15

Table XXIIe.2.
Mean number of dead adults of *C. chinensis* in red gram varieties (second month)

Variety	Mean value
4-64	182.33 a
MPA-1	185.00 a
DL-74-1	211.00 a
4-54	240.33 a
T-21	265.33 ab
CO-1	348.66 bc
JA-9-19	372.66 cd
HY-1	381.00 cd
S-8	396.33 cd
No.159	397.33 cd
Local	398.00 cd
4-84	415.33 cde
HY-4	434.33 cde
No.53	439.00 cde
HY-5	440.66 cde
KH-10	457.66 de
BR-172	495.66 e
HY-4	509.66 e

C.D. at 5% 96.23

Table XXIIe.3.
Mean number of dead adults of *C. chinensis* in red gram varieties (third month)

Variety	Mean value
4-84	2.00 a
KH-10	7.00 ab
MPA-1	12.33 ab
No.53	12.33 ab
T-21	13.00 ab
HY-4	13.00 ab
HY-1	15.00 ab
DL-74-1	16.00 ab
S-8	16.66 ab
No.159	20.00 abc
4-64	21.33 abc
HY-5	28.33 bcd
BR-172	28.66 bcd
JA-9-19	29.33 bcd
HY-4	29.66 bcd
4-54	45.66 cd
Local	49.66 de
CO-1	73.33 e

C.D. at 5% 25.48

Table XXIIe.4.
Mean number of dead adults of *C. chinensis* in red gram varieties (cumulative total)

Variety	Mean value
4-64	257.66 a
DL-74-1	294.00 ab
MPA-1	304.33 abc
4-54	327.66 abcd
CO-1	405.66 bcde
T-21	417.33 cde
HY-1	435.33 de
S-8	478.00 ef
Local	497.00 ef
No.159	499.33 ef
4-84	506.00 ef
HY-4	514.33 ef
JA-9-19	525.33 ef
BS-1	570.66 f
KH-10	571.33 f
No.53	573.00 f
HY-5	574.00 f
BR-172	599.33 f

C.D. at 5% 120.02

Treatments with same alphabets are not significantly different from each other

Table XXIIe.5.
Mean number of dead adults of *C. chinensis* in cow pea varieties (first month)

Variety	Mean value	
No.779	21.66	a
CG-5	33.00	a
Pusa-2	51.33	ab
CG-7	66.33	abc
Pusa-3	78.33	abcd
Pusa-4	109.00	bcde
P-1473	127.66	cde
Pusa-1	144.00	de
Mani Purple	162.66	e
C.D. at 5%	67.68	

Table XXIIe.6.
Mean number of dead adults of *C. chinensis* in cow pea varieties (second month)

Variety	Mean value	
Mani purple	51.00	a
No.779	120.66	a
CG-5	290.00	b
P-1473	341.66	bc
Pusa-3	396.33	bc
Pusa-4	411.66	bc
Pusa-2	432.66	bc
CG-7	484.00	c
Pusa-1	499.66	c
C.D. at 5%	162.92	

Table XXIIe.7.
Mean number of dead adults of *C. chinensis* in cow pea varieties (cumulative total)

Variety	Mean value	
No.779	149.00	a
Mani Purple	230.33	ab
CG-5	363.66	bc
P-1473	473.00	cd
Pusa-3	493.00	cd
Pusa-2	504.33	cd
CG-7	553.33	d
Pusa-4	555.66	d
Pusa-1	645.00	d
C.D. at 5%	180.45	

Treatments with sample alphabets are not significantly different from each other in respect of black gram and PIMS-3 in respect of green gram registered the lowest mean number of dead adults (6 and 39 in respective crops). The highest incidence of dead adults were recorded by JLVS-2 (213.50) in respect of black gram and ML-12 (966.00) in respect of green gram.

Among the varieties of cow pea and red gram, No.779 (149.00) of the former and 4-46 (257.66) of the latter recorded the lowest number of dead adults. The highest number of dead adults, was recorded in Pusa-1 (cow pea) and BR-172 (red gram) which accounted for 645.00 and 589.00 dead adults, respectively.

Based on the relative position occupied by each variety of pulse crops under each parameter under two testing situations (natural and artificial infestation), the study revealed interesting results. Among the five pulse crops, seeds of soy bean and black gram varieties were found to be least susceptible, followed by green gram and cow pea. Seeds of red gram varieties were found to be most susceptible.

Among the varieties of different pulses tested, Black Kulthi (soy bean), V.Panth U-30 (black gram), PS 2/1 (green gram), CG-5 and No.779 (cow pea) and 4-46 (red gram) were the least susceptible varieties while Hill (soy bean), local (black gram), PIMS-2 (green gram), Pusa-2 and Pusa-4 (cow pea) and No.53 (red gram) were found to be the most susceptible varieties to the attack of bruchids.

DISCUSSION

CHAPTER V

DISCUSSION

The present study included detailed investigation on the bruchid fauna infesting seeds of different pulse crops grown in the state of Karnataka, field infestation, seasonal incidence, biology and ecology of *Callosobruchus chinensis* (Linnaeus) both under laboratory and field conditions and on the relative susceptibility of seeds of different varieties of five crops namely, red gram, green gram, black gram, cow pea and soy bean to the attack of pulse beetles were carried out during the period September 1976 through September 1977.

Bruchid Fauna Infesting Pulse Crops and Their Distribution in Karnataka

Kunhikannan (1919) has reported the occurrence of *Bruchus chinensis* (Linnaeus), *Bruchus quadrimaculatus* (Fabricius), *Bruchus analis* (Fabricius) and an unidentified bruchid species on different pulse seeds in the erstwhile Mysore State. Similarly, Usman and Puttarudriah (1955) reported the existence of seven species of bruchids of which two species namely, *C. theobromae* (Linnaeus) was recorded on *Cajanus* pods in field and *C. analis* on Bengal gram, field bean and green gram throughout the State. Except *C. throbromae* recorded in red gram pods in the field the remaining records did not clearly indicate whether they were from field or stores. The present study which has revealed the existence of five species of bruchids namely, *C. chinensis*, *C. theobromae*, *C. maculatus*, *C. analis* and an unidentified species, associated with seven pulse crops grown in 10 districts of the State surveyed (Table I and II) were recorded from field infestation save C. analis which was recorded in stored green gram only. The present observation pertaining to C. theobromae is in complete agreement with that of Raina (1971). Further, C. maculatus was reported by the same author on cow pea, mung, urid and chick pea whereas in the present study, it was recorded on cow pea and for the first time on field bean. The unidentified bruchid which was collected in hand sweepings on ground nut and red gram at Raichur and Gulbarga districts only, appears to be a new species and needs further study. It may be stated conclusively that in respect of the above four species, field infestations constituted an important source for subsequent infestation or multiplication in stores.

The present investigations have also established that among the species reported, C. chinensis was the most common and predominant species as it was found widely distributed, infesting five out of seven pulse crops in nine out of ten districts which were surveyed.

As to the extent of field infestation by bruchids, the available information is restricted to cow pea and red gram in India with the first record of bruchid field infestation on cow pea pods by Fletcher (1918). Bridwell (1919) while giving an account of field biology of C. chinensis observed the bruchid to lay eggs either on the unbroken red gram pods or if the pod had burst open, upon the beans. According to Skaife (1918) it preferred dry and ripe pods of cow pea.

Kunhikannan (1919) from Mysore State reported that number of pods were dry and open at the time of harvest which enabled the beetles to lay eggs on the exposed seeds leading to possible infestation subsequently. Similar observations were also made by Raina (1971) by C. chinensis and C. maculatus. None of them specified the extent of infestation. Bindra and Jakhmola (1967) reporting on field infestation on red gram, stated that per cent pod attack varied from 1.2 to 10.2 per cent with a mean of 5.15 per cent and in the case of seeds, it ranged from 0.4 to 4.8 per cent with a mean of 2.25 per cent. In another instance, five per cent of pod samples and zero to 26.4 per cent (mean 3.49 per cent) of seed damage was reported (Anonymous, 1976). Field incidence ranging from 16.42 to 40.7 per cent on eight varieties of red gram was recorded by Gunathilagaraj et al. (1977).

The present study in field infestation based on percentage of seed damaged as well as percentage of samples damaged (Table I and II) showed maximum bruchid infestation in case of green gram (1.26 and 68.42 per cent) followed by red gram (0.90 and 49.41 per cent), field bean (0.33 and 22.22 per cent), cow pea (0.18 and 18.25 per cent) and horse gram (0.05 and 5.55 per cent). An interesting revelation was that both black gram and soy bean were not infested in the field.

Seasonal Incidence

Practically no information is available on seasonal incidence of bruchids on standing pulse crops in the field. The present study was conducted during the period from September 1976 to July 1977 on red gram crop and was confined to two species of bruchids namely, *C. theobromae* and *C. chinensis*. Throughout the investigation period, *C. theobromae* recorded comparatively higher incidence than *C. chinensis*. *C. theobromae* registered the lowest incidence during June 1977 (mean of 0.83 beetles) while for *C. chinensis* the lowest was during September 1976 with a mean of 0.00 beetles. The peak incidence in respect of both species was observed during January 1977 (mean of nine and eight beetles, respectively). The combined incidence of *C. theobromae* and *C. chinensis* was observed to be low (mean of 1.50 beetles) during September 1976 and April 1977. Bruchid incidence which was low during September 1976, incidentally the period of commencement of flowering of the main crop, was observed to rise during October 1976 (mean 7.80 beetles). The infestation gradually increased in December 1976 (mean 13.50) and culminated in the peak incidence of 17.00 beetles (mean) in January 1977, incidentally the period of harvest. While *C. theobromae* followed the above trend, the incidence of *C. chinensis* was observed to increase without any setback.

Subsequently, the combined incidence was noted to fluctuate with two small peaks of 3.17 (mean) beetles in March 1977, and 5.02 (mean) in July 1977. Individually, *C. theobromae* was observed to register a decrease in the incidence during February to June 1977 (mean 1.17 to 0.83 beetles) with a sudden rise in the month of July 1977 (3.90), whereas *C. chinensis* followed the trend of combined incidence with two smaller peaks in the month of March (mean 2.0 beetles) and June 1977 (mean 2.92 beetles).

Since the maximum field infestation of both species of bruchids *C. theobromae* and *C. chinensis* occurred during January 1977 coinciding with the period of harvesting of red gram, it was considered the most suitable time for taking up pre-harvest application with insecticides so as to reduce the subsequent infestation in the stores.

The incidence of *C. theobromae* and *C. chinensis* was negatively correlated to temperature (r =-0.754 and -0.672, respectively).

Life History of *C. chinensis*

The present observations relating to morphology of eggs that they were oval, pointed at one end and planoconvex agreed with those of Kunhikannan (1919) and Raina (1970). The former specified the length of the egg to be 0.3 mm and width to be half of that of length. In contrast, the length ranging from 0.52 mm to 0.60 mm with a mean of 0.56 mm and width ranging from 0.30 to 0.36 mm with a mean of 0.34 mm were reported in the present study.

An incubation period of 4.2 days at 30°C and 70 per cent relative humidity on cow pea (Hose and Currie, 1964), 3.5 days on green gram under similar conditions (Raina, 1970), and three to eight days on cow pea (Rajak and Pandey, 1965) were reported under laboratory conditions. As against this, the present investigation indicated an incubation period of (from the time of egg laying to the time of hatching and boring into the seeds) 6.67 days on red gram during April 1977 (ambient mean temperature of 28.56°C and mean relative humidity of 68.34 per cent) to 8.17 days on green gram during January 1977 (ambient mean temperature of 22.89°C and mean relative humidity of 63.10 per cent). The shorter incubation period observed by earlier workers is due to higher temperature and relative humidity. Further, the present observation that variations noted in the incubation period between egg laid in different days of oviposition was not marked, and this agreed with that of Raina (1970).

The period of incubation ranged from 6.19 days on red gram pods in the field during March 1977 (mean temperature of 26.40°C and mean relative humidity of 75 per cent) to 6.49 days during April 1977 (mean temperature of 26.75°C and mean relative humidity of 85.28 per cent). With an exceptional prevailing temperature of 33.07°C and 71.71 per cent relative humidity the incubation period was extended to 7.95 days, while Skaife (1918) stated 10 to 21 days of incubation period on cow pea during cold months in Africa.

The observations in the present study relating to the presence of a pair of pronotal plates/spines, atrophied conditions of thoracic legs are in agreement with the findings of Chittenden (1898), Kunhikannan (1919) and Van Emden (1946). That the pronotal plates were helpful to the grub at the time of hatching to get a proper hold of the egg shell (Kunhikannan, 1923) was observed in this study also. The hold in the egg shell established by the pronotal plates of the grub was clearly indicated by the presence of internal scratching at the broader end of the egg. The present observation on the measurements of the first instar larva (0.51 mm long and 0.32 mm broad) are in close agreement with that reported by Kunhikannan (1919). In the present investigations, subsequent instars differed from the first instar in respect of size as well as the absence of pronotal plates, the latter conforming to the observation of Kunhikannan (1919). Further, the present study showed that the head became indistinct and represented by mouth parts only and thoracic region became enlarged as compared to posterior part of the body. In subsequent instars the grub assumed curved shape like letter 'C'.

According to Howe and Currie (1964) and Rajak and Pandey (1965) the grub underwent four instars which was confirmed in the present study. In the present study, an attempt has been made to determine the larval instars based on the number of head capsules sandwitched sequentially between faecal pallets of preceding and succeeding instars. In the dissected seed, presence of the number of head capsules sandwitched between faecal pallets of preceding and succeeding instars indicated the number of instars completed by the grub. The duration of each larval instar was computed by dissecting a known number of seeds from among the seeds infested with eggs which were laid on the same day and hatched on the same day. This gave only the range. In the present investigation the I, II, III and IV instars occupied 1 to 4, 1 to 4, 2 to 4 and 2 to 5 days, respectively under ambient temperature. These observations were more or less comparable with that of Howe and Currie (1964) who carried out studies at 30°C and 70 per cent relative humidity, and partly with that of Rajak and Pandey (1965) who carried out studies under ambient conditions (except during winter). However, the exception in the case of the latter was with regard to the duration of IV instar (16.7 mean days).

The study on the behaviour of the grub revealed that it bored vertically into the seed upto the end of first instar. Then it tunnelled horizontally towards the seed coat. In the later stages of the fourth instar, when the grub reached the testa, it fed and left a thin layer of testa which appeared like a circular spot (window). These observations agree more or less with the earlier findings of Howe and Currie (1964) and Raina (1970). However, none have made any observations regarding the pupal chamber constructed by the grub through compressing the faecal pallets and the meal (obtained in the course of tunnelling and feeding) against the wall of the tunnel. The circular spot (window) which was the future exit for the adult, formed a part of the wall of the pupal chamber. Facing the window, the grub became inactive and underwent pre-pupal and pupal stages, which is in perfect agreement with the findings of Howe and Currie (1964) and Raina (1970). Again, both these workers did not specify the period of pre-pupal period. In the present investigation, the pre-pupal period was found to last for 1 to 4 days. The stage was easily recognized by the distinct head, comparatively narrower thorax followed by the bulged abdomen. The pupal stage occupied a period of more than two days, and extended upto nine days. These observations agree with that of Howe and Currie (1964) but disagree with those of (6 to 21 days) Rajak and Pandey (1965).

Under field conditions, the studies showed that the grub, after hatching and boring into the pod coat of red gram, successfully continued further boring into the seed if only the latter was in close contact with the pod coat without leaving any gap in between.

The successful entry of the grub into the pod was revealed by the presence of a pinhole seen through the egg shell. The post-entry behaviour of grub inside the seed followed similar trend observed earlier under laboratory conditions. The present observations are more extensive proving conclusively certain existing speculations of Sangappa and Balaraju (1977) to be true.

The mean larval-pupal developmental period under laboratory conditions was observed to be shortest during April 1977 (17.95 days on red gram) with a mean temperature of 28.56°C and relative humidity of 68.34 per cent and longest during January 1977 (23.67 days on green gram) with a mean temperature of 22.99°C and relative humidity of 63.10). The finding in respect of red gram is in agreement with that observed by Raina (1970) on mung (18.8 days). The longest period of 23.67 days observed on greengram in the present study fell little short of 26.4 days recorded on mung by Haricharan Singh (1962).

Under field conditions, the mean larval-pupal developmental period was observed to range from 25.07 days during June/July 1977, (mean temperature 24.28°C, mean relative humidity 94.42 per cent) to 30.91 days during March/April 1977 (mean temperature 27.87°C, mean relative humidity 86.22 per cent) on red gram pods. The influence of temperature on the mean larval-pupal developmental period was inversely proportional under laboratory conditions, while under field conditions, it was directly proportional. This incongruity between the observations under these conditions cannot be explained satisfactorily. However, according to Skaife (1918) the larval stages of C. chinensis on cow pea in South Africa lasted for four to five months during cold season but only about five weeks in summer.

As against the observations of Rajak and Pandey (1965) who observed a wide fluctuation in the total developmental period ranging from 17 to 114 days on cow pea seeds during different months, in the present study, the total developmental period varied from 24.62 days (during April 1977 in red gram) to 29.75, 31.84 and 32.36 days (in red gram during June and in green gram and cow pea respectively in January 1977). The variation seen may be attributed to the influence of host and the weather factors prevailing during the period of study. The extreme long period reported might have been observed under extremely low temperature prevailing during winter in North India. However, the above revelations come close to the observations of Raina (1970) who reported a total developmental period of 21 to 27 days on mung.

The observation of Booker (1967) that the pre-adult developmental period of C. maculatus had negative correlation with temperature was confirmed in the present study on C. chinensis too under laboratory conditions.

It is to be emphasized that field study pertaining to total developmental period is absolutely lacking. The present investigations showed the period to range from 31.52 days during May/June/July 1977 with a mean temperature of 24.28°C and relative humidity of 94.42 per cent to 37.00 days during March/April 1977 (temperature of 27.87°C and relative humidity of 86.22 per cent) showing a similar trend as in the larval-pupal development. Further, in one instance of exceptional situations prevailing in glass house which had mean temperature of 33.07°C and relative humidity of 71.77 per cent when the outside temperature and relative humidity was mean 24.33°C and 84.50 per cent respectively, the developmental period was extended upto 61.50 days in red gram pods (seeds).

Under laboratory conditions, adult was found to emerge from the seeds by cutting all along the border of the circular lid of the window and pushing it open. Under field condition, after emerging out of seed, it found itself in the space between the seed and pot coat, in which adult beetles made a circular cut and emerged (Fig.16). Mating and oviposition were observed to take place invariably outside the seed and pod. The present finding disproves the claims of Bridwell (1918) that adults of C. chinensis which had developed from eggs laid on unbroken pods of pigeon pea to mate and oviposit before cutting their way out of the pods. The observations of Raina (1971) that a few of the adults which developed on cow pea, mung, urid and red gram after 95 per cent larval mortality, could not chew their way out of pod leading to virtual failure of adult emergence was not substantiated in the present study. The present finding was in conformity with the observations of Sangappa and Balaraju (1977) that the adult emerged from red gram pods through circular holes.

Further findings in the present studies are related to the percentage of eggs successfully developing into adult in the case of red gram (81.36), green gram (86.79) and cow pea (82.03) under laboratory conditions. Further, it ranged from 2.22 to 22.02 per cent in red gram under field conditions. Another interesting finding during the current study was that of the different stages, green and mature green pods were proper stages for the development of C. chinensis and yellow pods supported low development (6.45 per cent), while tender and dry pods were not at all suitable for development. These findings are in perfect agreement with those of Sangappa and Balaraju (1973) and that of Gunathilagaraj et al. (1977) in respect of green and mature green pods. Raina (1970) reported that 93.33 per cent of eggs of C. chinensis laid on first day and 28.6 per cent of eggs laid on seventh day, developed into adults. Excepting a few cases, above trend was observed in the present study too.

There is a good deal of controversy in the reports about sex ratio, eg., males outnumbering females (Haricharan Singh, 1965; Adarsh and Sohi, 1969; Raina, 1970), more females in relation to males (Teotia and Singh, 1966) and the sexes almost in equal number (Raina, 1970). The present study almost conformed to the observations of Raina (1970) in that the sex ratio of C. chinensis was equal during January/February, April/May and May/June, and the ratio of male was slightly predominant over females during February/March (67 : 60.2) and March/April (47.5 : 36). These findings clearly indicate the seasonal fluctuations in sex ratio of this bruchid.

Under field conditions, males continued to dominate over females with the ratio of 2:0, 7.5:1, 1:0 and 3:1 as recorded during January to March under glass house conditions (with mean temperature of 33.07°C and relative humidity of 77 per cent), March/April, April/May and May to July months respectively, which may be due to the influence of developing seed as against dry seeds. These observations under field situations were in conformity with the findings of Haricharan Singh (1965), Adarsh and Sohi (1969) and Raina (1970) obtained under laboratory situations.

The present observations indicated that the adults didi not feed on any part of the red gram plant even when enclosed on them. The present observation is in agreement with that of DeLuca (1966) who stated that the adult of Callosobruchus species do not require food for survival or reproduction. However, it differed from the findings that adults consumed pollen of pea flowers reported by Pajoni and Mohingergill (1974).

The study on premating and mating period revealed a mean premating period of 45 minutes and 45 seconds with a range of 3 to 95 minutes in contrast to the observations of Raina (1970) according to whom the adults were sexually mature at the time of emergence and mated within an hour.

Here, an attempt has been made to explain the phenomenon of mating behaviour of <u>C. chinensis</u> on which information available is scanty. The males were found to be active as compared with the females in that the males took the active part in chasing the female. The female was passive and avoided the probing aedaegus with its hind legs. After a number of attempts, male succeeded and established union by climbing over the back of female. The mating period lasted for a mean duration [illegible] ? seconds ith a range of 2 minutes 10 seconds to 3 mim [illegible] which is less than the period of 5 to 8 minutes obse [illegible] 1970).

Repeated mating [illegible] g both sexes which is in conformity with the observ [illegible] aran Singh (1965) and Raina (1970). Mating was seen both [illegible] and dark conditions which is in agreement with the [illegible] Pajani and Mohindergill (1974).

Very short pre-oviposition period was observed by Howe and Currie (1964) without specifying the period. According to Raina (1970) mating and oviposition followed emergence. Disproving the contention of the latter, the present study has established the mean duration of 72 minutes 12 seconds with a range of 19 minutes and 45 seconds to 129 minutes and 30 seconds from first mating to deposition of the first legg.

As regards oviposition, though deposition of single egg per seed was common, laying of more than one egg upto three eggs per seed was also not uncommon inspite of the presence of seeds without eggs in the vicinity. The present findings are opposed to observations of Utida (1943) who reported an initial oviposition of one egg on each of the available seeds and further oviposition was at random, and those of Zaazou (1953) and Oshima <u>et al</u>. (1973) who claimed that <u>C. chinensis</u> inhibited second oviposition on seed through a chemical marker. The observations of Raina (1970) that usually 1 to 3 eggs were laid per seed although as many as seven eggs were noted on a single seeds while a few seeds without eggs were still there has been confirmed in the present study.

Under field conditions, the oviposition was observed to follow the trend seen under laboratory conditions, wherein egg laying at the rate of single egg per red gram pod to as many as six eggs confined to a small area on the pod. This study has not been carried out earlier elsewhere.

The earlier workers (Bridwell, 1918; Kunhikannan, 1979; Raina, 1971) studied that eggs were laid either on unopened red gram pods or on beans in the case of open pods. In the present study, eggs were seen laid on red gram pods to a greater extent and rarely seen on exposed seeds in the open pods.

The studies on egg laying as influenced by the stage of the pod showed the mature pods with maximum egg deposition (463) as the most preferred stage followed by yellow pods (118 eggs) and green pods (105 eggs). Dry and tender pods with only 25 and 10 eggs respectively laid on them were observed to be least attractive. Very tender pods flowers and buds did not attract *C. chinensis* for egg laying which is in conformity with the observations of Skaife (1918) that bruchid preferred dry and ripe pods of cow pea, and those of Prevett (1961) and Casewell (1961) who reported that the oviposition of *C. maculatus* commenced only after the cow pea pods were fully formed and appeared light coloured. But the present finding disagrees with the observations of Schalk and Russolion (1973) that *C. maculatus* preferred developing pods of cow pea over mature pods for egg laying. Similarly, the present observation also contradicted the findings of Sangappa and Balaraj (1977) and Gunathilagaraj *et al.* (1977) who observed highest number of egg on green red gram pod over yellow and mature pods. In the above references the criteria for determining the different stage of the pod or their duration were not specified which may be the prime reason for the present disagreement.

The lowest mean fecundity of 42.62 eggs and highest of 83.00 eggs observed under laboratory conditions (Fig.25) agree with the observations of Takasugi (1924), Howe and Currie (1964) and Raina (1970) who reported 70 to 80, 20 to 64 and 36 to 90 eggs respectively. However, the maximum egg laying of 103 reported by Rajak and Pandey (1965) was found to be too high.

Further, the observations of Raina (1970) that maximum daily number of eggs laid was observed during the first 24 hours was not confirmed in the present study where the maximum daily egg laying was noted on the second day which conformed to the observations of Howe and Currie (1964). Field studies showed fecundity of C. chinensis to range from 48 to 56 eggs (mean 52 eggs).

Very little variation was noted between the longevity of males (7.27 days) and female (7.30 days) (Fig.22) which was in agreement with the observations of Raina (1970). During the period of present study longevity in the case of both sexes never exceeded 9.5 days while Haricharan Singh (1965) recorded 12.3 days and 15.6 days respectively of males and females during November which was due to the influence of low temperature prevailing during that month.

The only report of Rajak and Pandey (1965) pertaining to the larvae of C. chinensis hibernating during coldest month of the year was not noticed in the present investigation due to, perhaps, the temperature prevailing at the period was not low enough to induce hibernation.

As many as seven parasites have been reported from various parts of the world on C. chinensis of which the three hymenopterous species Bruchobius colemani (Crwf.), B. vagabundus Timb., Bruchocida orientalis Crwf and a parasitic mite namely Pyemotes ventricosus Newp have been recorded from India and in particular from erstwhile Mysore State (Kunhikannan, 1919; Usman and Puttarudriah, 1955). The present finding included two hymenopterous parasites Dinarmus vagabundus Timb., a pteromalid parasite collected under laboratory conditions and an eupelmid parasite collected from bruchid infested pods from fields as well as *Pyemotes ventricosus* collected in the laboratory on *C. chinensis*. The pteromalid parasite is recorded for the first time on *C. chinensis* from India.

Studies on the Comparative Development of *C. chinensis* and *C. maculatus*

The studies on the comparative development of two species of bruchids, *C. chinensis* and *C. maculatus* have brought to light interesting information. Out of the eight hosts (Table XI) seeds in which their development was studied, both species successfully completed their development in the seeds of Bengal gram, field bean, cow pea and red gram. *C. chinensis* completed its development in lesser time than *C. maculatus* in all the four host seeds to complete its development. In black gram, field bean (var. Hebbal Avare-3) and soy bean, *C. chinensis* failed to develop, while *C. maculatus* successfully developed. The observation in respect of black gram comformed to the findings of Shivashankar *et al*. (1972). The study also reveals the fact that shorter developmental period as well as the extensive area under favourable hosts of *C. chinensis* are the factors which have favoured the former to dominate over *C. maculatus*.

Ecology Studies

Pajani and Mohindergill (1974) observed that the adults hid themselves under seed but copulated with equal efficiency both under darkness and light. Though the present study (Table X) showed that the adults of *C. chinensis* were attracted to light the females were found to prefer darker or shaded surface of the seed for laying eggs (upto 94 to 96 per cent) as compared to lighted surface which recorded only 15.13 per cent eggs.

A temperature of 30°C and relative humidity of 55 per cent were observed to be the most favourable for the rapid development of the bruchid (22.18 days) as established by the present study. Further increase or decrease in relative humidity at 30°C had adverse effect on the development in that it showed a tendency to prolong to 22.80 days (30°c and 90 per cent relative humidity) and 26.16 days (30°C and 33 per cent relative humidity).

Temperature of 10°C and 40°C at all levels of relative humidity were found to be unsuited for the development of the insect. The observations of Howe and Currie (1964) that 30°C and 70 per cent relative humidity were optimum for rapid development of C. chinensis and that none could develpp completely at 37.5°C as also that of Howe and Currie (1964) and Sinha and Utida (1967) regarding the minimum temperature for the development of C. chinensis agrees more or less with the present results.

As against the threshold development of 12°C to 13°C (Utida, 1971) of C. chinensis, a threshold development of 9.28°C was determined in the present study, C. chinensis required 481.10 degree days under laboratory conditions and 622.62 degree days under field conditions to complete one life cycle with 6190.75 degree days available under laboratory conditions and 5690 degree days under field conditions during the period of present study for the development of C. chinensis, it was found theoretically to complete 12.86 and 9.38

generations under laboratory and field conditions respectively. The observations almost agree with those of Haricharan Singh (1965) and Anonymous (1976).

The present study on life-table of C. chinensis as stored product pest during its field infestation is the first attempt in this line from India. The only life-table study on bruchid conducted under field conditions is that of Mitchel (Personal communication) on Mimoestes amicus (Horn), infesting pods of Circidium floridum Benthi wherein he has observed a mortality of 25 per cent during the egg stage owing to the desiccation because of desert conditions. Further, mortality was noted among the larvae after entering the pod and before entering the seed; most of the larvae that entered the seed survived to the adult stage.

In the present study, the mortality due to embryonic failure accounted for 23.24 per cent (stage of the pod-wise mortality ranged from 19.05 per cent in green pod to 45.45 per cent on dry pods). First instar larva showed the highest per cent mortality (56.57) than any other stages, the death of larvae being caused by both defective (weak) chorion of the egg resulting in the larval emergence through unusual exits and failure of the larvae to reach the seed after boring into the pod due to the gap in between the two. Tender and dry pods shared the above mortality as the gap between the pod coat and seed in both these stages frustrated the efforts of the larva to get into the seed. The suspicion of Sangappa and Balaraju (1977) has been proved beyond doubt as the factor in the present study. As the true legs of all the larval stages are atrophied, the presence of prothoracic plates in the first instar larva helps in hatching and boring into the seed or the pod coat as the case may be. When there is no gap between the pod coat and the seed as in the case of mature green and green pods the emerging larvae finds it easy to bore through the pod coat and then into the seed soon after its emergence from the egg, whereas when the gap is more as observed in the tender and dry pods the larva after boring through the pod coat, fails to crawl and bore into the seed because of lack of grip, resulting in its death. The mortality that was observed even in the case of the eggs laid on mature green and green pods may be due to the position of egg deposited on the pods. Mortality recorded by subsequent larval stages (27.52 per cent) and that of pupa (7.59 per cent) may be attributed to physiological and unknown causes. The death of adult due to trapping inside the pod was due to the relatively narrower size of the emergence hole. The mortality due to the predominance of males in the sex ratio may be due to the influence of developing seed, the physiology of which entirely differs from that of dry seed. However, this is only a chance factor. The negative trend index values in respect of tender, yellow and dry pods (zero) indicate that the mortality factors operating during these stages are effective in causing decline in the bruchid population. The positive trend index values of 2.85 (green pods) and 2.67 (mature green pods) indicate that mortality factors operating in these stages are not effective. Correspondingly, the generation survival was zero in tender, yellow and dry pods while 0.14 in green pods and 0.13 in mature pods.

Testing of Seeds of Different Pulse Crop Varieties for Their Relative Susceptibility to the Attack of Bruchids

In this study 17 varieties of red gram, 12 varieties of green gram, 9 varieties of black gram, 10 varieties of cow pea and 4 varieties of soy bean were tested using five parameters both under natural and artificial infestation conditions.

The present finding in respect of soy bean seeds that they were least susceptible to bruchid is in perfect agreement with the observation of earlier workers (Srivastava and Bhatia, 1958; Applebaum et al., 1968; Gokhale, 1973; Girish et al., 1974).

Among the varieties of soy bean, black kulthi was the least susceptible, while hill variety was the most susceptible one (Table XXII and XXIII).

Black gram was also found to be less susceptible to bruchids and was the next best to soy bean. The findings, while confirming the observations of Shivashankar et al. (1972) and Gokhale (1973) differ from those of Chopra and Khurup (1970) who stated that urid seeds were more susceptible.

In the case of varieties of black gram, V.Panth U-30 and local black gram were found to be least susceptible and highly susceptible varieties respectively. KH_3 variety of black gram tested and found resistant to bruchid attack (Shivashankar et al., 1972) repeated the performance in the present study (Table XXII and XXIII).

Green gram and cow pea ranked third and fourth in respect of comparative susceptibility. Chopra and Khurab (1970) stated that cow pea was resistant to the bruchid attack while green gram was highly susceptible. The claim of Gokhale (1973) and Girish et al. (1974) that green gram is having more food value than red gram did not agree with the present finding that red gram had more food value.

In regard to the varieties PS 2/1 (green gram), CG-5 and Ko.779 (cow pea) registered the lowest infestation of bruchids as compared to PIMS-2 (green gram), Pusa-2 and Pusa-4 (cow pea) which favoured the highest bruchid infestation in the respective crops (Table XXII and XXIII).

On the varieties of red gram, 4-46 was found to be the least susceptible and '53' was found to be the highly susceptible variety to bruchid attack (Table XXII and XXIII). Another important observation was that the seed preferred for oviposition was not necessarily preferred for further larval and pupal development (as revealed in case of soy bean in the present study). This finding is in conformity with that of Girish et al. (1974).

The findings in the present investigation in respect of seeds of different varieties of five pulse crops will be of great use to breeders and cultivators as well.

SUMMARY

CHAPTER VI

SUMMARY

Present investigations on bruchids dealing with fauna infesting various pulse crop seeds in the State of Karnataka, seasonal incidence of bruchids, field infestations, field and laboratory biology and ecology with special reference to Callosobruchus chinensis (Linn.), including life-table studies under field conditions, and testing of seeds of 52 varieties of five pulse crops to the attack of bruchids were carried out during the period from September 1976 to September 1977.

Studies on the bruchid fauna has revealed the presence of five bruchid species namely, Callosobruchus chinensis (Linnaeus), C. theobromae (Linnaeus), C. maculatus (Fabricius), C. analis (Fabricius) and an unidentified species infesting seven pulse crops grown in 10 districts of the State. Of these, C. chinensis was the dominant species by virtue of its attacking five out of seven crops that were surveyed.

The highest field incidence of bruchid was in green gram [Vigna radiata (L.) Wilczek, (Phaseolus aureus Roxb.)] followed by red gram (Cajanus cajan Linn), field bean (Lab-lab niger Medikus), cow pea [Vigna unguiculata (L.) Walp. Sub. sp. Cylindrica (L.) var. Eseltine, (V. sinensis Savi.)], and was the lowest in horse gram [V. unguiculata (L.) Walp Sub. sp Unguiculata, (Dolichos biflorus Linn)], soy bean (Glycine max Merr.) and black gram [V. mungo (L.) Hepper, (P. mungo Linn.)] were not infested at all.

Seasonal incidence studies of _C. chinensis_ on red gram revealed the lowest incidence of 1.50 numbers during September 1976 (period of commencement of flowering of main crop) and highest incidence during January 1977 which was incidentally the period of harvest of main crop. The bruchid incidence was found to be negatively correlated with the temperature.

Life history of _C. chinensis_ in the seeds of six hosts namely, green gram (local), cow pea (local), red gram (S_5), black gram (KH_3), field bean (Hebbal Avare-3) and soy bean (Hardee) under laboratory conditions and on red gram pods (Prabhat) under field conditions was studied. Developmental stages namely egg, larval, pre-pupal, pupal and adult were described in detail. Incubation period varied from 6.67 to 8.17 days under laboratory and 6.19 to 6.48 days under field conditions. The grub during the course of its developmental period passed through four larval instars and entered the pre-pupal stage which was followed by pupal stage. Four larval instars occupied 1 to 4, 1 to 4, 2 to 4, and 2 to 5 days, respectively. The pupation was in a pupal chamber constructed by the final instar grub by compressing the faecal matter against the walls of the excavation. The adult was observed to emerge from the seed by cutting a circular lid all along the periphery of the window which was made on the seed coat by the final instar grub before entering pre-pupal and pupal stage(s). Under field conditions, the adults emerged through the dry pod by cutting a circular emergence hole similar to the one on the seed. The larval and pupal periods ranged from 17.95 days (on red gram) during April 1977 to 23.67 days (on green gram) during January 1977. The duration under field conditions was shortest (25.07 days) during June/July 1977 and longest during March/April 1977 (30.81 days).

The total life-cycle of C. chinensis lasted for a period of 24.62 to 29.75 days on red gram and 31.84 to 32.36 days on green gram and cow pea, respectively under the laboratory conditions. The total developmental period was found to be negatively correlated to temperature which was significant. Sex ratio of C. chinensis was observed to be almost equal with male having slight predominance over females in laboratory. However, in the field, the preponderance of male was much higher. The present study revealed that adult bruchid neither fed on red gram flowers nor the pollen.

The act of mating has been described in detail. Pre-mating, mating and pre-oviposition occupied a duration of 45 minutes and 45 seconds, 2 minutes and 32 seconds, and 72 minutes and 12 seconds respectively under ambient temperature and relative humidity. The females laid eggs at the rate of one egg to as many as three eggs per seed. Similar was the trend under field condition, wherein on red gram pods as may as six eggs per pod confined fairly to a small area were recorded. Further, females were observed to prefer mature green and green pods for egg laying over yellow, dry and tender pods. The fecundity of C. chinensis as observed in the laboratory conditions ranged from 42.62 eggs during January 1977 to 83 eggs during February 1977. The maximum mean daily egg lay was observed on the second and first day which gradually decreased till the last day of oviposition. In the field, C. chinensis recorded a fecundity of 52 eggs. Adults of both sexes lived for a period which was almost equal, with female recording 7.30 days and male 7.27 days.

Besides the Pyemotes ventricosus Newp (Acari - Prostigmata - Pyemotidae), a parasite mite on C. chinensis, two more hymenopterus larval parasites namely, Dinarmus vagabundus Timb. (Hymenoptera; Pteromalidae) under laboratory conditions and an unidentified eupelmid parasite from field were recorded during the study.

Studies on the comparative development of C. chinensis and C. maculatus in eight host pulse seeds which included (1) Bengal gram, (2) black gram, (3) cow pea, (4) field bean (var. local), (5) field bean (var. Hebbal Avare-3), (6) horse gram, (7) red gram and (8) soy bean, showed that both species thrived in four hosts (1, 3, 4 and 7) while C. chinensis successfully completed its development over comparatively shorter period in five hosts (1, 3, 4, 6 and 7) C. maculatus was successful in completing its development in seven hosts taking relatively longer time, but with no egg laying in horse gram.

Studies on the effect of light on the oviposition trends revealed that C. chinensis inspite of being attracted to light, prefer shaded or darkened surface of the seed to the lighted surface for egg laying. Another study to determine the temperature and relative humidity favourable for the development of C. chinensis showed that a temperature of 30°C and relative humidity of

55 per cent to be most preferred. *C. chinensis* with a threshold development of 8.28°C, required 481.10 and 622.62 degree days (thermal constant) for the completion of one generation, respectively, under laboratory and field environments. *C. chinensis* was found theoretically to complete 12.86 and 9.38 generations under laboratory and field conditions respectively in one year.

The life-table studies of the above bruchid on red gram established the larval emergence outside through unusual exits because of defective (weak) chorion and failing to reach the seed because of gap between the pod coat and the seed as the key mortality factor which was effective in causing decline in bruchid population in tender and dry pod stages (negative trend index of zero). Positive trend index values observed in green (2.95) and mature green (2.67) pods indicated that mortality factors operating during these stages were ineffective in causing decline in bruchid populations.

Varietal evaluation studies pertaining to seeds of 52 varieties belonging to five pulse crops showed soy bean and black gram varieties to be the least susceptible followed by green gram and cow pea. Red gram varieties were found to be highly susceptible.

Similarly, among varieties under each pulse crops, black kulthi (soy bean), V.Panth U-30 (black gram), PS2/1 (green gram), CG-5 and 779 (cow pea) and 4-46 (red gram) were found to be least susceptible as opposed to varieties Hill (soy bean), local (black gram), PIMS-2 (green gram), Pusa-2 and Pusa-4 (cow pea) and No.53 (red gram) which recorded high infestation under respective crops.

REFERENCES

CHAPTER VII

REFERENCES

Adarsh, H.S. and Sohi, G.S., 1969, Effect of temperature and humidity on the development, survival, fecundity and longevity of Callosobruchus analis F. J. Res. Punjab. Agri. Univ., 6(1):207-213.

Anonymous, 1970, Selected statistical data - Storage where the loss is caused. Pesticides, 4(1):125.

Anonymous, 1971, New vistas in pulse production. Indian Agricultural Research Institute, New Delhi. pp.87-101.

Anonymous, 1976, Annual Report, 1975-76, Inter-national Crop Research Institute for Semi Arid Tropics. pp.101-135.

Applebaum, S.W., Southgate, B.J. and Podoler, H., 1968, The comparative morphology, specific status and host compatibility of two geographical strains of C. chinensis. J. Stored Prod. Res., 4(2):135-146.

Arora, G.L., 1966, Uscana sp. a new parasite of stored bruchids (Trichogrammatidae - Hym). Proc. Sem. Ent., Aligarh, Part.I.

Arora, G.L., 1977, Taxonomy of the bruchidae (Coleoptera) of North West India. Oriental Insects Suppl. No.7.

Atwal, A.S. and Bains, S.S., 1974, Applied Animal Ecology. Kalyani Publishers, Ludhiana. pp.111-180.

Atwal, A.S., Sidhu, A.S. and Gupta, J.C., 1968, Studies on the growth of population of Trogoderma granarium Everts of Callosobruchus analis (Fabricius). Indian J. Ent., 30(3):185-191.

Ayyar, T.V.R., 1940, Handbook of Economic Entomology for South India. Madras Government Publication. p.76.

Balraj Singh, J.S., Dhaliwal, J.S. and Atwal, A.S., 1977, Population studies on the maize borer, Chilo partellus (Swinhoe) in the Punjab. IV. Life-tables for determining key mortality factors. Indian J. Ecol., 4(1):107-117.

Beaver, R.A., 1966, The development and expression of population tables for the bark beetle, Scolytus scolytus (F). J. Anim. Ecol., 35:27-41.

Bindra, O.S. and Jokhmola, S.S., 1967, Incidence and losses caused by some pod infesting insects in different varieties of pigeon pea (Cajanus cajan (L.) Millsp.). Indian J. agric. Sci., 37(2):177-186.

Booker, R.H., 1967, Observations on three bruchids associated with cow pea in Northern Nigeria. J. Stored Prod. Res., 3(1):1-15.

Bridwell, J.C., 1918, Notes on the bruchidae and their parasites in the Hawaiian Islands. Proc. Hawaii. ent. Soc., 3(5):465-505.

Bridwell, J.C., 1919, Some additional notes on bruchidae and their parasites in the Hawaiian Islands. Proc. Hawaii. ent. Soc., 4(1):15-20.

Bridwell, J.C., 1929, The cow pea bruchid (Coleoptera) under another name - a plea for one kind of entomological specialist. Proc. ent. Soc. Wash., 31:39-44.

*Caswell, G.H., 1961, The infestation of cow pea in Western Region of Nigeria. Trop. Sci., 3:154-159.

*Chittenden, F.H., 1898, Insects injurious to beans and peas. Yb. U.S. Dep. Agric., pp.238-248.

Chondola, R.P., Trehan, K.B. and Bagrecha, L.R., 1969, Varietal resistance to Bruchus sp. in cow pea under storage conditions. Curr. Sci., 38:370.

Chopra, N.P. and Khurab, S.S., 1970, Relative resistance of some pulses to the attack of Callosobruchus analis (Fab.) (Bruchidae: Coleoptera). Bull. Grain Technology, 8:161-165.

*Corbett, G.H. and Miller, N.C.E., 1933, A list of insects with their parasites and predators in Malaya. Scient. Ser. Dep. Agric. Straits. Settl. F.M.S., 13:15.

Cotton, R.T., 1923, Aplastomorpha vendinei Tucker an important parasite of Sitophilus oryzae L. J. Agric. Res., 23(7):549-556.

*Crawford, J.C., 1913, Description of new Hymenoptera Nos.6, 7, 8. Proc. U.S. natn. Mus., 14:241-260.

DeLuca, Y., 1966, Adult feeding of bruchids. Parasitica, 22(1):26-54.

Fletcher, T.B., 1918, Report of Imperial Entomologist. Rep. agric. Res. Inst. Coll. Pusa 1917-1918. pp.84-116.

Girish, G.K., Karan Singh and Krishnamurthy, K., 1974, Studies on the oviposition and development of Callosobruchus maculatus (Fab.) on various stored pulses. Bull. Grain Technology, 12(1):113-116.

Girish, G.K. and Krishnamurthy, K., 1972, Losses of foodgrains in storage. Proc. Post-Harvest Techn. Cereals and Pulses, New Delhi. pp.199-205.

Gokhale, V.G., 1973, Developmental compatability of several pulses in the bruchidae-I. Growth and development of Callosobruchus maculatus (F.) as host seeds. Bull. Grain Technology, 2(1):28-31.

Gunathilagaraj, K., Muralidharan, V.N. and Rajendran, R., 1977, Observations on the field infestation of Callosobruchus chinensis (L.) on red gram. Madras agric. J., 64(9):626-627.

Harcourt, D.G., 1969, The development and use of life-tables in the study of natural insect populations. Ann. Rev. Ent., 14:175-196.

Harcourt, D.G., 1971, Population dynamics of Leptinotarsa decemlineata (Say). III. Major population processes. Can. Ent., 103:1049-1061.

Haricharan Singh, 1962, Biology of Pachymerus chinensis Linneaus on different food materials. Indian J. Ent., 24(4):287-289.

Haricharan Singh, 1965, Pachymerus chinensis Linn., its biology and extent of damage to grain. Pl. Prot. Bull., 16(1-2):23-28.

Howe, R.W. and Currie, J.E., 1964, Some laboratory observations on the rates of development, mortality and oviposition of several species of Bruchidae breeding in stored pulses. Bull. ent. Res., 55(3):437-477.

Jayarathnam, K., 1977, Studies on the population dynamics of the diamondback moth, Plutella xylostella (Linneaus) (Lepidoptera: Yponeumotidae) and crop loss due to the pest in cabbage. Ph.D. Thesis submitted to University of Agricultural Sciences, Bangalore.

Kunhikannan, K., 1919, Pulse beetles (store forms). Bull. Dep. Agric. Mysore (Ent. Ser.), 6:31.

Kunhikannan, K., 1923, The function of the prothoracic plate in Mylabird (Bruchid) larvae. Bull. Dep. Agric. Mysore (Ent. Sen), 7:1-47.

Lal, S.S., Mangal Sain, S.C., Behera. and Varma, B.K., 1975, Record of biotic agents of insect pests and weeds of Hyderabad (Andhra Pradesh). Indian J. Pl. Prot., 3(2):225-226.

Larson, A.O. and Fisher, C.K., 1938, The bean weevil and the southern cow pea weevil in California. U.S. Dep. Agric. Tech. Bull., 593:70.

Lin, T., 1964, Laboratory tests of chemicals for Callosobruchus chinensis Linn., control. J. Taiwan agric. Res., 13(2):55-59.

*Mani, M.S., 1935, First record of the Trichogrammatid chalcid genus Chaetatricha Walker from India with a description of a new species (C. mukerjii from eggs of B. quadrimaculatus F.). Rec. Indian Mus., 37(3):337-338.

Mitchell, R., 1975, The evaluation of oviposition tactics in the bean weevil, Callosobruchus maculatus (F.). Ecology, 56:696-702.

Morris, R.F. and Miller, C.A., 1954, The development of life-tables for the spruce budworm. Can. J. Zool., 32:283-301.

Mukerji, S. and Chatterjee, S.N., 1951, Morphology of the genital structure of some of the Bruchidae (Larriidae) of India and Ceylon and other taxonomic importance. Indian J. Ent., 13(1):1-28.

*Oshima, K., Honda, H. and Yamamoto, I., 1973, Isolation of an oviposition marker from the Azuki gean weevil, Callosobruchus chinensis (L). Agric. Biol. Chem. (JAP), 37:2679-2680.

Paddock, F.B. and Reinhard, H.J., 1919, The cow pea weevil. Texas Agric. Expt. Sta., College Station Bull., 256:92.

Pajani, H.R. and Mohindergill, K., 1974, Effect of light on the pests of stored products. Bull. Grain Technology, 12(1):151-153.

*Pic, M., 1902, Coleopteres Presumes nouveaux de la Rhodesia. Rev. Ent. Caen., 21:4-7.

Prevett, P.F., 1961, Field infestation of cow pea (Vigna unguiculata L.) pods by beetles of the families Bruchidae and Curculionidae in Northern Nigeria. Bull. Ent. Res., 52:635-646.

Pruthi, H.S., 1969, A Text Book on Agricultural Entomology. ICAR Publication. p.500.

Raina, A.K., 1970, Callosobruchus spp. infesting stored pulses (Grain legumes) in India and a comparative study of their biology. Indian J. Ent., 32(4):303-310.

Raina, A.K., 1971, Observations on bruchids as field pests of pulses. Indian J. Ent., 33(2):194-197.

Rajak, R.L. and Pandey, N.D., 1965, A life history study of the pulse beetle, Callosobruchus chinensis Linn. (Coleoptera:Bruchidae) Labdev J. Sci. Technol., 3:119-123.

*Riley, C.V., 1892, The Pea and Bean weevil. Insect Life, 4:300.

Saleh, K.E., 1954, The effect of weevily-seeds on the oviposition of Bruchus (Callosobruchus) maculatus F. (Coleoptera : Bruchidae) Bull. Soc. Fouad. I. Ent., 28:311-313.

Sangappa, H.K. and Balaraju, E.S., 1977, A note on Callosobruchus chinensis Linneaus as field pest of redgram (Cajanus Cajan Springal). Curr. Res., 6(6):105-106.

Shivashankar, G., Devaraj Urs, K.C., Gopalakrishna Bhat, M. and Vishwanatha, S.R., 1972, Study of varietal resistance to Callosobruchus chinensis (L.) in black gram (Phaseolus mungo). Mysore agric. J., 6:360-362.

Sinha, R.N. and Utida, S., 1967, Climatic areas potentially vulnerable to stored product insects in Japan. Appl. Ent. Zool., 2(3):124-132.

*Skaife, S.H., 1918, Pea and bean weevils. Union of S. Africa Dept. Agric., Pretoria Bull., 12:32.

Southgate, B.J., Howe, R.W. and Brett, G.A., 1957, The specific status of Callosobruchus maculatus (F.) and Callosobruchus analis (F.). Bull. ent. Res., 48:79-89.

Srivastava, B.K. and Bhatia, S.K., 1958, Development of Callosobruchus chinensis in certain vegetable seeds. Madras agric. J., 45(10):392-395.

*Takahashi, H., 1937, Kurze Ueberricht der Geyan Wartigen Kenutuisse uber die Vorratsach a dilinge auf der Insel Formosa (A brief survey of present knowledge of store pests in Islands of Formosa). Mitt. Ges. Vorratsschutz., 13(1):4-6.

*Takasugi, T., 1924, Studies on Bruchus chinensis L., insect pest of stored products. II. Plant Quarantine Station. Yokohama. pp.1-2

Teotia, T.P.S. and Singh, V.S., 1966, The effect of host species on the oviposition fecundity and development of Callosobruchus chinensis Linn. Bull. Grain Technology, 4(1):3-10.

*Timberlake, P.H., 1926, New species of Hawaiian chalcidflies (Hymenoptera). Proc. Hawaii. Ent. Soc., 6(2):305-320.

Usman, S. and Puttarudriah, M., 1955, A list of the insects of Mysore including the mites. Bull. Dept. Agric. Mysore (ent. Ser.). 16:103.

Utida, S., 1943, Studies on the experimental population of the Azuki bean weevil, Callosobruchus chinensis (L.). VIII. Statistical analysis, of the frequency distribution of the emerging weevils on beans. Kyoto Imp. Univ. Coll. Agric., Mem., 54:1-22.

Shivashankar, G., Devaraj Urs, K.C., Gopalakrishna Bhat, M. and Vishwanatha, S.R., 1972, Study of varietal resistance to Callosobruchus chinensis (L.) in black gram (Phaseolus mungo). Mysore agric. J., 6:360-362.

Sinha, R.N. and Utida, S., 1967, Climatic areas potentially vulnerable to stored product insects in Japan. Appl. Ent. Zool., 2(3):124-132.

*Skaife, S.H., 1918, Pea and bean weevils. Union of S. Africa Dept. Agric., Pretoria Bull., 12:32.

Southgate, B.J., Howe, R.W. and Brett, G.A., 1957, The specific status of Callosobruchus maculatus (F.) and Callosobruchus analis (F.). Bull. ent. Res., 48:79-89.

Srivastava, B.K. and Bhatia, S.K., 1958, Development of Callosobruchus chinensis in certain vegetable seeds. Madras agric. J., 45(10):392-395.

*Takahashi, R., 1937, Kurze Ueberricht der Geyan Wartigen Kenutuisse uber die Vorratsach a dilinge auf der Insel Formosa (A brief survey of present knowledge of store pests in Islands of Formosa). Mitt. Ges. Vorratsschutz., 13(1):4-6.

*Takasugi, T., 1924, Studies on Bruchus chinensis L., insect pest of stored products. II. Plant Quarantine Station. Yokohama. pp.1-2

Teotia, T.P.S. and Singh, V.S., 1966, The effect of host species on the oviposition fecundity and development of Callosobruchus chinensis Linn. Bull. Grain Technology, 4(1):3-10.

*Timberlake, P.H., 1926, New species of Hawaiian chalcidflies (Hymenoptera). Proc. Hawaii. Ent. Soc., 6(2):305-320.

Usman, S. and Puttarudriah, M., 1955, A list of the insects of Mysore including the mites. Bull. Dept. Agric. Mysore (ent. Ser.). 16:103.

Utida, S., 1943, Studies on the experimental population of the Azuki bean weevil, Callosobruchus chinensis (L.). VIII. Statistical analysis, of the frequency distribution of the emerging weevils on beans. Kyoto Imp. Univ. Coll. Agric., Mem., 54:1-22.

*Utida, S., 1971, Influence of temperature on number of eggs, mortality and development of several species of Bruchids infesting stored beans. Jap. J. appl. Ent. Zool., 15(1):23-30.

*Van Emden, F.I., 1946, Egg bursters in some families of polyphagous beetles and some general remarks on egg bursters. Proc. R. ent. Soc. Lond. (A), 21:89-97.

*Varley, G.C. and Gradwell, G.R., 1963, The interpretation of insect population changes. Proc. Ceylon Assoc. Adv. Sci., 18:142-156.

*Varley, G.C. and Gradwell, G.R., 1965, Interpreting winter moth population changes. Proc. XII Int. Cong. Ent., pp.377-378.

Vazirani, T.G., 1975, A contribution to the knowledge of Oriental bruchids. J. Bombay nat. Hist. Soc., 72(3):740-757.

Vevai, E.J., 1970, Know your crop, its pest problem and control-19. Pesticides, 4(4):28-39.

*Weiss, 1915, Preliminary list of New Jersey. Acarine Entom. News. Philadelphia, 25(4):149-152.

Winston, P.W. and Bates, D.H., 1960, Saturated solutions for control of humidity in biological research. Ecology, 41:232-236.

*Zaazou, H.T., 1953, The effect of previous infestation on host selection. Bull. Soc. Fouad I. Ent., 37:479-485.

*Original not seen