BIO-ECOLOGY OF PULSE BEETLE, *Callosobruchus* spp. (COLEOPTERA: BRUCHIDAE) AND POTENTIALITY OF THEIR SAFE MANAGEMENT IN STORAGE AT TERAI AGRO-CLIMATIC CONDITIONS

A
thesis
submitted to the
University of North Bengal
for the degree of Doctor of Philosophy
in Science (Zoology)
2003

The Registration Number
AM23787

By

Tusar kanti Ghosal

Department of Zoology
University of North Bengal
Siliguri, Dist.Darjeeling-734430,
West Bengal, India

Dedicated to
My
Beloved wife and
Researcher in the field
of
Stored pulses

UNIVERSITY OF NORTH BENGAL
FACULTY OF SCIENCE
DEPARTMENT OF ZOOLOGY

Dr. D.C. Deb
Professor, Department of Zoology
North Bengal University

Siliguri, Darjeeling,
W.B.-734430, India.
Phone : (0353) 2581136
E-mail: dcdeb@rediffmail.com

Ref ……………… *Date* 01.07.2003

CERTIFICATE

THIS IS TO CERTIFY THAT THE THESIS ENTITLED "BIO-ECOLOGY OF PULSE BEETLE, *CALLOSOBRUCHUS* SPP. COLEOPTERA: BRUCHIDAE) AND POTENTIALITY OF THEIR SAFE MANAGEMENT IN STORAGE AT TERAI AGRO-CLIMATIC CONDITIONS" IS THE RECORD OF BONAFIDE RESEARCH WORK CARRIED OUT AT THE ENTOMOLOGICAL RESEARCH LABORATORY, DEPARTMENT OF ENTOMOLOGY, UTTAR BANGA KRISHI VISWAVIDYALAYA AND DEPARTMENT OF ZOOLOGY, NORTH BENGAL UNIVERSITY BY TUSAR KANTI GHOSAL UNDER MY SUPERVISION. I FURTHER TESTIFY THAT ALL THE DATA PRESENTED IN THIS DISSERTATION ARE BASED ON OBSERVATIONS AND NO PORTION THEREOF HAS BEEN USED IN ANY OTHER THESIS FOR A DIPLOMA OR DEGREE. THE ASSISTANCE AND HELP RENDERED DURING THE COURSE OF INVESTIGATION AND THE SOURCE OF LITERATURE HAVE DULY BEEN ACKNOWLEDGED.

(Dr. D. C. Deb)
Supervisor

Acknowledgement

With a sense of deepest gratitude I do express immense indebtedness to Dr.(Prof) Debesh Chandra Deb, Department of Zoology, North Bengal University, Siliguri, Darjeeling, W.B., India and Dr. Sabita Kumar Senapati, Head, Agricultural Entomology, Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar, W. B., India for their able guidance, kind co-operation and above all, their unfailing and amiable behavior and incessant help in the preparation of the manuscript.

The authors are indebted to Dr. T. C. Narendran, Professor of Zoology, Calicut University, Kerala, India ,Prof. M.hayat of Aligarg Muslim University, India and Dr.(Prof.) P. Mukhopadhyaya, Head, Coleoptera Division, Zoological Survey of India, Calcutta, India who identified the parasitoids and insect pests respectively. The authors also extend their gratitude to Late Dr. Pranab Gayan of Agril. Genetics & Plant breeding, U.B.K.V. and Dr. S. Shela, Coleoptera Division, Z.S.I., Kolkata, India for the identification of legume seeds.

It is a pleasure that on my part to acknowledge the debt I owe to the Head of the Department of Zoology, N.B.U. Siliguri and the Dean, Faculty of Science and Faculty of Agriculture of both North Bengal University and U.B.K.V respectively for their help and affectionate behavior during the course of my study. I desire to express my immense gratitude to all the respected teachers namely Dr.(Prof.)A.K.Chakravarty, Dr.(Prof.) B. Pal, Dr. J. Paul, Dr.A..Mukherjee, Dr.T.Chaudhury, and Dr. S. Barat and Dr. M. Bahadur Dept. of Zoology, N.B.U. for their affectionate suggestions, sincere and fruitful guidance, sustained interest and enormous encouragement throughout the course of investigation.

With profound glee, I extend my gratefulness to Dr. J. Ghosh, Dr. N. Chowdhuri, H. Chatterjee, Mr. S. Paul, Mr. T. Dhar, Dr. D. Sarkar, Dr. T. K. Hath, Mr. H. Das, Mr. Haru Singh, Mr. R. Layak, Mr. C. M. Roy, Mr. Saikat Chacraborty and Mrs. S. Bhattacharjee, Dept. of Agril. Entomology and Mr. S. Roy, Dr. A. Chowdhury, Dr. S.K. Laha and Dr. S. Dutta, Mr. S. Mitra, Mr. A. Ghosh, Mr. P. Satya, Mr. D. Debnath, Mr. K. Bhattacharjee and U. Guha of U.B.K.V., W.B. Dr. A. Pramanik and Dr. K. Karmakar, Dept. of Agril. Entomology, B.C.K.V., W.B. for providing expertise and benevolent co-operation. Sincere thanks are extended to Sandip Sengupta, Aloke Kar, Anupam Mukerjii, Gopinath Raha and Bikash Mitra and Aloke Kar of N.B.U. West Bengal.

I wish to record my appreciation for the careful and painstaking Computer typing of this thesis by Mr. Biswajit Talukdar, Mr. Abir Routh Md. K.H. Islam and Shamir Kumar Majumder of Samrat Xerox Centre, Gunjabari, Cooch Behar, West Bengal.

On Omega, I cannot but admit that my words fail to express my cordial love and gratitude to my Mother, Father, Mother-in-low, and also to my beloved Wife and Children for their never ending heartfelt benedictions, unstilted inspirations and count less blessings which always act as my savior in the face of all difficulties.

In thanking all those people, I must emphasis that I am fully responsible for any shortcoming that remains.

Tusar Kanti Ghosal

Place: N.B.U.
Date: 1st July, 2003

Tusar Kanti Ghosal

CONTENTS

Sl. No.	CHAPTER	Page No.

LIST OF TABLES

LIST OF PHOTPLATES

LIST OF APPENDICES

LIST OF FIGURES

Chapter-1

INTRODUCTION

INTRODUCTION

Pulse crops have play an important role in Indian agriculture. Besides being rich in protein and other biochemical substances, they sustain the productivity of the cropping systems. Their ability to use atmospheric nitrogen through biological nitrogen fixation (BNF) has earned their fame as economically sounder and environmentally acceptable crops. Pulses occupy 67.8 million hectares area and contribute 55.2 million tonnes of the world's food basket. Asia is the major pulse producing continent sharing 52.1% of the global hectarage (Chhabra, and Kooner, 1998). India is the largest pulse producing country and contributes to 35% of worlds' area and 27% of production. These crops account for one-fifth of the cultivated area and one-twelfths of the food grains production in India. In Indai, the pulse production per year is around 15 million tonnes (Kumar, 2000). Of the total production in India 60% is grown as rabi crop and 40% as kharif crop. Pulses account for roughly 20% of the total area under food grain crops and contribute to about 08.3% of the total food grain production in the country. The area under pulse crops in India at present is around 23 million ha, the production is around 15 million tonnes and the productivity is about 650 kg/ha. India will need at least 23 million tonnes of pulses by 2005 AD and 30 million tonnes by 2020 AD. Thus, a boost to the production and proper management are required at the national level (Asthana and Chaturvedi,1999). The commonly grown legume crops in India are green gram, chick pea, pea, pigeon pea, black gram, horse gram, lentil, moth bean, kidney bean, Indian or country bean and soybean. Though pulses are grown in almost all parts of the country, the important pulse producing states are Madhya Pradesh, Rajasthan, Uttar Pradesh, Maharastra, Orrisa, Karnataka, Andhra Pradesh, Hariyana, Bihar and West Bengal. The most drought-tolerant among kharif pulses are green gram, pigeon pea, horse gram, moth bean and those among rabi pulses are green gram, grass pea, lentil, cowpea and other beans. Every pulse plant is in itself a mini-fertilizer factory for fixation of atmospheric nitrogen to the soil.

In a country like India where a large population is vegetarian, the cheap and best sources of protein are still the pulses. On an average, pulses contain protein about 2.5-3.0 times higher than that in the cereals. On account of a balanced amino acid composition in blend proteins of cereals and pulses, which matches the milk protein, the importance of pulses in vegetarian diet cannot be over emphasized. Since pulses are cheaper than animal proteins, they are often referred to as "poor man's meat" in a developing country like India (Chaturvedi and Ali, 2002). The pulse seed contains protein, carbohydrate, lipid, mineral and bio-chemical substances

(**Appendix XIII**) and rich in lysine and poor in sulfur containing amino acids, a reverse situation exits in the cereal protein (Jeswani and Baldev, 1987).

Of many insect pests the Pulses are badly damaged by pulse beetles of the genus *Callosobruchus* (Coleoptera : Bruchidae) during storage throughout the world and this discourages the poor farmers from large-scale production and storage of pulses. Moreover, the amount of moisture in the seed is one of the important factors influencing the length of time the seeds remain viable. Seed moisture is a function of relative humidity (**Appendix VII**); seeds have an equilibrium moisture level in relation to the relative humidity around them. Air can hold only a certain amount of water vapour or moisture at any given temperature. A considerable quantity of stored pulses is rendered unsuitable for consumption due to attack of stored grain insect pests. After the induction of high yielding cultivars the production of pulse crops has been increased significantly over the years and use of comparatively better production technology. In storage, these are damaged by various agencies such as insects, micro-organisms, rodents and moisture, which cause colossal quantitative and qualitative losses. The quantitative losses of food grains in storage have been estimated to be 9.33% in India in comparison to other underdeveloped countries where these losses are as high as 30 – 50 % (Harein and Clarke, 1995). The Expert Committee, Govt. of India estimated that loss at threshing yards is 1.68% during transport 0.15%, during processing 0.92% and in post-harvest storage the post harvest loss is about 9.30% (**Appendix VIII**) The pulses are stored by farmers in indigenous storage structures where the maximum losses occur. The food grains are virtually living organisms. Hence, the grains should be stored as a living seed. A grain is physiologically quite stable after harvesting and this stability as well as viability should be preserved by adopting a good storage method. Under natural conditions, stored grains undergo chemical changes. Its further deterioration is caused by external living organisms, such as insects, microorganisms, moulds, fungi, mites and rodents.

Bruchids are serious world wide distributed group, most abundant in the tropics, whose larvae develop inside seeds, most preferred hosts belong to the leguminous family and al together other 24 plant families have been recorded as host by Southgate (1978). Approximately 1300 species of bruchids have been recorded, mostly attack the growing crops, but they get carried into stores in the ripe pods and seeds and some species are successfully able to continue their development in the dry seeds (Hill, 1990). Few other pests such as the rice moth (*Coryra cephalonica*) rice weevil (*Sitophilus* spp.) and red floor beetle (*Tribolium* spp.) also damaged stored pulses. Besides these pests, a few saprotrophic insects, mites, fungus by way of render the pulses unconsumable.

The pulses have to be stored either for short or long duration for utilization in future for human consumption, animal feeds and as seed. Pulses are stored by the farmers mainly in indigenous store structures in the rural areas where the maximum losses occur. No up to date accurate estimation of losses have been published so far although the results of a survey on stored pulses conducted in India (**Appendix IX**) indicated a maximum of 98%, 73%, 64%, 46%, 29% and 4% infestation in mung bean (*Vigna radiata*), grass pea (*Lathyrus sativus*), chick pea (*Cicer arietinum*), lentil (*Lens culanaris*), black gram (*V. mungo*) and pea (*Pisum sativum*) respectively by the pulse beetles *Callosobruchus chinensis* Linnaeus and *C. maculatus* Fabriceous after 6-8 months of storage (Mookherjee *et al.*,1970). The seed losses of cowpea due to *C. maculatus* were reported to be as high as 30% in India (Shivankar *et al.,* 1989) and an average loss of 14.92% of black gram in storage by *Callosobruchus* sp. in different parts of India (Mookherjee *et al.*, 1970). In tropical and sub-tropical regions the losses of stored pulses due to pulse beetle were shown to the tune of 60% and 20% respectively (Casewell, 1973 and De Teledo, 1946). As a result of improved storage technology, these losses in government warehouses could be reduced but at farmer's level where the maximum produce is stored, the losses are still too high. Pests of stored products are widespread over the globe and cause much damage due to their high resistance to unfavorable conditions, their high fecundity and fast development. Potentially, these pests can infest various kinds of stored grains, but their distribution in a country or in an area is usually determined by storage climatic factors.

In India, stored pulses are damaged by pulse beetles such as *C. chinensis* Linn.,*C. maculatus* Fabr., *C. analis* Fabr., *C. affinis* Frol., *C. emerginatus* All., *C. phaseoli* Gyll., *C. albacallosus* Pic., and *C. pisorum* Linn. Among these, *C. chinensis* is the most serious pest in India and also abroad. However, all species and varieties of stored pulses are not equally susceptible to the attack and damage. Although the accurate estimate is not available, pulses in storage suffer from a substantial damage due to bruchids. According to Mookherjee *et al.* (1970), the degree of damage caused by *C. chinensis* was mung bean> grasspea > chickpea > lentil > black gram > pea (**Appendix IX**). Only five species of bruchids of the genus *Callosobruchus* are was known from India of which three species the most important pests of stored pulses (Raina,1970). These are *C. chinensis*, *C. maculatus* and *C. analis*. These three pests feed on several hosts such as green gram, red gram, cowpea, bengal gram, grass pea, pea, lentil, black gram and moth bean.

The Terai agro-climatic region of West Bengal includes the area of entire Coochbehar and Jalpaiguri district, Siliguri sub division of Darjeeling district, and Islampur sub division of Uttar Dinajpur district (**Appendix XI** and **Plate 1**) Pulses are generally grown and store in traditional ways and thereby results in huge loss. The production of pulses in this region is very low as compared to that of West Bengal and Indian average due to inherent soil-climate and pest-disease complex of this region. However, there is immense possibility of improving production in different districts of this region are furnished in **Appendix-II**.

As per the available technologies, the use of contact insecticides and few fumigants for the large scale storages is common practice in India. As a prophylactic measures premium grade contact insecticides has been used since 1954in storage (Islam, 1999). Their use has several problems, such as environmental pollution, development of resistance by the pests, high cost and sometimes non-availability. Moreover, the use of these chemicals against pests is hazardous to small farmers because of their traditional storage practices, knowledge-gap of using proper dose of chemicals and financial constraints. Insecticides have been found very promising in suppressing the pulse beetles, but they are hazardous to mammals. Their use results in the development of high degree of resistance in insects and the edible legume seeds are rendered toxic to mammals. The development of resistance and cross-resistance to insect pests, death of natural enemies and harmful effect on human health become a great problem to stored grain insect-pest management. Bhujbal *et al.* (2001) have studied the efficacy of several insecticides and their residual toxicity. These adverse effects of insecticides necessitate diversified efforts for evolving more convenient and safer protection strategy.

In the recent past, the use of indigenous plant materials or botanicals has assumed an important position in the modern approach of pest control, as they are comparatively safe to the mammals due to their biodegradable nature. Pest management can not operate without accurate estimates of pest and densities of natural enemies. Keeping in view the hazards from excessive use of chemicals on stored grains, researchers have attempted the management of various stored grain pests by oneness of certain indigenous plant products and such rational has gained worldwide attention. Numerous plant species have been reported to possess pest control chemicals (**Appendix X**) but only few of them seem to be ideally suited for management of stored grain pests. Plants afford a rich source of chemicals with diverse biological activities. So far over 200 plant species belonging to 60 families are known to possess insecticidal properties (Dhaliwal and Arora, 1998). A number of minor insecticides of plant origin have also been identified for the presence of pest control chemicals (**Appendix X**).

Moreover, the concept of bio-control is easy and economic to deliver through seeds. In storage, the seed treatment with bio-control agents can easily bė applied by the seed producrs at the time of their seed processing. The cost of such treatment is extremely low and practically negligible whereas the benefits are several folds. In view of these advantages, research on developing further products of bio-control agents and their methods of application is sure to pay high dividends to researchers, farmers, commercial firms as well as the society. Therefore, a fillip to research in this line is an urgent need in our country.

The assessment of occurrence, distribution and abundance of pest and parasitoids are essential prerequisites to rational control programmers. This becomes possible by undertaking a survey, especially a qualitative and quantitative survey which involves the identification of the different species occurring over an area. Extensive works on relative susceptibility and extent of damage to different species of stored pulses by *Callosobruchus* spp. have not yet been done in the present investigation.

An extensive survey has been carried out covering a vast area of Terai Agro-climatic regioni.e. Northern part of West Bengal, India to detect species of pests and their natural enemies of stored pulses for assessing the status of populations / damage, studying the influence of weather (Appendix II) **and seasonal factors** (Appendix III) **on pests and natural enemies, recording new species of pests and parasitoids, monitoring the behavior of pests and natural enemies populations, marking endemic districts, and for adopting suitable management schedule for suppressing the pest population. This region in a greater sense is characterized by a distinctive Agro- climatic area** (Appendix III). **There are local variations within this area. Accordingly, the nature and extent of damage of stored pulses by a particular pest species vary according to local conditions. Concomitantly the dynamics of pest infestation and the status of damage of the stored legume seeds are expectedly of different dimension. These warrant the investigation of the bio-ecology and their suitable management of important stored legume pests.** The management strategy will preferably be a safer and non-toxic one. The foregoing account of current status of knowledge on stored pulse pests and potentiality of their management with the help of botanicals and parasitoids deals with one or other aspects of the complexity of problem as a whole. Many workers have studied the bio-ecology of stored grain pests in different climatic zones of India and abroad. But no body in this region has undertaken work on this aspect. This justifies the undertaking of a comprehensive study on the problem in context to Terai Agro-climatic region, where the present study has been carried out. This region has a distinctive potentiality of pulse production. But because of very poor storage facility and lack of storage protection know how, farmers do not find any impetus for large-scale pulse production. Therefore, thorough base level information is required for this area to generate knowledge and transfer of knowledge to the farmers. Keeping this in mind the present work has been designed as under:

- Survey of pests and their bio-control agents on storage pulses at Terai Agro-climatic conditions of West Bengal, India.
- Studies on the bio-ecology of *Callosobruchus chinensis* Linn. (Coleoptera: Bruchidae) on the green gram (V*igna radiata*) in laboratory condition.
- Studies on bio-ecology of *C. analis* Fabr. (Coleoptera: Bruchidae) on green gram (*V. radiata*) in laboratory condition.
- Studies of host preference and adult emergence of both *C. chinensis* L. and *C. analis* Fab. on different species of stored pulses during summer and winter seasons.
- Effect of seed weight, thickness of seed coat, moisture and phenol contents of fourteen species of pulses on the persistency of both *C. chinensis* and *C. analis.*
- Morphological studies of naturally occurring two potential key parasitoids of bruchid pests, [the egg parasitoid, *Uscana mukerjii* (Hymenoptera: Trichogrammatidae) and the larval pupal parasitoid, *Dinarmus vagabundus* (Hymenoptera:Pteromalidae)], in a reversionary frame work including their historical and taxonomical background.
- Studies on the biology and parasitization potentiality of, *Uscana mukerjii* in controlling *C. chinensis.*
- Studies on the biology and role of, *Dinarmus vagabundus* in controlling *C. chinensis.*
- Effectiveness of different plant oils at different concentrations on adult *C. chinensis.*
- Efficacy of plant oils in controlling *C. chinensis* on stored green gram up to 120 days

Chapter-II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

2.1. Occurrence of insect Pests of the Germs *Callosobruchus* of stored pulses, Extent of Damage and bio-control agents

2.1.1. Occurrence

Among the bruchids (Coleoptera: Bruchidae), *Callosobruchus chinensis* Linn is one of the serious pest of pulses. This insect was believed to be of Asiatic origin but is now widely spread throughout the tropics (Hamilton, 1894). According to Goncalves (1939) and Calderon (1958), *C. chinensis* was distributed from Asian countries to west to Africa and Mediterranean basin and east to America. It causes exclusive damage to legume crops in America (German, 1917), Europe (Zachir, 1930) and Australia (Mayne, 1948). Later on, it spread to India, Japan, Bangladesh, Pakistan, Ceylon, Burma, U.K., France and America. *C. chinensis* is a well known pest of stored legume seeds in Japan and is commonly known as Adzuki Bean weevil (Morimoto, 1939). In India, it is known as pulse beetle (Rahman *et al.*, 1942). Pruthi and Singh (1950) described 8 species such as *C. chinensis* Linn. *C. maculatus*, Fabr. *C. analis* Fabr. *C. albocallosus* Pic., *C. phaseoli*, Gyll., *C. affinis* Frol., *C.emerginatus* All. and *C. pisorum* Linn. which damage pulses in India. Raina (1970) observed 3 species of *Callosobruchus* (*C. chinensis*, *C. maculatus* and *C. analis*) as the most important pests of stored pulses. Important bruchids reported from Mexico and Columbia are *Callosobruchus* spp. (Labeyrie, 1981). In fact, *C. chinensis* has been reported from almost all parts of the world. Fifty four species of bruchids are reported from Poland of which *C. chinensis*, and *C. maculatus* are the important pest species of the genus *Callosobruchus* (Borowick, 1980). According to the report of Bahr (1980), *C. chinensis* and *C. affinis* were common pests of pulses in German Democratic Republic. Williams (1980) reported *C. phaseoli* and *C. rhodesianus*, *C. maculatus* as the important pests of stored pulses from Nigeria. In Sudan, the major pest species is *C. maculatus, and C.(=Bruchus) rufimanus* (Howtin *et al.*, 1982 and Fam *et al.*, 1983). *C. chinensis*, *C. maculatus* and *C. analis* are the three species reported from Bangladesh (Begum *et al.*, 1982 and Karim *et al.*, 1989). Southgate (1982) mentioned 4 species that damage pulses in India were *C. chinensis*, *C. maculatus*, *C. analis* and *C. theobromae*. In Kenya, *C. rhodesianus*, *C. chinensis*, *C. phaseoli* and *C. analis* were reported; among them *C. rhodesianus* was serious pest. However, *C. maculatus* could not be recorded (Warni, 1984).

Reports on *C. analis* as a serious pest of stored pulses in India have been made by Lefroy (1909), Flether and Ghosh (1920), Kunhi Kunnan (1919) and Rahaman (1942) in Burma by

Ghosh, 1937), in Germany by Zachir (1930), in South Rhodisia by Jack (1936), in South Africa by Evans (1939),in Japan by Miyake and Odera (1939), in Australia by Whightman *et al.*(1982), in Bangladesh by Begum *et al.* (1984), in Bulgaria by Soedomov(1984) and in Kenya by Warni (1984).

C. (=*Bruchus*) *pisorum* has been reported as pest associated with seed of peas from India (Arora, 1977). It was also reported from countries like Russia, U.S.A., and Africa (Smith *et al.*, 1982) and Bulgaria (Sadomov *et al*, 1988).

C. maculatus is spread wide almost throughout the world as destructive pest of stored pulses. It has been reported in India by Pruthi and Singh (1950), Raina (1970) and by Southgate (1982), from Bangladesh by Begum *et al.*(1984) and Karim and Rahman (1989), from Australia by Whightman and Southgate (1982), from Sudan by Fam *et al.* (1983), from Poland by Borowick (1980), and from Nigeria by Williams, (1980) etc. It is now almost cosmopolitan insect pest of pulses like that of *C. chinensis. C. maculatus* is a widespread pest of stored pulses. It was also reported from soybean (Howe and Currie, 1964) and French bean (Edward *et al.*, 1973). Whightman and Southgate (1982) recorded *C. chinensis, C. maculatus* and *C. rhodesianus,* from Africa and *C. analis, C. maculatus, C. chinensis* and *C. subinnotatus* from Australia during a survey. *C. maculatus* and *C. subinnotatus* were also reported on bambara and geocarpa groundnut seeds stored in traditional storages in Ghana (Amuti and Larbi, 1981). Sadomov (1984) reported *C. chinensis, C. analis, C. maculatus, C. pisorum, C. lentis* and *C. rufimanus* to infest stored legume seeds in Bulgaria. Hagstrum (1985) reported *C. maculatus* on cowpea seeds in Florida, USA. Warni (1984) reported *C. rhodesianus, C. chinensis, C. phaseoli,* and *C. analis* in Kenya; among them *C. rhodesianus* was the most injurious pest. Oviposition and development of the bruchid *C. maculatus* on 9 legume seeds was studied during survey and storage conditions in the Bundelkhand Region of Madhya Pradesh. Bengal gram was the most preferred; it developed in green gram, cowpea, lentil and red gram only. The survey results also showed similar trends. (Roy and Roy, 1994).

2.1.2. Nature of infestation

Singh and Sharma (1982) observed that the proportion of damaged grain by *C. maculatus* varied from 42.53% to 57.77% in different varieties of mung bean. Gupta *et al.* (1985) conducted an experiment with 11 varieties of mung bean (*V. radiata*) for screening their relative susceptibility to *C. chinensis* and found that the variety PS-7 was the most resistant variety having 22% infestation while Rmg-56 and Rmg-62 were highly susceptible having 72% and 80% infestation respectively. Weight loss of infested seeds is directly related to the growth, development and survivability of bruchid beetles. These parameters ultimately indicate the preference/non-preference of seed by beetles, which are again governed by the heritability of the concerned genotype. Gupta *et al.*, (1985) observed 36.22% and 73.80% weight loss for resistant and susceptible varieties of mung bean respectively.

Manohar and Yadav (1990) reported maximum weight loss (44.97%) by *C. maculatus* in susceptible variety of the cowpea Udaipur-2 and least (16.25%) in the variety CO-1. Damage by *C. maculatus* to seeds of bengal gram, black gram, black-eyed cowpea, green gram, chickpea, kidney bean, lentil, moth bean, red gram and rice bean was studied in indigenous storages in India. Females preferred green gram, black-eyed cowpea, moth bean for oviposition. Percent damage in term of exit holes and weight loss were in the descending order of black-eyed cowpea (69.2% and 34.5%) > moth bean (53.7 and 21.9%) > green gram (50.3 and 19.4%). (Ramzan *et al.*, 1990). The number of healthy seeds (percentage of infestation) was found to be highly heritable one for characterizing resistant genotype as documented by Sarkar *et al.* (1991) when tested with 16 mung bean genotype (*V. radiata*) against *C. maculatus.* Moreover, percentage of infestation was also influenced by size of seeds as higher number of seed damage (23-32%) by *C. chinensis* was noticed in case of large and medium sized seeds as compared to below 10% infestation in case of small seeds (Akhtari *et al.*, 1993). Again percentage of grain infested by *C. chinensis* varied significantly in different pulses in species as reported by Ashraf *et al.* (1991) and mung bean (*V. radiata*) suffered 100% damage by *C. maculatus* after three months of infestation period (Osman *et al.*, 1991). In another experiment, Ashraf *et al.* (1991) observed that the varieties of mung bean, mash and chickpea differed significantly in respect of weight loss caused by *C. chinensis* and among the varieties of mung, mung-141 was relatively more susceptible, sustaining a weight loss of 27.2%. Subsequently, it was observed that the percentage of weight loss was directly related to the number of holes and the position of hole in a seed as the undamaged seed gave the highest seed weight followed by single holed, hole near micropile, two holed and multi-holed damaged seed (Charjan and Tarar, 1994). Muhammad *et al.* (1997) carried out an experiment to evaluate susceptibility for eight different strains of mung bean (*V. radiata*) against *C. chinensis* which revealed that the strains MB-246 and Kanti were highly susceptible to the said beetle sustaining 13.6% and 13% weight loss respectively. Moreover, a significant difference was also observed in percentage of seed damage of pea by Bhagwati *et al.* (1995) when the infestation ranged from 10.00% to 42.67% with maximum damage noticed in JP Acacia (42.67%) and minimum in JP Batri Br-3, Br-4 (10%). Dias and Yadav (1998) reported the incidence of *C. maculatus*, *C. analis*, *C. theobromae* and *C. pisorum* in chickpea, green gram, black gram, pigeon pea, cowpea and pea from different Ecological Zones of India. *C. maculatus* was the dominant species followed by the *C. chinensis*, *C. analis*, *C. theobromae* and *C. pisorum.* Average per cent damage of pigeon pea, cowpea, green pea, chickpea and black pea was 14.65, 14.36, 10.08, 9.38 and 3.47 respectively. It was reported that the moisture contents of the seeds had a positive correlation with percent infestation (Singh, 1999).

2.1.3. Occurrence of parasitoids of *Callosobruchus* spp.

Bruchobius (=*Dinarmus*) *vagabundus* was first report from Hawai (Timberlake, 1926). In India, it was first reported by Mani (1939). At least 4 other species of pteromalid such as *D. basalis* Rondani, *D. acutus* Thompson, *D. laticeps* Ashmead, *and D. stringifrons* Waterson have been reported in India (Chatterjee, 1954; Cheema *et al.*, 1962; Verma, 1989; Mani, 1989; Verma, 1990 and Gupta *et al.*, 1997). Chatterjee (1954) and Cheema *et al.* (1962) also reported and observed the ovipositional behaviour of *D. vagabundus*. Gupta *et al.* (1997) studied the biological potentiality of *D. basalis* and *D. acutus* on bruchids. Kapoor *et al.* (1972) observed the biological activity of *Dinarmus* sp. *Ceralina* sp. (Apidae) and *Norbanus* sp. (Pteromalidae) in *Oberia brevis* (Lamiidae). *Cerocephala dinoderi* Gahan (Hymenoptera: Pteromalidae) was reported from the host insect, *Sitophilus* spp. and cosmopolitan in habitat (Mani, 1989). He also reported the occurrence of *D. vagabundus* in Pakistan, SriLanka and India (Mani, 1989). *Anisopteromalus calandrae* Howard, *Chaetospila elegans* Westwood, *Lariophagus distinguendus* Foerter, *Habrocytus cerealellae* Ashmead, *Dinarmus* spp. are the other species recorded by Hill (1990) and Baker *et al.* (1995) reported the braconid parasitoid *Bracon hebetor* (Hymenoptera: Braconidae) in Georgea. *U.mukerjii* (Mani) a potential parasitoid of bruchid pests was reported in India by Kapila *et al.* (1995) and Pajni *et al.*(1996). Nashimura and Jahn (1996) reported *D. basalis*, *A. calandrae* parasitaids of *C. chinensis* on *Vigna angularis*. According to the study of Tomer *et al.* (1997), *Dinarmus* sp. occurs in the field up to the last week of March. Alebeek *et al.*(1998) reported *D. vagabundus* in France. *D. basalis* and *Eupelmus vuilleti* were also known as parasitoids of *C. maculatus* and *Bruchidius atrolineatus* (Coleoptera: Bruchidae) when reared on cowpea seeds from West Africa (Anon *et al.*, 1998). Islam (1998) reported *D. basalis* and *D. acutus* on *C. maculatus* in Bangladesh. *Uscana lariophaga* Steffan (Hymenoptera: Trichogrammatidae) was reported on *C. maculatus* infested cowpea seeds in Egypt (Zaghloul *et al.*, 1998).

2.2. Biology of *Callosobruchus chinensis* Linn. in laboratory rearing

Utida (1942) reported an initial oviposition of an egg on each available seed, further, laying was at random. The number of eggs laid on a single seed varies with the size of the seed. The number of eggs laid in different food materials varied from 11-77.45 where minimum being on mung and maximum on chickpea seeds. The newly emerged larva bears a large spine on either side of the first abdominal segment and two groups of smaller spines dorsally on the target plate of the pronotum (Van Emden, 1946). The larva undergoes 4 moulds before pupation. Larval and pupal period lasts for about 18-20 days. A full-grown larva is about 6.3 mm long with wrinkled body. Pupal stage lasts for 4 days during summer. The complete development from egg to adult requires on an average of 22 to 23 days. There are several generations in a year. Singh (1962) observed that the incubation period 5.5-5.8 days and combined larval-pupal period recorded 18.9-38.3 days on different pulses at room temperature. Howe and Currie (1964) noted an average of 45 eggs with a range of 20-64 at 20^{0}C temperature and 70% relative humidity. They also observed that the incubation period was 4.2 days, pupal period took 2.7 days and the total development period varied from 18-22.5 days. Rajak and Pandey (1965) studied the biology of *C. chinensis* in India and reported that a female lays 50-103 eggs in her lifetime. An egg when freshly laid appeared translucent, smooth and become pale-yellowish with age. Eggs were about 0.57 mm in length. Incubation period ranged from 3-18 days. The average larval period was 29 days with 4 larval instars at 30^0 C temperatures and 75% r.h. The mean duration for 1st, 2nd, 3rd and 4th instars were 2.4, 3.5, 6.4 and 16.7 days respectively. The grubs hibernated during winter months from November to February. Pupal period varies from 6-21 days. Six generations were recorded from July to May. Duration of life cycle varied from season to season with minimum 27 days and maximum 114 days. Atwal (1968) reported the completion of life cycle in 21.89 days at 30^0 C and 70% R.H. He advocated that it did not exceed more than 31 days and average incubation period at 30^{0}C and 70% r.h. is 3-5 days, and per cent hatching ranged from 94-99. Raina (1970) reported larval and pupal period completed in 25 days at 30^0 C and 70% r.h., but it may take 23-26 days. Usually 1-3 eggs are laid per seed although as many as 7 eggs are reported. Dina(1971) observed that *C. chinensis* completed its life cycle with an average of 24.5-31,21.2-23.2,21.3-24,22-26.8 and 24.7-29 days in Bengal gram, green gram, cowpea, lentil and peas respectively. Siddiqui (1972) reported that an average incubation period was 5.5days, larval-pupal period varied 23,23.5, 25.5 and 36 days and 5.7, 5.6, 6 and 6 days for cowpea, green gram, chickpea and garden pea respectively. The percentages of total number of eggs developed into adult were 95.5, 96, 89.9 and 58.9 for cowpea, red gram, chickpea and garden pea respectively. Survival and growth responses of the species were the highest at 30^{0}C and least at 35^{0}C as recommended by Chandrakantha *et al.* (1986). Begum *et al.* (1987) studied the fecundity, fertility and adult longevity of the mated *C. chinensis* in Bangladesh. The mated females laid 74% viable eggs and no viable egg was laid by the unmated females. The mated females died faster than the unmated females. The insect mated several times during their life span and the average frequency was 3.7. *C. chinensis* had as many as 13 overlapping generations/year on lentil in the Chitwan district in

Nepal. The life cycle was completed in 3 weeks during March-October, whereas the life cycle was up to 3 months during November-March, 1988-89. (Parajulee *et al.*1989).

Han and An (1990) studied the bio-ecology of *C. chinensis*. The duration of life stage increased as temperature increased from 20 to 30^0 C. The threshold for development was 12^0 C and the temperature sum for development was 380.9 day-degrees C. There were 4 generations a year in central Korea, with peak adult emergence in May (in storage), early July (moving out to the field), mid August and early October (in fields). Over wintering took place in stored pulse grains.Islam (1991) studied the mating behavior of *C. chinensis*. Courtship was accomplished in 2 phases, mate locating and copulatory phase. In each phase, the male performed a series of discrete action. Lifting of the female's abdomen was essential for successful copulation. Shinoda *et al.* (1991) studied the population ecology of *C. chinensis* on 2 wild leguminous hosts, *Vigna angularis* var. *nipponensis* (an annual) and *Dunbaria villosa* (a perennial). Females laid their eggs on the mature pods of both legumes from mid-September to mid- October in Honshu, Japan. Most active oviposition was in late September. The larval survival rate decreased rapidly until 1st instar larvae penetrated into pod seeds. The percentages of seeds infested by *C. chinensis* ranged from 0-13.5%. These percentages changed yearly, but were almost always <5%. Biological studies on *C. chinensis* clarified that the optimum temperature for development was 27°c and 70% RH. Less humidity and higher or a lower temperature than 27°c decreased the hatchability (%) and adult emergence. At 20°c, these percentages were substantially lowered. An increase in temperature from 20 - 34°c shortened the incubation period, larval - pupal durations as well as adult longevity (Boshra, 1993). Hussain (1994) studied the effect of parental age of progeny of *C. chinensis* on stored pulses. The viability of eggs laid during the first 3 days of the female's life was constant but declined thereafter. The embryonic and post-embryonic development time and the sex ratio did not differ significantly with parental age. The sex ratio was almost 1:1. Fecundity was constant for the first 3 days and thereafter it decreased significantly with maternal age. Females which oviposited on day 6 had 60.68% less fitness than females which oviposited on the first day. Pandey and Singh (1997) studied the biology of *C. chinensis* on *V. mungo* and *Cicer arietinum* at 28^{0}C ± 5. Females laid an average of 70 eggs, with the maximum number of eggs being laid on the 1st day of oviposition. The incubation period lasted for 4-5 days. The combined larval and pupal period ranged from 20-28 days. Mortality during egg-adult stage was 24%, with most mortality occurring during the egg and early larval stages. He also observed that maximum daily egg laying occurred in the first day of oviposition, the number gradually dropped till the last day of oviposition. Hence the fecundity of a single female of *C. chinensis* had been 30-110 eggs at the rate of 1-35/day.

2.3. Biology of C. *analis* Fab. in loboratory rearing

De Luca (1966) advocated that it can develop in mature dry seed and do not require for survival or reproduction. Males are more active and better flier than females. Males live for 7-10 days while female for 5-10 days. The biology of *C. analis* is similar to *C. chinensis*. Females lay on an average of 96 eggs ranging from 57-127 or even more. It was also observed that in the seed from which adults did not emerge most of the mortality occurred in the egg and early larval stages. Similar observations were made by Howe and Currie (1964). Population of C. *analis* was found to attain its optimum intrinsic rate 32.5^{0}C, at which the doubling time, mean generation time and development period became minimal. The study was conducted at 20-30^{0}C temperature on green gram seeds in Bangladesh and the highest fecundity was observed at 35^0 C temperature (Begum *et al.,* 1984). Sadomov (1984) described the notes on the biology, harmfulness and control of the most important quarantine pests namely, *C. chinensis, C. maculatus, C. pisorum, C. lentis, C. rufimanus* and *C. analis* posing a threat to stored legume seeds in Bulgaria. Pandey and Singh (1997) observed that entire stage of mortality was 27% in *C. chinensis* and it was only 15% in *C analis*.

2.4. Host preference and relative susceptibility of pulses to bruchids

2.4.1. Host preference of C. *chinensis*

Srivastava and Bhatia (1958) also observed that development of *C. chinensis* was very fast in susceptible seeds of cowpea. They reported the effect of different pulses as food on the growth and development *C. chinensis*. Emergence of adults took place only on cowpea, broad bean, chick pea and garden pea. In sword bean, hyacinth bean, kidney bean and soybean, the larva entered the seed up to a pin point but all were found dead when seeds were dissected out. Larval growth was very fast in cowpea and chickpea but was slow in garden pea

They studied the development of *C. chinensis* with several host species and reported that in sword bean (*Canavalia gladita*), hyacinth bean (*Dolicos lab lab*), cluster bean (*Cyamopsis tetragonoloba*), Kidney bean (*Phaseolus vulgaris*) and soybean (*Glycine max*), the adult could not develop. The biology was relatively slower in garden pea and broad bean. Raina (1970) worked out on the biology of *Callosobruchus* sp. in the laboratory on the seeds of mung (*Phaseolus aureus*) at 30^{0}C and 70% r.h. He observed that 94-99% eggs were hatched and the developmental period was 18.8 days in case of *C. chinensis*. In other experiment in Iran, Seddiqui (1972) carried out the biology of *C. chinensis* on seeds of five types of pulses. The duration of larval-pupal period on mung bean was 23.5 days at 25.7^{0}C and 17% r.h. 96% of egg gave rise to adults. Bato and

Sanchez (1972) reported that the duration of egg, larval and pupal stage of *C. chinensis* on mung (*Phaseolus aureus*) were 4.61, 12.48 and 3.94 days respectively on an average at 83.61^{0}F and 67.79% r.h. with 14.7% moisture content in the seeds. The bionomics of different species of *Callosobruchus* have been studied by many investigators namely, Bato and Sanchez (1972), Southgate (1978), Arora and Singh (1970), Begum *et al.*(1982), Giga and Smith (1983) and Khare and Johari (1983). Singh *et al.* (1980) studied the ovipositional preference, growth and development of both *C. chinensis* and *C. maculatus* on different types of pulses. The authors also reported a resistance factor influencing the growth of *C. chinensis* and *C. maculatus* on black gram. The descending order of preference of *C. chinensis* for oviposition is cowpea > black gram > lentil > red gram > chick pea > green gram > pea wherein *C. maculatus* chick pea > black gram > green gram > cowpea > red gram > pea > lentil. *C. chinensis* can complete the growth and development on cowpea, lentil, red gram, green gram, chickpea and pea but it fails to complete development on black gram. Green gram was found to be the most suitable and lentil is the most unsuitable for growth and development in case of *C. maculatus.* On lentil, the developmental period was prolonged and the size and weight of adults, fecundity and life span were reduced. Ahmed *et al.* (1981) carried out an experiment on the biology of *C. chinensis* on broad bean seeds at 26±10^{0}C and 65±5% r.h. They reported that the duration of incubation period, larval period and pupal period were 5.39, 16.57 and 7.31 days respectively. Epino *et al.* (1982) observed that the developmental period of *C. chinensis* became prolonged on the resistant varieties of mung bean. Govindarajan and Balasubraniam (1983) made an observation on the effect of seed size on the ovipositional behavior of *C. chinensis* and *C. maculatus* on mung bean (*V. radiata).* Two bruchids preferred to oviposit on seeds weighing more than the average of those seeds used and the number of eggs on them was in proportion to seed weight.Tauthong and Wanleelag (1983) studied the biology of *C. chinensis* in Thailand at 4 types of temperature and R.H. The investigation showed that the optimum condition for development were 30^0 C and 80-100% r.h. At 30^0 C temperature and 95-100% r.h., the largest number of eggs was laid per female, but the highest percentage of hatching occurred at 80-85% r.h. Seven pulse grains, namely sweet peas, green gram (*V. radiata*), black gram (*V. mungo*), bengal gram (*Cicer aerietinum*), cowpea (*V. unguiculata*), pigeon pea (*Cajanus cajan*) and wild mung, *V. vexillata* (hard seeded, soft seeded and black seeded lines) were screened against the bruchid, *C. chinensis.* Percentage seed damage and the mean number of beetles which emerged per seed were significantly lower for all the 3 lines of *V. vexillata.* Percentage loss of seed weight was least in *V. vexillata* (0.97 – 2.5%), followed by that in sweet peas (2.7%) and *V. mungo* (2.2%). Of all these pulses, *V. vexillata* is the least susceptible to *C. chinensis* (Gabindan *et al.,* 1989). Parajulee *et al.* (1989) reported that lentils were preferred most by *C. chinensis* in Nepal. Although adult females laid more eggs on soybeans and kidney beans, only a few adults reached maturity.

Srivastava and Pant (1990) studied the growth and development of *C. chinensis* on seeds of 11 legumes. The preferred legumes were lentil, green gram *(V. radiata),* red gram *(Cajanus cajan),* bengal gram (*Cicer arietinum*) and cowpea (*V. unguiculata).* Pea and grass pea (*Lathyrus sativus)* was less preferred. Bhut (black-seeded soybean), soybean, black gram *(V. mungo)* and kidney bean (*Phaseolus vulgaris*) were unsuitable for growth and development of the pest. In a laboratory observation made by Dwivedi and Sharma (1993) on 7 different pulses where cowpea and soybeans were the most and least preferred food of *C. chinensis* respectively. Ahmed *et al.* (1991) studied genetic resistance in chickpeas (*Cicer arietinum) to C. chinensis* attack. Grain of 47 varieties was evaluated for number of damaged seeds, number of emergence holes and seed coat texture after exposed to the bruchid beetle using a free choice test. Varieties with a rough, hard, wrinkled and thick seed coat showed less seed damaged and were therefore, more resistance than varieties with small, soft and thin seed coats. Correlation between the 2 damage parameters was positive and highly significant. Oviposition and development of *C. maculatus* on 9 legume seeds was studied during survey and storage conditions in the Bundelkhand Region of Madhya Pradesh. Bengal gram was most preferred both under no choice conditions, bruchids developed in green gram, cowpeas, lentils and red gram only. The survey results also showed similar trends. (Roy and Roy,1994). Bhagwati *et al.,* (1995) reported that the development period of *C. chinensis* varied from 19 to 22.67 days in different genotypes of pea. Sison *et al.* (1996) reported that the total developmental period (egg to adult emergence) for the bruchid ranged from 21 to 30 days. Pupation took place in a cell inside the seed and the adults emerged through the entrance hole made by the larva. Pandey (1997) studied the biology of *C. chinensis* on black gram (*V. mungo*) and chickpea (*Cicer arientinum*) seeds at 28±2°C and 70±5% r.h. The incubation period was found to be lasted for 4-5 days and the larval-pupal period varied from 20 to 28 days. The mortality during the development from egg to adult stage was 24% while working on the life history of *C. chinensis* on mung bean .Pandey and Singh (1997) studied the biology of the *C. chinensis* infesting stored pulses like Urd (*V. mungo)* and chickpea (*Cicer arietinum*) seeds at 28 ± 2°C and 70±5% r.h. An average of 70 eggs was laid by each female, incubation period lasted for 4–5 days and combined larval-pupal period lasted for 20-28 days. Mortality during development from egg to adult stages was 24%, with most mortality occurring during egg laying and early larval stages. Srinivasacharyulu and Yadav (1997) studied the olfactory and ovipositional preference of two strains of *C. chinensis.* A soybean strain of *C. chinensis* and a local IARI strain were tested for olfactory attraction, oviposition, adult emergence, mean development period and growth index parameters of 4 legumes (Soybeans, cowpeas, chickpeas and pigeon peas). Choice and no-choice tests were conducted. The local strain failed to damage soybean.

Lambrides and Imrie (2000) studied the susceptibility of mung bean varieties to the bruchid species *C. chinensis, C. maculatus, C. phaseoli* and *A. obtectus.* Twenty-six (26) mung bean (*V. radiata*) varieties and accessions were screened for resistance to 4 bruchid species. On the basis of percentage of seeds damaged, all Australian commercial mung bean varieties tested were highly susceptible to strains of *C. chinensis* and *C. maculatus,* the species that cause most damage worldwide to mung bean in storage. Babu Jagadeesh *et al.* (2000) also reported that the development period of *C. chinensis* on different genotypes of mung bean varied from 21 to 23 days. An observation was made on 16 varieties of 7 species of legume seeds for assessing resistance to infestation by the *C. chinensis.* The greatest damage was observed on mung bean (*V. radiata*) and least on lentil, broad bean (*Vicia faba),* cowpea (*V. unguiculata)* and one variety of chickpea (*Cicer arietenum)* whereas damage of pigeon pea (*Cajanus cajan),* Adzuki bean *(V. angularis)* and most chickpeas was of intermediate category.

2.4.2. Host preference of *C. analis*

Rahman (1945) reported *C. analis* from Punjab, India which breeding, feeding on different pulses in the storage and it attacks on green gram, moth bean, Bengal gram, soybean and red gram. Mehta and Chandel (1970) studied on lost preference of pulse beetle, *C. analis* to different pulses. The most eggs were laid on cowpeas (15.33 eggs/seed), followed by peas (8.17 eggs/seed), green gram (5.67 ggs/seed) and Black gram (507 eggs/seed). No eggs laid on bengal gram, kabli gram and lentil. A few eggs were laid on French bean, soybean, split gram and horse gram. It was concluded that *V. radiata, V. mungo,* cowpeas and peas were preferred by *C. analis.* The incidence of *C. chinensis, C. maculatus, C. analis, C. theobromae* and *C. pisorum* on chickpea, green gram, black gram, pigeon pea, cowpea and pea was observed by Dias and Yadav (1988). Pods, fresh seeds were obtained from different ecological zones of India, percentage of damaged seeds and species of bruchids were recorded. Average infestation of seeds of pigeon pea, cowpea, green gram, chickpea and black gram was 14.65, 14.36, 10.08, 9.38 and 3.47 percent respectively. In another experiment Dias and Yadav (1988) studied the oviposition preference of females of *C. maculatus, C. chinensis* and *C. analis* on seeds of 4 legumes namely chickpea, pigeon pea, cowpea and green gram. Dark-brown pigeon pea and chick pea most and females of all 3 species oviposited on pods of cowpea, green gram and chickpea. The infestation resistance of various beans of the genus *Vigna* using 5 species of bruchids , *C. analis, C. chinensis, C. maculatus, C. phaseoli* and *Zabrotes subfasciatus* was studied by Fuji *et al.* (1989). *V. sublobata* TC 1966, showed the same resistance as TC 1966 itself. *V. mungo*, was resistant only to *C. phaseoli* and *C. chinensis*. *C. analis*, *C. maculatus* and *Z. subfasciatus* could successfully emerge as adults from *V. mungo*, although their developments were substantially slower than in commercial *V. radiata*. *V. sublobata* race 1 (Plu-416), a wild relative of *V. mungo*, showed complete resistance against all bruchid species examined in that study.

2.4.3. Physical characters of stored pulses in relation to the susceptibility to bruchids

Different characters of seeds like size, weight, color, roughness, thickness of seed coat and seed moisture affect the preference of pulse beetle.

Booker (1967), Raghupati *et al.* (1970), Schalk *et al.* (1973), and Choudhury *et al.* (1989) reported that the roughness of the seed coat was apparently related to the susceptibility of chickpea genotypes. The bruchids preferred to oviposit on seeds having more weight which was in turn positively, proportionate with the number of eggs laid. However, a decade ago, it was depicted that there was a positive correlation between seed size and oviposition of *C. chinensis* in case of mung bean seed and the damage was low in small seeded wild variety and it might be due to the preference for large seeds (Jakhmola and Laxman, 1971). Girish *et al.* (1974) carefully observed that the ovipositional behavior of *C. maculatus* was preferred by the smoothness of surface of seed coat and the size of grains. On the contrary, it had been reported that weight volume, hardness and color of seeds had no impact either on the susceptibility or on the resistance of cowpea varieties of pulse beetles (Debi *et al*, 1979). The above findings were also supported by Manohar and Yadav (1990) while screening susceptibility of cowpea cultivars to *C. maculatus*. Talekar and Lin (1981) depicted the seed coat hairiness to the resistance in mung bean to *C. chinensis*. In this support of this respect, Epino and Morallo (1983) demonstrated that *C. chinensis* preferred to oviposit on hard, large, heavy seeds and heavy seeds were found to be more susceptible to weevil damage. Singal (1987) reported that thick seed coat acts as a barrier for penetration of 1st instar larvae. The bruchids preferred to oviposit on seeds having more weight, which was in turn positively, proportionate with the number of eggs laid.

Han and An (1990) reported that rough seed coat of cowpea reduced damage and it was found to be a resistant factor to *C. chinensis*. Modi *et al.* (1994) revealed that seed color and egg laying behaviour of *C. chinensis* had no relation with each other. On the contrary several findings as reported by several workers stated that seed size had no impact on the susceptibility to the pest. In this aspect Talekar and Lin (1992) demonstrated that small seed size of resistant mung bean impeding accession was not the cause for resistance to *C. chinensis*. Similar findings were reported by Muhammad *et al.* (1997) and Padmavathi *et al.* (1999). Ramanagoudar and

Viswanatha (1998) reported that seed size and weight were positively correlated with relative susceptibility parameters like number of adult emergence, percentage of weight loss, level of seed infestation in case of horse gram. Instead of seed size, hardness, weight, color, other characters like seed coat texture also regulated the ovipositing behavior of *Callosobruchus* sp. In this regard several workers have carried out several investigation. Moisture content of seed was also an important significant factor in determining the degree of susceptibility (Katiyar and Khare, 1984 and 1985). Similar findings were also observed by Singh (1999). In a recent study Lambrides and Imrie (2000) observed that the 3 resistant accessions of mung bean comprising the characters of small seed size and presence of well-formed texture layer caused as a feeding deterrent effects to *C. chinensis* and *C. maculatus*.

2.4.4. Bio-chemical properties stored pulses and their relation to the susceptibility to bruchids

Bio-chemical characters of seed like protein content and others may be responsible for the resistance of different pulses against the pulse beetle. Epino and Morallo (1983) observed that the chemical component of seeds of mung bean was correlated with the varietals susceptibility to *C. chinensis* and it was found that the resistant accession had higher protein content than the susceptible one.

Talekar and Lin (1992) indicated the possible presence of antibiotic factors in the resistant accession of mung bean and black gram against *C. chineneis.* Modgil and Mehta (1994) observed that had a bearing *C. chinensis* infestation in stored pulses (green gram, red gram and chickpea) on calcium, phosphorus, iron and the B- vitamin contents. Sharma (1993) studied the extent of damage caused and host preference of *C. chinensis* on cow peas and soybeans. There was a low preference by the bruchid with increasing protein and fat content in the grains. The similar result was recorded by Dwivedi and Sharma (1993) where the low preference by *C. chinensis* was associated with increasing protein contents of the grains. De Paula (1994) studied the resistance of 6 chickpea genotypes to *C. maculates* and *C. phaseoli.* The resistance to bruchids may be related to the tegument components such as pigments, presence of linoleic fatty acid, affecting oviposition and also larval feeding or larval biology. Moreover, Modgil and Mehta (1994) observed that with the increase in infestation of green gram by *C. chinensis* the protein content decreased significantly. Singh, *et al.* (1995) studied the relative resistance of gram varieties to *C. chinensis.* On the basis of bio-chemical parameters, the effect of various chemical characters of gram (chick-pea) varieties on the growth and development of *C. chinensis* were observed in the laboratory. Fecundity, F1 progeny and index of susceptibility were comparatively lower on the varieties of gram with certain characters such as high protein content, and low oil and starch contents. The varieties with high protein content, and low oil and starch contents caused less egg production, F1 progeny and index of susceptibility than the varieties having low protein, and high oil and starch contents. The protein content of different varieties showed a highly significant negative correlation with fecundity, F1 progeny and index of susceptibility. Contents of total sugars and ash showed no significant correlation with fecundity, F1 progeny or index of susceptibility. While Singh *et al.,* (1995) reported that the protein content of different gram (chickpea) varieties was found significantly and negatively correlated with fecundity, F1 progeny and index of susceptibility to *C. chinensis*. However, Muhammad *et al.* (1997) had a contradictory opinion, the protein contents of the seeds had no influence on the susceptibility of mung bean seed to *C. chinensis*. Several studies have been made on the presence of antibiotic factors for to the resistance to pulse beetle. Oigiangbe and Onigbinde (1996) studied the association between physical characteristic and the tannin content of cowpea and their susceptibility to infestation by *C. maculatus*. The physical characteristics were seed coat color, texture, and seed height, length and width and the thickness of the seed coat. The dimensional parameters showed a significant correlation with the number of eggs laid with seed height accounting for about 70% of the variance. The tannic acid content, however, became increasingly significant with the growth of the larvae to adult hood. The tannic acid content accounted for 14.3 and 39.9% of the variance in the number of F_1 progeny and percentage of adult emergence respectively.

However, nothing is known about the exact causes for which the pulse beetle couldn't complete the development inside the pulse seeds such as soybean (*Glycine max*) and kidney bean (*P. vulgaris* L.). Almost no work has been carried out on the relation between phenol contents of pulses in storage and the degree of resistance against the attack of bruchids.

2.5. Morphological studies on a pteromalid and a trichogrammatid parasitoid

Mani (1989) studied and morphological characteristics of both *Dinarmus vagabundus* (Hymenoptera :Pteromalidae :Pteromalinae) and *Uscana mukerjii* (hymenoptera: Trichogrammatidae). He also described the parasitoids including their habit and habitat.

Saxena and Saxena (1997) described the ovipositor apparatus in *D. basalis* Rondani. Ovipositor sclerites, abdominal sclerites modified in relation to ovipositor functioning, and oviposition mechanism are considerably different from others reported earlier.

An original viewpoint on the phylogeny of the family Pteromalidae has been substantiated by Dhanokmen (2000). Twenty-seven pairs of characters, whose polarity has been determined a priori, were selected to specify phylogenic relation. The characters were processed using computer programmed for reconstructing phylogeny. Xiao *et al* (2000) listed 19 species of 15 genera from Haina of China and have a taxonomic study on family Pteromalidae (Hymenoptera) including their distribution.

2.6. Biology and per cent parasitization of egg parasitoids

Huis *et al.* (1991) described *U. lariophaga* as an egg-parasitoid of *C. maculatus* and *Bruchidius atrolineatus* in West Africa. In a choice situation, *B. atrolineatus* was the preferred host, however, in a no-choice situation; the highest rate of successful parasitization was obtained on hosts of the species from which they had been reared.

Kapila and Agarwal (1995) studied the biology of *U. mukerjii* (Mani) which parasitizes the eggs of *C. maculatus*. Mated adult males and females of *U. mukerjii* lived for 5.0 $\pm$ 0.8 and 4.7 $\pm$ 0.9 days respectively. The females copulated only once, whereas the males up to 4 times. The maximum parasitization of eggs took place within the 1^{st} 24 hours of egg laying by the host and declined thereafter. The parasitoid completed its development inside the host egg in 7.2 days at 27^0C and 60-63% r.h., and emerged after cutting a circular hole on the chorion of the host egg. Mated and unmated females on an average laid 35.4 $\pm$ 1.4 and 36.0 $\pm$ 2.2 eggs respectively in their life time, out of which 27.3 $\pm$ 1.8 and 23.2 $\pm$ 2.8 larvae could hatch out. The degree of parasitization varied with the pulses species on which the host eggs were laid. The authors concluded that this egg-parasitioid may be useful in controlling populations of *C. maculatus*.

Huis *et al.* (1995) studied the diurnal pattern of parasitisation and eclosion of the trichogrammatid *U. lariophaga*, an egg parasitoid of *C. maculatus*. The percentage eclosion during the photo phase was similar to that during scotophase. The average development time was 8.9 days, with male development being completed 6-8 hours before the female. More female's eclosed during scoto phase than during phase photo.

Islam and Kabir (1995) observed the larval, pre-pupal and pupal stage of *D. basalis*. Developmental stages of the host affected longevity and fecundity of the parasitoid significantly. Both longevity and fecundity were highest on 4^{th} host instar larvae but lowest on 2^{nd} instar. Longevity of female parasitoid recorded 8-26 days on different stages of the host (larval, pre-pupal and pupal stages of *C. chinensis*). He observed that fecundity varied 34-58 in 2^{nd} instar, 124-266 in 3^{rd} instar, 365-601 in 4^{th} instar, 393-559 in pre-pupa and 256-400 in pupal stages of *C. chinensis*.

Pajni *et al.* (1996) studied the biology of *Uscana mukerjii* (Hymenoptera: Trichogrammatidae) a potential parasitoid for bio-control of bruchid pests. The average pre-oviposition period after mating fluctuated between a maximum of 29.14 min. and a maximum of 59.42 min in hot and cold months respectively. Eggs of *C. maculatus* up to 72 hour old were accepted for oviposition by the egg-parasitoid. The longevity and developmental period were shorter in May and June but increased appreciably during winter months. The sex ratio under optimum conditions (30^{0}C and 70% r.h.) was approximately 1: 2.7.

Zaghloul and Mourad (1998) studied the egg parasitoid, *U. lariophaga* Steffan with reference to its role due to *C. maculatus* infestation on cowpea in Egypt. Laboratory studies revealed that mated males and female adults lived for 7.0 and 6.0 days at 25^{0}C$\pm$1 and 65% r.h. The females copulate only once. While the males up to four times. The parasitoid completed its development inside eggs in 6.3 days. Mated and unmated females laid 40.5 and 42.7 eggs on the average in their lifespan, of which 77.4 and 65.0 per cent emerged as adults.

2.7. Biology and per cent parasitization of larval-pupal parasitoids

Chatterjee (1954) and Cheema *et al.* (1962) reported and observed the ovipositional behaviour of *D. vagabundus*. Kapoor *et al.* (1972) observed the biological activity of *Dinarmus* sp. *Ceralina* sp. (Apidae) and *Norbanus* sp. (Pteromalidae) in *Oberia brevis* (Lamiidae). Kapoor *et al.* (1972) carried out the biology of few parasitoids on soybean at Madhya Pradesh, India. The egg and larval stages of *Dinarmus* sp. (Hymenoptera: Pteromalidae) was described in brief. Adult females oviposited directly on or near the host larva. The egg, larval and pupal stages and complete life cycle (from egg – adult) lasted 1.2, 6-8, 8-10 and about 16-5 days respectively. About eight to twelve *Dinarmus* adult emerged from one host larva. Kundra (1976) observed the biology of *D. vagabuadus*, a parasitoid of bruchids. The adults were found almost throughout the year in infested stored pulses, especially it was association with *C. maculatus*, *C. analis* and *C. chinensis*; there prevalence was the highest in summer, especially during July-September and fall noticeably during December- February. Mating lasted for 15-45 seconds and one male can mate with up to 38 females. Average life span of adults was about 4 days during summer and 8 days during winter. The ratio of males to females was about 1: 1 in moderate temperature and humidity, but attained 1: 2 at higher temperatures. Dhir (1977) observed the oviposition behavior of *D. vagabundus*. Oviposition was observed to take place within 2-3 min when the host larva was at early stage of development. Oviposition period varied from 2.7-6.7 days and number of eggs per female varied from 9-26 at different sets of temperature and humidity (25-28^{0}C and 30-70% r.h.). The fecundity of *D. vagabundus* does not, therefore, correspond to the high rate of reproduction of its hosts.

Rojas *et al.* (1988) evaluated the reproductive strategy of *D. vagabundus* (Timb.), real sex ratio, sequence of emitting diploid and haploid eggs and effect of inbreeding on progeny. The sex ratio of emerging adult parasitoids (3 female to 1 male) was found to be the same as that at oviposition. The sequence of emission of diploid and haploid egg indicated that the majority of the first eggs laid were fertilized, the haploid eggs parasitoid parents occurred with 60-89% of the females. The productivity of females after 6 generations of sibling crosses was unaffected and there was no significant change in the sex ratio of the progeny. In another experiment,Rojas *et al.* (1988a) studied the nutritional balance during the development of the gregarious ecto-parasite *D. vagabundus* and the solitary *D. basalis* (Hymenoptera : Pteromatidae). Females' larvae of both the species developing individually in a host larva consumed significantly more food than the male's larvae, resulting in adult females weighing more tham adult males. The mean weight of males and females of *D. vagabundus* decreased significantly at higher larval densities. Some host larvae of *C. maculatus* may attack 3-8 larvae of *D. vagabundus.*

Fabres and Reymonet (1991) observed the marital induction of larval diapauses in *D. acutus* in France. Continuous brooding under semi-natural temperature and photoperiods showed the simultaneous presence of diapausing and non-diapausing larvae throughout the winter and a total absence of diapausing larvae in spring. They suggested that diapauses length and viability are controlled by a chemical clock. Ahmed (1997) carried out the parasitism of different stages of the host, *C. maculatus* infesting different pulses by *D. basalis.* Parasitization was greatest in *C. maculatus* infesting red gram (*Cajanus cajan*) and least in pea. Maximum parasitization was observed in 4th instars *C. maculatus* larvae on red gram (93.02%), pea (73.17%) and black gram (88.37%). Smaller host were also acceptable for parasitization. Parasitization rate varied with the time required to drill suitable oviposition sites and optimum host stages. Gupta *et al.* (1997) collected two parasitic wasps, *D. acutas* and *D. basalis* and observed these as potential parasitoids with parasitism ranging from 13-29%. Only the final-instars larvae and pupae of *C. maculatus* were parasitized. Gupta *et al.* (1997) studied the biological potentiality of *D. basalis* and *D. acutus* on bruchids. Islam (1998) worked out the rearing and release of the pulse beetle parasitoid *D. basalis.* The release of *D. basalis* was carried out in sealed rooms to determine its potential as a biological control agent of the *C. maculatus.* In the mentioned culture, 1000 parasitoids were capable of producing >35000 parasitoids per week. The parasitoid suppressed approx 85% of the population of *C. maculatus* when 40-50 pairs were introduced and approx. 45% when only 5 pairs were introduced into the test system.

Raja *et al.* (2000) studied the effect of solvent residues of *Vitex negundo* and *Casea fistula* (0.5 and 1%) on egg laying and adult emergence of *C. maculatus* and on percentage of larval parasitization by *D. vagabundus*. Both the plant extracts did not affect the parisitization by *D. vagabundus* on *C. maculatus* larvae.

2.8. Safe management of insect pests of pulses with plant oils

Use of botanicals as protectants of stored grains has had long history of use by Indian farmers to protect the stored products from insects attack. It has been revealed that oils normally acts as repellent and feeding deterrent as well as partial oviposition deterrents for quick knockdown effect in the IPM (Saxena, 1989 and 1995; Schmutterer, 1990).

2.8.1. Bio-chemical properties of plant oils

According to Singh (1975) the thin layer of the oils blocks O_2 supply to the embryo. Schoonhoven (1978) used palm kernel, cotton seed, maize, soybean and coconut oil against the attack of bruchids and observed decrease in the bruchid population build up.

Hill and Schoonhoven (1981) found that tri-glyceride fraction of African palm oil has adverse effect on the survival of adult beetle. The use of some edible and non-edible oils obtained from different species of plants is now in contemplation. Coconut (*Cocos nucifera*) kernel contains 35-50% fat. The main fatty acids are lauric (45%), myristic (18%), palmitic (9.5%), oleic (8.2%), caprylic (7.8%), capric (7-6%), stearic (5%) and linoleic (1-2.6%). Coconut oil contains 84% trisaturated glycerides (Jasper, 1978). Mustard *(Brassica juneea.)* is a cruciferous plant containing glucoside sinigrin and the enzyme myrosin. The oil components are allyl isothiocynate (0.72-1.3%). Soybean *(Glycine max)* seed oil contains 21-40% protein and glycoside genistin, diadzin and 4 saponins. Fatty acids composition is palmitic acid 7-14%, stearic 2-6% and oleic acid 23-24%, linoleic acid 52-60 linolinic acid 3% and higher saturated acid 2%. The mode of action of different oils is partially attributed to influence the normal respiration, resulting in suffocation. Their action is more complex as insects deprive of O_2 survived longer than those treated with oils. Oils are used against insects especially to kill dormant eggs. Apart from neem, the use of some edible and non-edible oils obtained from different species of plants is now in contemplation. Coconut (*Cocos nucifera*) kernel contains 35-50% fat. The main fatty acids are lauric (45%), myristic (18%), palmitic (9.5%), oleic (8.2%), caprylic (7.8%), capric (7-6%), stearic (5%) and linoleic (1-2.6%). Coconut oil contains 84% trisaturated glycerides. Mustard *(Brassica juneea.)* is a cruciferous plant containing glucoside sinigrin and the enzyme myrosin. The oil components are allyl isothiocynate (0.72-1.3%). Soybean *(Glycine max)* seed oil contains 21-40% protein and glycoside genistin, diadzin and 4 saponins. Fatty acids composition is palmitic acid 7-14%, stearic 2-6% and oleic acid 23-24%, linoleic acid 52-60 linolinic acid 3% and higher saturated acid 2%. The mode of action of different oils is partially attributed to influence the normal respiration, resulting in suffocation. Their action is more complex as insects deprive of O_2 survived longer than those treated with oils. Oils are used against insects especially to kill dormant eggs (Jasper, 1978). Citronella oil is extensively used as soap perfume and insecticidal propagation for making important aromatic chemicals such as genranoil, citronellol and their derivatives. Niger (*Guizotia obyssimia* Cass) silage contains 69.9% water, 3.3% fat, 3.9% crude protein, 2.7% true protein, 12.5 % carbohydrate, 7.3% fibre and 3.5% ash. Niger oil has fatty acids such as linoleic 5-11 %, myristic o.5-6%, oleic 40-50%, palmitic 35-40%, stearic 2-8% are present. In palm oil, linoleic 29-42%, linolenic 0-1%, myristic 0.4-1%, oleic 40-50%, palmitic 13-18%, stearic 1-3% in rice bran ; ricinoleic 89.5%, linoleic 4.2%, oleic 3%, stearic 1%, palmitic 1%, dihydroxylsteatic 0.7%, eicosanoic 0.3 %, linoleic 0.3%. In castor; oleic 30-405, linoleic 48-55%, palmatic 5.5-8.5%, stearic 2.5-5.4%, arachidic 0.3-0.5%, myristic 0.3-0.4%, linolenic 1-1.25% in niger respectively (Maity,1988).

Neem (*Azadirachta indica*) oil is now produced commercially, and it exhibits enormous potential as insecticide (Stains law *et al.,* 1995). The active ingredient azadirachtin, extracted principally from the seeds, has growth regulating and antifeedant properties against numerous pests.The bioactive principles of neem have been identified as limonoids comprising more than 100 tetranor-triterpenoids, diterpenoids, triterpenoids, pentanor-triterpenoids, hexanor-triterpenoids and some norterpenoids. Such a vast array of bioactive compounds makes these botanicals a good tool for the management of storage insect pests (Dhaliwal and Arora, 1998). However, neem cannot replace the chemical pesticides but the amount of chemical pesticides can be reduced particularly in the developing countries due to their high toxicidal effect on human beings (Saxena, 1998). Chaulmoogra (*Hydnocarpus kurjii*) is indigenous medicine oil having acid value 23.9%, and iodine value 103.2%. This oil consists of the glycerol esters of two or more new fatty acids. These acids are named as chaulmoogric ($C_{18}\,H_{32}\,O_2$) and hydnocarpic ($C_{18}H_{28}O_2$) acids (Chopra *et al.,* 1994).

2.8.2. Pesticidal effect of plant oils on adult *Callosobruchus* spp.

Misra *et al.* (1989) were evaluated the toxicity of same essential oils against pulse beetle, *C. maculatus*. In laboratory tests, essential oils of *Callistemon lanceolatus* (*C. citrinus*) and *Eupatorium capillifolium* were found to be toxic to *C. maculatus*. The LC50 was lower for *C. citrinus* and for both oils the LC50 decrease with the increase in expose duration.

In laboratory experiments, the toxicity of refined and crude soybean oil of *C. chinensis* was studied by Singh and Singh (1989). Dosages of 0.1, 0.25 and 0.5 ml/100g of seed were applied to pigeon peas. Crude oil was more toxic than refined oil and higher dosages produced better results.

The effectiveness of some essential oils (basil, geranium, rue, lemongrass, citronella, eucalyptus and lemon) in protecting faba beans against *C. chinensis* was studied. Essential oils of basil followed by geranium, citronella, basil and rue had insecticidal effect whereas lemon, eucalyptus was not toxic to adult (Richa *et al.*, 1993).

Majeed *et al.* (1994) studied the toxicity of neem extract Nfc (Acetone extracts of whole neem fruits) and N-7 (Methanol extract of whole fruit) against adults of the stored products pest, *C. analis*. LD 50's using the filter paper impregnation method was found to be 7.8, 18.0 and 3.6 Ag / cm^2 for Nfc and N-7. The order of efficacy were Nfc > N-7.

Lienward and Seck (1994) reviewed of control methods against *C. maculatus* on cowpea in tropical Africa. In rural areas where preservations techniques and facilities are limited, it causes post-harvest weight and quality losses. The importance of damage which can reach 100% in a few months justifies the development of effective and appropriate control methods are inadequate because their application requires equipment and technical knowledge which are not found in rural areas. Biological control is an attractive alternative but is still at an experimental stage. All these limitations support promotion to traditional control methods. Among them, the use of indigenous plants and their by-products, in many cases, gave satisfactory control of *C. maculatus*.

2.8.3. Efficacy of plant oils on *Callosobruchus* spp.

Several workers including Mummigatti and Ragunathan (1977) and Das (1987) reported the effect of neem oil against *C. chinensis* in Chickpea and different vegetable oils against *C. chinensis* in green gram. Palm (*Elaeis guineensis* Jac.) oils were found effective for control of bruchids oviposition having ovisidal properties (Cotton, 1963). Ketkar (1976) found that when 2% neem oil was mixed with bengal gram (*Cicer arietinum*) seeds was protected from damaged by *Callosobruchus* spp. up to three months. They also found that 0.3%oil of caster, mustard and sesame inhibited the multiplication of *C. chinensis* when reared on green gram. Similar result was also obtained with 0.5% coconut and groundnut oils. In contrast, sunflower oil was found ineffective even at higher dosages. Tikku *et al.* (1981) observed that *V. radiata* when treated with groundnut, castor, coconut and mustard oils at 1 and 5 ml/kg proved effectively as grain protectants against *C. chinensis*.

Studies on the evaluation of edible oils against *C.chinensis* on chickpeas revealed that coconut, sunflower and sesame oils , when used at 2 and 4 ml/kg seed, resulted in reduced egg laying at 30, 90 and 150 days after treatment. Oils applied at 4ml always provided better protection against infestation than oils applied at 2ml. At 4 ml/kg palm, mustard, taramira, groundnut and coconut oils inhibited the development of *C. chinensis* almost completely at up to 90 days of storage, consequently there was no weight loss or seed damage. Sesame, sunflower and soybean oils did not inhibit the complete development of *C. chinensis* after 30 days of storage. At 2 ml/kg, palm, rapeseed, coconut and groundnut oils were able to inhibit complete development only up to 30 days after treatment.

The effect of 7 different plant oils at 0.4, 0.6 and 0.87 v/w concentrations/100 grams of pigeon pea seed on oviposition of *C.chinensis* were studied at 30 ± 3 C and 75 ± 6% R.H. Ovservation were taken at 1,15,30 and 45 days after treatment. All the oils (*Cymbopogon citranus, Madhuca longifolia, Ricinus communis, Cocos nucifera, Arachis hypogaea, Glycine max* and *Azadirachta indica*) significantly affected oviposition at all 3 concentrations at one day after treatment.

Sujatha and Pannaiah (1985) worked out on the effect of vegetable oil after mixed with stored seeds of green gram on the development of pulse beetle. They recorded that oils of cotton seed, sesame, palm and neem oils at a concentration of 0.25 per cent and groundnut and coconut oils at 0.5 per cent can effectively control *C. chinensis.* In Bangladesh, Das (1987) investigated the effectiveness of various concentrations (4,6,8 and 10 ml/kg seeds) of neem oil on adult mortality and oviposition of *C. chinensis* in laboratory at 32.5^{0}C and 83-8% r.h. and found that the dose of 8ml/kg seed was the most economic concentration to control *C. chinensis* infestation in chickpea seeds. Neem oil @ 10ml/kg of seed prevented adults from laying eggs when they came in contact with the seeds immediately after treatment. Yadav (1985) applied seed oil @ 20-50 ml/10g seeds of green gram inoculated with groups of adults of both sexes of 3 species of *Callosobruchus.* Treatment with 50 ml/10g completely prevented oviposition of *C. maculatus, C. chinensis* and *C. analis.* Khaire *et al.* (1987) tested vegetable oils in the laboratory at a dose of 5-10 ml/kg seeds against adults, of *C. chinensis* infesting pigeon peas and found that the oils of neem and karanja at higher concentration of 10ml/kg were most toxic. Babu *et al.* (1989) studied the effect of pre-storage treatment of mung bean var. PS-16 with neem, karanja, mustard, groundnut and castor oils; each with the dose of 2.5, 5.0 and 10ml/kg seed. They recorded that the karanja oil (5 and 10 ml/kg) and castor oil (10ml/kg) could effectively reduced oviposition of *C. chinensis* while maintaining a high level of germination for over 18 months after storage.

Begum and Quiniones (1990) observed that the coconut, soybean, mustard and peanut oils at higher dosage (3ml/kg) protected mung bean seeds from the attack of *C. chinensis*. Oil at 3 ml/kg had long residual effect since all treated seeds even after 4 month of storage reduced oviposition and killed the eggs at their early stage. Khaire (1992) tested the efficacy of ten vegetable oils @ 0.5, 0.75 and 1% (v/w) as grain protectants of pigeon pea against *C. chinensis* and found that the adult emergence was completely prevented by karanja oil with 0.75 and 1% dosages and neem oil up to 100 days. No adult's emergence occurred up to 66 days with castor oil at 0.75 and 1% levels. Minimum grain less was noticed with castor, mustard and groundnut oils at 1% concentration up to 100 days after treatment. There was no adverse effect of various oils on seed germination. According to Singh *et al.*(1994), different vegetable oils, namely, sesamum, sunflower, soybean, linseed, mustard, safflower, karanja, castor, coconut, groundnut, rice bran, taramira (*Eruca* sp.) were evaluated as grain protectant @ 1 ml and 3 ml/kg seed against *C. chinensis*. The results indicated that the minimum numbers of eggs were laid on seeds treated with Taramira oil followed by coconut, sunflower, safflower and castor. Kachare (1994) screened the efficacy of different vegetable oils as seed protectant in increasing storage ability of pigeon pea against *C. chinensis*. The treatments with neem, castor and karanj oils at one per cent showed significantly repellent action for egg laying by adult bruchids up to 100 days. No hatching of eggs after 33 days of storage was noticed in castor, neem, karanja and groundnut oils. After 56 and 100 days, neem, karanja and castor oils were quite effective in suppressing the egg hatching.

Chapter-III

MATERIALS AND METHODS

MATERIALS AND METHODS

The survey of insect pests of stored pulses was initiated in January 1999 and continued up to July 2002 (a total period, three years seven months) in Terai Agro-ecological conditions of W.B., India. The experiments were carried out in different seasons at ambient laboratory temperature and relative humidity (**Appendix V** and **appendix VI**) in the Entomology laboratory, Uttar Banga Krishi Viswavidyalaya, Cooch Behar, W.B. (formerly, B.C.K.V., N.B.Campus, Cooch Behar) and Department of Zoology, North Bengal University, Siliguri, Darjeeling, W.B., India.

3.1. Survey of Insect Pests, Nature Enemies and their Incidence on stored Pulses

3.1.1. Collection, preservation and identification

Coleopteran, hymenopteran and other insects were killed with ethyl acetate vapor or chloroform. The insects were collected by hand searching, brush searching and sometime with the aspirator. These were mounted on card points with water-soluble glue or preserved in 70% alcohol or in Kohli's solution.

Primary identification was made with the help of identification key (Annexure-) and then sent to the authorized institute or scientists for confirmation. The taxonomic identification of the pulse beetle, *Callosobruchus chinensis and C. maculatus* (Coleoptera: bruchidae) used for the studies on bio-ecology, host preference and management under present investigation were made by Zoological Survey of India, Calcutta. The parasitoids of insect pests of stored pulses, *Dinarmus vagabundus* (Timberlake) (Hymenoptera: Pteromalidae), *Bracon sp.* (Hymenoptera: Braconidae) & *Cercocephala dinoderi* Gahan (Hymenoptera: Pteromalidae) have been identified by Prof. T. C. Narendran of Calicut University, Kerala, India and *Uscana mukerjii* Mani (Hymenoptera: Trichogrammatidae) by Prof. M. Hayat of Aligarh Muslim University, India.

3.1.2. Insect pests and parasitoids

The assessment of occurrence, distribution and abundance of insect pests are essential prerequisites to rational control program. This is made possible by likely quantitative and qualitative survey works. Qualitative survey involves the identification of the different species present over an area whereas quantitative survey involves the estimation of population of one or more species of insect pests. Modern pest management of storage pulses can not operate without accurate estimates of pests and natural enemies' population or per cent damage of the stored product and suitable control measures. Hence an extensive survey has been undertaken following the method as described by Saha *et al.* (1995) and Saini (1999) with partial modification for assessing the per cent egg-infestation by bruchids on stored pulses.

3.1.3. Estimation of damage of stored pulses

To estimate the per cent infestation, weight of 200 (no.) sound seeds and 200 (no.) damaged seeds were taken for each sample with the help of an electronic balance and the per cent infestation was computed by using the following formula as described by Khare (1972).

$$\textbf{Per cent damage} = \frac{(X - Y)}{X} \times 100$$

where, X = weight (g) of 200 sound grains

Y = weight (g) of 200 infested grains

3.1.4. Estimation of qualitative weight loss (%) of stored pulses

The qualitative weight loss of stored pulse seeds has been estimated following the formula of Boxell *et al.* (1977).

$$\textbf{Qualitative weight loss (\%)} = \frac{(UNd) - (DNu)}{U\,(Nd + Nu)} \times 100$$

where, U = the weight (g) of undamaged pulse seeds

Nu = the number of undamaged pulse seeds

D = the weight (g) of damaged pulse seeds

Nd = the number of damaged pulse seeds

Nd + Nu = 200

3.2. Biology of *C. chinensis* on Green gram

The biological study was restricted to the fecundity, incubation period (days), larval-pupal period (days), adult longevity (days), mean development period (egg to adult emergence), emergence of adult, sex ratio and growth index. The investigation was carried out in the laboratory on green gram, *Vigna radiata* var. *radiata,* variety – SML 229 (**Plate 2**). Studies of life history and biology of *C. chinensis* started on mid January every year for three consecutive years. Accordingly daily temperature and relative humidity were recorded separately. The data were computed on weekly basis (Table 1) and the average daily temperature and relative humidity were evaluated (Table 2).

Fecundity- It denotes the number of eggs laid / mated female insect .

Incubation period- Incubation period denotes the time between egg laying and egg hatching

Larval-pupal period - It denotes the time between the hatching of eggs and adult emergence.

Adult longevity - It denotes the time from emergence of adult to their death.

Mean development period - It denotes the mean of oviposition to adult emergence periods.

Growth index - It denotes the per cent adult emergence/ mean of total developmental period.

Table 1. Weekly temperature and humidity of the experimental laboratory.

(Average of 3 years from, January 1999 to July 2002)

Standard week	Mean daily Temperature °c			Mean daily Relative humidity %		
	Min.	Max.	Average	Min.	Max.	Average
1	17.49	20.46	19.09	57.51	76.52	67.21
2	16.62	19.69	17.99	59.50	75.75	66.17
3	17.96	20.45	19.40	61.75	78.31	69.71
4	17.71	21.10	19.58	61.25	76.75	66.85
5	17.89	21.20	19.64	64.75	74.51	68.19
6	18.77	21.83	20.14	61.75	79.25	70.40
7	18.68	23.01	20.84	55.75	71.52	63.43
8	20.80	23.56	22.09	53.75	68.61	61.74
9	19.96	23.89	21.96	47.21	65.74	54.01
10	20.60	24.90	22.72	43.50	67.55	56.95
11	23.49	26.94	25.19	43.25	67.23	57.04
12	24.62	27.67	26.19	45.51	60.41	51.13
13	25.19	28.45	26.76	54.25	70.25	61.21
14	25.79	28.97	27.38	52.31	79.61	64.19
15	26.07	29.28	27.85	59.25	75.25	68.06
16	26.83	29.76	28.30	59.50	70.25	65.24
17	24.91	28.37	26.48	63.50	76.25	69.39
18	24.49	27.64	26.11	62.75	79.42	70.99
19	27.13	30.76	28.92	65.25	80.55	71.56
20	28.44	32.22	30.26	64.25	77.75	72.46
21	27.13	30.63	28.95	72.59	80.56	76.35
22	27.06	29.81	28.27	76.25	86.25	61.53
23	28.19	30.53	29.36	77.75	85.75	81.85
24	27.94	30.61	29.27	72.24	86.56	80.63
25	27.88	30.35	29.11	76.75	87.24	82.06
26	27.87	29.92	28.82	77.58	84.75	81.03
27	27.90	30.29	29.07	79.55	85.53	82.92

Contd...

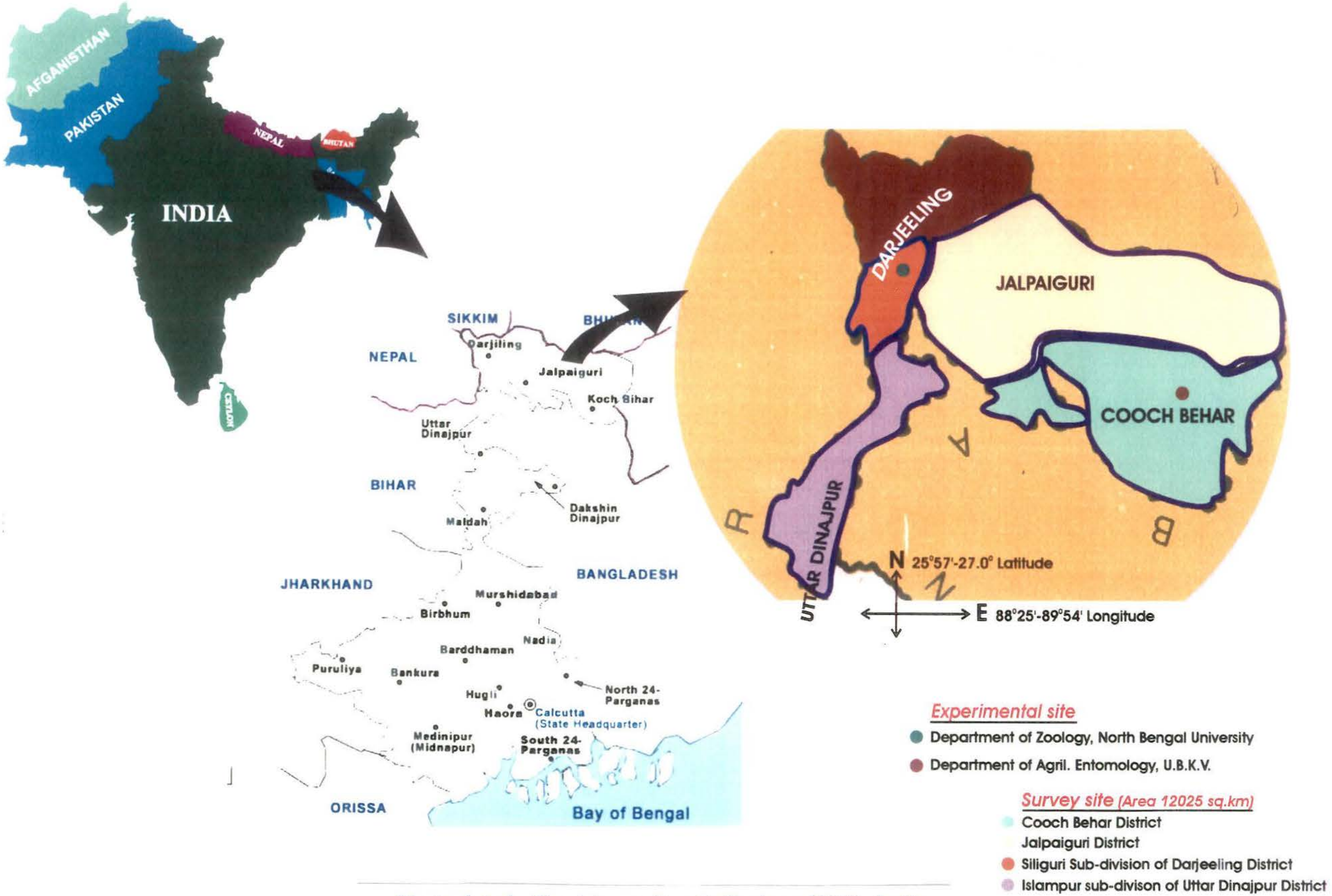
Standard week	Mean daily Temperature °c			Mean daily Relative humidity %		
	Min.	Max.	Average	Min.	Max.	Average
28	27.83	30.94	29.45	78.25	86.25	81.17
29	27.56	30.19	28.87	78.25	83.25	81.10
30	27.74	30.22	28.98	77.25	84.57	80.55
31	27.77	30.46	29.01	77.66	85.66	82.28
32	28.25	31.09	29.67	75.66	84.66	81.26
33	28.30	30.20	29.24	78.66	87.74	83.18
34	27.73	30.30	29.02	78.66	89.25	83.78
35	27.66	29.63	28.65	81.33	88.66	84.54
36	27.68	29.83	28.75	78.34	87.33	82.48
37	27.63	29.97	28.80	75.66	86.66	82.79
38	26.75	29.04	27.89	77.66	85.62	81.37
39	26.40	29.11	27.75	79.33	90.66	82.23
40	26.71	28.59	27.56	80.41	88.66	84.56
41	26.90	29.06	27.98	66.71	82.66	76.18
42	25.83	29.59	27.71	68.66	75.66	72.29
43	25.61	28.77	27.07	66.66	82.23	74.82
44	23.33	27.18	25.24	61.33	83.53	70.52
45	22.78	26.11	24.44	60.66	77.33	70.23
46	21.49	24.54	23.01	63.33	76.36	69.28
47	21.83	24.73	23.28	62.42	72.33	67.04
48	21.33	23.85	22.59	53.81	67.52	59.71
49	19.51	22.28	21.12	52.33	65.66	62.37
50	19.37	21.67	20.58	60.66	75.66	72.74
51	19.02	21.37	20.20	58.22	76.63	67.28
52	18.64	21.21	19.95	57.82	74.02	65.91

Table 2. Prevailing temperature and humidity in the laboratory during the study of bio-ecology of *C. chinensis*

(Average of 3 years, January 1999- December 2001)

Month	Mean daily minimum to maximum temperature °C	Average daily temperature °C	Mean daily Min. to Max. R.H. (%)	Average daily R.H. (%)
January -February	16.90-28.23	21.83	51.00-68.38	60.16
March -April	23.97-30.55	27.25	52.11-68.91	59.67
April -May	26.47-31.02	29.02	62.75-78.96	69.80
May	27.68-31.92	29.65	69.50-78.96	74.57
May -June	27.36-31.60	29.19	69.59-84.64	78.16
June -July	26.36-30.25	28.73	73.25-84.92	80.76
July -August	26.96-30.42	28.72	72.11-84.86	80.74
August- September	26.26-30.06	28.32	77.25-85.21	81.29
September-October	25.57-29.59	25.91	67.50-82.34	77.45
October-November	22.92-28.66	25.62	60.00-78.11	69.78
November-December	19.43-25.30	22.38	55.75-68.98	65.56

PLATE 1



Photoplate 1. Terai Agro-climatic Region of W.B., India

PLATE 2

Photoplate 2. Green gram seeds (*Vigna radiata* L., variety-SML229) used for the study of bio-ecology of *Callosobruchus chinensis* and *C. analis*

3.3. Biology of C. *analis* on Green gram

The study biology was also restricted to fecundity/ female, incubation period (days), larval-pupal period (days), adult longevity (days), mean development period (egg to adult emergence), emergence of adult, sex ratio and growth index following the formula adopting previously. The investigation was carried out in the laboratory on green gram seeds, *Vigna radiata* var. *radiata*, Variety – SML 229 (**Plate 2**). Studies of life history and biology of *C. analis* started on end of July every year for three consecutive years. Accordingly daily temperature and relative humidity were recorded separately (**Appendix V**).The data were computed on weekly basis and the average daily temperature and r.h. were worked out (Table 1 and 3).

Table 3. **Prevailing temperature and humidity in the laboratory during the study of bio-ecology of C. *analis***

(Average of 3 years,July 1999 – July 2001)

Month	Mean daily minimum to maximum temperature ^0C	Average daily temperature ^0C	Mean daily minimum to maximum relative humidity (%)	Average daily relative humidity (%)
July	27.57-30.09	28.98	78.85-83.28	77.77
July-August	28.56-30.09	28.78	79.25-81.72	80.74
August-September	27.92-28.72	28.32	77.29-80.87	80.29
September-October	27.32-28.27	27.51	65.58-74.04	69.78
October-November	24.13-27.11	25.62	65.53-74.04	69.78
November-January	20.63-24.13	22.38	60.00-65.59	65.56
January-February	17.82-22.19	19.69	51.00-62.21	61.84
February-March	19.69-27.03	23.53	55.31-63.23	57.27
March-April	26.12-28.39	27.25	54.31-65.03	59.67
April	27.32-29.10	28.39	62.75-68.91	65.50
May-June	28.73-29.65	29.19	74.57-81.76	78.16

3.4. Host preference and relative susceptibility of C. *chinensis* and C. *analis* to fourteen different species of stored pulses

The host preference was studied on 14 different species of pulses. Of the species the green gram seeds (*Vigna radiata* var. *radiata*, Variety SML229) were procured from the Dept. of

Genetics & Plant breeding, B.C.K.V. (**Plate 2**).The other 13 legume seeds such as black gram, thakri kalai, moth bean, cow pea (black-eyed),horse gram, kidney bean, grass pea, pea, garden pea, lentil, chickpea, soybean and red gram were collected from the farmers (**Plate 3**).The assessment of susceptibility of *Callosobruchus* spp. To the pulses was done in respect of thickness of seed coat (millimeter), seed weight (gram), seed moisture content (%) and analysis of phenol contents (milligram).

Table 4. Indian, common english and scientific names including physical characters of the stored pulses

NAME OF THE PULSES			COLOUR	SHAPE	TEXTURE
INDIAN	ENGLISH	SCIENTIFIC			
Mung or moong	Green gram	*Vigna radiata* Linn	Green	Cylindrical	Glossy
Urd or Urad	Black gram	*V. mungo* Linn.	Blue green mosaic	Cylindrical	Rough
Khesari or chatti matti	Grass pea	*Ladhyrus sativus* Linn.	Grayish brown	Irregular	Rough
Chola or chana	Bengal gram or chick pea	*Cicer areitinum* Linn.	Brown	Oblong	Rough
Motor or mottor	Pea	*Pisum sativum* Linn.	Cream white	Round	Rough
Krishna motor or chota motor	Field pea or small pea	*P. arvense* Linn.	Greenish mosaic	Round	Rough
Arhar or khesari	Red gram or pigeon pea	*Cajanus cajon* Milsp.	Brownish red	Round	Glossy
Lobia or barbati	Cowpea (black-eyed)	*Vigna catiang* Walp.	Cream white	Kidney	Rough
Thakri or mash kalai	Black gram	*V.mungo silvestries* Linn.	Amber brown	Cylindrical	Rough
Masoor or musuri	Lentil	*Lens esculentum* Moench.	Light brown mosaic	Round flat	Rough
Kulastha or kulthi kalai	Horse gram	*Dolicos biflorus* Rosb.	Light brown	Kidney flat	Glossy
Moth or Biri mung	Moth bean	*V. aconitifolia* Jack.	Light brown	Cylindric al	Glossy
Rajmash or French bean	Kidney bean	*Phaseolus vulgaris* Linn.	Tan brown	Kidney	Glossy
Soya bean or bhat	Soybean	*Glycine max* Merr.	Yellow	Round flat	Glossy

PLATE - 3

Photoplate 3. Methodology for the study of host preference by *Callosobruchus* spp. in free-choice test

3.4.1. Free- choice test

In order to study the host preference and relative susceptibility of both *C. chinensis* and *C. analis* in free choice test, equal volume of healthy, clean and disinfected grains of each of the fourteen stored pulses was spread over an equal area in for each in large plates (30 cm diameter) and thereafter ten pairs of freshly emerged bruchids were collected from stock culture and released inside the plate (**Plate 3**). After completion of egg laying, all insects were removed and the number of eggs laid on different pulses were counted. Each species of the pulses were kept in glass jars with cloth cover to count the number of adults emerged and studied their ovipositional preference, adult emergence, mean development period and growth index. The mated was followed for both the pest species. The experiment was conducted twice, during summer and winter seasons. There were 4 replications for each season.

3.4.2. No-choice test

The test insects (0-1 day old) obtained from stock culture was used for the experiment. Ten grams of healthy, clean and disinfected stored pulse seeds were kept in glass-tubes (10cm long and 2.4 cm diameter) with clean cloth plug and two pairs of mated *Callosobruchus* spp. (0-1day old) were released in each glass-tube for egg laying. After completions of oviposition dead insects were removed and number of eggs laid, number of adults emerged and mean development period were evaluated. The experiment was conducted in two seasons , summer and winter. There were 4 replications each time.

3.4.3. Measurement of the thickness of seed coat

After soaking the seeds for 8 to10 hours in blotting paper, the sections of fourteen different species of pulses were made with the help of sharp blade and the thickness of seed coat were recorded by using compound microscope through the use of ocular and stage micrometer and was expressed in millimeter (mm).

3.4.4. Estimation of moisture contents of the stored pulses

For estimating the initial moisture content, 10 gram pulse seeds were taken at random from a well-dried seed stolk and replicated 4 times. Sample grains were placed in aluminum foil and dried in an electric oven at 40^0C until constant weight was attained. Then the sample was cooled in a desssicator and weighed with the help of electronic balance.

The per cent moisture content was estimated by using the following formula adopted by Islam (1999).

$$\textbf{Moisture content (\%)} = \frac{100\,(M_1 - M_2)}{M_1 - M}$$

where, M_1 = Weight in (g) of pulses including aluminum foil before drying
M_2 = Wt. in (g) of pulses including aluminum foil after drying
M = Wt. in (g) of the aluminum foil

3.4.5. Analysis of Phenol Contents of stored pulses

The phenol content of each pulse species was estimated using folin-ciocaltu reagent and the procedure followed by Malick and Singh (1980).

Materials :

- 80% ethanol
- Folin-ciocalteau reagent
- Na_2CO_3, 20%
- Standard (100-mg catechol in 100-ml water) diluted10 times for working standard.

Procedure :

1) Weighed exactly 1 g of the pulse sample and ground it with a pestle and mortar in 10 (10 ml ethanol) volume of 80% ethanol.
2) Centrifuged the homogenate at 10,000 r.p.m. for 20 minutes. Saved the supernatant. Re-extract the residue with five times the volume of 80% ethanol, centrifuged and cooled the supernatants.
3) Evaporated the supernatant to dryness.
4) Dissolved the residue in a known volume of distilled water (5 ml).
5) Pipetted out different aliquots (1 ml) into test tubes.
6) Made up the volume in each table to 3 ml (1 ml + 2 ml) with water.
7) Added 0.5 ml of folin-ciocalteau reagent.
8) After 3 minutes, added 2 ml of 20% Na_2CO_3 solution to each tube.
9) Mixed thoroughly. Placed the tubes in a boiling water for exactly one minute, cool and measured the absorbance at 650 mm against a reagent blank.
10) Prepared a standard curve using different concentrations of catechol.

Calculation :

From the standard curve the concentration of phenol content in the test sample was estimated and expressed as mg phenols/g pulses. Completely Randomized Block Design was (CRBD) carried out in for statistical analysis.

3.5. Morphological studies of two naturally occurring parasitoids

The pteromalid, *Dinarmus vagabundus* (Timberlake) and *Uscana mukerjii* (Mani) were collected from the stored pulses, *Vigna mungo* var. *mungo* and *V. radiata* var. *radiata* respectively. The hymenopteran parasitoids were reared on the larvae and eggs of the bruchid, *C. chinensis*. The specimens of both parasitoid and host insects were preserved individually in 70% ethanol and dry individuals were preserved in insect box for identification and subsequent study. Very minute body parts of the parasitoids were measured with the help of a compound microscope. A prism type *Camera Lucida* was used to draw the diagrams of mounted specimens and their body parts. The measurements were taken with the help of ocular and stage micrometers . The photographs were taken with the help of Leitz stereo-binocular microscope. Morpho-metrical data were based on 6 to 10 individuals. The data thus obtained were subjected to statistical analysis (standard deviation).

3.6. Biology and degree of parasitization of the egg parasitoid, *U. mukerjii*

3.6.1. Ovipositional preference for the host' age

Two mated females of *C. chinensis* were put in to glass tubes each containing 100 fresh soybean seeds. These were allowed to oviposit. About 0-12, 24, 48 hours after oviposition mated females of the egg-parasitoids were released into the tubes. The mated females were obtained from simultaneous cultures in separate vials. The number of eggs laid by each parasitoid species on the eggs of *C. chinensis* was calculated.

3.6.2. Host and egg-parasitoid culture

A large number of mated females of *C. chinensis* were introduced to different petri-dishes (11.5 on diameter) containing fresh healthy green gram seeds (*Vigna radiata*) covered with transparent glass cover for raising sufficient number of *C. chinensis.*

Naturally occurring egg-parasitoids were introduced in the petridish containing sufficient number of pulse beetle infested eggs on soybean seeds in the laboratory. The host eggs parasitized by the egg -parasitoid turned brownish to black at larval-pupal stages up to adult emergence.

3.6.3. Biology and and percentage of parasitization

In this case *C. chinensis* was allowed to lay eggs on green grams. *U. mukerjii* was released in Petri dishes containing 100 seed infested with 24-48 hr old eggs of *C. chinensis.* The parasitized eggs turned light to deep brown color and finally blackish before the emergence of adult parasitoid. Twenty percent honey + water solution was provided on wax paper strips inside the Petri dish. Observing the color of eggs, the fecundity /female of the parasitoid was evaluated.

In another experiment where the host insect (0-1 day old) and one pair mated egg-parasitoid just after first mating (polygamous) were given to the test tube with the help of aspirator were set for oviposition of egg-parasitoid. After 4 – 10 days, according to the seasons, the adult egg-parasitoids emerged out and the numbers of adult were counted. Simultaneously, the developmental period (day), adults longevity (day), sex ratio (male: female) and per cent parasitization of egg-parasitoid were recorded. Percentage of parasitization was calculated with following formula:

$$\textbf{Percentage of parasitization} = \frac{\text{Total number of host's eggs parasitized by single mated female parasitoid}}{\text{Total number of parasitized + healthy eggs (laid by one pair mated pulse beetle)}} \times 100$$

Each experiment was replicated four times and the data obtained were statistically analyzed. The methodology made out with the help of literature cited by Pajni *et al.*(1996) with some modifications.

3.7. Biology and per cent of parasitization of the larval-pupal parasitoid

Both males and females of *C. chinensis* were kept at a ratio of 1: 1 in glass tubes for mating. A large number of mated females were introduced in different petri-dishes (11.5cm.diameter) containing fresh seeds of green gram (*Vigna radiata*) and covered by transparent lids. During summer 8, 10, 12, 14, 16, 18, 20 and 22 day after oviposition when the development progressed up to larval-pupal stage and similarly during winter during summer and 24, 26, 28, 30 , 32, 34, 36, 38, 40 and 42 day after oviposition, the dead insects were removed from the petri-dishes. The seeds containing larvae and pupae of host insects were used to study the per cent parasitization by the parasitoid, *D. vagabundus*.

The virgin females (less than 24 hours old) of *D. vagabundus* were kept with the virgin males in another separate set of vials for mating. The males became excited in the presence of females within a minute. Courtship behavior lasted for 20-60 seconds. After mating, the females and males (our pair/replication) were transferred to the Petri dish containing the larvae/papae bearing pulses. Fifty percent honey + water (1:1) solution was provided on wax paper strips inside the Petri dish as their food.

Few mated females of the parasitoid before oviposition (within 12-24 hours of mating) were killed in ethanol 50%+ glycerin 50% and their abdomens were mounted permanently and the eggs present inside the abdomen were viewed with the help of compound microscope to count the average fecundity. Same procedure was followed for both continued in summer and winter seasons.

One hundred 8 to 22-day-old (during summer) and 16 to 32-day-old (during winter) larval pupal stage of *C. chinensis* infested green gram seeds were taken in the Petri dish inside and 2 pairs of mated parasitoids were transferred inside the petri-dish to oviposit on the host larvae or pupae before their death. After emergence of adult parasitoid the developmental period (days) (egg to adult) was recorded. The male and female parasitoids after emergence were taken in separate test tube from the petri dish with the help of aspirator and adult longevity of both sexes and sex ratio were recorded.

Green gram seeds infested by *C. chinensis* per pair adults were taken inside the petri dish. After 8-22 days (in summer) and 16-32 days (in winter), one pair of freshly emerged (24 hours old) mated parasitoids (male: female = 1:1) were introduced inside the petri dish for their oviposition till their death. After exposure the parasitized larvae/pupae of host insect were dissected out to observe the number of parasitized larvae and pupae under a simple stereo binocular microscope. The per cent parasitization per female was calculated during both summer and winter seasons under laboratory storage conditions using the formula given below:

$$\textbf{Per cent perasitization} = \frac{\text{Total number of parasitized larvae pupae of the host}}{\text{Total number of healthy and + parasitized larvae and pupae of the host}} \times 100$$

Each experiment was replicated four times and the data obtained were statistically analyzed. The above mentioned methods were adopted as described by Islam (1995) and Jalali *et al.* (1987) with some modifications because the parasitoid, *D. vagabundus* is gregarious larval-pupal ecto-parasitoid of bruchid pests.

3.8. Safe management with plant oils

3.8.1. Screening and selection of plant oils

The control measures with few vegetable oils have been carried out for safe control management in the laboratory storage conditions. The oils were collected from farmers, markets and agricultural farms of this region.

Table 5. Common name, scientific name and family of the plant oils:

Common name	Scientific name	Family
1. **Mustard oil**	*Brassica juncea* Linn.	Cruciferae
2. **Soybean oil**	*Glycine max* (L.) Merr.	Leguminosae
3. **Coconut oil**	*Cocos mucifera* Linn.	Palmaceae
4. **Neem oil**	*Azadirachta indica* (A Juss.)	Meteaceae
5. **Niger oil**	*Guizotia obyssinica* Cass	Compositae
6. **Safflower oil**	*Carthamus tinctiorius* Linn.	Compositae
7. **Palm oil**	*Elaeis guineensis* Jac.	Palmaceae
8. **Rice bran oil**	*Oryza sativa* Linn.	Graminae
9. **Citronella oil**	*Cymbopogon winterianus* Jowitt.	Graminae
10. **Sunflower oil**	*Helianthus annuus* Linn.	Compositae
11. **Castor oil**	*Ricinus communis* Linn.	Euphorbiaceae
12. **Chaulmoogra oil**	*Hydnocarpus kurzii*	Flacourtiaceae
13. **Clove oil**	*Eugenia* sp. Spregal.	Myrtaceae
14.**Sesame**	*Sesamum indicum*	Cruciferae

3.8.2. Effectiveness of plant oils on adult C. *chinensis*

Six non-edible plant oils *viz.* clove, neem, castor, chalmoogra, palm and citronella were used to test the toxicity against pulse beetle, *C. chinensis* Linn. The oils were measured with the help of micropipettes and diluted in 5 ml acetone. Edible plant oils of mustard, niger, rice bran, soybean, coconut, sesame, sunflower and safflower and the non-edible plant oils such as clove, neem, castor, palm, citronella and chaulmoogra were applied at different concentrations (v/v)(%) likely 0.05,0.025,0.01 ml (for edible oils) and 0.01, 0.005, 0.002, 0.001 ml. (for non-edible oils) to test the effectiveness on adult *C. chinensis*.(Table 5) Oil film was prepared by delivering oil solutions of the required concentration into the two parts of the petri dishes (dia. 9 cm). The petri dishes were rotated in such a way so as to form a uniform layer of oil solution. The petri dishes were left as such for about 45 min. to evaporate the acetone as recommend by Pathak and Jha (1999) with some partial modification of this experiment. Twenty freshly emerged 1 to 2 days old pulse beetles were released in each petri dish (9 cm. dia.) covered with transparent lid. petri dishes treated with acetone served as control. The observations on mortality were recorded after 24 hours of releasing the insects. The moribund insects were counted as dead. Each treatment was replicated four times in a completely randomized block design (CRBD). The methodology followed was as recommended by Pathak *et al.* (1999).

3.8.3. Efficacy and persistency of nine different plant oils

An adequate culture of *C. chinensis* was maintained on green gram seeds (Untreated) as per the procedure described by Islam (1999). Plant oils of rice bran, niger, mustard, soybean, neem, safflower, citronella, chaulmoogra and clove oil were applied @ 0.05 ml/100g, 0.1 ml/100g and 0.3ml/100g. (Table 6) A stock of requisite quantity of 200g oil treated seeds was stored in perforated polythene bags. Samples of each 10g for each replica were drawn periodically at the intervals of 30 days (October), 60 days (November), 90 days (December) and 120 days (January). During the period of experiment average room temperature ranged from 18.5 to 27.11 ° C and mean temperature was 22.58 ° C whereas average relative humidity ranged from 65 to 75% and mean r.h.(%) was 67.5%. The samples were kept in small glass tubes (3″ x 1″). Three replications were used in each treatment. Two pairs of *C. chinensis* (0-1 day old) were introduced from stock culture (without oil treatment) in each glass tubes covered with muslin cloths secured firmly with rubber band. The dead beetles were removed after their death. The number of eggs laid and the number of adults emerged / female and mean development period

(d) were recorded. The methodology was followed with some modification as described by Islam (1999) and kachare *et al.* (1994)

Table 6. Required doses applied in increasing storage duration of green gram up to 120 days

	Treatments (Plant oil)		Dosages (Concentrations) (V/W)
1.	**Rice bran oil**	a)	0.05/100g
		b)	0.10/100g
		c)	0.3/100g
2.	**Niger Oil**		*I bid*
3.	**Mustard oil**		*I bid*
4.	**Soybean oil**		*I bid*
5.	**Neem seed oil**		*I bid*
6.	**Citronella grass oil**		*I bid*
7.	**Chaulmoogra oil**		*I bid*
8.	**Clove oil**		*I bid*
9.	**Untreated (Control)**		___

Chapter-IV

OBSERVATIONS

OBSERVATIONS

4.1. Occurrence of Insect Pests of Stored Pulses and their Parasitoids at Terai Agro-climatic Condition

4.1.1. The species of *Callosobruchus* recorded

A district wise occurrence of insect pests of the genus *Callosobruchus* of stored were recorded. The data are furnished in **Table 7** and **Appendix XI.** The photographs of the insect pests are furnished in **Plate 4.**

It was found that *C. chinensis* were the most abundant and destructive insect pest of green gram, lentil, red gram and grass pea. The pest also caused damage to chick pea, cowpea, pigeon pea, Indian bean, moth bean, horse gram and pea. *C. analis* is also harmful to green gram followed by black gram, thakri kalai, cowpea, pigeon pea and grass pea. The buggy pea beetle, *C. pisorum* was recorded only on pea and their infestation occurred in the field and adult emerged out after few months in the storehouses **(Plate 6)** The insect, however, couldn't complete its life cycle in stored peas. *C. maculatus* was obtained from all the places of collection and infestation was moderate **(Table 7)**.

Table 7. District wise distribution of pests and their infestation
(Recorded during 1999, 2000 and 2001)

Name of the Pulses	Insect pest species (Scientific name)	Name of the district			
		Cooch Behar	Jalpaiguri	Darjeeling	Uttar Dinajpur
Green gram (*Vigna radiata*)	*C. chinensis* L.	M+++	M+++	M++	M+++
	C. maculatus	M++	M+	M+	M+
	C. analis	M++	M++	M+	NR
	Sitophilus sp.	T	T	NR	T
	Corcyra cephalonica	T	NR	NR	NR
Chickpea (*Ciser arietinum*)	*C. chinensis*	M++	M++	M+	M+
	C. maculatus	M+	M+	M+	M+
	Sitophilus sp.	T	T	NR	NR
	Corcyra cephalonica	T	NR	NR	NR
Black gram (*V. mungo mungo*)	*C. analis*	M+++	M+++	M+	NR
	C. maculatus	M++	M++	M++	M++
	C. chinensis	M++	M++	M+	M+
Thakri kalai (*V. mungo silvestries*)	*C. analis*	M+++	M+++	M+	NA
	C. maculatus	M++	M++	M+	M++
	C. chinensis	M++	M++	M++	M++
Grass pea (*Lathyrus sativus*)	*C. chinensis*	M+++	M+++	M++	M+++
	C. analis	M+	NR	NR	NR
	C. maculatus	M++	M+	M+	M+

Name of the Pulses	Insect pest species (Scientific name)	Name of the district			
		Cooch Behar	Jalpaiguri	Darjeeling	Uttar Dinajpur
Pea (*Pisum sativum*)	*C. chinensis*	M+	M+	T	M+
	Sitophilus sp.	T	T	NR	NR
	C. pisorum	T	NR	T	NR
Lentil (*Lens esculentum*)	*Sitophilus* sp.	T	T	NR	NR
	C. chenensis	M+++	M+++	M++	M++
	C. maculatus	M+	M+	M+	M+
Cowpea (*Vigna catiang*)	*C. chincnsis*	M+	M+	M+	M+
	C. analis	M+	T	NR	NR
	C. maculatus	M+++	M++	M++	M+
Horse gram (*Dolicos biflorus*)	*C. chinensis*	M+	M+	NR	NR
	C. analis	M+	M+	NR	NR
	C. maculatus	M+	M+	NR	NR
Soybean (*Glycine max*)	Bruchid eggs	T	T	T	NR
Kidney bean (*Phaseolus vulgaris*)	Bruchid eggs	T	NR	NR	NR
Red gram (*Cajanus cajan*)	*C. chinensis*	M+	M+	T	M+
	C. analis	M+	NR	NR	NR
	C. maculalus	M+	M+	NR	NR
	Sitophilus sp.	T	T	NR	NR
Small pea (*Pisum arvense*)	*C. pisorum*	T	T	T	NR
Moth bean (*Vigna aconitifolia*)	*C. chinensis*	M+	M+	NR	NR
Indian bean (*Dolicos lab lab*)	*C. chinensis*	T	T	NR	NR

+ = Presence of eggs on the seeds of stored pulses.
M+++ = Maximum egg-infestation on seeds (above 25%)
M++ = Moderate egg-infestation on seeds (10-24%)
M+ = Minimum egg-infestation on seeds (4-9%)
T = Trace egg-infestation on seeds (below 5%)
NR = No egg-infestation on seeds

4.1.2. Parasitoids recorded

A few minute hymenopteran bio-control agents were found with the bruchid pests. Three parasitoids of bruchids and two of other host insects pests were recorded from this area of investigation. The parasitoid *Uscana mukerjii,* is an egg parasitoid of *C. chinensis* and *C. analis*. It was found to be a potential bio-control agent (**Plate 11**). Another larval-pupal gregarious ecto-parasitoid, *Dinarmus vagabundus* was also collected from *C. analis* on stored black gram (*Vigna mungo mungo*). Another species of *Dinarmus* also recorded on bruchids infested stored red gram. The district wise occurrence of the natural enemies and their hosts are furnished in **Table 8, Plate 5** and **Appendix XI.**

Table 8. The district wise distribution of parasitoids
(Record of 1999, 2000 and 2001)

Parasitoid	Host insect	Storage pulse	Occurrence
***Dinarmus vagabundus* (Timb.)** (Hymenoptera : Pteromalidae)	*C. chinensis* Linn. & *C. analis* Fabr.	Black gram (*Vigna mungo* & *V. mungo silvestries*)	Coochbehar, Jalpaiguri
***Dinarmus* sp.** (Hymenoptera : Pteromalidae)	*C. maculatus* Fabr. *C. chinensis* Linn.	Red gram (*Cajanus cajon*)	Coochbehar, Jalpaiguri Darjeeling, Uttar Dinajpur
***Cercocephala dinoderi* Gahan** (Hymenoptera : Pteromalidae)	*Sitophilus* spp.	Green gram (*Vigna radiata)*	Coochbehar
***Bracon* sp.** (Hymenoptera : Braconidae)	*C. cephalonica* Staint.	Green gram (*Vigna radiata*)	Coochbehar
***Uscana mukerjii* (Mani)** (Hymenoptera : Trichogrammatidae)	*C. chinensis* Linn. *C. analis* Fabr.	Green gram & Black gram	Coochbehar, Jalpaiguri
***Uscana mukerjii* (Mani)** (Hymenoptera : Trichogrammatidae)	*C. chinensis* Linn. *C. analis* Fabr.	Green gram & Black gram	Coochbehar, Jalpaiguri

4.1.3. Extent of infestation and damage caused by the bruchids
(Recorded during 1999-2001)

This observation involved the estimation and assessment of the per cent seed damage (**Table. 9** and **Plate 6**) and quantitative weight loss (**Table 10**) caused by different species of pests on stored pulses.

Table 9. Estimation of per cent damage
(Average of 3 seasons, 1999-2001)

Pulses	Insect pests	Damage (%)			Average of 3 seasons
		Winter	Summer	Rainy	
Green gram	*C. chinensis*	22.85	30.33	36.66	29.94
	C. analis.	16.04	18.12	17.39	17.18
	C. maculatus	15.49	17.11	16.19	16.26
Black gram	*C. chinensis*	-	-	2.29	00.76
	C. analis	19.43	15.93	16.42	17.26
	C. maculatus	20.91	19.12	19.62	19.88
Red gram	*C. chinensis*	17.92	16.22	21.92	18.68
	C. maculatus	18.29	19.03	19.92	19.08
Horse gram	*C. chinensis*	13.45	14.90	15.02	14.45
Bengal gram	*C. chinensis*	9.75	12.87	22.49	15.03
Lentil	*C. chinensis*	33.66	45.27	46.01	42.64
Pea	*C. chinensis*	10.02	08.14	13.58	10.58
Cowpea	*C. chinensis*	13.59	13.01	15.06	13.88
	C. maculatus	19.02	20.13	19.92	19.69

Pulses	Insect pests	Damage (%)			Average of 3 seasons
		Winter	Summer	Rainy	
Thakri kalai	*C. analis*	16.92	15.37	16.85	16.38
	C. chinensis	-	-	3.12	01.04
Grass pea	*C. chinensis*	21.4	21.42	24.44	22.42
	C. maculatus	12.11	14.99	14.87	13.99
Soybean	*Callosobruchus* sp.	-	-	-	-
Kidney bean	*Callosobruchus* sp.	-	-	-	-
Moth bean	*C. chinensis*	22.22	21.5	29.98	24.56
Small pea	*Callosobruchus* sp.	-	-	-	-

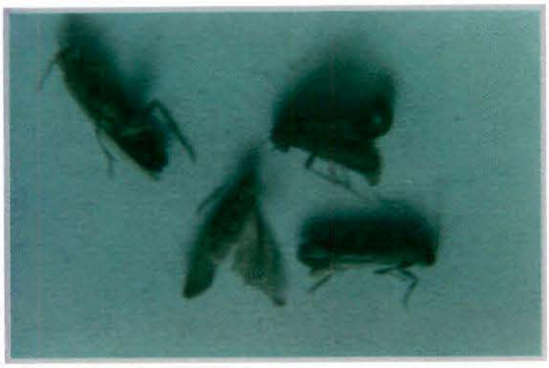
The percentage of damage of stored pulses (Table 9) by *C. chinensis* was the highest (average of 3 seasons). Damage of lentil was 42.6%, grass pea 22.4%, green gram 29.4%, red gram 18.6%, cow pea 13.8%, horse gram 14.45, chick pea 15.03% , pea 10.5% , black gram 00.7% and thakri kalai was 1.04%. Estimation of damage (%) caused by *C. analis* recorded maximum on black gram (17.2%) and thakri kalai (16.3%) whereas *C. maculatus* caused maximum damage on cow pea, pigeon pea, black gram, grass pea and green gram (**Table 9**). These bruchids could not damage stored soybean (*Glycine max*), kidney bean (*Phaseolus vulgaris*) and small pea (*Pisum arvence*) seeds (**Fig.1**). The highest damaged was caused during rainy season followed by summer and winter. The damage caused by *C. analis* on black gram was 17.2%, thakri kalai 16.3% and green gram 14.1%.This bruchid could not able to damage lentil, soybean, kidney bean and small pea (**Fig.1**). Quantitative weight loss (%) of stored peas by *Callosobruchus* (=*Bruchus*) *pisorum* was the highest (17.08%) followed by *C. analis* and *C. chinensis* (**Table 10** and **Fig. 2**).

Table 10. Estimation of per cent weight loss

(Average of 3 seasons, 1999-2001)

Pulses	Insect pests	Loss of wt. (%)			Average of 3 seasons
		Winter	Summer	Rainy	
Green gram	*C. analis*	11.73	12.51	14.95	13.06
	C. chinensis	10.36	11.83	14.15	12.11
Grass pea	*C. chinensis*	05.72	07.78	09.98	07.82
	C. analis	07.42	10.11	12.11	09.80
Pea	*C. chinensis*	03.79	04.11	05.42	04.40
	C. analis	06.87	07.78	09.02	07.89
	C. pisorum	15.13	17.79	18.21	17.08
	Sitophilus sp.	01.64	01.21	02.27	01.70
Black gram	*C. analis*	10.37	11.26	11.39	11.00
Cowpea	*C. chinensis*	10.03	11.79	12.68	11.50
	C. analis	09.20	12.42	14.21	12.60
Bengal gram	*C. chinensis*	10.42	11.20	12.42	11.30
Red gram	*C. chinensis*	07.21	09.21	10.42	08.94
Lentil	*C. chinensis*	16.63	18. 74	19.42	18.20
	C. analis	-	-	-	-

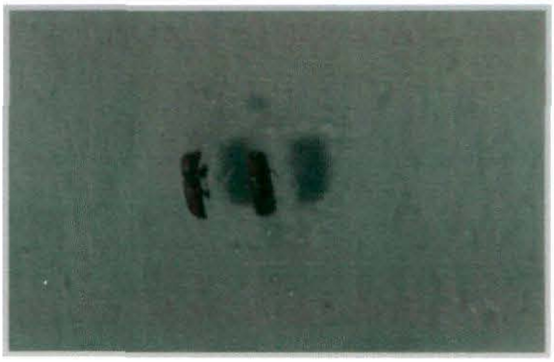
PLATE 4



Grain moth,
Corcyra cephalonica Stainton
(Lepidoptera: Galleriidae)

Grain weevil,
***Sitophilus* sp.**
(Coleoptera : Curculionidae)

Pulse beetle,
Callosobruchus chinensis Linn.
(Coleoptera: Bruchidae)



Red floor beetle,
Tribolium sp.
(Coleoptera : Tenebrionidae)

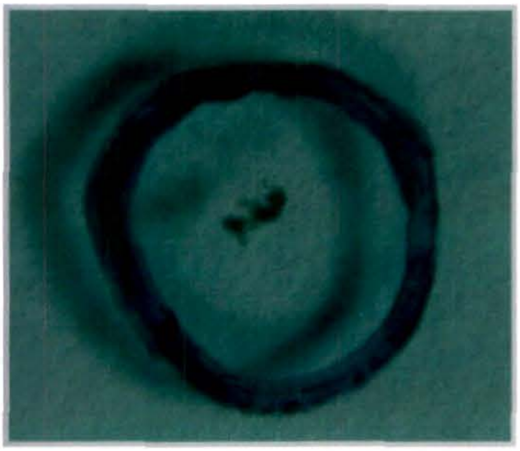
Pea buggy weevil,
Callosobruchus pisorum Linn.
(Coleoptera : Bruchidae)

Callosobruchus analis Fabricious
(Coleoptera : Bruchidae)

Photoplate 4. Insect-pest of stored pulses

Egg-parasitoid of pulse beetle,
Uscana mukerjii (Mani)
(Hymenoptera:Chalcidoidea:Trichogrammatidae)

Larval parasitoid of grain moth,
***Bracon* sp.**
(Hymenoptera:Ichneumonoidae:Braconidae)

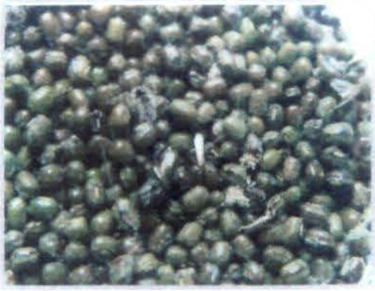


Larval-parasitoid of grain weevil,
Cerocephala dinoderi Gahan
(Hymenoptera:Chalcidoidea:Pteromalidae)

Larval-pupal ectoparasitoid of pulse beetle,
Dinarmus vagabundus (Timberlake)
(Hymenoptera:Chalcidoidea:Pteromalidae)

Photoplate 5. Natural enemies of insect-pest of stored pulses

PLATE 6



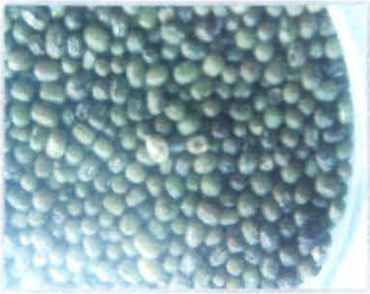
Stored green gram (*Vigna radiata* L.) infested by grain moth, *Corcyra cephalonica* Stainton.

Egg infestation of pulse beetle on soybean (*Glycine max* Merr.)

Storage pea (*Pisum sativam* L.) damaged by *C. pisorum* L.

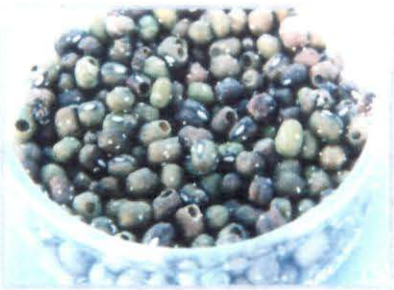
Red gram (*Cajanus cajon* Milsp.) damaged by *C. chinensis* L.

Grass pea (*Lathyrus sativus* L.) damaged by *C. chinensis* Linn.



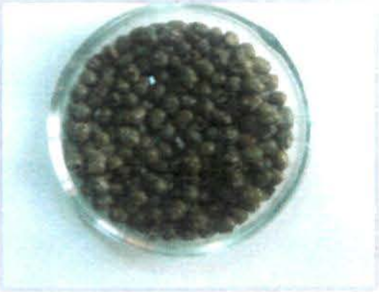
Green gram (*Vigna radiata* L.) damaged by *Sitophilus* sp.L.

Black gram (*V. mungo silvestries* L.) damaged by *C. analis* Fab.



Green gram (*V. radiata* L.) damaged by *C. chinensis* L.

Kidney bean (*Phaseolus vulgaris* L.) infested by *Callosobruchus* sp.



Green gram (*V. radiata* L.) damaged by *C. analis*

Pea (*Pisum sativum* L.) damaged by *C. chinensis* Linn.

Photoplate 6. Infested/damaged stored pulses

Fig 1. Damage (%) of stored pulses by *C. chinensis*

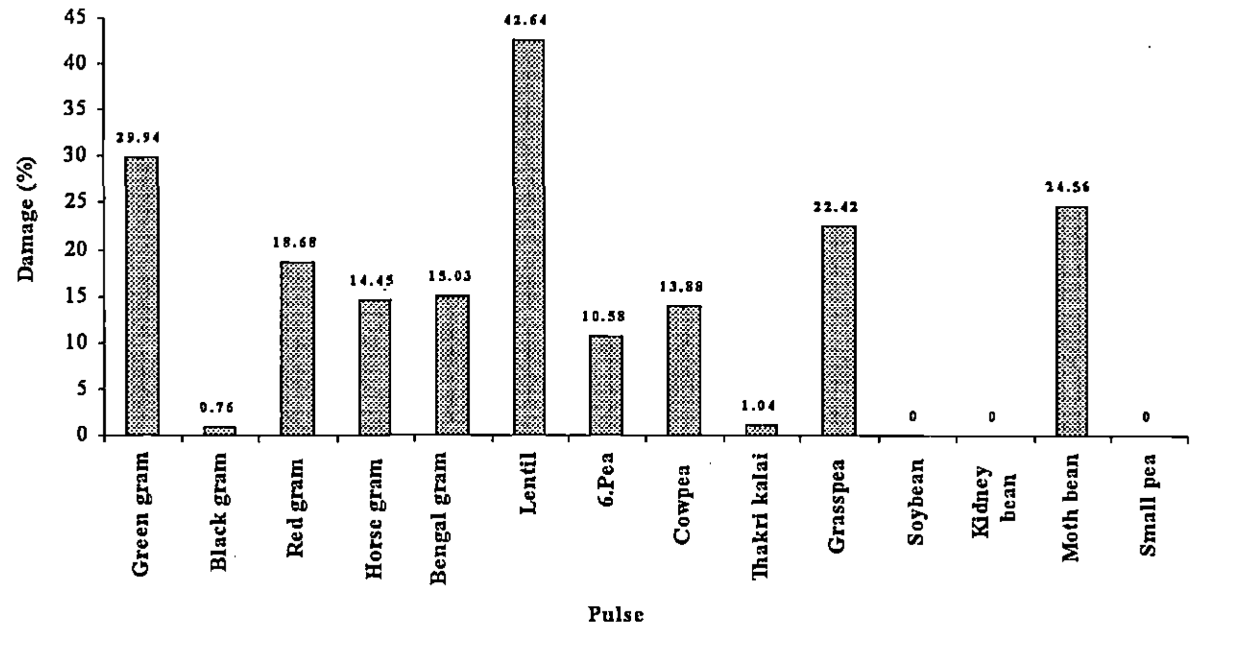
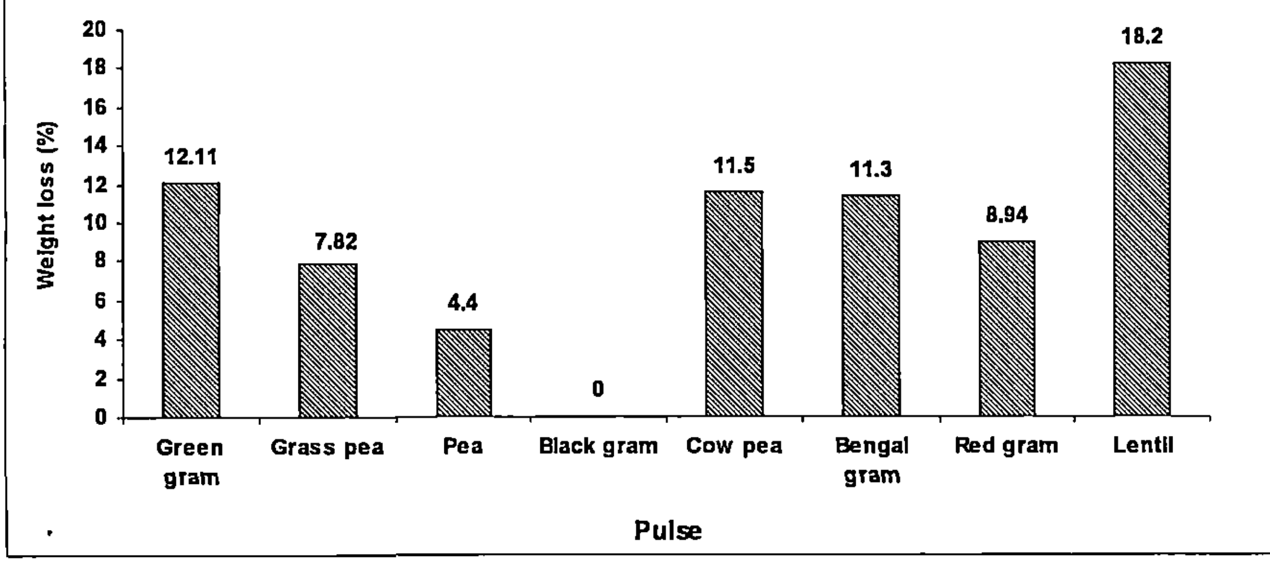
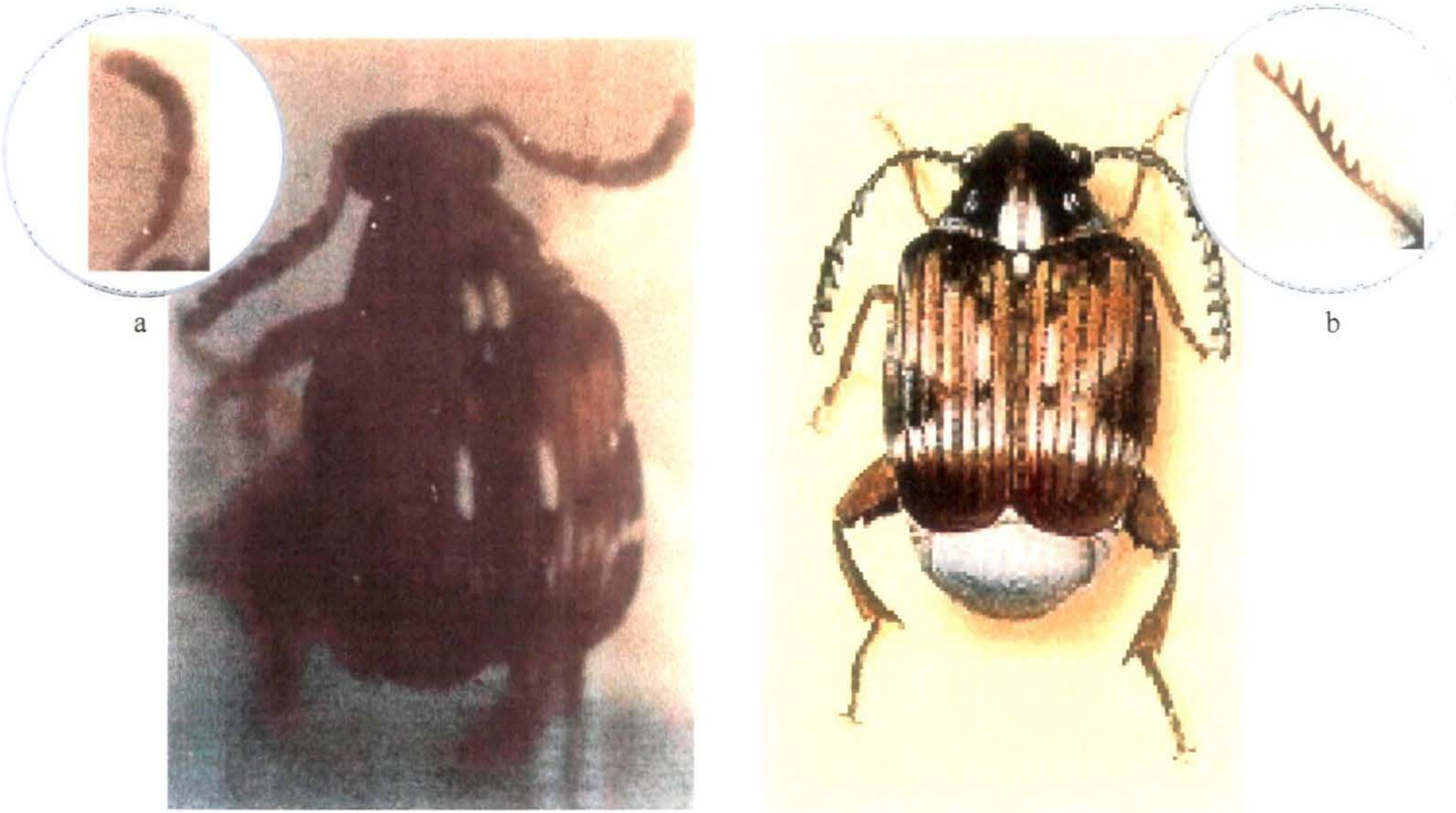


Fig.2. Weight loss (%) of stored pulses due to *C. chinensis*





a b

Female Male

Photoplate 7. ***Callosobruchus chinensis*** **Linnaeus**
(**Inset :** a. Female antanae b. Male antanae)

4.2. Bio-ecology of C. *chinensis* on green gram in the laboratory

The eggs were oval, plano-convex and broad anteriorly, narrow at the posterior. The freshly laid eggs were transluscent, milky-white with yellow tinge and smooth. The eggs later become pale yellowish or grayish. Newly emerged adults of same age were found to mate within an hour during summer or took a maximum of three hours during winter. The adults were polygamous. After mating the females were laid eggs singly if the seeds were found to be sufficient but if the seeds are insufficient then it laid maximum up to six on a single green gram seed.

These observations (**Table 11**) were taken from eleven sets of different temperature and relative humidity on monthly basis (**Table 12**).

4.2.1. Oviposition period

A prolonged oviposition period from 11 to12 days was observed during January - March. It was only 6 to 9 days (mean 7.5 days) during November - December, 6-8 days (mean 7.0 days) during March - April and 5-7 days (mean 6.25 days) during October - November. The shortest oviposition period from 4 to 5 days (mean 4.25 days) was observed during May. During the major period of the year the duration was from 4 to 6 days.

4.2.2. Incubation period

It was prolonged, 9 to 12 days (mean, 10.75 days) and 7 to 10 days (mean, 8.75 days) during January-February and November-December respectively. The period shortened during March-April (4.75 days) and April-May (3.75 days).The shortest incubation period was observed during May (3.5 days). From May- June to October-November the period ranged from 4.25 to 6.62 days).

4.2.3. Larval-pupal duration

The mean duration ranged between 18.55 and 36.50 days. The longest duration was during January-February and the shortest during June-July, the values were 34-37 and 16-22 days respectively.

4.2.4. Developmental period

The values were similar to the combined values of incubation and larval-pupal durations. The pest took as long as 47.25 days during January-February and the shortest of 22.75 days during May.

4.2.5. Longevity of adult

Longevity of adult males' during January-February differed significantly from that of other periods. During this period the mean life span was 14.10 days which was the maximum life span within a year. Shortest life span of 7.27 days was during May. During the period from April to June the span of three generations did not differ. Again, during June-December the life span did not differ significantly.

Life span of adult female was always shorter in comparison to that of the adult males.. Prolonged life span of females was 11 to 14 days with a mean of 12.00 days during January - February followed by 7 to 10 days during November - December and 7 to 9 days during March - April and July - September. The shortest longevity of adult females was 6 to 9 days during May with a mean of 6.50 days.

4.2.6. Sex ratio

Sex ratio (female : male) showed very little differences in different generations of a year. In general, the females were of less number than the males. During Aug. - Sep. the female and male ratio was 1: 0.52.

4.2.7. Fecundity

There were differences in fecundity in different generations of a year. The highest fecundity was recorded during June-July with a mean of 95.62. The lowest was during November - December with a mean of 64.09. In other generations of a year the values were 93.81 (March - April), 93.22 (July - August), 89.66 (May), 88.5 (April - May), 85.2 (May - June), 79.0 (Jan. - Feb.) and 75.37 (Aug. – September).

4.2.8. Hatchability

The hatchability (%) of eggs laid by *C. chinensis* on green gram seeds was the highest of 78.45 during March - April followed by 67.7 (Jan. - Feb.), 66.75 (April - May), 59.1(May), 51.88 (May - June) and 51.27 (October - November). It was below fifty percent during other months. The Lowest hatchability was observed during July-August when the percentage was 39.27 only.

4.2.9. Adult Emergence

The adult emergence (%) of *C. chinensis* varied in different months. Mean adult emergence percentage was in the following descending order 64.2% (April - May) > 53.7% (Mar. - April) > 47.74% (May) > 41.29% (Jan. – Feb.) > 41.15% (Nov. –Dec.) > 31.01 (Oct. – Nov. > 29.91% (May - June) > 26.5% (Sept.- Oct.) > 23.54% (Aug. –Sept.) > 23.19% (July – Aug.) > 21.1% (June – July).

Fig. 3. Ovipositional period of *C. chinensis*

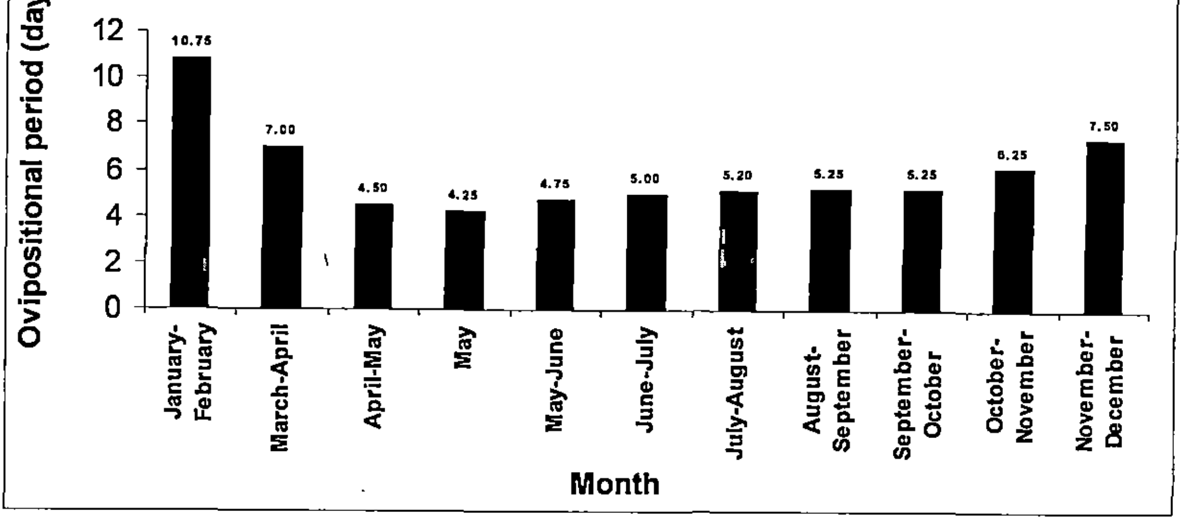


Fig. 4. Incubation period of *C. chinensis*

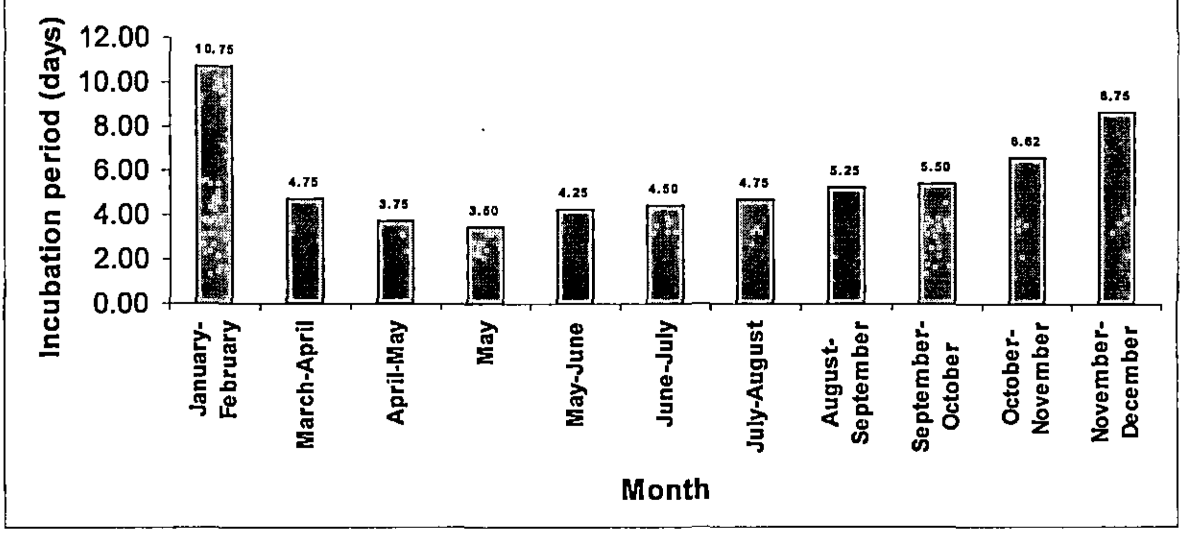


Fig.5. Hatchability of *C. chinensis*

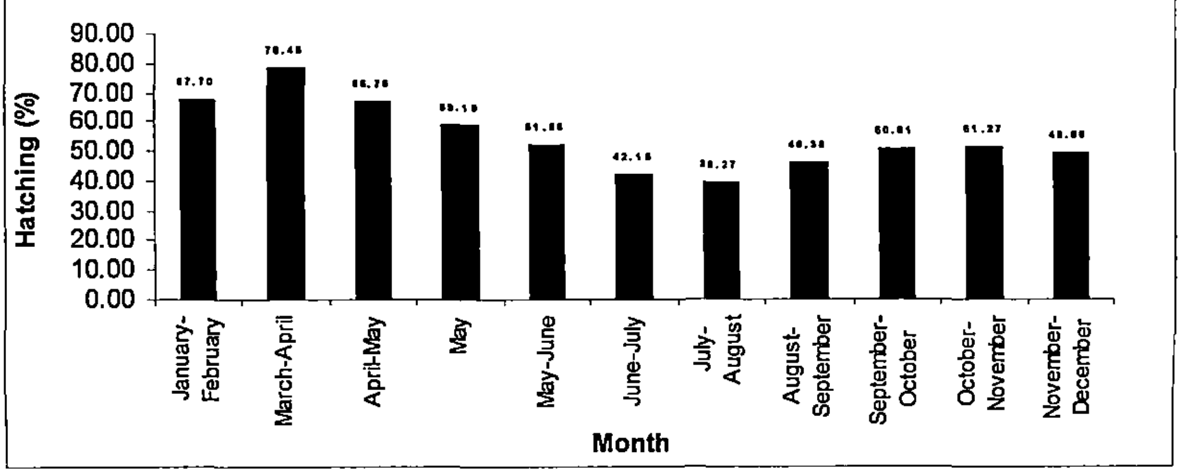


Fig.6. Larval-pupal period of *C. chinensis*

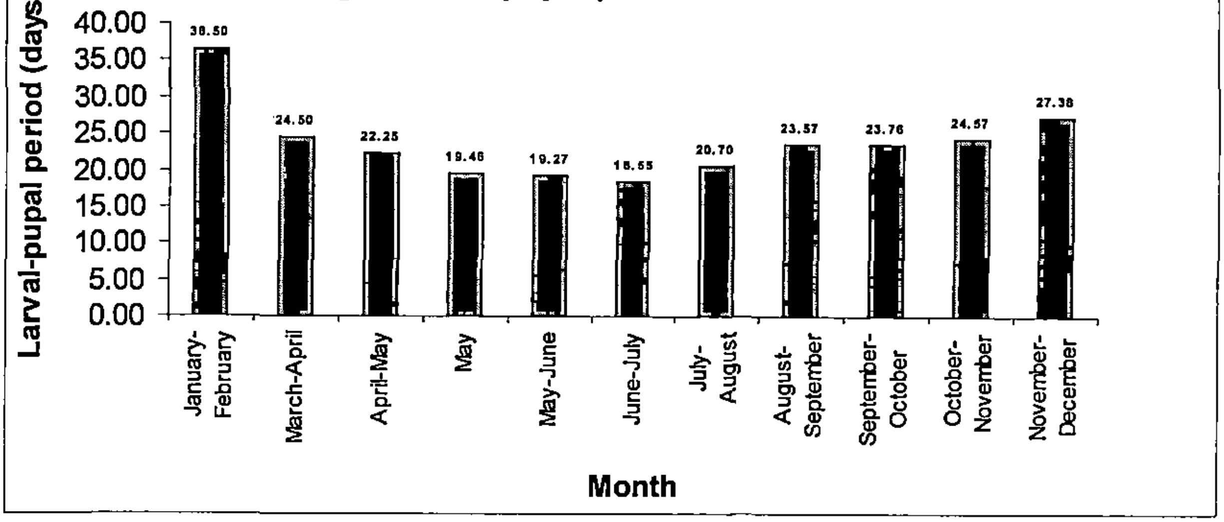


Fig. 7. Longevity of adult C. chinensis

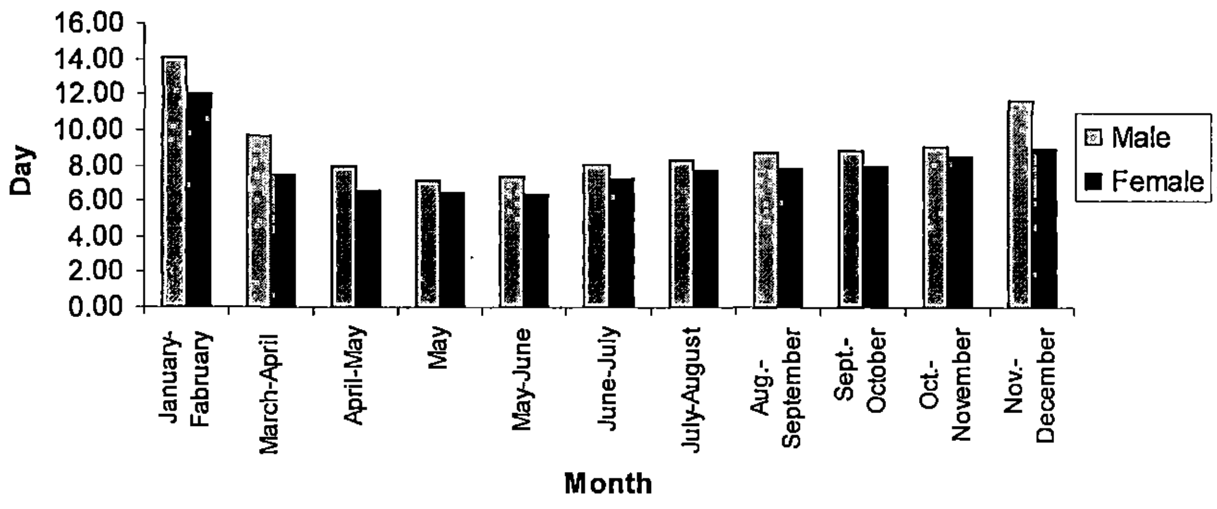
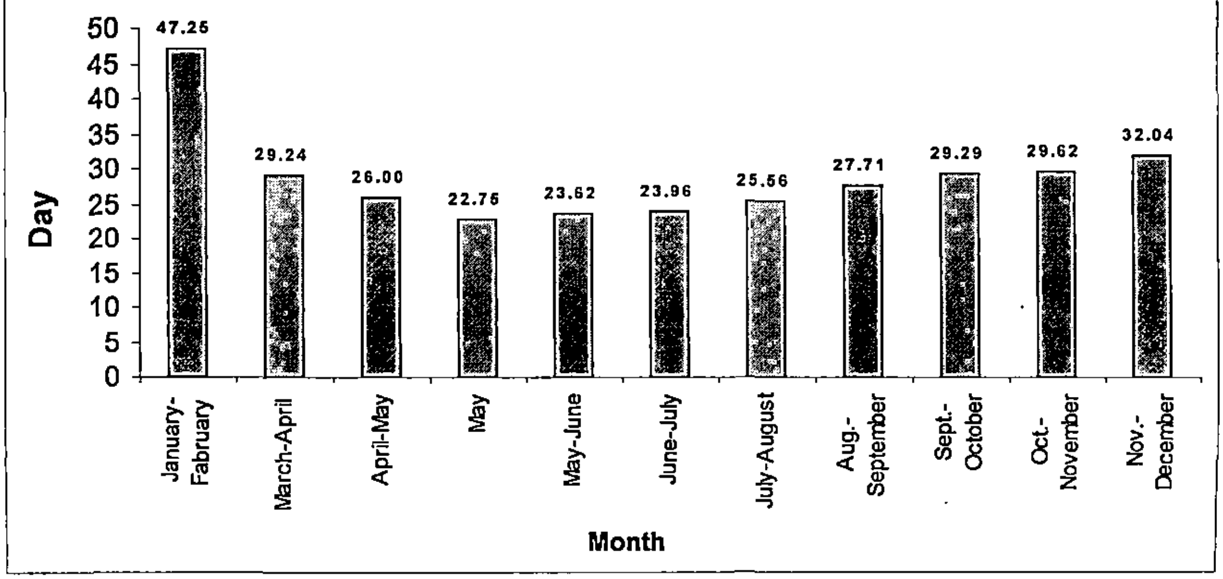


Fig.8. Total development period of *C.chinensis*



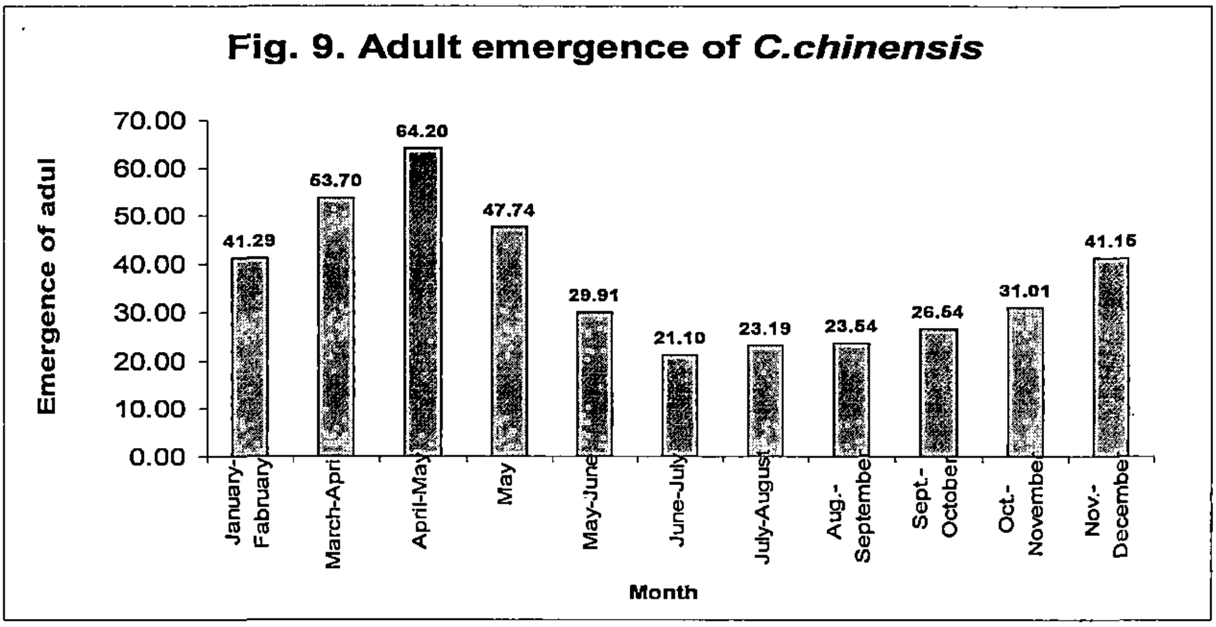


Fig. 9. Adult emergence of C.chinensis
Emergence of adul
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
41.29
53.70
64.20
47.74
29.91
21.10
23.19
23.54
26.54
31.01
41.15
January-Fabruary
March-Apri
April-May
May
May-June
June-July
July-August
Aug.-Septembe
Sept.-October
Oct.-Novembe
Nov.-Decembe
Month

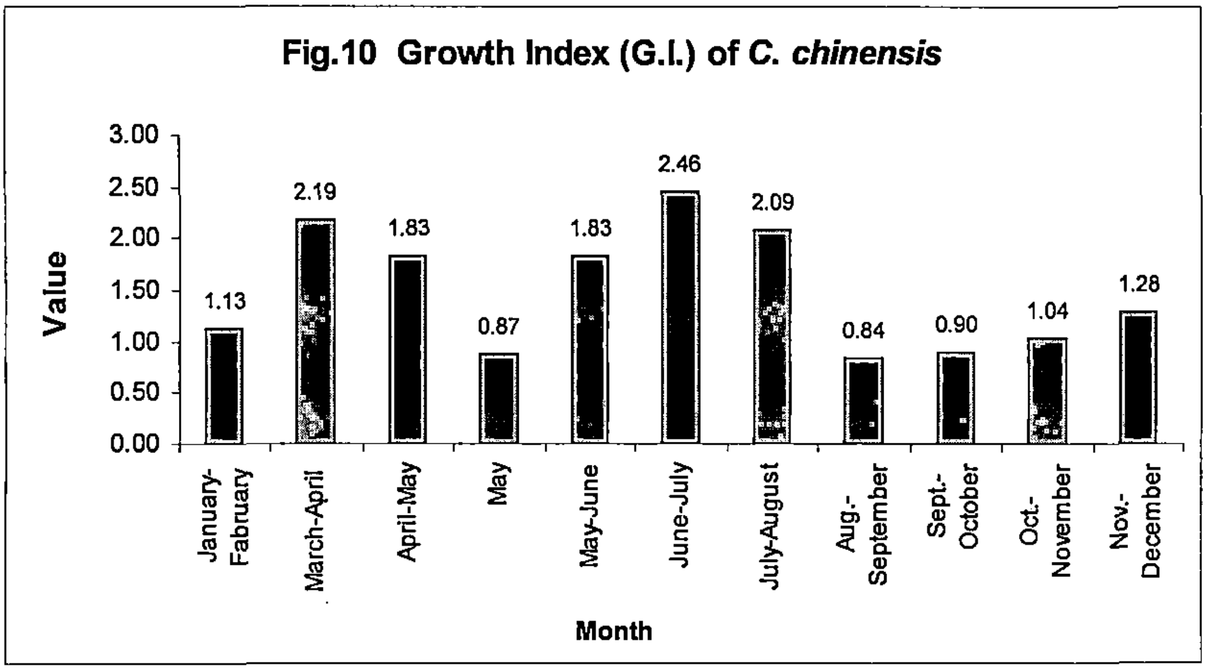


Fig.10 Growth Index (G.I.) of C. chinensis
Value
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1.13
2.19
1.83
0.87
1.83
2.46
2.09
0.84
0.90
1.04
1.28
January-Fabruary
March-April
April-May
May
May-June
June-July
July-August
Aug.-September
Sept.-October
Oct.-November
Nov.-December
Month

4.2.10. Growth index (GI)

The growth index (Mean per cent adult emergence / mean development period) differ in different generations. The highest GI (2.19) and the lowest GI (0.52) were observed during March-April and August-September respectively. Growth Index value also recorded 0.71 during September-October followed by 0.73 (June-July) and 0.84 (November - December).

Association of biological characters of *C. chinensis* to the temperature and relative humidity of different months revealed that only the fecundity of *C. chinensis* was positively correlated with the laboratory temperature and relative humidity where fecundity with temperature showed highly significant value. Others biological parameters were negatively correlated. Growth Index (GI) of *C. chinensis* was non-significant with temperature and relative humidity (**Table 12** and **13**).

Table 11. Bio-ecology of *C. chinensis* : a laboratory study

(Average of 3 years, January 1999 to December 2001).
The values are means ±SD and ranges in parenthesis

Month	Oviposition period (day)	Fecundity (no)	Incubation period (day)	Hatching (%)	Larval-pupal period (day)
Jan.-Feb.	10.75 ± 1.25 (11-12)	79.00 ±10.16 (62-92)	10.75±1.61 (9-12)	67.70 ± 5.49 (60-79)	36.50 ± 1.75 (34-37)
Mar.-April	7.00 ± 0.81 (6-8)	93.81±7.31 (85-109)	4.75 ± 0.72 (4-6)	78.45 ± 6.13 (71-88)	24.50 ± 1.60 (23-26)
April-May	4.50 ± 0.57 (4-5)	88.50 ±5.73 (86-95)	3.75±0.65 (3-5)	66.75 ± 4.93 (63-74)	22.25 ± 1.38 (20-24)
May	4.25 ± 0.54 (4-5)	89.66 ±6.07 (81-97)	3.50 ±0.47 (3-4)	59.10 ± 5.98 (46-71)	19.46 ± 1.48 (17-22)
May-June	4.75 ± 0.57 (4-6)	85.20 ±6.23 (74-92)	4.25 ±0.52 (4-5)	51.88 4.96 (44-58)	19.27 ± 2.50 (16-21)
June-July	5.00 ± 0.84 (4-6)	95.62 ±3.85 (88-98)	4.50 ±0.47 (4-5)	42.15± 2.40 (39-46)	18.55 ± 1.74 (16-21)
July-Aug.	5.20 ± 0.90 (4-6)	93.22 ± 6.39 (86-106)	4.75 ± 0.21 (4-5)	39.27± 2.86 (36-44)	20.70 ± 2.49 (18-23)
Aug-Sept.	5.25 ± 0.95 (4-6)	75.37 ±7.17 (63-82)	5.25± 0.48 (5-6)	46.30 ± 4.42 (39-61)	23.57 ± 2.69 (19-25)
Sept.-Oct.	5.25 ± 0.50 (5-6)	68.81 ±5.36 (59-78)	5.50± 0.59 (5-6)	50.81 ± 5.45 (42-.59)	23.76 ± 2.85 (20-26)
Oct.-Nov.	6.25 ± 0.95 (5-7)	65.41 ±5.28 (57-75)	6.62 ± 0.51 (6-8)	51.27 ± 2.55 (44-61)	24.57 ± 2.54 (21-27)
Nov.-Dec.	7.50 ± 1.29 (6-9)	64.09 ±5.12 (59-74)	8.75 ± 1.31 (7-10)	49.60 ± 3.26 (45-59)	27.38 ± 2.66 (24-31)
SEm ±	**0.34**	**2.98**	**0.34**	**2.41**	**0.68**
CD at 5%	**0.74**	**6.44**	**0.79**	**5.28**	**1.47**

Table 11. Continued

Month	Adult emergence (%)	Developmental period (day)	Longevity of adult female (day)	Longevity of adult male (day)	Sex ratio (female: male)	Growth Index (GI)
Jan.- Febr.	41.29±2.16 (38-44)	47.25±3.21 (43-51)	12.00 ± 2.06 (11 –14)	14.10 ± 2.02 (12-17)	1:1.1	0.87
Mar.-Apr.	53.70±5.05 (47-59)	29.24± 2.19 (27-32)	7.55 ± 0.72 (7 –9)	9.70± 1.13 (8-11)	1:2.19	1.83
Apr.-May	64.20±3.09 (59-68)	26.00 ± 2.61 (23-28)	6.66 ± 0.50 (6 –7)	7.90± 0.73 (7-9)	1:1.83	2.46
May	47.74±4.71 (42-52)	22.75± 2.19 (19-24)	6.50 ± 0.53 (6 –7)	7.27 ± 1.27 (6-8)	1:1.99	2.09
May-June	29.91 ± 5.26 (23-36)	23.62± 1.79 (20-24)	6.40 ± 0.51 (6 – 7)	7.41 ± 2.51 (6-9)	1:1.26	1.26
June-July	21.10 ± 3.06 (18-24)	23.96± 2.01 (21-25)	7.36 ± 0.08 (7 –8)	8.18 ± 1.16 (7-9)	1:0.73	0.88
July-Aug.	23.19 ± 3.46 (20-26)	25.56 ± 2.64 (21-28)	7.79 ± 1.05 (6 – 8)	8.33 ± 1.00 (8-10)	1:1.13	0.90
Aug.-Sept.	23.54 ± 3.02 (20-27)	27.71 ± 3.52 (23-30)	7.87 ± 0.51 (7-9)	8.79 ± 0.77 (8-11)	1:0.52	0.84
Sept.-Oct.	26.54 ± 3.39 (23-29)	29.29 ± 2.02 (25-31)	7.92 ± 0.86 (7-9)	8.98 ± 0.78 (8-11)	1:0.73	0.90
Oct.-Nov.	31.01 ± 4.69 (34-38)	29.62 ± 2.71 (26-33)	8.54 ± 2.03 (7-10)	9.18 ± 1.08 (8-11)	1:1.38	1.04
Nov.-Dec.	41.15 ± 5.73 (36-47)	32.06 ±3.69 (28-36)	9.07 ± 1.08 (8-11)	11.79 ± 1.43 (10-13)	1:0.84	1.28
SEm.±	1.74	0.85	0.61	0.50	-	0.04
CD at 5%	3.76	1.84	1.09	1.08	-	0.09

Table 12. Temperature and relative humidity in the experimental laboratory
(Average of 3 years, Jan. 1999 – Dec. 2001)

Month	Mean daily temperature (°C)		Average daily temperature (°C)	Mean daily relative humidity (%)		Average daily relative humidity (%)
	Min	Max		Min	Max	
Jan. -Feb.	16.90	28.23	21.83	51.00	68.38	60.16
Mar. -April	23.97	30.55	27.25	52.11	68.91	59.67
April -May	26.47	31.02	29.02	62.75	78.96	69.80
May	27.68	31.92	29.65	69.50	78.96	74.57
May -June	27.36	31.60	29.19	69.59	84.64	78.16
June -July	26.36	30.25	28.73	73.25	84.92	80.76
July -Aug.	26.96	30.42	28.72	72.11	84.86	80.74
Aug.- Sept.	26.26	30.06	28.32	77.25	85.21	81.29
Sept.-Oct.	25.57	29.59	25.91	67.50	82.34	77.45
Oct.-Nov.	22.92	28.66	25.62	60.00	78.11	69.78
Nov.-Dec.	19.43	25.30	22.38	55.75	68.98	65.56

Table13. Association of biological characters of C. *chinensis* to the average of different months.

Biological parameters	Average Temperature °C	Average relative humidity (%)
Ovipositional period (d)	- 0.8977 (**)	- 0.7503 (**)
Fecundity (no.)	0.6007 (**)	0.1607
Incubation period (d)	- 0.9644 (**)	- 0.5757 (*)
Hatching (%)	- 0.204 0	- 0.8121 (**)
Larval-pupal period (d)	- 0.8592 (**)	- 0.7030 (**)
Adult emergence (%)	- 0.1689	- 0.8129 (**)
Developmental period (d)	- 0.8836 (**)	- 0.6536 (**)
Longevity of adult male (d)	- 0.8625 (**)	- 0.5989 (*)
Longevity of adult female (d)	- 0.8549 (**)	- 0.5077 (*)
Growth Index (G.I.)	- 0.2854	- 0.5003 (*)

(*) Significant at 5% level (**) Significant at 1% level

4.3. Studies on bio-ecology of C. *analis* on green gram in the laboratory.

These observations (**Table 14**) were taken from twelve sets of observations in each month of the year at different temperatures and relative humidity on monthly basis (**Table 15**.).

4.3.1. Ovipositional period

It was observed that ovipositional period differed in different generations. The mean longest period of 11.25 days was recorded during January -February and the shortest period was 5.2 days recorded during May-June. The range of ovipositional period was relatively long during November - March (ranged, 8 to 14 days) where the temperature and relative humidity (%) were relatively lower than the other months. During the period from April - October the span of oviposition was short, the range was being 5 to 7 days.

4.3.2. Incubation period

The longest incubation period was during January - February (10-12 days), followed by during November - January (9-11 days) and Feb.-March (8-10 days). During the warm months the incubation period was relatively short. The shortest period recorded 5.31 ±0.78 days during the month of May - July.

4.3.3. Larval - pupal duration

It was the longest during November – January (50 to 53 days) with a mean of 51.51 days which was almost three times longer than the minimum duration of 17-20 days with a mean of 19.16 days recorded during June-July. The duration exhibited a trend similar to that of incubation period.

4.3.4. Total development period

The developmental period of C. analis took as long as 59-63 days during January – February, followed by November – January and February – March. The shortest period recorded durimg May – September (21 to 25 days).

4.3.5. Longevity of adults

The females had a shorter life span in comparison to that of the males. Males of January - February generation survived for 12 to 16 days whereas females survived for 11 to 14 days. Minimum longevity of both males and females were recorded 5 to 6 days respectively during May - June.

4.3.6. Sex ratio

Sex ratio (female: male) differed in different generations. Males out-numbered the females in all the generations during November - July. But the females out-numbered the males during July-November. The highest proportion of males (female: male = 1:1.5) was obtained during January -February and the lowest proportion during September – October (female: male = 1:0.8).

4.3.7 Fecundity

Fecundity had considerable differences in different generations (**Table 14**)The descending order of fecundity was April (105-109), March-April (95-101), June-July (96-99), May-June (93-98),August - September (92-96), July - August (83-87), September - October (74-78), November - January (55-63), October – November (51-62), February - March (33-37) and the lowest fecundity was of 21 to 24 eggs obtained during January - February (21 to 24).

4.3.8. Hatchability

Percentage of hatching of eggs also differed considerably in different months. More than fifty per cent hatching occurred during winter and summer (Nov. to April). It declined significantly from May onwards and up to Oct.-Nov. and lowest hatchability of 25 to 29 % was observed during July.

4.3.9. Adult emergence

Adult emergence percentage were March-April (59 to 60%), Feb.- Mar. (54 to 60%), Oct.- Nov. (51 to 54%), Sept.- Oct.(37 to 40%) and May - June (32 to 36%). It was lower (below 25%) during the month of Nov.-Jan.(19-21%), Aug.-Sept.(19-22%), June-July (19-23%) and the lowest per cent of adult emergence was recorded in the generation during Jan.-Feb. (6-10% only).

4.3.10. Growth Index (GI)

In case of growth index (mean percent of adult emergence / mean development period), the highest value (**Table 14**) above the level of 1.00 was obtained during March-April (1.98 ± 0.02) followed by April (1.78 ± 0.04), Oct.-Nov. (1.72 ± 0.06) and May-June (1.45 ± 0.40). The minimum GI value was recorded during Jan.-Feb. (0.14 ± 0.01), Nov.-Jan. (0.33 ± 0.01), July-Aug. (0.46 ± 0.05), Aug.-Sept. (0.84 ± 0.06), June-July (0.96 ± 0.05).

The association of the above biological characters to the laboratory temperature and relative humidity showed mostly significant and negative value. Only the fecundity was positively correlated but non-significant (**Table 15** and **16**).

Table 14. Temperature and relative humidity in the laboratory during the study of bio -ecology of C. *analis*

(Average of 3 years, July 1999 – July 2001)

Month	Mean daily temperature (0C)		Average daily temperature (0C)	Mean daily relative humidity (%)		Average daily relative humidity (%)
	Min	Max		Min	Max	
July	27.57	30.09	28.98	78.85	83.28	77.77
July to Aug.	28.56	30.09	28.78	79.25	81.72	80.74
Aug. to Sept.	27.92	28.72	28.32	77.29	80.87	80.29
Sept. to Oct.	27.32	28.27	27.51	65.58	74.04	69.78
Oct. to Nov.	24.13	27.11	25.62	65.53	74.04	69.78
Nov. to Jan.	20.63	24.13	22.38	60.00	65.59	65.56
Jan. to Feb.	17.82	22.19	19.69	51.00	62.21	61.84
Feb. to Mar.	19.69	27.03	23.53	55.31	63.23	57.27
Mar. to Apr.	26.12	28.39	27.25	54.31	65.03	59.67
April	27.32	29.10	28.39	62.75	68.91	65.50
May to June	28.73	29.65	29.19	74.57	81.76	78.16
June to July	27.50	30.13	28.73	79.77	81.76	80.73

Fig.11. Oviposition period of *C.analis*

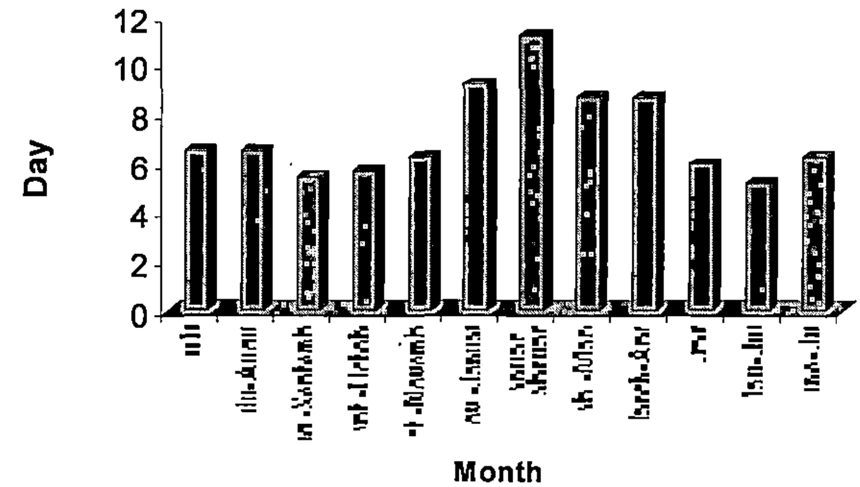


Fig.12. Fecundity of *C.analis*

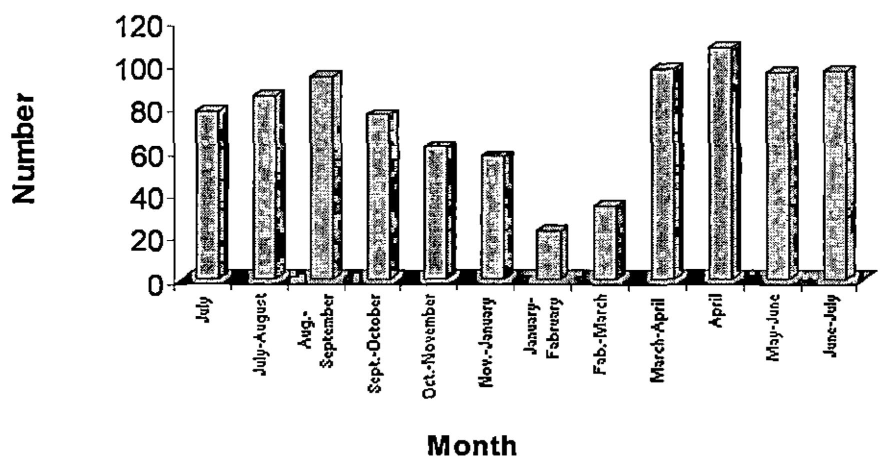


Fig.13. Incubation period of *C.analis*

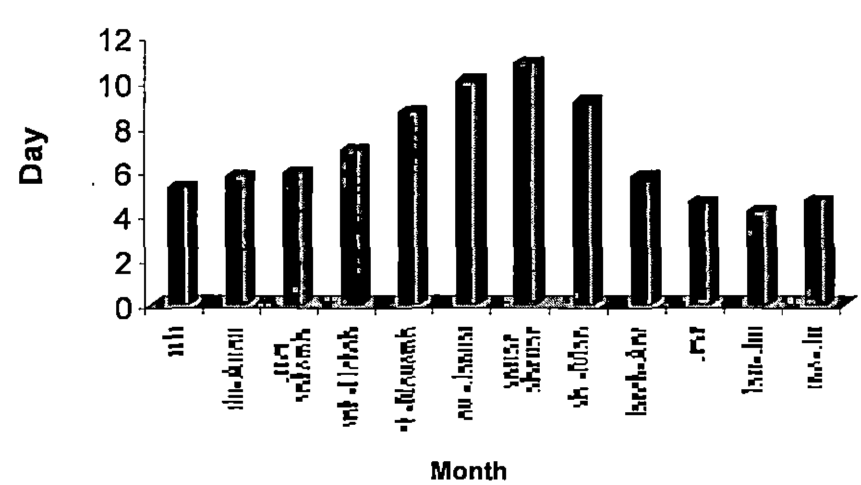


Fig. 14. Hatchability of *C.analis*

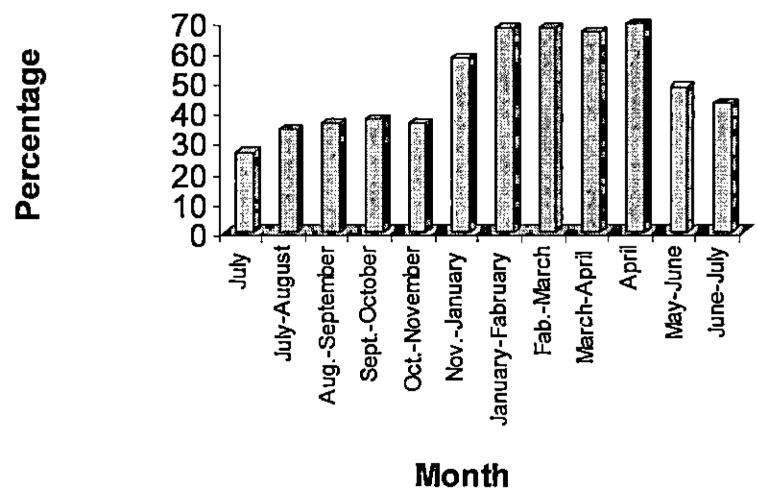


Fig. 15. Larval-pupal period of *C.analis*

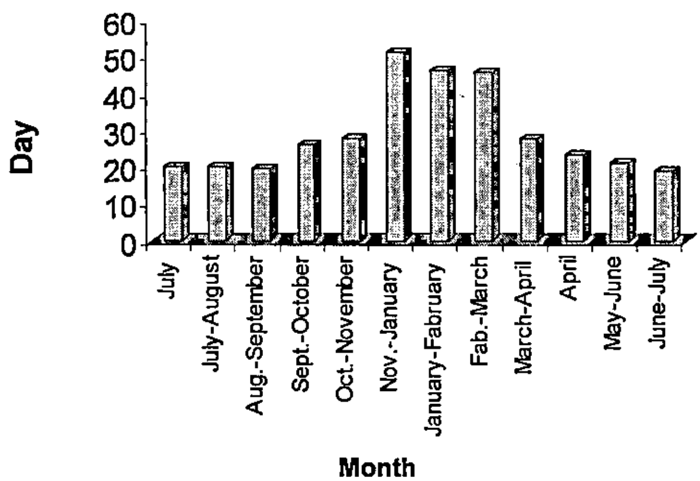


Fig. 16. Developmental period of C.analis

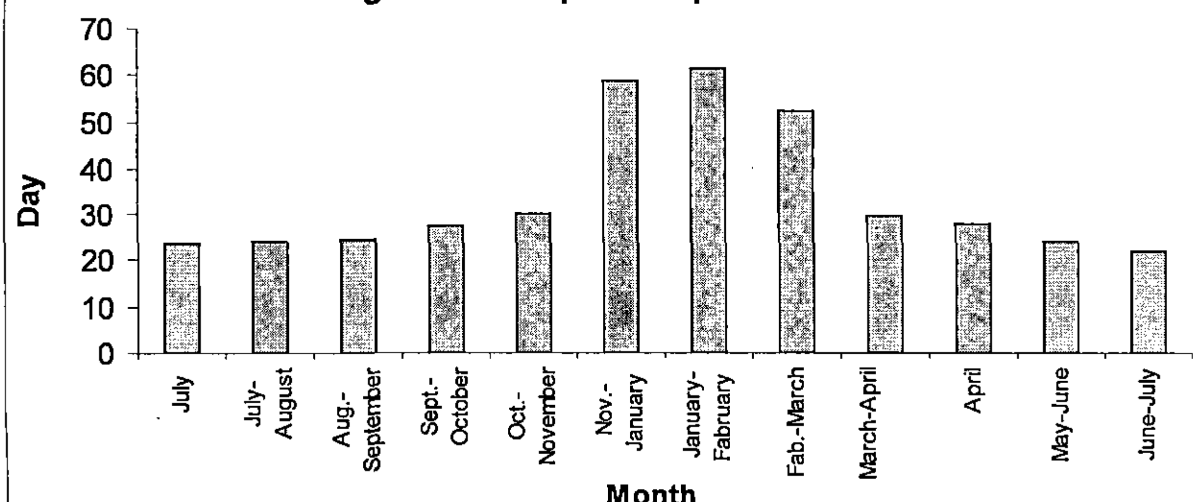


Fig. 17. Adult emergence of *C.analis*

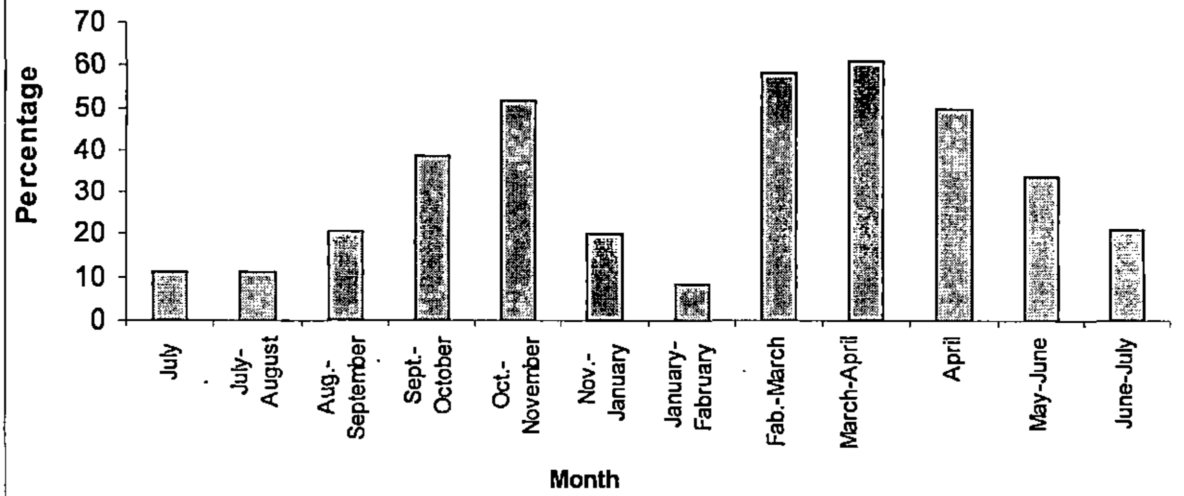


Fig. 18. Longevity of adult female

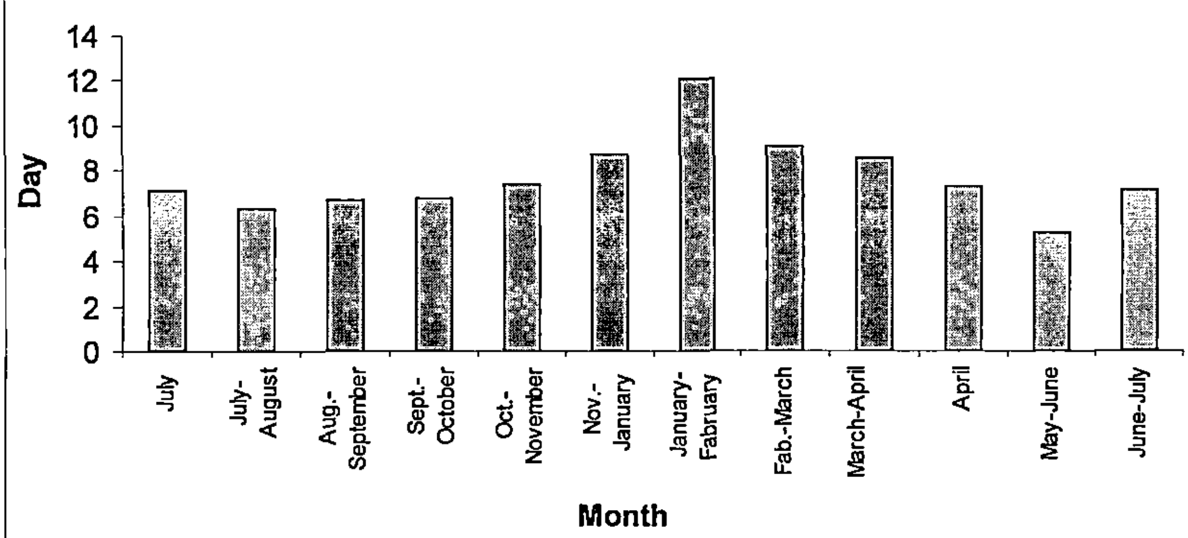


Fig. 19. Longevity of adult male

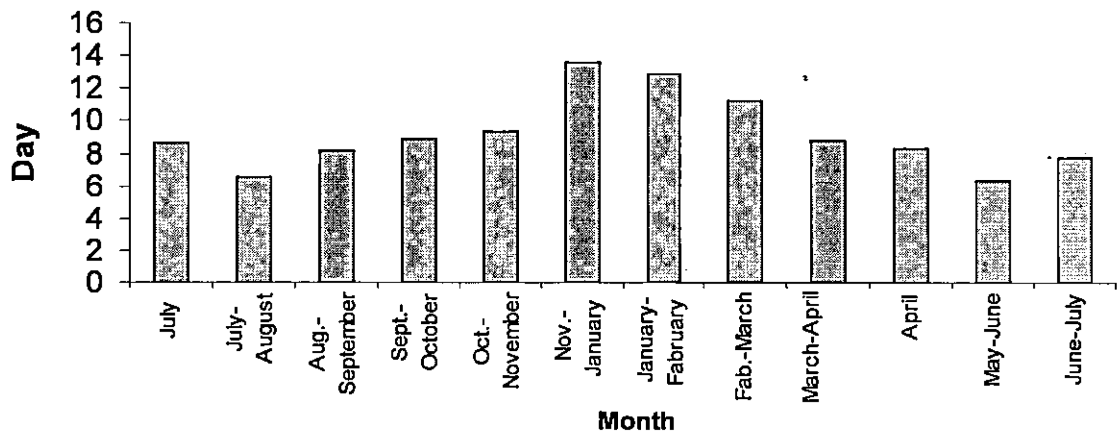


Fig. 20. Growth Index (GI) of *C. analis*

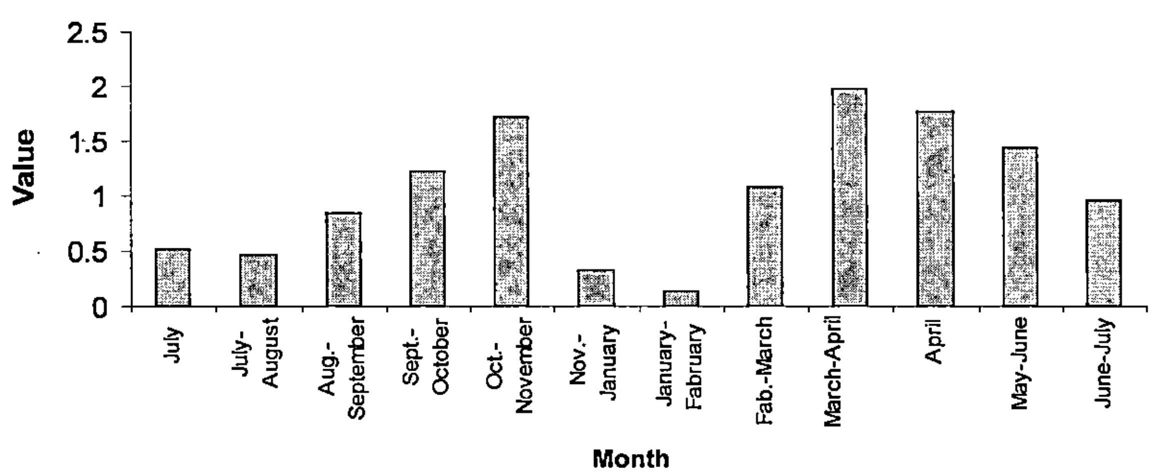


Table 15. Bio-ecology of *C. analis* : a laboratory study

(Average of 3 years, July 1999 – July 2001). The data are mean ±S.D. and ranges

Month	Ovipositional period (day)	Fecundity/female (no)	Incubation period (day)	Hatching (%)	Larval-pupal period (day)
July	6.50±0.57 (6-7)	78.25±1.71 (76-80)	5.31±0.78 (4-5)	26.75±1.70 (25-29)	20.12±0.82 (19-21)
July -Aug.	6.50±0.54 (6-7)	85.25 ± 1.70 (83-87)	5.81±0.62 (4-6)	34.25±1.62 (32-35)	20.29±0.94 (19-21)
Aug.-Sept.	5.50±0.58 (5-6)	94.25 ± 1.70 (92-96)	5.97±0.31 (5-6)	36.50±1.29 (35-38)	19.61±1.21 (18-21)
Sept.- Oct.	5.75±0.95 (5-6)	77.00 ± 2.16 (74-78)	6.96±0.52 (5-7)	37.75±1.39 (36-40)	26.27±1.72 (24-28)
Oct.- Nov.	6.25±0.91 (5-7)	61.84 ±1.86 (51-62)	8.61±0.41 (7-9)	36.25±1.52 (34-38)	27.92±0.99 (27-29)
Nov.- Jan.	9.25±0.95 (8-10)	57.27±2.20 (55-63)	10.02±0.68 (9-11)	58.00±1.82 (56-60)	51.51±1.20 (50-53)
Jan.- Feb.	11.25 ± 1.75 (09-14)	22.75 ± 1.25 (21-24)	10.81±1.32 (10-12)	67.75±3.20 (66-71)	46.52±1.27 (45-48)
Feb.- March	8.75 ± 0.95 (8-12)	34.75 ± 1.70 (33-37)	9.10±0.91 (8-10)	67.80±3.76 (68-73)	46.00±2.12 (44-49)
Mar.- April	8.75 ± 1.25 (7-10)	98.5 ± 3.00 (95-101)	5.82±0.97 (5-7)	66.50±3.00 (64-68)	27.75±0.59 (23-24)
April	6.00 ± 0.81 (5-7)	107.75 ± 1.89 (105-109)	4.62±0.79 (4-5)	69.25±1.89 (68-72)	23.28±0.61 (23-24)
May to June	5.25± 0.57 (4-6)	96.00 ± 2.16 (93-98)	4.21±0.58 (3-5)	48.50±1.29 (47-50)	21.21±0.82 (20-22)
June to July	6.25±1.59 (6-7)	97.5 ± 1.29 (96-99)	4.69±0.72 (3-5)	43.00±1.82 (41-45)	19.16±1.41 (17-20)
SEm ±	**0.46**	**2.37**	**0.29**	**1.16**	**0.56**
C.D. at 5%	**0.96**	**4.69**	**0.61**	**2.42**	**1.18**

Table 15. Continued.

Month	Adult Emergence (%)	Developmental period (day)	Longevity of adult female (day)	Longevity of adult male (day)	Sex ratio (female: male)	Growth Index (GI)
July	11.50±01.29 (10-13)	23.75±0.98 (23-25)	7.16±0.46 (6-8)	8.66±0.81 (8-10)	1:1.1	0.51
July -Aug.	11.25±0.23 (9-13)	24.25±0.50 (24-25)	6.31±1.01 (5-7)	6.59±0.71 (6-7)	1:0.9	0.46
Aug.-Sept.	20.50±1.29 (19-22)	24.29±0.95 (23-25)	6.68±0.54 (6-7)	8.12±0.82 (7-9)	1:0.9	0.84
Sept.- Oct.	38.50±1.21 (37-40)	27.50±1.29 (26-29)	6.76±0.72 (6-7)	8.82±0.52 (8-9)	1:0.8	1.23
Oct.-Nov.	51.75±1.68 (51-54)	30.20±0.87 (29-31)	7.39±0.87 (7-8)	9.39±0.62 (9-10)	1:0.9	1.72
Nov.- Jan.	20.00±0.81 (19-21)	58.72±0.87 (58-60)	8.72±0.94 (8-10)	13.58±1.77 (11-16)	1:1.2	0.33
Jan.- Feb.	8.33±1.86 (6-10)	61.5±1.73 (59-63)	12.14±1.46 (11-14)	12.85±1.77 (12-16)	1:1.5	0.14
Feb.- Mar.	58.25±1.62 (54-60)	52.25±1.68 (50-54)	9.14±1.06 (8-10)	11.25±1.25 (10-13)	1:1.4	1.09
Mar.-April	61.25±1.59 (59-63)	29.50±1.29 (28-31)	8.60±1.14 (7-9)	8.79±1.28 (7-10)	1:1.2	1.98
April	49.75±1.42 (48-52)	28.00±0.89 (27-29)	7.32±0.84 (6-8)	8.26±1.11 (8-10)	1:1.1	1.78
May -June	33.75±1.64 (32-36)	24.25±0.97 (23-25)	5.29±0.58 (5-6)	6.36±0.98 (5-7)	1:1.3	1.45
June-July	21.00±1.82 (19-23)	22.00±0.85 (21-23)	7.12±0.72 (6-8)	7.69±0.95 (7-9)	1:1.2	0.96
SEm ±	**0.87**	**0.53**	**0.36**	**0.56**	-	**0.03**
C.D. at 5%	**1.82**	**1.18**	**0.75**	**1.14**	-	**0.07**

Table 16. Association of biological parameters of *C. analis* to the average temperature and average r. h. of different months.

Biological parameters	Average Tem. °C	Average r. h. (%)
Ovopositional period (d)	- 0.8751 (**)	- 0.6943 (**)
Fecundity (no.)	0.2331	0.3703
Incubation period (d)	- 0.8585 (**)	- 0.4921
Hatching (%)	- 0.5551(*)	- 0.8199 (**)
Larval-pupal period (d)	- 0.9384 (**)	- 0.7478 (**)
Adult emergence (%)	- 0.0605	- 0.5843 (*)
Developmental period (d)	- 0.9663 (**)	- 0.7019 (**)
Longevity of adult male (d)	- 0.9322 (**)	- 0.6882 (**)
Longevity of adult female (d)	- 0.8239 (**)	- 0.7204 (**)
Growth index (GI)	- 0.4143	- 0.2281

(*) Significant at 5% level
(**) Significant at 1% level

4.4. Relative preference and susceptibility of *C. chinensis* and *C. analis* to fourteen species of stored pulses during summer and winter by CHOICE TEST

4.4.1. Ovipositional preference by free choice test

This test was carried out during summer with 0-1 day old 10 pairs of *C. chinensis* (10 male and 10 female). The average number of eggs laid by each female was considered. There were differences in ovipositional preference of both the species to different species of stored pulses *C. chinensis* laid the highest number of 13 eggs on red gram followed by green gram (11.3), moth bean (7.3), pea (7.0), soybean (6.3), small pea (6.3), black gram (5.6), thakri kalai (5.3), cow pea (5.3), kidney bean (4.6), lentil (4.3), grass pea (4.0), Bengal gram (3.6) and horse gram (1.3). *C. analis* showed a similar pattern of ovipositional preference with few exceptions. Here, less preferred pulses were lentil (1.3), horse gram (1.3) and kidney bean (2.3) during summer whereas higher numbers of eggs were laid on green gram (09.3), black gram (9.5), pea (9.0), small pea (9.0) and cow pea (8.0). On rest of the pulses, the number of eggs laid/female was 3 to 5 only (**Table 17**).

During winter, *C. chinensis* preferred to lay maximum number of eggs on red gram (9.3), followed by on green gram (7.6), lentil (6.6), small pea (6.6), soybean (5.0), pea (4.6), moth bean (4.3), grass pea (3.6) and black gram (3.6). Less preferred pulses were kidney bean (2.0), Bengal gram (2.3), horse gram (2.6), thakri kalai (3.3) and cowpea (3.0). In this respect there was significant differences between the two species of *Callosobruchus*. *C. analis* had a maximum choice for black gram (12.0), red gram (10.0) followed by thakri kalai (9.6), cow pea (8.0), grass pea (7.6), green gram (7.0), soybean (7.0) and small pea (6.0). Less preferred pulses were lentil (1.3), kidney bean (1.6), horse gram (1.6), pea (2.6), chick pea (3.6) and moth bean (3.6) (**Table 17**).

4.4.2. Emergence of adult by free choice test

Mean percentage of adult emergence of both the species differed considerably during summer *C. chinensis* emerged in higher number from red gram (70 %), green gram (63 %), cow pea (59.3%), moth bean (57.3 %), lentil (50.6 %), Bengal gram (44.7%), grass pea (40.3 %), pea (29.0%) and horse gram (14.6%). A very low percentage of adult emergence took place from black gram (5.6 %) and thakri kalai (3.0 %). Adults could not emerged at all from soybean, kidney bean and small pea (**Table 18**).

C. analis emerged in highest number from green gram (27.3 %) followed by thakri kalai (19.3%), red gram (19.6%), black gram (17.3%), cow pea (16.0 %) chick pea (13.7%), moth bean (8.6%), grass pea (8.0%), horse gram (7.3%) and pea (4.6%). Adults could not emerge at all from lentil, soybean, kidney bean and small pea during summer (**Table 18**).

The percentage of adult emergence from different pulses did not differ much during winter in comparison to that during summer. In general the emergence was low during winter. *C. chinensis* emerged in highest percentage from green gram (58.3%) followed by red gram (53.3%), moth bean (51.6%), lentil (50.3%), cow pea (47.3%), Bengal gram (40.0%), grass pea (33.6%), pea (17.6%), horse gram (14.6%). No adult emergence occurred from black gram, thakri kalai, soybean, kidney bean and small pea during summer (**Table 18.**). But in case of *C. analis* the values were 25.6 %, 19.3 %), 16.0 %, 7.3 %, pea 6.0 %, 5.3 %, 5.3 %, 5.0 % and 3.3 % from cow pea, green gram, red gram, chick pea, black gram, thakri kalai, grass pea and horse gram respectively. In spite of egg lay there was no emergence of *C. analis* from lentil, moth bean, soybean, kidney bean and small pea (**Table 18**).

Table 17. Ovipositional preference of *C. chinensis* and *C. analis* on fourteen species of stored pulses by FREE CHOICE TEST

(Average of 3 seasons, 1999 -2001)

PULSE	Mean umber of eggs laid / female			
	SUMMER		WINTER	
	C. chinensis	*C. analis*	*C. chinensis*	*C. analis*
Green gram (*Vigna radiata*)	11.3	09.3	07.6	07.0
Grass pea (*Lathyrus sativus*)	04.0	04.6	03.6	07.6
Cow pea (*V. catiang*)	05.3	08.0	03.0	08.0
Red gram (*Cajanus cajon*)	13.0	06.5	09.3	10.0
Bengal gram (*Cicer areitinum*)	03.6	03.3	02.3	03.6
Pea (*Pisum sativum*)	07.0	09.0	04.6	02.6
Lentil (*Lens esculentum*)	04.3	01.3	06.6	01.3
Black gram (*V. mungo*)	05.6	09.5	03.6	12.0
Horse gram (*Dolicos biflorus*)	01.3	01.3	02.6	01.6
Moth bean (*V. aconitifolia*)	07.3	05.0	04.3	03.6
Soybean (*Glycine max*)	06.3	07.0	05.0	07.0
Kidney bean (*Phaseolus vulgaris*)	04.6	02.3	02.0	01.6
Thakri kalai (*V.mungo silvestries*)	05.3	06.3	03.3	09.6
Small pea (*P. arvense*)	06.3	09.0	06.6	06.0
SEm.±	**0.47**	**0.52**	**0.41**	**0.74**
C.D. at 5%	**0.94**	**1.03**	**0.82**	**1.46**

Figures in the tables are mean number of eggs laid / female

Table 18. Mean adult emergence (%) of C. *chinensis* and C. *analis* from fourteen species of stored pulses by FREE CHOICE TEST

(Average of 3 seasons, 1999-2001)
The Figures in parenthesis are angular transformed values

Pulses	Adult emergence (%) / female			
	SUMMER		WINTER	
	C. chinensis	*C. analis*	*C. chinensis*	*C. analis*
Green gram (*Vigna radiata*)	63.3 (52.7)	27.3 (31.4)	58.3 (49.7)	19.3 (26.0)
Grass pea (*Lathyrus sativus*)	40.3 (39.4)	08.0 (16.4)	33.6 (35.4)	5.0 (12.9)
Cow pea (*Vigna catiang*)	59.3 (50.3)	16.0 (23.5)	47.3 (43.4)	25.6 (30.3)
Red gram (*Cajanus cajon*)	70.0 (56.7)	19.6 (26.2)	53.3 (46.8)	16.0 (23.5)
Bengal gram (*Cicer areitinum*)	44.3 (41.7)	13.7 (24.8)	40.0 (39.2)	07.3 (15.6)
Pea (*Pisum sativum*)	29.0 (32.5)	04.6 (12.3)	17.6 (24.8)	06.0 (14.1)
Lentil (*Lens esculentum*)	50.6 (45.3)	0.0 (0.0)	50.3 (45.1)	0.0 (0.0)
Black gram or Urd (*Vigna mungo*)	5.6 (13.6)	17.3 (24.5)	0.0 (0.0)	5.3 (13.3)
Horse gram (*Dolicos biflorus*)	14.6 (22.4)	7.3 (15.6)	14.6 (22.4)	3.3 (10.4)
Moth bean (*Vigna aconitifolia*)	57.3 (49.1)	8.6 (17.0)	51.6 (45.9)	0.0 (0.0)
Soybean (*Glycine max*)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Kidney bean (*Phaseolus vulgaris*)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Thakri kalai (*Vigna mungo silvestries*)	3.0 (9.9)	19.3 (26.0)	0.0 (0.0)	05.30 (13.30)
Small pea (*Pisum arvense)*	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
SEm ±	**1.26**	**0.98**	**1.26**	**0.91**
C.D. at 5%	**2.50**	**1.95**	**2.50**	**1.49**

4.4.3. Ovipositional preference by no choice test

The study was undertaken on of fourteen different species of pulses during both summer and winter seasons (**Table 19**). The values differed in the two species of *Callosobruchus* .During summer, both the laid eggs differently on of different pulses. Mean number of eggs laid by a female *C. chinensis* on green gram were the highest (99.3) followed by Bengal gram (93.0), cow pea (87.0), grass pea (81.6), thakri kalai (*V. mungo silvestris*) (78.0), black gram (*V. mungo*) (77.3), lentil (72.3), pea (72.0), moth bean (70.0), red gram (69.0) and horse gram (67.3), whereas less preferred pulses were kidney bean (33.0), small pea (50.6) ad soybean (59.6). On the other hand *C. analis* deposited maximum of 88.6 eggs on black gram followed by green gram (86.3), cow pea (82.6), red gram (82.0), moth bean (75.3), Bengal gram (74.3), horse gram (74.0), pea (72.6) and soybean (71.6).The less preferred pulses were kidney bean (49.3) and small pea (65.3).

During winter *C. chinensis* laid much more number of eggs on different pulses than *C. analis*. The pattern of egg laying preference for the pulses was somewhat similar in the two species. However, *C. chinensis* preferred green gram the most and *C. analis* preferred black gram the most. Less preferred hosts of both the species were kidney bean , small pea , horse gram and soybean although *C. analis* didn't prefer lentil. In addition to the eggs laid on the surface of pulses, both the species laid quite a good number of eggs on the wall of test tubes (**Table 19**).

4.4.4. Adult emergence by no-choice test

The highest per cent of *C. chinensis* adults emerged from lentil (71.0) followed by red gram (67.3), green gram (63.3), grass pea (61.1), moth bean (57.0), cow pea (53.3), horse gram (49.0), chick pea (36.8) and pea (33.3). Only 6 % adult emerged from black gram seeds. In case of *C. analis* the mean percentage of adult emergence also differed in different pulses, although the percentage of damage was comparatively less than that of *C. chinensis*. The highest emergence took place from red gram (65.3%) and the lowest was from thakri kalai (16.3%). Interestingly, there was no adult emergence in case of of both the species from soybean, kidney bean and small pea (**Table 20**).

Percentage damage by both the species has shown significant differences during winter (**Table 20**). In case of *C.chinensis* 66.1% adult emergence took place from lentil which was followed by grass pea (60.8%), green gram (54.6%), moth bean (51.6%), horse gram (50.9%), red gram (47.0%), cow pea (45.3%), Bengal gram (36.0%), pea (24.6%), thakri kalai (3.6%) and black gram (0.6%). With regard to *C. analis*, the percentage of adult emergence recorded was in the descending order of grass pea (27.9) > cow pea (27.2) > red gram (26.1) > green gram (23.5) > moth bean (22.2) > chick pea (20.7) > thakri kalai (18.7) > black gram (16.1) > horse gram (15.3) > pea (13.7). During the two seasons, both the beetles couldn't develop on small pea, kidney bean and soybean. It was revealed that lentil was less susceptible to the attack of *C. analis* during winter

Table 19. Ovipositional preference of *C. chinensis and C. analis* by NO CHOICE TEST

(Average of three seasons, 1999-2001)

Pulses	Mean ovipositional preference / female (in no.)			
	SUMMER		WINTER	
	C. chinensis	*C. analis*	*C. chinensis*	*C. analis*
Green gram (*Vigna radiata*)	99.3	86.6	78.6	55.6
Grass pea (*Lathyrus sativus*)	81.6	81.0	61.6	60.3
Cow pea or Lobia (*Vigna catiang*)	87.0	82.6	46.0	66.0
Red gram (*Cajanus cajon*)	69.0	82.0	50.3	59.0
Chick pea (*Cicer areitinum*)	93.0	74.3	65.6	58.3
Pea (*Pisum sativum*)	72.0	72.6	64.0	62.0
Lentil (*Lens esculentum*)	72.3	65.3	66.6	51.3
Black gram (*Vigna mungo*)	77.3	88.6	63.6	72.0
Horse gram (*Dolicos biflorus)*	67.3	74.0	57.3	58.0
Moth bean (*Vigna aconitifolia*)	70.0	75.3	66.6	64.0
Soybean (*Glycine max*)	59.6	71.6	64.4	64.0
Kidney bean (*Phaseolus vulgaris*)	33.0	49.3	46.6	46.0
Thakri kalai (*Vigna mungo silvestries*)	78.0	92.0	63.0	66.0
Small pea (*Pisum arvense*)	50.6	65.3	57.6	49.3
SEm ±	**1.14**	**0.95**	**1.13**	**0.74**
C.D. at 5%	**2.95**	**1.89**	**2.24**	**1.46**

Table 20. Per cent adult emergence of *C. chinensis* and *C. analis* by no-choice test

(average of 3 seasons,1999-2001)

Pulses	Mean per cent adult emerge / female			
	SUMMER		WINTER	
	C. chinensis	*C. analis*	*C. chinensis*	*C. analis*
Green gram (*Vigna radiata*)	63.3 (53.1)	44.1 (41.6)	54.6 (45.5)	23.5 (29.0)
Grass pea (*Lathyrus sativus*)	61.1 (51.4)	44.4 (41.7)	60.8 (51.1)	27.9 (31.6)
Cow pea or Lobia (*V. catiang*)	53.3 (46.8)	51.6 (45.9)	45.3 (42.3)	27.2 (31.4)
Red gram (*Cajanus cajon*)	67.3 (55.1)	65.3 (53.9)	47.0 (43.2)	26.1 (30.7)
Bengal gram (*Cicer areitinum*)	36.8 (37.3)	40.0 (39.2)	36.0 (36.8)	20.7 (27.0)
Pea (*Pisum sativum*)	33.3 (35.2)	30.5 (34.1)	24.6 (29.7)	13.7 (21.7)
Lentil (*Lens esculentum*)	71.0 (57.0)	18.3 (25.3)	66.1 (54.3)	6.0 (14.1)
Black gram or Urd (*V. mungo*)	6.0 (14.1)	26.6 (31.0)	0.6 (14.1)	16.1 (23.6)
Horse gram (*Dolicos biflorus*)	49.0 (44.4)	19.1 (25.9)	50.9 (45.5)	15.3 (23.0)
Moth bean (*Vigna aconitifolia*)	57.0 (49.0)	30.8 (33.7)	51.6 (45.9)	22.2 (28.0)
Soybean (*Glycine max*)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Kidney bean (*Phaseolus vulgaris*)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Thakri kalai (*V. mungo silvestries*)	6.8 (15.1)	16.3 (23.8)	3.6 (10.9)	18.7 (25.6)
Small pea (*Pisum arvense*)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
SEm ±	**1.20**	**1.14**	**1.28**	**0.99**
C.D. at 5%	**2.38**	**2.26**	**2.54**	**1.96**

Figures in parenthesis are the angular transformed values

4.4.5. Effect of physical characters, moisture contents and phenol contents of stored pulses on the oviposition, adult emergence and developmental period of both *C. chinensis* and *C. analis*

Physical characters:

Fourteen different kinds of stored pulses were studied group wise for their physical characters such as single seed weight, thickness of seed coat, moisture and also for phenol contents (**Table 24**). Interaction of the physio - chemical characters on the degree of infestation by assessing the number of eggs laid/female, emergence of adults/female and developmental period of both the species were studied during summer.

The seed color, shape and texture (**Table 4**) had no relation to the oviposition of eggs, emergence of adults and their development. Only kidney bean (*Phaseolus vulgaris*) having tan-brown color and small pea (*Pisum arvense*) having grayish mosaic color with rough texture affected oviposition of both the *C. chinensis* and *C. analis*.

The seed weights had significant negative correlation with the oviposition of *C. chinensis* where as *C. analis* had a significant positive correlation. Mean adult emergence of both the species showed a non-significant negative correlation. Mean developmental period was also negatively significant at 0.01% level (**Table 26**).

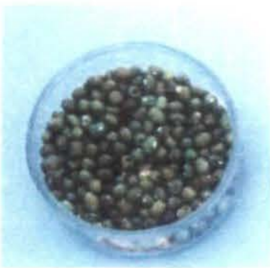
The thickness of seed coat differed significantly among the pulses. The thickness of seed was in the order of kidney bean (0.164mm) > bengal gram (0.138mm) > small pea (0.109mm)> cow pea (0.106mm) > grass pea (0.104mm) > thakri kalai (0.097mm) > horse gram (0.092mm) > black gram (0.091mm) > red gram (0.082mm) > pea (0.081mm) > green gram (0.078mm), moth bean (0.064) and lentil (0.048). This character showed a negative correlation with oviposition, adult emergence and developmental period of both *C. chinensis* and *C. analis* (**Table 26**).

The moisture content different pulses also differed significantly. The highest and the lowest moisture contents were on kidney bean (7.76%) and horse gram (5.09%) respectively. Among the rest of the pulses, the moisture (%) ranged in between 5 – 7 %. The seed moisture (%) had a non-significant negative correlation with egg laying, emergence of adult and developmental period of *C. chinensis* and *C. analis* (**Table 24** and **26**).

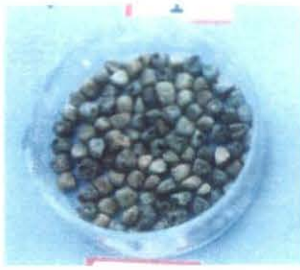
Phenol contents and their impact:

The phenol contents were in the order of kidney bean (1.43 milligram) > soybean (1.32mg) > pea (0.92mg) > small pea (0.87mg) > horse gram (0.79mg) > black gram (0.74mg) > chick pea (0.70mg) > thakri kalai (0.68mg) > cowpea (0.67mg) > lentil (0.64mg) > moth bean (0.62mg) > red gram (0.54mg) > green gram (0.48mg) > and grass pea (0.31mg). The differences were signify=cant (**Table 24**). The phenol contents were inversely proportional to the oviposition, adult emergence and developmental period. However, there was no adult emergence from soybean and kidney bean where the contents were 1.32 and 1.43 respectively (**Table 26**).

PLATE 8



1. Green gram
(*Vigna radiata* Linn.)



2. Grass pea
(*Lathyrus sativus* L.)

3. Cow pea (black-eyed)
(*Vigna catiang* Walp.)

4. Red gram
(*Cajanus cajan* Milsp.)

5. Pea
(*Pisum sativum* L.)

6. Bengal gram
(*Cicer areitinum* L.)

7. Lentil
(*Lens esculentum* Moench.)

8. Black gram or Urd
(*Vigna mungo mungo* L.)

9. Horse gram
(*Dolicos biflorus* Roxb.)

10. Moth bean
(*Vigna aconitifolia* Jacq.)

11. Soybean
(*Glycine max* Merr.)

12. Kidney bean
(*Phaseolus vulgaris* L.)

13. Black gram or thakri kalai
(*Vigna mungo silvestris* L.)

14. Small pea or garden pea
(*Pisum arvense* L.)

Photoplate 8. Photographs of fourteen species of legume seeds

Table 21. Seed weight (g) of stored pulses in summer

(Average of 3 seasons)

Weight of single seed (g)			
Pulse	No. of Observations / season	Range	Mean ± S.D
Kidney bean	6	0.45 – 0.82	0.64 ± 0.18
Soybean	8	0.11 – 0.13	0.12 ± 0.01
Pea	6	0.24 – 0.28	0.26 ± 0.02
Small pea	7	0.14 – 0.20	0.17 ± 0.03
Horse gram	8	0.02 – 0.26	0.25 ± 0.001
Black gram	6	0.03 – 0.04	0.03 ± 0.005
Bengal gram	9	0.14 – 0.20	0.16 ± 0.03
Thakri kalai	8	0.03 – 0.04	0.03 ± 0.004
Cowpea	9	0.65 – 0.70	0.57 ± 0.03
Lentil	6	0.01 – 0.01	0.01 ± 0.02
Moth bean	6	0.03 – 0.04	0.03 ± 0.005
Red gram	7	0.15 – 0.19	0.17 ± 0.002
Green gram	7	0.04 – 0.03	0.03 ± 0.002
Grass pea	7	0.03 – 0.04	0.03 ± 0.002
SEM ±			0.13
C.D at %			0.25

Table 22. Thickness (mm) of the seed coat of stored pulses

(Measurement of the thickness of seed coats is in millimeter)

Thickness of seed coat (mm)			
Pulse	No. of observations	Range	Mean ± S.D
Kidney bean	08	0.152 – 0.176	0.164 ± 0.01
Bengal gram	08	0.112 – 0.176	0.138 ± 0.02
Small pea	08	0.088 – 0.112	0.109 ± 0.014
Cowpea	10	0.096 – 0.120	0.106 ± 0.006
Grass pea	08	0.096 – 0.112	0.104 ± 0.007
Black gram	08	0.08 – 0.112	0.097 ± 0.012
Horse gram	08	0.064 – 0.112	0.092 ± 0.01
Thakri kalai	09	0.064 – 0.012	0.09 ± 0.02
Red gram	08	0.08 – 0.084	0.082 ± 0.007
Pea	09	0.08 – 0.102	0.081 ± 0.009
Green gram	08	0.064 – 0.08	0.078 ± 0.01
Soybean	08	0.064 – 0.08	0.065 ± 0.01
Moth bean	08	0.064 – 0.072	0.064 ± 0.008
Lentil	08	0.044 – 0.072	0.048± 0.01
SEm ±			0.07
CD at 5%			0.15

Table 23. Moisture of stored pulses in summer

Moisture (%)			
Pulse	**No. of Observations**	**Range**	**Mean ± S.D**
Kidney bean	06	7.52-8.02	7.76 ± 0.25
Soybean	05	5.12-6.04	5.65 ± 0.47
Pea	07	5.49-6.99	6.26 ± 0.75
Small pea	07	5.61-6.02	5.81 ± 0.20
Horse gram	04	5.04-5.13	5.09 ± 0.04
Black gram	06	5.38- 6.20	5.84 ± 0.42
Bengal gram	06	5.92-6.29	6.08 ± 0.18
Thakri kalai	06	5.63-6.02	5.75 ± 0.23
Cowpea	06	5.84-7.21	6.67 ± 0.73
Lentil	06	5.41-6.12	5.78 ± 0.35
Moth bean	04	5.72-6.03	5.85 ± 0.15
Red gram	07	6.24-7.03	6.55 ± 0.41
Green gram	07	5.91-6.01	6.21 ± 0.30
Grass pea	07	5.69-6.21	5.97 ± 0.30
SEm ±			0.26
C.D at %			0.52

Table 24. Phenol contents of fourteen species of stored pulses

Phenol contents (milligram /gram)			
Pulse	**Number of Observation**	**Range**	**Mean ± S.D**
Kidney bean	06	1.40 –1.48	1.43 ± 0.03
Soybean	06	1.32 – 1.35	1.32 ± 0.02
Pea	07	0.90 – 0.96	0.92 ± 0.02
Small pea	07	0.86 – 0.89	0.87 ± 0.01
Horse gram	06	0.77 – 0.82	0.79 ± 0.02
Black gram	06	0.71 – 0.77	0.74 ± 0.03
Bengal gram	06	0.68 – 0.72	0.70 ± 0.02
Thakri kalai	06	0.65 – 0.75	0.68 ± 0.03
Cowpea	06	0.65 – 0.70	0.67 ± 0.03
Lentil	06	0.62 – 0.66	0.64 ± 0.01
Moth bean	06	0.60 – 0.65	0.62 ± 0.02
Red gram	07	0.50 – 0.57	0.54 ± 0.02
Green gram	07	0.40 – 0.55	0.48 ± 0.04
Grass pea	07	0.27 – 0.35	0.31 ± 0.03
SEm ±			0.008
C.D at %			0.01

Table 25. Ovipositional preference, adult emergence and total developmental period of C. *chinensis* and C. *analis* in reference to seed weight, thickness of seed coat, moisture and phenol content of fourteen.

Pulses	Oviposition (no)		Adult emergence (%)		Development period (d)		Single seed weight (g)	Thickness of seed coat (mm)	Moisture (%)	Phenol contents (mg/g)
	C. chinensis	*C. analis*	*C. chinensis*	*C. analis*	*C. chinensis*	*C. analis*				
Green gram	99.3	86.3	63.3	44.1	23	26	0.037	0.078	6.14	0.48
Grass pea	81.6	81.0	61.1	44.4	23	30	0.034	0.104	5.97	0.31
Cowpea	87.0	82.6	53.3	51.6	24	26	0.190	0.106	6.67	0.67
Red gram	69.0	82.0	67.3	65.3	26	26	0.126	0.082	6.55	0.54
Bengal gram	93.0	74.3	36.8	40.0	25	27	0.166	0.138	6.08	0.70
Pea	72.0	72.6	33.3	30.5	28	31	0.260	0.081	6.26	0.82
Lentil	72.3	65.3	71.0	18.3	22	28	0.017	0.050	5.78	0.64
Black gram	77.3	88.6	06.0	26.6	30	28	0.038	0.091	5.84	0.74
Horse gram	67.3	74.0	49.0	19.1	24	29	0.025	0.092	5.09	0.79
Moth bean	70.0	75.3	57.0	30.8	23	26	0.035	0.064	5.85	0.62
Soybean	59.6	71.6	0.0	0.0	-	-	0.120	0.065	5.65	1.32
Kidney bean	33.0	49.3	0.0	0.0	-	-	0.640	0.164	7.76	1.43
Thakri kalai	78.0	92.0	06.8	16.3	31	29	0.035	0.097	5.85	0.68
Small pea	50.6	65.3	0.0	0.0	-	-	0.173	0.109	5.81	0.87
SEm±	**2.98**	**2.37**	**1.74**	**0.87**	**0.85**	**0.53**	**0.13**	**0.07**	**0.26**	**0.008**
CD at 5%	**6.44**	**4.69**	**3.76**	**1.82**	**1.84**	**1.11**	**0.25**	**0.15**	**0.52**	**0.01**

Table 26. Association of physico-chemical characters of pulses seed with oviposition, adult emergence and total developmental period

(**) = highly significant at 1%
(*) = significant at 5%

Physico-chemical characters of seed	Oviposition (no.)		Adult emergence (%)		Total developmental Period (d)	
	C. chinensis	*C. analis*	*C. chinensis*	*C. analis*	*C. chinensis*	*C. analis*
Moisture (%)	- 0.325	- 0.396	- 0.118	0.107	- 0.262	- 0.303
Single seed weight (g)	- 0.635*	- 0.706*	-0.430	0.311	- 0.524*	- 0.568*
Seed soat thickness (mm)	-0.279	- 0.356	- 0.415	- 0.128	- 0.285	- 0.325
Phenol content (mg)	0.750 **	.671**	0.730**	0.741**	0.718**	0.769**

4.5. Biosystematics and sexual dimorphism of the egg parasitoids, *Uscana mukerjii*

4.5.1. Taxonomy and historical back ground:

The family Trichogrammatidae can be separated from other hymenopteran families by the presence of 3 segmented tarsi, forewings are short, broadly rounded epically; distal cilia arranged in rows of distinct lines; veins *m* and *st* united to form a strong backward curve; hind coxae not enlarged; mesopleura impressed and axillae triangularly advanced into scapula in front of tegulae (**Appendix 1**). This family exclusively includes small sized wasps which can parasitize the eggs of insect pests (Richard and Davis, 1983 and Narendran, 2000).

The *Chaetotricha* Girault can parasitize the eggs of different species of bruchids (Coleoptera: Bruchidae) although a few species are also associated with the eggs of buprestids (Coleoptera : Buprestidae). About 166 species have been so far been described under the genus *Chaetotricha* (=*Uscana*) and 11 species have been reported with known hosts of which as many as 9 species parasitize the eggs of bruchids alone (Huis *et al.,* 1991a).

<u>Systematic position</u>

Order – Hymenoptera

Family – Trichogrammatidae

Subfamily – Trichogrammatinae

Tribe – Trichogrammatini

Genus – *Uscana*

Species – *mukerjii*

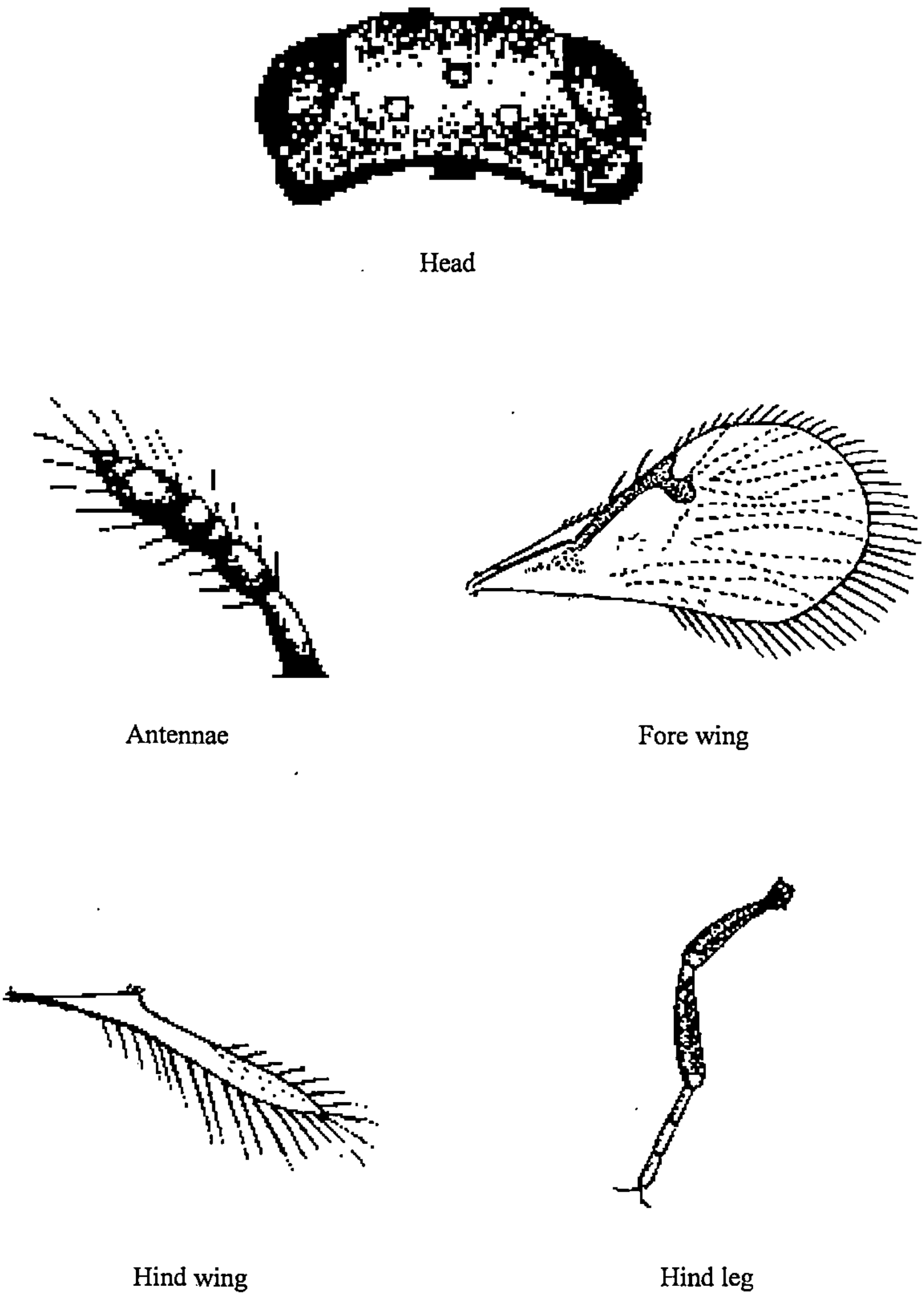


Fig. 21. Diagram of *Uscana mukerjii* (Mani)

Previous report, distribution and host :

Mani (1935) : *Uscana* (= *Chaetotricha*) *mukerjii* , *Rec. Indian Mus.*, **37** :337- 338.
Mukerji and Bhuya (1936): *Bol. Soc. Brazil, Agron.*, **5**: 441
Chatterji (1953) : *Indian J. Ent.*, **16:** 77.
Steffan (1954) : *Uscana mukerjii* (Mani), *Bull. Mus. Hist. Nat. Paris 2e ser.*, **26:** 667-673.
De Luca (1965) : *Uscana mukerjii* (Mani), *Stored Prod. Res.*, **1**: 51-98.
Pajni and Singh (1973) : *Uscana mukerjii* (Mani), *Res. Bull. Panjab Univ.*, **24**: 163-164
Mani (1989) : *Uscana mukerjii* , *The Fauna of India and Adjacent Countries*, **2** :1353-1377.
Kapila and Agarwal (1965):*J. Stored Proc. Res.*, **31**: 334-341
Pajni *et al.*(1996) :*Res. Bull. Punjab Univ.*, **46:** 77-87.

Type species : *Chaetotricha* (= *Uscana*) *semifumipennis* Girault (1911).

Type species : *Hawii,U.S.A.*

Host : Bruchids (*Callosobruchus chinensis, C. maculatus, C. analis).*

Distribution : Hawii, U.S.A.; Africa; france and North-west plain, North-east plain and Northern hill zone of India (**Appendix X11**)

4.5.2. Morphology and sexual dimorphism

Adult male : Length 0.40 - 0.43 mm body at a glance generally brownish to black. Head deeply and broadly striated in front and behind. Length of the head 0.11-0.12 mm and width 0.12-0.15 mm. Antennae light brown, densely clothed with moderate fine setae (except scape and pedicel), stout, with 7 segments; pedicel about 0.60-0.65 times of scape; club about 2.5 times pedicel, gradually tapering to the rounded tip, more slender than the funicle, the basal 2 segments sub equal, apical segment slightly more slender and longer; ocellocular space sub equal to ocellar diameter; compound eye almost oval and crimson-red color, outer surface of the compound eye yellowish-brown (**Plate 11**). Thorax is 0.15-0.22 mm in length and 0.18-0.20 mm in width; brownish, about 0.50 times of body; mesonotum and scutellum smooth; legs brownish except the dirty white or pale brown bases and tips of femora and tibiae; length of tibia > Femur > tarsus; tarsi with 3 segments; hind coxae not enlarged; 1st tarsal segment > 2nd > 3rd; length of forewing (0.41-0.43 mm), about 2 times as long as wide; marginal frimge or discal cilia short and cover 0.75 part of the total marginal area; stigmal vein (*st*) forming an angle with the vein m. hind wing 0.28-0.29 in length, slender, apical portion pointed and with 3 hamuli. Abdomen 0.12 - 0.19 mm long and 0.18-0.19 mm width, shorter than the length of thorax; yellowish-brown in color and dorsal segmented area slightly sclerotised; aedeagus with bacilliform apodeme (**Table 27**).

Adult female : The morphological features of Female (**Plate 5**) are almost similar to male except size. Body length is 0.44-0.51 mm; the length of abdomen is longer than the male (length 0.24-0.28 mm); length (0.13-0.16 mm) and width (0.14-0.17 mm) of thorax is always shorter than the male; length of forewings (0.02-0.03 mm) and hind wings (0.20-0.30 mm) also shorter than male (**Table 27**).

Table 27. Sexual dimorphism of *Uscana mukerjii* in respect of adult body morphometry

(All measurements are in millimeter)

Uscana mukerjii	Body length of adult		Length of head		Width of head	
	Male	Female	Male	Female	Male	Female
No. of individuals	13	12	12	13	13	11
Range	0.40 - 0.43	0.44 - 0.51	0.11 - 0.12	0.08 - 0.11	0.12 - 0.15	0.12 - 0.14
Mean ± SD	0.41 ± 0.01	0.47 ± 0.04	0.14 ± 0.0006	0.1 ± 0.01	0.14 ± 0.0009	0.13 ± 0.01

Table 27. Contd.

Width of abdomen		Length of antennae		Length of forewing		Width of forewing	
male	female	male	female	male	female	male	female
13	09	12	10	10	10	09	11
0.08 - 0.19	0.2 - 0.24	0.1 - 0.12	0.09 - 0.12	0.41 - 0.43	0.38 - 0.42	0.100 - 0.108	0.18-0.2
0.19 ± 0.0009	0.22 ± 0.01	0.1 ± 0.0006	0.11 ± 0.0008	0.42 ± 0.01	0.4 ± 0.01	0.104 ± 0.0002	0.19 ± 0.01

4.6. Studies on the role of biology and percentage of parasitization of the, *Uscana mukerjii* (Mani)

The *Uscana mukerjii* (Hymenoptera: Chalcidoidea: Trichogrammatidae) parasitizeds singly on an eggs of *Callosobruchus chinensis* and other bruchids (**Plate 11**) The bruchids are particularly suitable for control through the agency of egg-parasitoids because they lays eggs on the surface of the pulses.

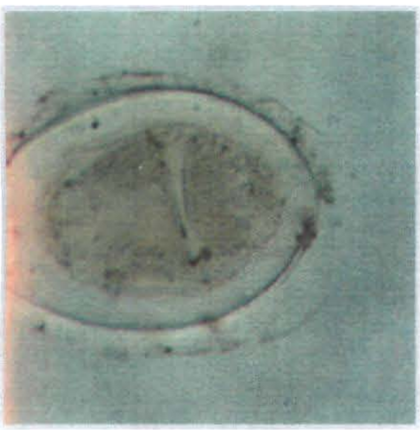
4.6.1. Ovipositional preference

After mating the females climbed to the pulse seed and detected host's egg with their antennae. This process was referred to as 'drumming' by Strand and Vinson (1984). Then it

PLATE 11

Diagram of an egg of *U. mukerjii*

Eggs of pulse beetle parasitized by *Uscana mukerjii*



Larval stage

Pupal stage

Adult male

Adult female

Photoplate 11. Microphotographs of different biological stages of *Uscana mukerjii* (Mani)

drilled a hole on the egg-chorion for egg-laying. The females were very specific to prefer eggs for oviposition and usually rejected the old eggs (**Table 28**) They preferred most (56.8±7.4) the eggs of 0 to 12 hours, followed by 12 to24 hrs (47.6 ± 9.6) and 24 to 48 hrs (31.5 ± 4.6).

4.6.2. Developmental period

The developmental period was studied in the laboratory in different seasons. The data are presented in the **Table 29**. The longest developmental period of 15.0 ± 3.5 days was recorded during winter followed by autumn (8.0 ± 2.01 days), summer (6.5 ± 1.39 days) and rainy seasons (6.4 ± 1.42 days).

4.6.3. Life span of the adult

The life span of adult (**Table 29**) parasitoids differed not only in the two sexes but also in the mated and unmated individuals of each sex. In general the life span of the females was shorter than that of the males. Maximum life span of 10.7 ± 0.65 days was recorded for the unmated males during winter whereas the life span of unmated females was close (9.5 ± 1.52 days) to the females. Minimum life span 4.1 ± 0.9 days was recorded during rainy season. The life span of both mated and unmated adults of both the sexes did differ considerably during summer and rainy seasons.

4.6.4. Sex ratio

The sex ratio (male: female) did not differ in different seasons (**Table 29**) although the lowest of 1: 2.94 was recorded during summer. In every season the sex ratio of the parasitoid was predominated by females and went up to 1: 2.84 during autumn followed by rainy (1:2.49) and winter (1: 2.07).

4.6.5. Percentage of parasitization

Eggs of *C. chinensis* parasitized by *U. mukerjii* could be identified from the healthy eggs by yellowish to black coloration of the embryo of the parasitoid. The larvae became deep yellow, followed by brown color of the early pupae and black of the late pupae (**Plate 11**).The result of per cent parasitization is furnished in the table. The mated females parasitized up to a maximum of 49.6 ± 2.59 (%) during summer which was very close to the per cent parasitization during rainy seasons (48.9 ± 2.71%). During autumn, the percentage of parasitization recorded was 39.5 ± 3.02 and the lowest percentage was 35.2 ± 3.19% during winter (**Table 30**).

Table 28. Ovipositional preference of *U. mukerjii* to *C. chinensis* eggs of different ages

Age of host eggs (in hours)	Number of egg laid /mated female
	Mean ± S.D.
0-12	56.8 ± 11.0
12 -24	52.6 ± 12.6
24-48	31.5 ± 4.6

Table 29. Development period, adult life span and sex ratio of *U. mukerjii*

(The figures are averages of 3 years ± S.D.)

Seasons (Temperature) (°C)	Development period (day)	Adults longevity (day)				Sex ratio
		Male		Female		Male : Female
		Mated	Unmated	Mated	Unmated	
Winter (18.42 –21.5°C)	15 ± 3.50	9.5 ± 1.2	10.7 ± 0.65	7.25 ± 1.11	9.5 ± 1.52	1 : 2.07
Autumn (24.2 – 26.9 °C)	08 ± 2.01	6.2 ± 0.9	6.8 ± 0.91	5.70 ± 0.21	6.12 ± 1.02	1: 2.84
Summer (26.9 –30.1 °C)	6.5 ± 1.39	4.2 ± 0.8	5.1 ± 0.62	4.16 ± 0.71	4.92 ± 0.79	1: 1.94
Rainy (26 – 30 °C)	6.4 ± 1.42	4.1 ± 0.90	5.2 ± 0.12	4.02 ± 0.98	4.54 ± 0.44	1: 2.59

Table 30. Number of host eggs parasitized by one mated female adult of *U. mukerjii*

(The figures are averages of 3 years ± S.D.)

Seasons (Temperature °C)	Number of egg parasitized by one mated female
	Mean ± S.D.
Winter (18.42 –21.5°C)	35.2 ± 3.19
Autumn (24.2 – 26.9 °C)	39.5 ± 3.02
Summer (26.9 –30.1 °C)	49.6 ± 2.59
Rainy (26 – 30 °C)	48.9 ± 2.71

Fig. 23. Parasitization potentiality (%) of *Uscana mukerjii* in different seasons

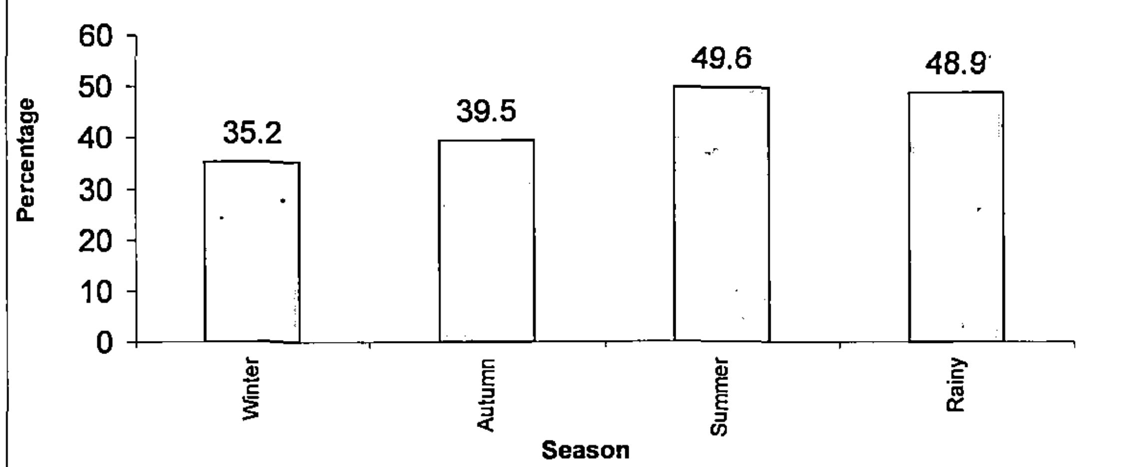
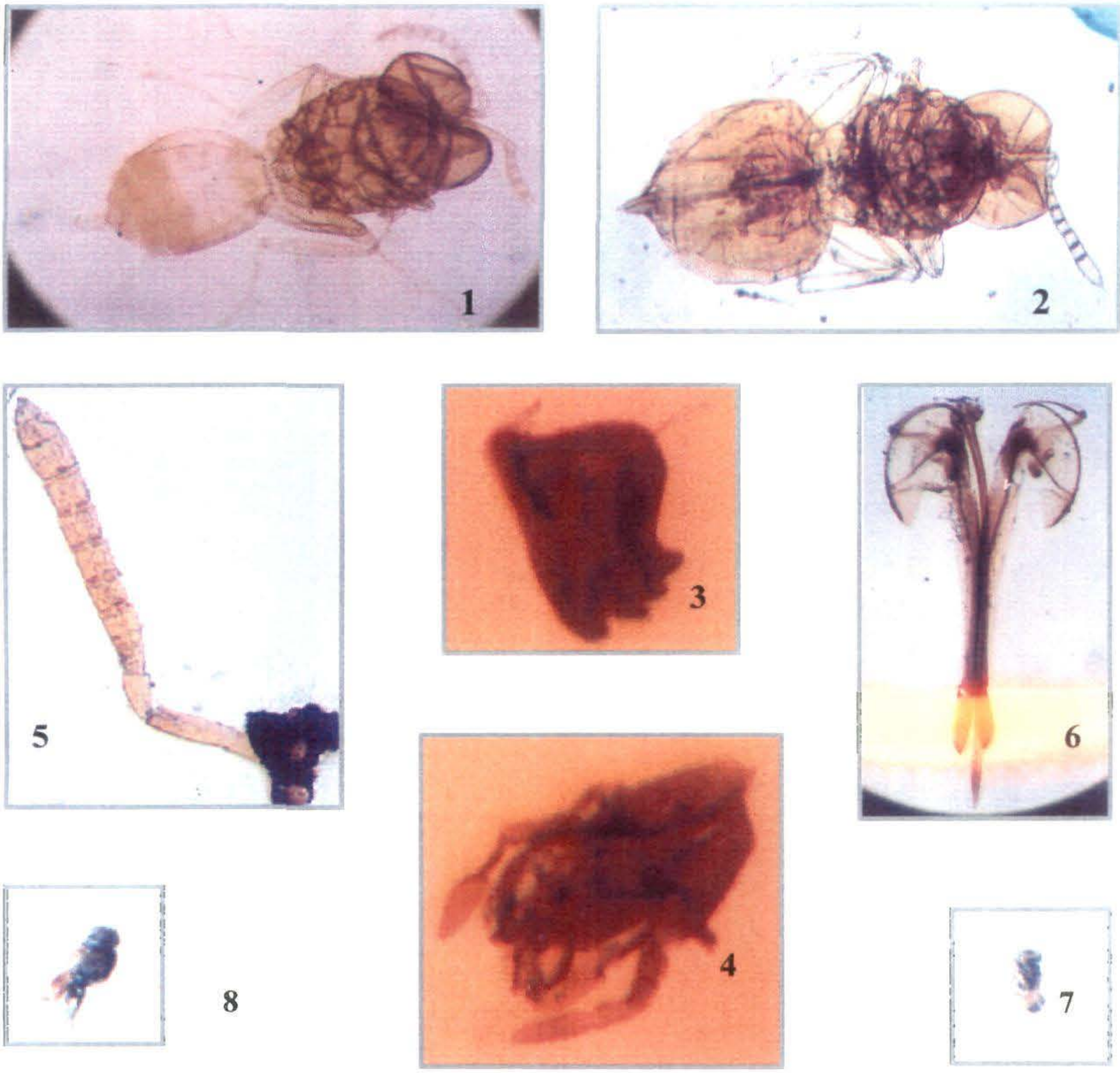


PLATE 9



Photomicrograph 9. **Morphological features of *Dinarmus vagabundus* (Timberlake)**

1. **Male adult 30x**
2. **Female adult 30x**
3. **Mandible 950x**
4. **Maxillae and labium 900x**
5. **Antennae 80x**
6. **Ovipositor apparatus 80x**
7. **Lateral view of female adult 7x**
8. **Dorsal view of male adult 6x**

4.7. Biosystematics, morphology and sexual dimorphism of *Dinarmus vagabundus*

4.7.1. Taxonomy, historical back ground and distribution

Systematic position :

Order - Hymenoptera

Super family – Chalcidoidea

Family – Pteromalidae

Subfamily – Pteromalinae

Tribe – Pteromalini

Genus – *Dinarmus*

Species – v*agabundus*

Genus	:	***Dinarmus* subg. *Dinarmus* Thomson**
		1878 *Dinarmus* Thomson, *Hymen Scancl.*, **5**: 56.
Type species	:	*Dimachus* (*Dinarmus*) *acutus* Thomson
Type locality	:	Europe
Distribution	:	Hawii, U.S.A.; France; Brazil, Pakistan; Ceylon and North-east plain, Northern hill and South part of India (**Appendix X11**)
Host	:	Bruchids.

Previous description :

In course of a survey during 1999-2000, in the terai region of West Bengal , India a very interesting hymenopteran ecto-parasitoid, *Dinarmus vagabundus* (Timberlake) (Chalcidoidea : Pteromalidae : Pteromalinae) was collected from stored black gram (*Vigna mungo* var. *mungo*) infested by the pulse beetles, *Callosobruchus chinensis* and *C. analis* (Coleoptera : Bruchidae). The genus *Dimachus* subg. *Dinarmus* Thomson was first described by Thomson (1878) based on *D. acutus* Thomson as its type. Ashmead (1904) redescribed and ranked to as genus *Dinarmus* which belongs to the subfamily Pteromalinae of Pteromalidae.

Timberlake (1926) first described and separated *Dinarmus vagabundus* (Timberlake) from other allied species of *Dinarmus* by original designation .Mani (1939), Boucek *et al.* (1978), and Mani(1989) redescribed and illustrated its morphological characteristics. Unfortunately, no comprehensive study of this species with special emphasis to their mouthparts, ovipositor apparatus and sexual dimorphic characteristics has been published so far. However, the information on the occurrence and distribution of this parasitoid in India is confined only to some occasional local records. Here is an attempt to provide a comprehensive account in a reversionary framework. The type locality and host of *Dinarmus vagabundus* (Timberlake) is Hawii and bruchids respectively (Mani,1989). It has been frequently recorded from Brasil (Lima, 1942);

France (Rojas *et al.,* 1988); Pakistan and Ceylon (Boucek *et al.,* 1978 and Mani, 1989). It was first recorded from India by Mani (1939). It was also reported as potential gregarious ecto-parasitiod of bruchids from Northern India (Kundra, 1976) and Southern India (Mani, 1989 and Raja *et al.*, 2000) and North-east plain of India by Ghosal *et al.*, 2003.

***Dinarmus* vagabundus (Timberlake)**

1926	*Brochobius vagabundus*, Timberlake, *Proc. Hawaii Ent. Soc.*, **6**:305-307.	
1939	*Brochobius vagabundus*, Mani, *Indian J. Ent.*, **1**: 69-88.	
1942	*Dinarmus vagabundus*	Lima, *Bol.Soc. Brazil,Agron.*, **5**:441.
1962	*Dinarmus vagabundus*	Chema and Misra, *Curr. Sci.*, **31**: 21.
1977	*Dinarmus vagabundus*	Dhir, Curr. Sci., **46**: 63-70
1978	*Dinarmus vagabundus*,	Boucek, Subba Rao & Farooqi, *Oriental Insect*, **12**(4): 442
1988	*Dinarmus vagabundus*	Rojas *et al.*, *Entomol.Exp. et Applicata*, **46**: 63-70
1989	*Dinarmus vagabundus*,	Mani, *The Fauna of India and the Adjacent Countries*, **1**: 567-568.
1994	*Dinarmus vagabundus*	Alebeek *et al.*, *Proc. Selec. Exp. Appl. Ent.*, **5**: 145-150
2000	*Dinarmus vagabundus*	Raja *et al. Indian J. Exp.Bio.*, **38**: 290-292
2003	*Dinarmus vagabundus*	Ghosal *et al.*, *Proc. Zool. Soc. Calcutta*, **56**: 21-26.

4.7.2. Morphology and sexual dimorphism

Adult male : Body length is 1.58-2.31 mm. Color of the body is black except the anterior half of the abdomen (yellowish-brown); front surface of the head and thorax is black but with greenish reflections (**Table 31, Plate 9** and **10**).Head width is almost 2-times larger than the length, and is also larger than the maximum width of the thorax or abdomen; compound eyes ovate, bulging and devoid of cilia; ocelli 3, very small, round and arranged in obtuse triangle. The length of antennae is 0.81-0.95mm; elbowed and 13 segmented; 0.40mm part of the scape is yellowish-white, rest of antennae brownish-yellow; scape long; pivot is triangular subequal to the total summation of the first three segments of flagellum; annuli 2; apical 3 segments of flagellum form a typical club.Thorax is well developed; metapostnotum fused with the first abdominal tergite to form propodeum; pronotum disconnected from prothorax and attached to the front part of the mesothorax; neck of the propodeum short.Leg is yellowish-brown except coxae (length 1.36-1.58mm.); femur long, partially sclerotised; apical portion of tibia with short spines, tibial spur single; tarsus 5 segmented, spinose, the length of tarsal segments are in the descending order of 1st >2nd >5th >3rd >4th.Fore wing (length 1.18-1.2mm.) is membranous; hyaline; spotted upto 0.75 part; marginal fringe short, occupying about half of the total marginal area; single solitary compound vein; post marginal vein (pm.) is subequal to stigmal vein (*st*); sub-marginal vein (*sm*) is setose; stigmal vein (*st*) is ovate.Hind wing (length 0.91-0.96mm.) is blunt apically; membranous, hyaline, spotted; marginal fringe short, spaced by a distance equal to 0.40 part of the wing margin; an unbranched single vein (r+m), setose; 3 frenal hooks or hemulli along the costal margin.Gaster is longitudinally ovate; smaller than the thorax; 5 segmented;

part of the wing margin; an unbranched single vein (r+m), setose; 3 frenal hooks or hemulli along the costal margin.Gaster is longitudinally ovate; smaller than the thorax; 5 segmented; anterior half is yellowish-brown; anal point of hypo-pygium short, yellowish-brown, setose at the apex (**Table 31**).

Adult female : Body length is 1.66-2.41mm. Color of the body is black; front surface of head and thorax black with bluish reflection; gaster black with brassy luster (**Table 31; Plate 9** and **10**). Antennae (length 0.78-0.85mm.) is 13 segmented; Annuli 3, where 1st >2nd >3rd and the 3rd one is sub square; length is somewhat smaller than that in male.Thorax is always smaller than gaster and width is sub equal to head, scutellum a little wider than the length; neck of propodeum short.Leg (length 1.35-1.41mm.) is always small in comparison to that of adult male.Fore wing (length 1.20-1.50 mm.) and hind wing (length 0.90-1.00 mm.) are longer than those of an adult male. Gaster is longitudinally ovate; ovipositor long (length 0.70-0.76 mm.) and originate from tip of the gaster; long forward extension of the 9th abdominal tergum provide a tall hoist or stinger for deep drilling ovipositor shaft.

Mouthparts : Mouthparts (**Plate 9**) typically orthopteroid, characterized by the great flexibility of the maxillae-labium complex. Marginal end of the labrum (length,0.03 mm) carinated. Mandibles (length, 0.02-0.03mm) quadric-dentate and maxillae with 4 segmented maxillary palpi ; cardo well developed and yellowish in color, stipes long and deep brownish-black and galea yellow; labium well developed, 3 segmented palpi with first segment deeply sclerotised, glossa short and bifid (**Table 31**).

Ovipositor apparatus : Length 0.70-0.76 mm.. It comprises of the lateral gonophyses of the 9^{th} segment forming the sheath of the sting; the median gonophyses of the 9^{th} segment fused together as the sting canal; the valvifers of the gonophyses of the 8^{th} segment (stylet) articulate with the homologous parts of the 9^{th} segment instead of the tergite; the stylet modified into sting (length 0.07-0.11mm.) lying with the retraction of the 8^{th} segment just like a complicated stinging apparatus within the sting chamber. The long forward extensions of the 9^{th} abdominal tergum provide a long hoist for deep drilling ovipositor shaft (**Table 31** and **Plate 9**). The modifications of the ramus helps in turning the ovipositor shaft to a vertical position of action from the horizontal position of repose with the help of modified ovipositor muscles (Saxena *et al.*, 1997).

Sexual dimorphism : Body length (1.87mm) and wing span (2.97) always shorter in male than those in female. Length of antenna (0.87) and hind legs (1.39) are longer in female than those of male (**Plate 9**). In male, front surface of head and thorax is black with greenish reflection. Anterior half of the gaster is yellowish-brown in color. Abdomen always shorter than the combined length of head and thorax. Antennae 13 segmented: 1.1.2.6.3. (annuli 2, flagel 6).

Table 31. Sexual dimorphism of *D. vagabundus* uin respect of adult body morphometry
(All measurements are in millimeters)

Dinarmus vagabundus	Body length of adult		Body width of adult		Length of antennae		Length of fore wing		Width of fore wing		Length of hind wing	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
	1	2	3	4	5	6	7	8	9	10	11	12
Number of individuals	10	10	10	10	9	9	8	8	8	8	8	7
Range	1.58-2.31	1.66-2.41	0.61-0.76	0.55-0.80	0.81-0.95	0.78-0.85	1.18-1.20	1.20-1.58	0.71-0.78	0.71-0.78	0.91-0.96	0.28-0.31
Mean ± SD	**1.87±0.25**	**2.04±0.28**	**0.71±0.05**	**0.72±0.08**	**0.85±0.03**	**0.80±0.02**	**1.19±0.01**	**1.41±0.13**	**0.72±0.01**	**0.75±0.0 2**	**0.94±0.01**	0.29±0.0 0

Table 31. Contd.

Dinarmus vagabundus	Width of hind wing		Wing span		Length of hind leg		Length of ovipositor apparatus	Length of stinger	Length of the mandible
	Male	Female	Male	Female	Male	Female			
	13	14	15	16	17	18	19	20	21
Number of individuals	8	7	8	8	9	9	9	7	6
Range	0.25-0.28	0.28-0.31	2.69-3.08	2.75-3.83	1.35-1.41	1.36-1.58	0.70-0.76	0.07-0.11	0.029-0.035
Mean ± SD	**0.26±0.01**	**0.29±0.01**	**2.97±0.05**	**3.79±0.03**	**1.39±0.04**	**1.47±0.06**	**0.73±0.02**	**0.09±0.01**	**0.031±0.01**

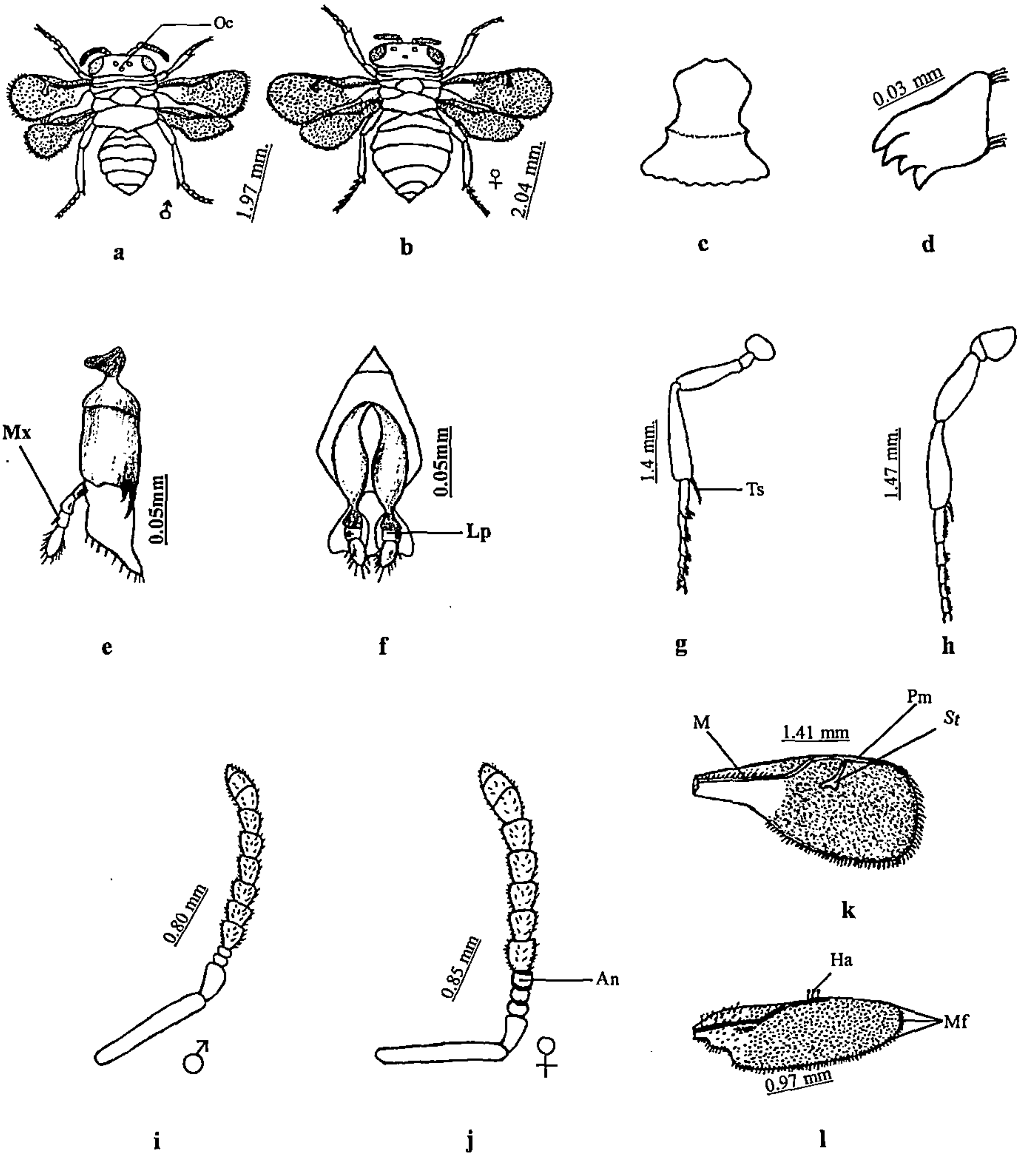


FIGURE 22

Morphological features of *Dinarmus vagabundus* (Timberlake)

a. Dorsal view of adult male b. Dorsal view of adult female c. Labrum d. Mandible e. Maxillae f. Labium g. Fore leg h. Hind leg i. Antennae (Male) j. Antennae (Female) k. Fore wing l. Hind wing

Abbreviation used : An., annulus; Oc., Ocellus; Mx., Maxillary palp; Lp., Labial palp; Ts., Tibial spur; M., Median vein; Pm., Post median vein; St., Stigmal vein; Mf., Marginal fringe; Ha., Hamullus

4.8. Studies on the role of biology and percentage of parasitization of *D. vagabundus*

4.8.1. Biology

Being a larval-pupal parasitoid of *C. chinensis*, the females of *D. vagabundus* pierced the seed coat of pulses by its sharp and pointed ovipositor. After access to larva/pupa the female oviposited on the outer surface of the integument. Single to several eggs were laid on a single host larva/pupa. The adult males were always shorter than the females and were polygamous. The courtship duration during summer and winter was recorded 56.23 ± 6.33 and 47.73 ± 8.47 seconds respectively. The mean mating duration was 14.14 ± 1.47 seconds during summer and 13.79 ± 1.04 seconds during winter. The fecundity was studied during summer and winter seasons only. It was higher during summer (42.8 ± 2.89) than in winter (38.5 ± 1.47). The time took for completion of life cycle (egg-adult) during winter was 51.71 ± 2.43 days which was much longer than in summer (19.14 ± 2.31 days). The life span of adult females was always longer than that of males in every season. The female survived for 7.71 ± 1.11 days and 11.88 ± 2.05 days during summer and winter respectively. The male life span was recorded 5.55 ± 0.75 days during summer and 9.88 ± 2.57 days during winter. The sex ratio (male: female) was 1: 2.07 during summer and 1:1.55 during winter (**Table 32**).

4.8.2. Percentage of parasitization

The number of adults emerged out of a single green gram, Bengal gram, red gram and cowpea seed each infested with single larva/pupa of *C. chinensis* was 2.71 ± 1.52, 2.96 ± 0.98, 3.01 ± 1.08, and 3.66 ± 1.29 respectively during summer.

The per cent parasitization the larva and pupa of *C. chinensis* by *D. vagabundus* on green gram, bengal gram, cowpea and red gram stored pulses during summer and winter is provided in the **Table 33**. The mean parasitization (%) of *D. vagabundus* on host pulses was always higher during summer (20.82±4.65). Mean per cent parasitization of two seasons on 4 different species of pulses could be arranged in the followed descending order: cowpea (25.90%) > red gram (20.38%) > green gram (17.96%) > chick pea (15.52%).

Table 32. Biology of *Dinarmus vagabundus* and temperature snd relative humidity of rearing room

(Mean of 3 years, 1999-2001)
The values are the mean ± S. D. Figures in the parenthesis are the ranges

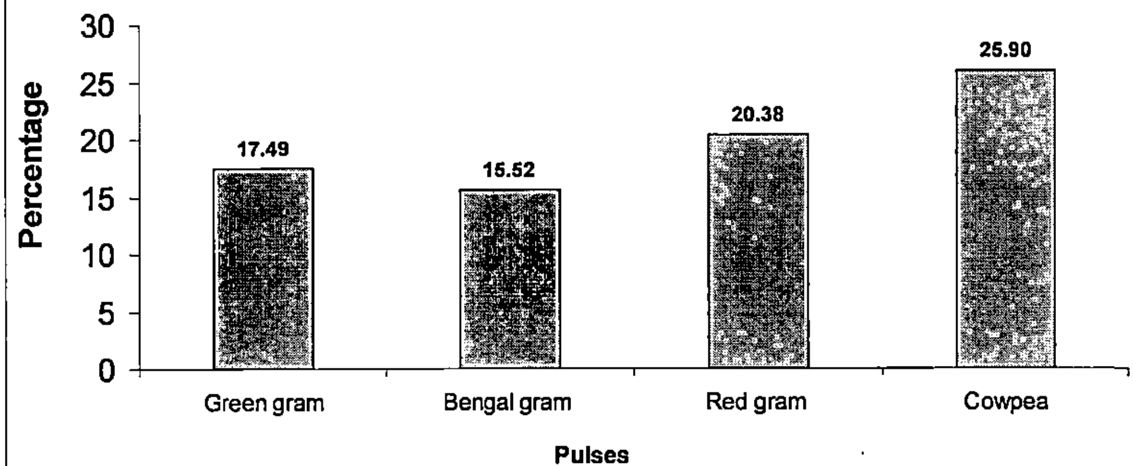
Biology	Seasons		
	Summer	Winter	Average of seasons
Courtship duration (second)	56.26 ± 16.33 (40-73)	47.73 ± 18.47 (29-64)	51.98±17.4 (34.5-68.5)
Mating duration (second)	14.11 ± 1.47 (11.5-16.0)	13.79 ± 1.04 (11.0-15.0)	3.95±1.25 (11.25-15.5)
Fecundity/ female (number)	42.8 ± 2.89 (38-47)	38.5 ± 1.47 (31-42)	40.65±2.18 (34.5-44.5)
Life cycle (egg – adult) (day)	19.14 ± 2.31 (16-22)	51.71 ± 2.43 (48-54)	35.42±2.37 (32-38)
Longevity of adult male (day)	5.55 ± 0.75 (4-7)	9.88 ± 1.57 (7-12)	7.71±1.16 (5.5-9.5)
Longevity of adult female (day)	7.71 ± 1.11 (7-9)	11.88 ± 2.05 (8-15)	9.79±1.58 (7.5-12)
Sex ratio (male : female)	1:2.07	1 : 1.55	1 : 181
Average temperature °C	28.05	20.00	
Average r. h. (%)	64.63	63.92	

Table 33. Parasitization and emergence of adult *D. vagabundus* from a single larva/pupa of *C. chinensis*

(Average of 3 years, 1999-2001)
The values represent mean ± S.D. and the ranges in parenthesis

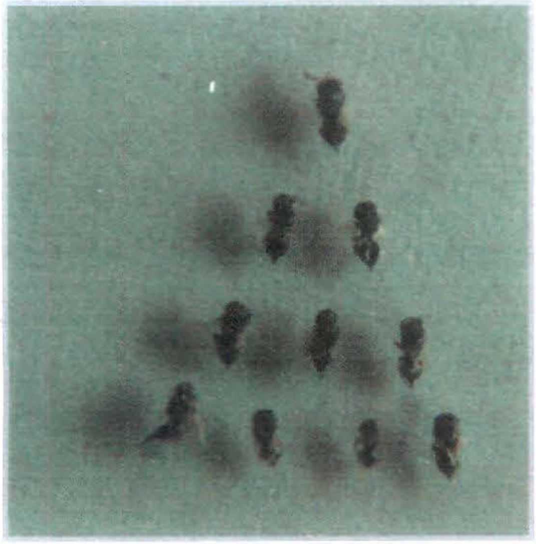
Pulse	Parasitization (%)			No. of adult / larva or pupa
	Summer	Winter	Average of two seasons	
Green gram	18.22 ± 5.26 (12 – 25)	16.77 ± 3.04 (13 – 21)	17.49 ± 4.15 (12.5 – 23)	2.71 ± 1.52 (1-4)
Bengal gram	16.33 ± 2.54 (13-19)	14.72 ± 2.54 (11 – 17)	15.52 ± 2.34 (12 – 18)	2.96 ± 0.98 (1-5)
Red gram	2172 ± 6.02 (16-28)	19.04 ± 4.16 (14 – 24)	20.38 ± 5.09 (15 – 26)	3.01 ± 1.08 (1-6)
Cowpea	27.01 ± 4.79 (22-32)	24.79 ± 3.48 (20 – 29)	25.9 ± 4.13 (21 – 30.5)	3.66 ±1.21 (1-7)
Mean	**20.82 ± 4.65 (12-32)**	**18.83 ± 3.30 (11-29)**	**19.82 ± 3.92 (11.5-30.5)**	**3.08 ± 1.91 (1-7)**

Fig. 24. Parasitization potentiality of *Dinarmus vagabundus*



Larvae of pulse beetle,
Callosobruchus chinensis Linn.

Pupae of pulse beetle ,
Callosobruchus chinensis Linn.



Adult female of *Dinarmus vagabundus*

Adult male of *Dinarmus vagabundus*

Photoplate 10. Host insect's (*C. chinensis)* larva and pupa and its parasitoid, *Dinarmous vagabundus* (Timberlake)

4.9. Pesticidal effect of plant oils on adult pulse beetle, C. *chinensis*

Five non-edible plant oils such as clove, neem, castor, chaulmoogra, and citronella and nine edible plant oils (mustard, niger, rice bran, soybean, coconut, sesame, sunflower, palm and safflower) were used to test their effectiveness against pulse beetle, *C. chinensis.*. The edible plant oils were applied at required concentration (v/v) of 0.05, 0.02 and 0.01 per cent and non-edible plant oils of 0.01, 0.005, 0.002 and 0.001 pre cent to test the effectiveness to kill the adult beetles.

4.9.1. Pesticidal effect of nine edible oils

The result presented in **table 34** indicated that the effectiveness of these oils on the mortality of adult beetles were statistically significant. A marked concentration dependant effect on adult mortality was observed. The highest mortality was recorded in all the cases at 0.05 % concentration and the lowest with 0.01 % concentration. The 0.05 per cent dose of safflower oil caused 100 % death of the adult. At 0.01 % concentration, mustard and niger oils showed no adult mortality. The relative effectiveness of the oils at 0.05 per cent was in the descending order of safflower > soybean > sesame > coconut > sunflower > rice-bran > mustard > niger > palm. The mortality percentage was nil in control (untreated) experiment.

4.9.2. Pesticidal effect of five non-edible oils

It was observed (**Table 35**) that non-edible oils at the concentration of 0.01 were very effective. The highest (100%) mortality at this concentration was the maximum in case of chaulmoogra oil (100%) followed by clove oil (90.0%), citronella (36.3%), and castor (10.0) and neem (9.00%). At subsequent lower concentrations (0.001, 0.002 and 0.005) neem and castor oils has no effect. The death caused due to both edible and non-edible oils differed significantly at different concentrations. The non-edible oils were more effective to cause the death of adult beetles. Among the all fourteen plant oils tested at 0.01% concentration, chaulmoogra (*Hydnocarpus kurzii*) oil appeared to express the best pesticidal effect on the adult beetle followed by clove, safflower, citronella, sesame and soybean. Uses of botanicals as protectants of stored grains have had long history of use by farmers. The actual mechanism of their toxicidal effect on insect is not known but the basis may either be physical or bio-chemical or both. In view of encouraging results obtained in this study, the chaulmoogra, clove, safflower, citronella, soybean and sesame oils appear to have distinct potentiality as bio-pesticides and good additives for the management of insect pests especially the bruchid pests (Coleoptera: Bruchidae) of stored pulses.

Table 34. Effectiveness of nine edible oils against the adults of *C. chinensis*

(Parentheses are the angular transformed values)

Edible plant oils	Mean death (%) after 24 hours exposure		
	Concentrations (v/v)		
	0.05 %	0.02 %	0.01 %
1. **Mustard**	66.0 (54.32)	13.3 (21.39)	00.0 (00.0)
2. **Niger**	65.3 (53.93)	19.6 (26.31)	00.0 (00.0)
3. **Rice bran**	68.0 (55.55)	39.3 (38.83)	15.6 (23.28)
4. **Soybean**	82.3 (65.13)	62.6 (52.32)	27.0 (31.28)
5. **Coconut**	78.0 (62.02)	26.6 (31.03)	16.0 (23.54)
6. **Sesame**	80.0 (63.44)	61.3 (51.54)	33.0 (35.05)
7. **Sunflower**	72.3 (58.27)	48.0 (43.05)	24.0 (29.31)
8. **Safflower**	100.0 (90)	68.6 (55.96)	37.3 (37.65)
9. **Palm**	65.0 (53.7)	37.6 (37.8)	23.3 (28.8)
CV (%)	**1.77**	**5.44**	**8.95**
SEM ±	**0.42**	**0.76**	**0.56**
CD at 5%	**1.57**	**2.85**	**2.10**

Table 35. Effectiveness of five non-edible oils against the adults of *C. chinensis*

(Parentheses are the angular transformed values)

Non-edible plant oils	Mean death (%) after 24 hours exposure			
	Concentrations (v/v) (%)			
	0.01 %	0.005 %	0.002 %	0.001 %
1. **Chaulmoogra**	100 (90.0)	77.6 (61.81)	48.0 (43.85)	22.6 (28.41)
2. **Neem**	26.6 (31.03)	16.0 (23.54)	00.0 (00.0)	00.0 (00.0)
3. **Castor**	10.0 (18.37)	00.0 (00.0)	00.0 (00.0)	00.0 (00.0)
4. **Clove**	90 (71.62)	58.0 (49.6)	32.0 (34.43)	26.0 (27.71)
5. **Citronella**	36.3 (36.27)	13.6 (21.67)	00.0 (00.0)	00.0 (00.0)
CV (%)	**6.32**	**4.26**	**7.01**	**10.89**
SEM ±	**1.45**	**0.66**	**0.65**	**0.57**
CD at 5%	**7.85**	**3.58**	**3.51**	**3.08**

4.10. Efficacy of different edible and non-edible oils in suppressing egg laying, emergence of adults and developmental period of C. *chinensis.*

4.10.1. Impact on the egg laying

The result presented in Table 36, indicats a marked effect of three different doses (0.05, 0.1 and 0.3 in 10g of pulses) on egg laying (number of eggs laid / female). There were declines in eggs laying with the increase of oil concentration and hence, extended storage duration of green gram seeds treated with different plant oils. At different days after storage (i.e. 30, 60, 90 and 120 days) the non-edible oils likely chaulmoogra and clove oil were more effective than citronella and neem oils. Among the edible oils, soybean oil was the most effective in suppressing egg infestation up to 120 days over the control at all levels of per cent concentration (v/w). Although the per cent concentration 0.3 (v/w) slowed most effective in all the oils used for the present investigation. Chaulmoogra oil suppressed to the highest extend of eggs 40.8 no./female at 0.3% concentration and was significantly superior to all other oils. Clove oil at 0.3% level appeared to next promising agent (34.8 eggs /female). Among the edible oils soybean at all levels of concentrations was superior to niger and mustard. The oil could protect the seeds well even up to 120 days (**Table 36**).

4.10.2. Impact on the developmental duration

It is evident from the data (**Table 37**) that mean developmental period was the highest (49.2days) on seeds treated with soybean oil at 0.3 percent concentration. The result was very close to the seeds treated with 0.3 percent concentration of chaulmoogra oil (46.5days). The developmental period in rest of the treatments was also significantly different in comparison to untreated seeds (control). However, the lengthening of different periods of *C.chinensis* evaluated in the present treatments were statistically significant from the (control) result and the lengthening in descending order in comparison to that of control was soybean (4.7 days)> chaulmoogra (2.9 days)> clove (2.7 days)> citronella (2.6 days)> neem (2.4 days)> rice bran (1.6 days)> (1.2 days) and niger (1.2 days) and mustard (1.3 days).

4.10.3. Impact on the emergence of adult

A trend of suppression of adult emergence was observed with increase in concentrations of the oils (Table 38). The emergence of adult beetle was suppressed to the highest extent in case of chaulmoogra oil followed by clove oil, neem oil, soybean oil, citronella oil, niger oil, rice bran mustard oil. At 30 days after application of chaulmoogra oil all the three concentration proved to be most effective, as there was no adult emergence. Clove oil treated seeds of green gram also showed significant result. These two treatments were significantly superior to all other plant oils. The citronella, neem and soybean oils at all the three levels appeared to be promising. The effectiveness of the oils persisted satisfactory up to 120 days (**Table38**).

Table 36. Efficacy of different plant oils in suppressing egg laying by *C. chinensis* at every 30 days after treatment up to 120 days

OIL	Conc. (v/w) (%)	Number of eggs laid / 100 (g) green gram seed					
		30 days	60 days	90 days	120 days	Mean	Number decrease over control
Rice bran	0.05	16.9	25.6	29.3	57.0	32.2	15.2
	0.10	16.0	23.0	24.6	55.0	29.6	17.1
	0.30	14.0	20.0	20.3	51.3	26.4	20.3
Niger	0.05	19.6	27.0	32.6	61.3	35.1	11.6
	0.10	18.6	22.0	29.6	51.0	30.3	16.4
	0.30	16.6	21.0	21.4	41.0	25.0	21.7
Mustard	0.05	16.3	20.6	32.3	54.0	30.8	15.9
	0.10	14.6	27.3	29.3	47.3	29.6	17.1
	0.30	14.0	25.6	24.3	43.2	29.6	20.0
Soybean	0.05	14.6	23.3	29.6	37.0	26.1	20.6
	0.10	12.0	21.6	25.6	34.0	23.3	23.4
	0.30	09.3	14.6	20.6	31.3	18.9	27.8
Neem	0.05	16.3	21.0	29.3	52.6	29.8	16.9
	0.10	13.3	19.0	24.1	46.0	25.6	21.1
	0.30	12.6	17.3	18.6	44.3	23.2	23.5
Citronella	0.05	17.3	26.0	31.6	52.6	31.8	14.9
	0.10	14.3	21.0	29.3	49.0	28.4	18.3
	0.30	00.0	00.0	04.3	19.3	05.9	22.1
Chaulmoogra	0.05	00.6	02.6	09.0	31.0	10.8	35.9
	0.10	00.3	01.5	07.0	26.3	08.7	38.0
	0.30	00.0	00.0	04.3	19.3	05.9	40.8
Clove	0.05	03.6	04.6	15.2	39.6	15.7	31.0
	0.10	02.9	03.6	10.9	36.3	13.4	33.3
	0.30	02.3	03.0	08.3	34.3	11.9	34.8
Control		39.0	43.0	41.0	64.0	46.7	-

Interaction of oils (A) with concentrations (B) and observation days (C)

	(A)	(B)	(C)	AxB	AxC	BxC	AxBxC
S Em ±	0.28	0.16	0.18	0.48	0.56	0.32	0.97
CD at 5%	0.77	0.44	0.49	1.33	1.55	0.88	2.66

Table 37. Efficacy of different vegetative oils on developmental period of *C. chinensis* at every 30 days up to 120 days

OIL	Conc. (v/w) (%)	Mean developmental period (oviposition - adult emergence)					
		30 days	60 days	90 days	120 days	Mean	Day increase over control
Rice bran	0.05	24.3	38.0	43.3	44.0	37.4	0.6
	0.10	24.3	38.6	43.6	45.3	37.9	1.1
	0.30	24.6	38.8	43.6	45.6	38.4	1.6
Niger	0.05	24.6	36.0	44.6	44.6	37.4	0.6
	0.10	24.9	37.0	44.8	44.8	37.8	1.0
	0.30	24.9	37.3	44.8	45.0	38.0	1.2
Mustard	0.05	23.1	38.6	44.3	45.3	37.6	0.8
	0.10	23.3	38.6	44.5	45.3	37.8	1.0
	0.30	23.6	38.7	44.8	45.6	38.1	1.3
Soybean	0.05	25.6	39.3	46.3	48.3	39.8	3.0
	0.10	26.0	41.0	47.0	49.0	40.5	3.7
	0.30	26.6	41.6	47.5	50.3	41.5	4.7
Neem	0.05	25.0	38.7	44.5	46.3	38.5	1.7
	0.10	25.2	38.9	44.9	46.8	38.8	2.0
	0.30	25.4	39.2	45.3	47.3	39.2	2.4
Citronella	0.05	24.1	37.0	45.3	45.3	37.9	1.1
	0.10	24.8	37.6	45.6	45.8	38.4	1.6
	0.30	24.8	38.0	45.8	46.1	39.2	2.6
Chaul moogra	0.05	-	41.3	46.3	47.1	44.6	2.6
	0.10	-	-	46.6	47.6	46.4	2.6
	0.30	-	-	46.8	48.5	46.5	2.9
Clove	0.05	-	39.0	47.3	46.0	44.1	2.4
	0.10	-	39.3	47.6	46.3	44.3	2.6
	0.30	-	39.6	48.0	46.8	44.6	2.7
Control		23.2	37.3	43.5	44.3		

Interaction of oils (A) with concentrations (B) and observation days (C)

	(A)	(B)	(C)	AxB	AxC	BxC	AxBxC
S.Em ±	0.28	0.16	0.18	0.48	0.56	0.32	0.97
CD at 5%	0.77	0.44	0.49	1.33	1.55	0.88	2.66

Table 38. Efficacy of different vegetable oils in suppressing emergence of adult *C. chinensis* at every 30 days up to 120 days

OIL	Conc. (%)	Number of adult emergence / 100 green gram seeds after					
		30 days	60 days	90 days	120 days	Mean	Number decrease over control
Rice bran	0.05	09.3	15.6	19.3	31.0	18.8	9.4
	0.1	08.0	13.0	17.4	28.3	16.6	11.6
	0.3	05.3	11.3	14.6	25.5	14.1	14.1
Niger	0.05	09.6	14.2	18.2	32.6	18.6	9.6
	0.1	07.3	12.5	15.9	28.7	16.1	12.1
	0.3	06.1	09.6	14.2	26.2	14.0	14.2
Mustard	0.05	12.3	16.3	21.4	32.6	20.6	7.6
	0.1	10.0	14.6	19.6	29.7	18.4	9.8
	0.3	08.3	11.9	16.6	27.5	16.0	12.2
Soybean	0.05	08.6	12.6	14.6	25.6	15.3	12.9
	0.1	08.0	11.0	13.0	24.9	14.2	14.0
	0.3	06.0	10.2	11.9	23.2	12.8	15.4
Neem	0.05	08.3	09.0	11.3	24.4	13.2	15.0
	0.1	06.4	08.3	08.3	24.0	11.7	16.5
	0.3	05.3	07.3	07.0	21.5	10.2	18.0
Citronella	0.05	08.9	12.3	13.4	28.0	15.1	13.1
	0.1	07.6	11.9	12.9	24.9	14.3	13.9
	0.3	06.3	10.6	11.6	23.0	12.8	15.4
Chaul moogra	0.05	00.0	00.6	04.6	08.0	03.3	24.9
	0.1	00.0	00.3	03.0	06.0	02.3	25.9
	0.3	00.0	00.0	02.6	04.0	01.6	26.6
Clove	0.05	03.0	07.3	11.4	14.6	9.07	19.1
	0.1	02.2	06.6	08.5	12.6	7.4	20.3
	0.3	01.5	04.3	06.5	11.3	5.9	22.3
Control	27.0	23.0		26.0	37.0	28.2	-

Interaction of oils (A) with concentrations (B) and observation days (C)

	Oil (A)	Concentration (%) (B)	Days after application (C)	A x B	A x C	B x C	A x B x C
SEm ±	0.19	0.11	0.13	0.34	0.39	0.23	0.69
C.D. at 5%	0.52	0.30	0.36	0.94	1.08	0.63	1.91

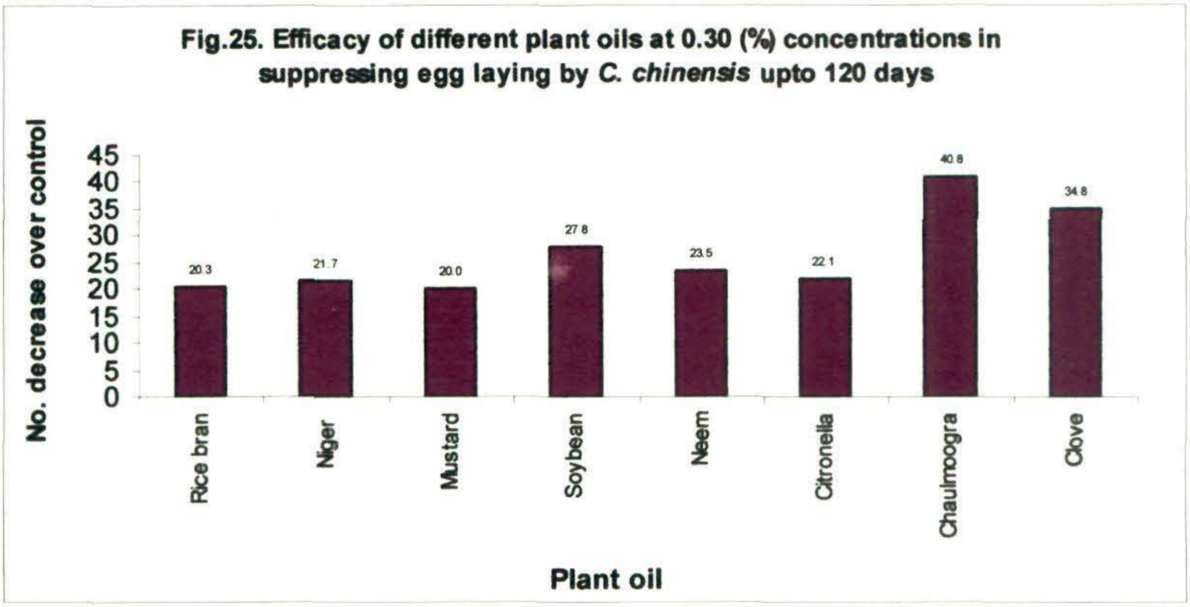


Fig.25. Efficacy of different plant oils at 0.30 (%) concentrations in suppressing egg laying by C. chinensis upto 120 days
No. decrease over control
45
40
35
30
25
20
15
10
5
0
20.3
21.7
20.0
27.8
23.5
22.1
40.8
34.8
Rice bran
Niger
Mustard
Soybean
Neem
Citronella
Chaulmoogra
Clove
Plant oil

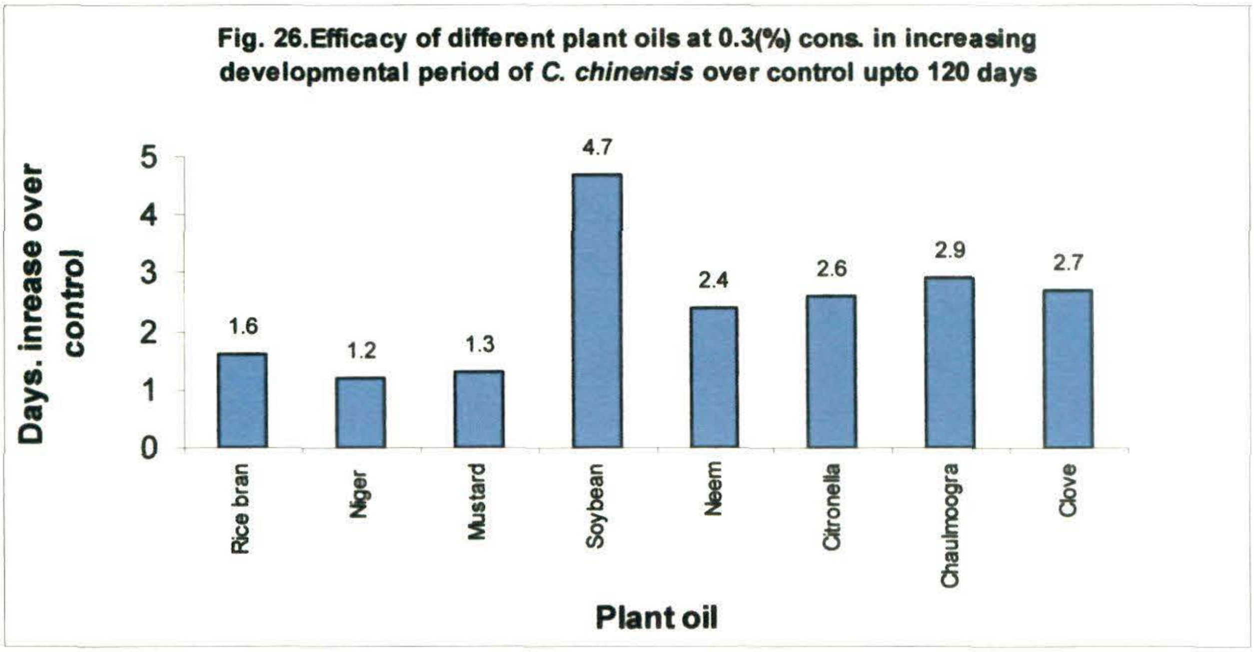


Fig. 26.Efficacy of different plant oils at 0.3(%) cons. in increasing developmental period of C. chinensis over control upto 120 days
Days. inrease over control
5
4
3
2
1
0
1.6
1.2
1.3
4.7
2.4
2.6
2.9
2.7
Rice bran
Niger
Mustard
Soybean
Neem
Citronella
Chaulmoogra
Clove
Plant oil

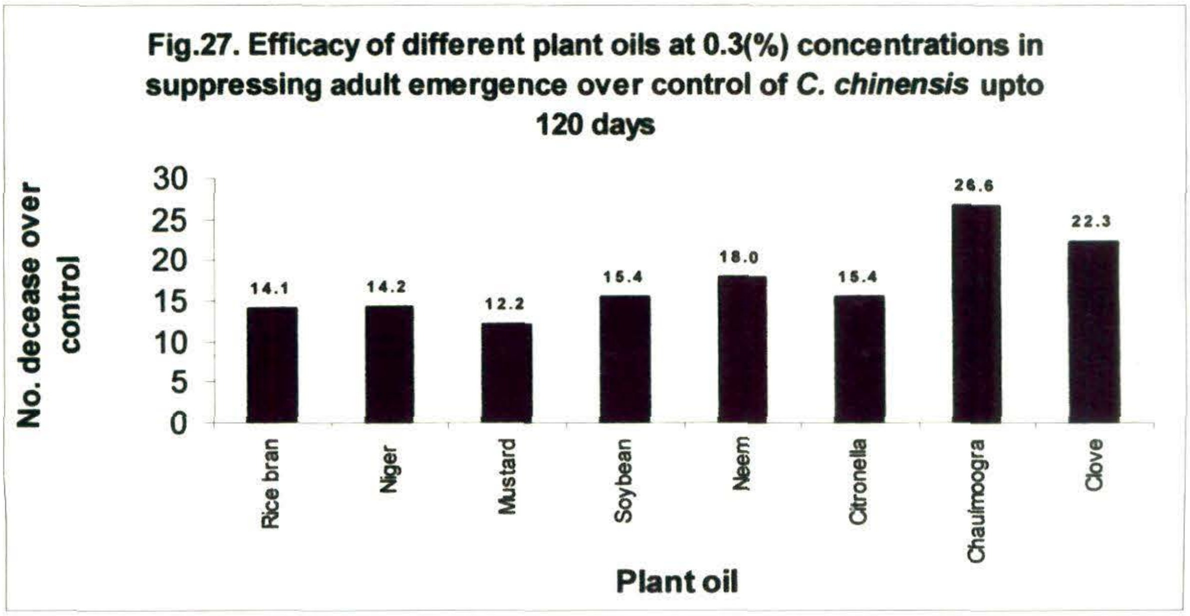


Fig.27. Efficacy of different plant oils at 0.3(%) concentrations in suppressing adult emergence over control of C. chinensis upto 120 days
No. decease over control
30
25
20
15
10
5
0
14.1
14.2
12.2
15.4
18.0
15.4
26.6
22.3
Rice bran
Niger
Mustard
Soybean
Neem
Citronella
Chaulmoogra
Clove
Plant oil

Chapter-V

DISCUSSIONS

DISCUSSIONS

5.1 Occurrence of insect pests, nature of infestation and their bio-control agents

Storage facilities at the village and assembling centre is still very poor. At the farm level the big growers store pulses in 'gola' made of bamboo and mud. The small and marginal farmers have no storage facilities due to which they forced to sell the produce immediately after harvest. The farmers of Terai Agro-ecological region West Bengal, India do not find any impetus for large scale production of pulses due to poor storage facility and suitable safe management. This becomes possible by undertaking a survey which involves the identification of the different species occurring over an area. India (8^0 - 30^0 North and 60^0 -97.5^0 East) has been recognized as one of the worlds' top mega-diversity nation and is very rich in faunal wealth. It has nearly 75,000 animal species where 80% of are insects (Agarwal,1999). The coleopteran includes some 2,50,000 species of beetles and weevils. Approximately 1,02,000 species of hymenopterans have been recorded and some 50% of these, primarily wasps, are parasitic (Narendran, 2001).The country demanded a clear comprehensive bio-safety under the conversions on biodiversity particularly, which are potential economic and scientific value. Insect pest and natural enemies of stored pulse of this Agro-ecological Region is still unexplored. The main objective of survey is to record different species of pests and their parasitoids on stored pulses, assess the levels of damaged of the pests, study the biological control potentiality of the natural enemies to define new species of pests and their control agents, marked endemic areas (here different district under Terai region) and finally launch timely protection measures.

The main objectives of pest survey is to detect species of pest on storage pulses and their natural enemies, assess the levels of infestation caused by the the pests, know new species of pests and their control agents. Another bruchid pest, *C. analis* which have already been reported from different countries likely India, (Lafrey,1909) island group of pacific (Archibald,1988), Kenya (Warni, 1984), Burma (Ghosh, 1939), Germany (Zascher, 1930), South Africa (Evans, 1939), Japan (Miyake, 1939), Bangladesh (Begum et al, 1984), Bulgaria (Sodomov, 1984), Australia (Whightman *et al*, 1982) South Africa (Evans,1939) and South Rodesia (Jack, 1936) but still it is not a dominant pest of storage pulses like *C. chinensis and C. maculatus.* Common and almost cosmopolitan insect pests of storage pulse namely *C. chinensis* Linn. is found to the most destructive pests of legume seeds like other countries including India as reported previously by Goncalves (1939), Colderon (1958), Morimota (1939), Pruthi and Singh (1950), Raina (1970), Southgate (1982) and many others. This species caused damaged to almost all pulses, which are cultivated locally except soybean, French bean, field pea and black gram (Table 2). The pea beetle, *Callosobruchus (=Bruchus) pisorum* Linn. was also recorded only on pea and their infestation occurred in the field and adult emerged out after few months in the storehouses. The insect, however, couldn't complete its life cycle in stored peas (Arora , 1977). Bruchids are an interesting world widely distributed group, most abundant in the tropics, whose larvae develops inside seeds, most preferred hosts belonging to the leguminous family and all together other 24 families have been recorded as host by Southgate (1978). Approximately 1300 species of bruchids have been recorded, mostly attack the growing crops, but they get carried into stores in the ripe pods and seeds and some species are successfully able to continue their development in the dry seeds (Hill, 1990). The Pulses are badly damaged by pulse beetles of the genus *Callosobruchus* (Coleoptera: Bruchidae) during storage throughout the world and this discourages the poor farmers from large-scale production and storage of pulses. In India, stored pulses are damaged by pulse beetles such as *C. chinensis* Linn.,*C. maculatus* Fab., *C. analis* Fab., *C. affinis* Frol., *C. emerginatus* All., *C. phaseoli* Gyll., *C. albacallosus* Pic., and *C. pisorum* Linn. Among these, *C. chinensis* is the most serious pest in India and also abroad.

The common and most destructive bruchid pest of stored pulses in India found to be *C. chinensis* (Goncalves, 1934; Colderon, 1958; Pruthi and Singh, 1950; Raina, 1970; Southgate, 1982 and many others). It is almost cosmopolitan and globally distributed. This species is distributed to all the districts of this region and egg-infestation occurred on green gram, grass pea, cow pea, lentil, black gram, chick pea, thakri kalai, pea, moth bean, horse gram, soy bean, kidney bean and small pea (Table 1). It caused damage to almost all the important pulses cultivated locally except the soybean, kidney bean and small pea. Black gram (*Vigna mungo*) and thakri kalai (*V. mungo silvestris)* is susceptible to this pests.

Another bruchid pest, *C. analis* which have already been reported from different countries likely Indian (Lefroy, 1909), Bangladesh (Begum *et al.,* 1984), Burma (Ghosh, 1937), Japan (Miyake, 1939), South Africa (Evans, 1939), Germany (Zachir, 1930), Australia (Whightman *et al.,* 1982), Kenya (Warni, 1984), Bulgeria (Sadonov, 1984) and South Rhodesia (Jack, 1936) but still it is not a notorious pest like *C. chinensis*. No mution of this species from terai region and from North Eastern part of India is found in the literature. During the survey it has observed that the beetle could not damage red gram, horse gram, chick pea, lentil, pea, cow pea, grass pea, soybean, kidney bean, moth bean and small pea (Table 9). They preferred to oviposit on the stored pulses – and damaged green gram, black gram and thakri kalai mostly in the indigenous store houses of this area.

C. maculatus is wide spread almost throughout the world and now almost cosmopolitan insect pest of stored pulses like *C. chinensis*. It was also reported from soybean (Howe and Currie, 1964) and kidney bean (Edward *et al.,* 1973). Oviposition and development of *C. maculatus* on nine legume seeds was studied during a survey in the Central part of India by Roy and Roy (1994). Chick pea is found to be most preferred followed by green gram, cow pea, lentil and red gram only. In the present survey, the occurrence of *C. maculatus* restricted only in Siliguri sub-division of Darjeeling and Islampur sub-division of Uttar Dinajpur only (Table 8). It is not a serious pest of stored pulses like that of *C. pisorum, Sitophilus* sp., *Corcyra cephalonica* and mention to be the minor pests of stored pulses. Pea beetle, *C. pisorum* has been collected only from pea seed and their biology could not evaluate in the laboratory. The infestation occurred in the field and adult emerged out in the laboratory. It is very uncommon race and host specific pest of peas in fields and distribution restricted to India (Arora, 1977), Russia, U.S.A., Africa (Smith *et al.,* 1982) and Bulgaria (Sadomov, 1988). All pests mentioned here are not reported previously from this region and no such extensive survey on stored pulses was done previously in North Eastern part of India.

A large number of biological control agents were collected but only few were identified till today. Among the natural enemies of stored pulses *Dinarmus vagabundus* and *Dinarmus* sp. (Hymenoptera: Pteromalidae), *Uscana mukerjii* (Hymenoptera : Trichogrammatidae), *Cerocephala dinoderi* (Hymenoptera : Pteromalidae) and *Bracon* sp. (Hymenoptera : Braconidae) have been recorded. *D. vagabundus, Dinarmus* sp. and *U. mukerjii* were the key parasitoids of bruchid pests whereas *C. dinoderi* and *Bracon* sp. were the minor parasitoid of *Sitophilus* sp. and *C. cephalonica* respectively. *Dinarmus vagabundus* was recorded as an important, gregarious larval-pupal ectoparasitoid of bruchid pests. Furthermore, *Uscana mukerjii* was a very minute, rare solitary potent egg parasitoid of bruchids (Mani, 1989 and Pajni *et al,*1976). These two are naturally occurring key parasitoids of Terai Agro-ecological Region of West Bengal, India.

The bio-control agent *Dinarmus vagabundus* (Hymenoptera : Pteromalidae) is a gregarious ecto-parasitoid of bruchid pests (Kundra, 1976) and their abundance is restricted to Hawaii Island of U.S.A., Brazil, India, Sri Lanka, Pakistan and French only (Timberlake, 1926; De Luca, 1966; Mani, 1939 and Rojas *et al.,* 1988). It was only reported from Northern zone of India and southern zone of India as a potential peresitoid of bruchids (Mani, 1989).

Cerocephala diondiri Gahan (Hymenoptera: Pleromalidae) is found once during the study and is a minor bio-control agent of stored pulses. *Bracon* sp. (Hymenoptera: Bracohidae) is also a minor control agent because *Corcyra cephalonica* rarely infested pulses (Baker *et al.,* 1995). *Uscana* *mukerjii* (Hymenoiptera : Trichogrammatidae) is a solitary potential egg parasitoid of bruchids (Pajni *et al.,* 1996) and appears to be a naturally occurring bruchids infesting stored pulses in this area. All the bio-control agents of stored pulses infesting different pests are reported for the first time from this agro-climatic region of W.B., India. Among them *Uscana mukerjii* and *Dinarmus vagabundus* was previously reported as potential parasitoids of bruchid insect pests.

5.2. Studies on bio-ecology of *Callosobruchus chinensis* on green gram (*Vigna radiata*) in the laboratory

The safety of storage from pulses depends on proper maintenance of room temperature and humidity. All these two abiotic factors are needed for the growth and development of bruchid pests. The fecundity of *C. chinensis* tends to increase from the period January- February. A study increase is maintained till July- August generation followed by a noticeable decline in fecundity in the next generation of August-September and ending at the generation of September- October the fecundity is minimum in the area of study. Obviously the population build up during the period of minimum fecundity can be arrested at a subthreshold level by adopting suitable control measure.

Hatchability percentage has been declined during June-September which is the rainy season and relative humidity has been the highest (above 80%) at this time. The correlation studies also proved that hatchability has a highly significant positive correlation with rrelative humidity. The emergence of adult also shows a some what similar kind of result although the best suitable months for the emergence of adults are November to May (r.h. was above 40%). The moisture above 80% disrupts the development of the beetle. The sex-ratio differs in different months, an almost 1 : 1 ratio was observed in January-February and July-August. Number of male adults emerged out were noticed to be higher than female except June-July, August-October and November-December (1994) studied the sex ratio in Bangladesh which was recorded 1 : 1. He could not mention the environmental conditions of that area.

The present investigation has been carried out round the year in the laboratory where temperature (°C) and relative humidity (%) varied in different seasons. Rearing protocol in the laboratory remained the same except the natural variations of temperature and relative humidity. Therefore, the differences in respect of the life history criteria of different generations in a year have been influenced by prevailing temperature and humidity. This observation is corroborates somewhat with Han and An (1990) and Pandey and Singh (1997). Han and An (1990) studied the bio-ecology of *C. chinensis* in Korea. The developmental duration increased as temperature decreased from 30 to 20°C. There were 4 generations in a year, with peak adult emergence in

May and over wintering took place in stored pulses. Pandey and Singh (1997) studied the biology of *C. chinensis* on *Vigna mungo* and *Cicer arietinum*. The incubation period lasted for 4-5 days and combined larval-pupal period for 20-28 days where temperature was 28^0C ± 5. *C. chinensis* is polygamous. The adult male mated several times (Begum *et al.,* 1987). The mated females started egg laying within 6-12 hours and usually laid single egg on single green gram seed when the seeds are sufficient in number (Utida, 1942).

Ovipositional period, incubation period, combined larval-pupal period, developmental period and life span of adult beetles varied significantly in different months. No such work on the biological periods has been periods were increased as temperature decreased (Parajulee *et al.,* 1989). Incubation period (9-12 days), larval-pupal period (34-37 days) and developmental period (43-51 days) was observed to be prolonged during January-February (Winter) followed by November to December (Winter) in this area. Shortest period of incubation, larval-pupal and developmental was observed during May (summer) followed by April-May (summer) and June-July (rainy season). Rajak and Pandey (1965) reported that the life cycle varied from season to season of with minimum 27 days and maximum 114 days. Moreover, the grabs hibernated during winter months from November-February. All mentioned parameters in this study are negatively correlated and developmental period was highly significant with both temperature and relative humidity (Table 13). Significant variations in the above mentioned biological parameters during different months might be due to climatologically differences especially temperature and relative humidity in the laboratory.

Information on growth index (GI) of the *C. chinensis* is not available for any month/season and from any area/place. As rebealed from growth index data provided in Table 11, the favourable environmental conditions for *C. chinensis* infestation has been March-May (1.83-2.19) (summer) followed by October-November (1.38) respectively. The number of generations of *C. chinensis* completed in a year is eleven. However, Parajulee *et al.* (1989) have recorded 13 overlapping generation/year at Chitwan district of Nepal. Han and An (1990) have obtained only 4 generations in a year in Central Korea where temperature ranged 12-30^0C. In the present area of study the optimum temperature (23.97-30.55^0C) and r.h. (52.11-68.91) for fecundity and development of *C. chinensis* was appeared to be during March-April (summer). Lhaloui *et al.* (1988) recommended optimal temperature for fecundity and development of stored product insect ranged 25-30^0C. Prevailing temperature (26.26-30.42^0C) as well as r.h. (72.11-85.21%) during rainy season of this area was not susceptible for the growth and development of *C. chinensis*. Atmospheric humidity during these periods (June-October) is considerably higher in comparison to that of other months. Humidity and grain moisture contents are closely related factors. Even though stored green gram seeds are dried to reach the safe moisture level before storage, moisture content in due course comes to equilibrium with humidity in the air.

5.3. Studies on bio-ecology of *Callosobruchus analis* on green gram (*Vigna radiata*) in the laboratory

Biology of *C. analis* is less known from the works of few researchers namely de Luca (1965), Howe and Currie (1964), Begum *et al.* (1984), Sadomov (1984) and Singh and Pandey (1997). Its distribution is still restricted to few countries and biology in relation to climatic condition is the warrant of research.

It is evident from Table 11 that the growth and development was somewhat similar to *C. chinensis* (De Luca, 1965). Total generation in a year has been noticed to be twelve. After the termination of over wintering of ovipositional, incubation, combined larval-pupal and development period was investigated during November-April, where March and April is the summer of this area. The rainy season favours the expeditions development as is evident from the developmental period (June-July). Both temperature and r.h.(%) have a highly significant positive correlation. Oviposition period, combined larval-pupal period, hatching (%) and longevity of adults show a negative correlation and significant with both temperature and relative humidity. Incubation period has a significant correlate but non-significant to r.h. (%). The fecundity is positive but non-significant. The growth and development (G.I.) have a positive correlation with temperature and negatively correlated with the r.h. (%). Adult emergence of this beetle also shows similar trend of result (Table 11). De Luca (1965) advocated that the biology of *C. analis* is similar to *C. chinensis*. Population of *C. analis* has been found to attain its optimum intrinsic rate 59-63% (Table 11) during summer (March-April) and minimum rate has noticed to be 9-13% during July-August which is the rainy season of this area. Growth index of *C. analis* also corroborates a somewhat simmilar observation. Longevity of adult male beetle is always higher than female in every generation. Sex ratio (female: male) is almost 1: 1 during the period of investigation. Optimal temperature prevails (27.12-28.39^{0}C) and r.h. (54.31-65.03%) was recorded for their growth and development during March-April. Most unfavourable temperature (28.56-30.09^{0}C) and r.h. (79.25-81.72%) has been recorded July-August which is the rainy season of this area. Heavy rain and humid atmosphere (**Appendix VI**) of this area hampered their biological activity. The present investigation is not coinciding with Begum *et al.* (1984).

5.4. Host preference and relative susceptibility of *C. chinensis* and *C. analis* to fourteen different species of stored pulses.

In free choice test, it appeared that both the species prefer to oviposit on seeds during summer in the following order green gram > red gram > pea > small pea > black gram > cow pea > soybean > moth bean > thakri kalai > grass pea > Bengal gram > kidney bean > lentil >

horse gram. Almost a similar result has been obtained during winter (Table 17). Among the host species, horse gram and lentil are the least preferred host of both the species. Observation made by Singh *et al.* (1980) was somewhat similar to the present study. Mehata and Chandel (1970) studied the host preference of *C. analis* to ten different species of stored pulses. The highest numbers of eggs were laid on cowpeas, followed by peas, green gram and black gram and a few on kidney bean, soybean, split gram and horse gram. No eggs laid were laid chick pea and lentil. The authors did not refer to the environmental condition or season of the study. Percentage of adult emergence of both the species differs significantly in respect of pulse species during summer and winter. Maximum emergence of adult beetles occurs during summer which is the suitable season than the winter. Emergence of *C. chinensis* and *C. analis* has been the highest from cowpea and the least from thakri kalai (*V. mungo silvestries*) and pea. A mere or less result has also been observed during winter also (Table 18). Both the species are unable to complete their growth and development in the soybean, kidney bean and small pea (Srivastava and Pant, 2000). It is to be mentioned that black gram (*V. mungo*) and thakri kalai (*V. mungo silvestries*) which are locally cultivated, are susceptible to *C. chinensis* whereas lentil of this area is also susceptible to *C. analis*. On the who;e, soybean, kidney bean and small pea are highly susceptible to both the species.

In case of no choice test, it has been observed that during summer *C. chinensis* lays the highest number of eggs on green gram and the lowest on kidney bean. Both the species lay maximum number of eggs during summer. Green gram is the most preferred host while least preferred host of both the species is kidney bean. However, both the species are unable to complete their life cycle on soybean, kidney bean and small pea as is evident from the total absence of adult emergence.

Ovipositional performance of *Callosobruchus* spp. on pulse species has been attributed to the seed weight (Raghupathi and Rangaswami, 1970), texture, color and shape (Gupta and Sehgal, 1987). *C. chinensis* can not cause damage soybean, horse gram, small pea and black gram whereas *C. analis* could not damage soybean, kidney bean, small pea and lentil (Fuji *et al.,* 1989). Singh *et al.* (1995) evaluated the effect of various bio-chemicals such as high protein, oil, starch and ash present in the seeds. Correlation studies of both the oil and starch with fecundity observed to be positive and highly significant where protein content was negatively correlated and highly significant. Contents of sugars and ash showed no significant correlation with fecundity. Lambrides and Imrie (2000) studied the susceptibility on green gram varieties.

In case of wild green gram, small size and presence of a well-formed texture act as ovposition deterrents. Fuji *et al.* (1989) again observed a resistance gene in *Vigna sublobata* race (a wild relative of *V. mungo*) which have had complete resistance against *C. chinensis, C. maculatus, C. analis* and *C. phaseoli.* Pandey and Singh (1997) observed that the mortality of all the stages of development of *C. chinensis* and *C. analis* was 27% and 15% respectively. In the present result the seasonal variations influence their biological activities especially their developmental periods although the oviposition and emergence of adult have been higher during summer and winter. Persistency of oviposition and adult emergence of both the species have a higher significance on soybean, kidney bean and small pea due to the physico-chemical properties of the seeds. The black gram (*V. mungo mungo*) seed (a wild relative of *V. mungo*) is completely resistant against *C. chinensis.* On the other hand, lentil seeds (*Lens esculentum*) are susceptible due to their small size. *C. analis* can not complete its development due to the shortage of space and food amounts. In addition to the physco-chemical factors the variations of biological parameters during two seasons are also responsible for the fluctuation of environmental conditions, especially the temperature and relative humidity (Menuson, 1935; El Sawaf, 1956; Howe and Currie, 1964).

Bruchid pests lay egg on stored pulses directly; the larvae enter into the seed boring the seed coat, enter within the seed coat and feed on the inner content of seed. Therefore, the seed weight, thickness of the seed coat moisture percentage of the seeds and bio-chemical substances (**Appendix XIII**) of the seed should be the main factors influencing their biological activities. Roughness of seed coat was apparently related to the susceptibility (Booker, 1967; Raghupathi *et al.,* 1970; Schalk *et al.,* 1973 and Choudhury and Pathak, 1989).

Epino and Morallo (1983) advocated that *C. chinensis* preferred to oviposit on hard, large and heavy seeds. Singal (1987) reported that thick seed coat acts as a barrier for penetration of 1st instar larvae. He also supported the observation made by Epino and Morallo (1983). On the contrary, Talekar and Lin (1992) demonstrated that smaller seed size of resistant pulse was not responsible for the resistance to *C. chinensis.* Similar findings were reported by Muhammad *et al.* (1997) and Padmavathi *et al.* (1999). In the present observation (Table 21) the seed weight has a significant negative correlation with the oviposition of *C. chinensis* whereas it shows a highly significant positive correlation in case of *C. analis.* The seed weight also shows a significant negative correlation with developmental period of both the species. Thickness of seed coat with the biological characters i.e. oviposition period, adult emergence and developmental period, have shown a non significant negative correlation.

Epino and Morallo (1983) recommended that the chemical component of green gram was correlated with the varietal susceptibility to *C. chinensis.* In the last decades, Telekar and Lin (1992), Sharma (1993), De Paula (1994), Modgil and Mehta (1994), Singh *et al.,* (1995), Oigiangbe and Onigbinde (1996) studied the physio-chemical properties of pulses. However, nothing is known about the exact causes for which the pulse beetle could not complete the growth and development inside the seeds namely soybean (*Glycine max*), kidney bean (*Phaseolus vulgaris*) and small pea (*Pisum arvense*). Malick and Singh (1980) stated that aromatic compounds with hydroxyl groups are widespread in all parts of plants. Phenols are said to be resistance to disease and pests in plants. Grains containing high around of polyphenol are resistant to bird attack. In this study kidney bean, soybean, small pea, pea, black gram contain to be higher phenol contents (Table 24). Moreover, from the study of the ovipositional preference, adult emergence and developmental period it appears that both are less susceptible to the kidney bean, soy bean, small pea, pea and black gram. On the whole, the correlation studies support the low level of infestation. Both the biological parameters were positively correlated and highly significant (Table 26). Among the different bio-chemical properties illustrated in the **appendix XIII** it should be mention that the phenol contents (Table 26) of the stored legume seeds appear to be the most important and significant criteria responsible for the susceptibility and persistency of bruchid pests.

From a critical analysis of results (Table 25) it is imperative that low phenol contents accelerate the oviposition, penetration of larvae as well as combined larval-pupal growth and development of bruchids. Pulses having higher contents of phenol prolong the developmental period, prevent the growth and development and results in the low preference of *C. chinensis* and *C. analis*.

5.5. Morphological study of the egg parasitoid, *U. mukerjii*

The first record of the Trichogrammatid chalicid genus *Chacetotricha* Girault (1911) was from India, with a redecoration of the species name as *Uscana* (=*Chaetotricha*) *mukerjii* was studied by Mani (1935). Latter on, De Luca (1965) reported and gave a taxonomical including their morphological characteristics. Though, detail morphological and sexual dimorphic characters of this naturally occurring potential parasitoid have not yet been revised. In this study, a detail comprehensive morphological feature including its morphometry of different parts of adults, sexual dimorphic characters with figures and illustrated micro-photography have been provided for further study. This potential solitary naturally occurring egg parasitoid has been recorded for the time in this region as a bio-control agent of the bruchid pests. First record of the Trichogrammatid genus *Chacetotricha* Girault (1911) from India, with a description of a new species name as *Uscana* (=*Chaetotricha*) *Mukherjii* was studied by Mani (1935) and Pajni *et al.* (1973). Mani (1989) redescribed its taxonomical note although a detail morphological and sexual dimorphic characters of this potential parasitoid has not yet been revised. In this study, a detail comprehensive morphological including its morphometry of different parts of adults, sexual dimorphic characters with draw-pictures and photography has been for further study of this typical genus (Stiffan, 1954) and first report from both *C. chinensis* and *C. analis* as a potential naturally occurring bio-control agent storage pulses.

5.6. Biology and parasitization potentiality of *U. mukerjii*

According to the earlier of reports, *Uscana mukerjii* (Mani) is a solitary egg parasitoid of *C. maculatus* (Mukerjee and Bhuya, 1936), *C. analis* (Chatterjee, 1953) and *C. chinensis* (Papai *et al.*, 1996). It has been observed in the present study that the ovipositional preference is determind by the age of host' eggs. The preference decreases with the advancement of age of the eggs. The development inside the eggs is accelerated with the increase of temperature. During winter the sex ratio is the lowest. The ratio increases with the rise of temperature in the assending order of rainy > autumn > summer. This result point out that low temperature stress during winter promotes higher number of female production for perpetuation of the species. The number of eggs are no problem, because one male can mate viably with more female. Also the increased temperature shortens the adult life span. The sex ratio at a temperature of 30^{0}C and 70% r.h. was approximately 1: 2.7 (Pajni *et al.*, 1996) in Punjab, India. This finding differs from the present result. Almost such a ratio has been obtained at a lower temperature of 24-27 ^{0}C during autumn.

Potentiality of parasitization is the to be highest during summer followed by rainy season. The prevailing temperature in the laboratory ranged from 26-30^{0}C which is the optimum temperature for parasitization. The maximum parasitization took place within 0-48 hours of egg layed by the host and declined thereafter. This solitary egg-parasitoid is naturally occurring in this area and very useful and easy to apply in stored pulses infested by *C. chinensis*.

5.7. Morphological study of the larval pupal parasitoid, *Dinarmus vagabundus*

In female, front surface of head and thorax black with bluish reflection, gaster is black with brassy luster. Gaster is always longer than the combined length of head and thorax. Antennae 13 segmented: 1.1.3.5.3. (annuli 3, 3rd annulus is sub square and flagel 5). Body length (2.04 mm.), wing span (3.79 mm.), length of forewing (1.41 mm.) and hind wings (0.75 mm.) are always longer than those of male (Mani,1989). *Dinarmus vagabundus* (Timberlake) confirmed its occurrence for the first time from Eastern India as a host and larval-pupal ecto-parasitoid of *C. chinensis* and *C. analis* on storage pulse, *Vigna mungo*. In comparison to earlier descriptions, a revision with a detailed description of its morphology, mouthparts, ovipositor apparatus and sexual dimorphism has been added for easy identification. Furthermore, the morphometry of sexual dimorphic characteristics of *D. Vagabundus* (Timberlake) such as body length and width, length of antennae, forewing, hind wing, hind leg, ovipositor apparatus, stinger etc including front surface color of head, thorax and gaster of both the sexes were not adequately described earlier.

5.8. Biology and parasitization potentiality of *D. vagabundus*

The female parasitoid with the help of its sharp and pointed ovipositor reaches and oviposits on the surface of host's larvae or pupae (Dhir, 1976 and Islam, 1995). The courtship (seconds) was recorded to be four time prolonged than the mating. Mating lasted for 15-45 seconds and male can mate with up to 38 females as observed by Kundra (1976). All the biological parameters namely courtship, mating or copulation, fecundity and sex ratio (male: female) show higher values during summer and lower during winter season. Adult'longevity of female always greater than that of the adult male during both the seasons. Developmental period also prolonged during winter. The temperature and relative humidity directly influence their biological activities. Dhir (1977) observed the variation of egg laying at different sets of temperature and r.h.(%).

The highest fecundity (47) has been recorded during summer and lowest during the winter. Dhir (1977) observed 9-26 eggs/female in his study although 'the actual count of fecundity is a difficult task' as emphasized by Islam (1995). The fecundity of *D. vagabundus* has the high rate of reproduction of the host. Temperature and relative humidity have direct impact on the biology. It has been observed in France that continuous brooding, semi-natural temperature and photoperiod cause the simultaneous occurrence of diapausing and non-diapausing larval stage in the spring season (Fabres and Reymount, 1991).

The emergence of adult from a single seed varied with different species of pulses. Kapoor (1972) was probably for the first time recorded the gregarious characteristics of the parasitoid. The potentiality of parasitization has been observed to vary with different species of stored pulses. On the average, the degree of parasitization is higher in summer when the average temperature is 28^{0}C and r.h. is 64.6 %, which seem to be the most favourable for their parasitization. *D. vagabundus* is not very frequently recorded in nature, it is regarded as an important larval-pupal ecto-parasitoid of bruchid. In the north astern part of India, this parasitoid may effectively be utilized as bio-control agents for suppression of the bruchid pest of pulses.

5.9. Effectiveness different plant oils on adult *C. chinensis*

Use of botanicals especially the various plant oils is one of the important alternatives to minimize excessive chemicalization of stored foods and seeds. The pesticidal contamination of pulses found to be above forty per cent in India. The presence of residues of synthetic insecticides widely used in storages has proved toxic to humans, domestic animals, birds and non-target faunas of storage ecosystem (Dhaliwal & Arora 1998). So far over 200 plant species belonging to 60 families are known to possess pesticidal properties and they are comparatively safer to mammals due to their biodegradable nature. The work done so far by entomologists to test the pesticidal properties of different genera of plants is mainly restricted to *Azadiracta, Pongomia, Cassia, Clerondron, Eupatorium, Acorus, Chenopodium, Eucalyptus, Mentha, Ocimum, Piper, Progostemon, Callistemon, Brassica, Sesamum, Cocos, Glycine, Helianthus, Elaeis, Ricinus* etc.(Agarwal *et al* 1973; Deshpandey *et al* 1974; Deshmuk *et al* 1975; Pandey *et al* 1976; Hill & Schoonhoven 1981; Ali *et al*1983; Ketkar *et al* 1986; Stanislow *et al* 1995; Dewadi & Maheswaswari 1996; Pandey & Singh 1997; 1998; Negi *et al* 1997; Pandey *et al* 1998).

It was observed that non-edible oils at the concentration of 0.01 were very effective. The highest (100%) mortality at this concentration was the maximum in case of chaulmoogra oil (100%) followed by clove oil (90.0%), citronella (36.3%), and castor (10.0) and neem (9.00%). At subsequent lower concentrations (0.001, 0.002 and 0.005) neem and castor oils had no such effect. The death caused due to both edible and non-edible oils differed significantly at different concentrations. The non-edible oils were more effective to cause the death of adult beetles. The dose dependant efficacy of the oils in this result corroborates the earlier observation by Pandey & Singh (1997) who worked with some other oils. Among the all fourteen plant oils tested at 0.01% concentration, chaulmoogra (*Hydnocarpus kurzii*) oil appeared to express the best pesticidal effect on the adult beetle followed by clove, safflower, citronella, sesame and soybean. Uses of botanicals as protectants of stored grains have had long history of use by farmers. The actual mechanism of their toxicidal effect on insect is not known but the basis may either be physical or bio-chemical or both. The oils may affect the respiration leading to asphyxiation of the insect pest (Pandey & Singh1997). The commonly observed secondary bio-chemical compounds particularly the fatty acids, acids, esters, enzymes and alcohol's of different oils may be responsible for insects' death. These secondary metabolites of the plant oils (Table 1), which have no known function in photosynthesis, growth or other aspects of plant physiology, may be the effective protectants of the plants against the insect attack (Bell *et al* 1990). Plants oils which provide large or economic yields of these key bio-chemical secondary metabolites may responsible for insects' death. They can affect insects in several ways: they may disrupt major metabolic pathways and cause death, act as attractants, deterrents, phago-stimulants, anti-feedants and retard or accelerate development of insect biology.

Among the plant oils tested in this study, the non-edible oils were more toxic on the adult beetles than the edible oils. It has also been mentioned that the mortality of adult *C. chinensis* was directly proportional to the increase in percent concentration (v/v) of the oils (Pandey and Singh, 1997). According to Agarwal *et al.* (1973) and Despande *et al.* (1974) non-edible oils namely *Aconus calamus* and *Progostemon* sp. were more toxic to *C. chinensis.* In another laboratory experiments, essential oils of *Callistemon citrinus* and *Expatoriun capillifolium* were found to be tonic to *C. maculatus* (Misra *et al.*(1989). Non edible oils likely geranium, citronella, basil and rue had insecticidal effect against *C. chinensis* whereas lemon, eucalyptus was not toxic to adult (Richa *et al.*, 1993).

In the present study, the extracted oils at different concentrations were exposed (24 hours) to adult *C. chinensis*. Both edible and non-edible oils were significantly differed at different percent concentrations. Chaulmoogra (*Hydnocarpus kurzii*) oils found to be highest toxicidal effect on the adult beetle followed by clove, safflower, citronella, neem and soybean (Graph -). Majeed et al. (1994) studied the toxicity neem fruit extracts against C. avali and the order of efficacy was acetone extracts methanol extract. According to Stanislow *et al.* (1995) neem oil is now produced commercially and exhibits enormous potential as insecticide due to the presence of bio-chemical properties. Citronella oil has some important aromatic compounds such as geranoil, citronellol (alcohol) and their derivatives. Maity (1988) worked out the main fatty acids namely linoleic, lauric, myristic, palmitic, oleic, caprylic (ester), capric (esters), azadirachtin (ester), stearic from the vegetative oils. Chaulmoogra is a indigenous medicinal oil having two imported fatty acids namely chaulmoogric and hydnocarpic acids (Chopra *et al.*, 1994). Use of botanicals as protectants of stored grains have had long history of use by farmers. The actual mechanism of their toxicidal effect on insect is not known but it should be both physical and bio-chemical (Singh, 1997). The commonly observed bio-chemicals and their fatty acids, esters and alcohol's **(AppendixX)** may responsible for insects' mortality. The presence of so-called secondary aromatic compounds of the plant oils, which have no known function in photosynthesis, growth or other aspects of plant physiology, gave plant materials or their extracts their anti-insect activity. The mode of action of these oils is partially attributed to influence the normal respiration, resulting in suffocation.

In view of encouraging results obtained in this study, the chaulmoogra, clove, safflower, citronella, soybean and sesame oils appear to have distinct potentiality as bio-pesticides and good additives for the management of insect pests especially the most notorious bruchid pest, *C. chinensis* (Coleoptera: Bruchidae).

5.10. Efficacy of different plant oils in protecting stored green gram up to 120 days against the attack of *C. chinensis*

With a view to developing a alternative approach for the safe management of pulse beetles, several control measures (Oils, containers, ashes, synthetic chemicals, physio-chemical factors and bio-control agents) has been chosen, assessed, evaluated and documented by many researchers namely Kachare *et al.*(1994), Islam (1999), Singh *et al.* (1994), Negi *et al.* (1997), Pandey and Singh (1997), Mummigatti and Raghunathan (1997), Babu *et al.*(1989), Kahaire (1992) Begum and Quiniones (1990), Pereira (1983), Sujatha and Punnaiah (1985) and many others. For poor or small farmers plant seed oils could be better option because these are easily available, low cost device and easy to apply. On the other hand, for big farmers/traders, the use of the oils might also be advantageous to protect stored pulses from insect attack either for food or seed purposes. In the present study, among the plant oils, chaulmoogra and niger have been trialed for the first time to protect stored pulses from bruchid attack. Many researchers have studied the efficacy of various vegetable as well as non-vegetable oils as protectants of stored pulses against bruchid pests.Most of the studies involved short term observation. A long term and dose related investigation is urgently required for evolving a protection schedule. In the present study, a dose specific protection has been explored for a storage period up to 120 days.

All the observations (Table 36-38) and figures (23-25) reveal that all the treatments and experiments are found to be statistically significant. In view of encouraging results obtained in this study, the number of egg-laying and adult emergence have decrease a noticeably over control (untreated seeds). The developmental period of the beetle has been prolonged considerably than in the control. The chaulmoogra oil has appeared as the most effications and promising than all other vegetable oils. No information is available whether this oil cause any hazard to human health. Hence, it is premature to recommend for protection of pulses meant for human consumption. But this oil does not impair germination of the seeds. Hence, this oil has a distinct potentiality for storage of pulses for seed purpose. The next promising oils in respest to suppressing egg-laying and adult emergence have been the clove, soybean, neem and citronella. Soybean oil also prolongs the developmental period followed by choulmoogra, clove, neem and citronella. Considering the efficacy of chaulmoogra, a dose of 0.3 (v/w) per 100 grams of green gram seeds appears to be the best quite a long term of storage. Moreover, the oils of clove and soybean can be considered as good protectantsat least up to a period of 120 days.

D. vagabundus (Timberlake) (Hymenoptera:Pteromalidae) is gregarious ecto-parasitoid of pulse beetle (Kundra, 1976). It is very uncommon and their abundance is restricted on in India, Sri Lanka, Pakistan, Brazil and France (De Luca, 1966; Rojas, 1988; Mani, 1989). This parasitoid is first time reported from this region and also from Eastern Zone of India. It is previously reported from Punjab, Karnataka and Tamil Nadu states of India (Mani, 1989).

In female, front surface of head and thorax black with bluish reflection, gaster is black with brassy luster. Gaster is always longer than the combined length of head and thorax. Antennae 13 segmented: 1.1.3.5.3. (Annuli 3, 3rd annulus is sub square and flagel 5). Body length (2.04 mm.), wing span (3.79 mm.), length of forewing (1.41 mm.) and hind wings (0.75 mm.) are always longer than those of male. Timberlake (1926) first described and designated *D. vagabundus* from other allied species *D. acutus* which is the type species of *Dinarmus*. Latter on, Mani (1939), Boucek *et al.*(1978) and Mani (1989) redescribed and illustrated its morphological characteristics. Unfortunately, no comprehensive study of this naturally occurring potential bio-control agent of *C. chinensis* with special emphasis to their ovipositor and sexual dimorphic characters has been published so far. *D. vagabundus* confirmed its occurrence for the first time from Eastern India as a host and larval-pupal ecto-parasitoid of *C. chinensis* and *C. analis* on storage pulse, *Vigna mungo*. In comparison to earlier descriptions, a revision with a detailed description of its morphology, mouthparts, ovipositor apparatus and sexual dimorphism has been added for easy identification. Furthermore, the morphometry of sexual dimorphic characteristics of *D. vagabundus* such as body length and width, length of antennae, forewing, hind wing, hind leg, ovipositor apparatus, stinger etc including front surface color of head, thorax and gaster of both the sexes were not adequately described earlier.

Chapter-VI

SUMMARY

SUMMARY

The Terai Agro-ecological Region of West Bengal (Location: $25^0 57'$- 27.0^0 N and $88^0 25'$-$89^0 54'$ E and Altitude: 40-50 meter) is under the North Eastern Plain Agro-ecological Zone of India and is a part of the Tropical Humid Climatological Zone of the World. The insect pests of stored pulses of the Terai Region are very rich, diverse and still unexplored. Total survey area covered during the present study was 12015 sq. km. including four administrative districts, ten sub-divisions and thirty two blocks. Pulses in this region are largely stored by the farmers in indigenous store houses/devices. This region is characterized by prolong rainy season coupled with worm humid condition that favours multiplication of insect pests of stored grains including stored pulses. However, dynamics of pests on stored pulses their extent of damage, natural enemy complex and safe management is still unexplored. The thesis embodies the results of investigation on the occurrence of *Callosobruchus* spp., their biology and preference for pulse species, extent of damage caused by these pests, their parasitoids, and efficacy of the parasitoids in suppressing the population of *Callosobruchus* spp., and safe management of the insect pests using botanicals, particularly the plant oils.

A survey was conducted during the period from 1999 to 2002 in indigenous storage of farmers and markets on different species of *Callosobruchus* spp. Infesting different species of pulses *Vigna radiata* (green gram or mung), *V. mungo* (black gram), *V. aconitifolia* (moth bean), *V. catiang* (cowpea), *Lathyrus sativus* (grasspea), *Cajanus cajon* (red gram or pigeonpea), *Cicer areitinum* (Bengal gram or chickpea), *Pisum sativum* (field pea), *Lens esculentum* (lentil), *Dolicos biflorus* (horse gram) *Glycine max* (soybean) *Pisum arvense* (small pea or garden pea) and *Phaseolus vulgaris* (kidney bean). Four pest species of the genus *Callosobruchus* infesting stored pulses were recorded. Among them, *Callosobruchus chinensis* (Coleoptera:Bruchidae) was the most notorious pests of green gram, lentil, red gram, black gram, cowpea, grass pea, pea and Bengal gram, horse gram, moth bean. *C. analis* and *C. maculatus* were the next harmful insects caused damage to pulses. *C. analis* preferred mainly the black gram, green gram, grass pea and cowpea. Whereas *C. maculatus* preferred cow pea, green gram, black gram and grass pea. Another bruchid, *Callosobruchus(=Bruchus) pisorum* was specific to pea as host. Its infestation takes place in the field, and the adult beetles emerge after few months in the storage. It can not complete its biology in the storage.

Among the natural enemies of *Callosoburchus* spp. Of stored pulses, *Dinarmus vagabundus* (Timberlake) (Hymenoptera: Pteromalidae), *Uscana mukerjii* (Mani) (Hymenoptera:

Trichogrammatidae), *Cerocephala dinoderi* Gahan (Hymenoptera: Pteromalidae) and *Bracon* sp. (Hymenoptera : Braconidae) were recorded during the survey. *D. vagabundus* and *U. mukerjii* were the key parasitoids of bruchid pests whereas *C. dinoderi* and *Bracon* sp. were the minor parasitoid of *Sitophilus* sp. and *C. cephalonica* respectively.

In the area of investigation the damage caused by the bruchids, *C. chinensis* and *C. analis*, has been maximum on green gram followed by black gram, lentil, grass pea, cow pea, red gram, chick pea and pea. The bruchids could not damage soybean (*Glycine max*), Frenchbean (*Phaseolus vulgaris*) and smallpea (*Pisum arvense*).Quantitative weight loss (%) of green gram caused by *C. maculatus* recorded to be maximum followed by *C. analis* and *C. chinensis*.

The bio-ecology of *Callosobruchus chinensis* and *C. analis* has been studied in the laboratory maintaining natural temperature and relative humidity. The biological parameters such as oviposition, hatchability, adult emergence, ovipositional period, incubation period, combined larval-pupal period, total developmental period, longevity of both the sexes of adults and growth index were observed for three consecutive years from 1999 to 2002. Altogether *C. chinensis* completed 11 generations and *C. analis* completed 12 generations in a year. In case of *C. chinensis* the data on monthly incidence revealed that egg infestation occurred almost round the years but reached to the maximum level during June-July (95.6%), March-April (93.8%) and July-August (93.2%). The infestation gradually decreased to a minimum up to December and again increased up to March. The percentage of adult emergence was the maximum during March-April and minimum during the period from June-September. Developmental period of *C. chinensis* was the shortest in May when temperature was the maximum. It increased with the decreasing temperature. Hatchability of eggs was minimum during June-September (rainy season) when the relative humidity was maximum in comparison to other months. Sex ratio of *C. chinensis* was always female dominated except during the period from Aug. to September (female: male=1:1). For the growth index, March-April was the most suitable for their growth and development (G.I. = 2.19) whereas the maximum retardation of growth and development was recorded during August- September (G.I.= 0.52). All the bio-ecological parameters showed a significant negative correlation with temperature and r.h. except the fecundity. The fecundity of *C. chinensis* had a highly significant positive association to temperature and relative humidity.

The fecundity of *C. analis* was the maximum during the period from March-July although the adult emergence did not correspond to the fecundity. Adult emergence was the least during July. Hatchability also showed similar pattern of result. March to April was the most suitable for their growth and development (G I = 1.98). January to February was the least preferred months for them. All the bio-ecological parameters had significant negative correlation and significant only the fecundity showed a highly significant positive association and highly with the temp. and relative humidity.

Relative susceptibility of *C. chinensis* and *C. analis* to the 14 pulse species have been studied. Ovipositional performance was dependant on the seed texture, seed weight, thickness of seed coat, seed moisture and phenol contents of seeds. The fecundity and adult emergence of the bruchids showed a highly significant positive correlation with phenol contents. Higher phenol contents of *Glycine max* (soybean), *Pisum arvense* (small pea) and *Phaseolus vulgaris* (kidney bean) resulted in complete inhibition of adult emergence of the bruchids. The phenol content > 0.87 mg/g of seeds drastically retarded the growth and development of bruchid pests.

Dinarmus vagabundus (Timberlake) was recorded for the first time from North-astern India as an important, gregarious larval-pupal ectoparasitoid of bruchid pests. The earlier description, it was revised through systematic detail and description of its morphological features especially morphometrical diagnosis, structure of mouthparts, genital apparatus and sexual dimorphism. Furthermore, the morphological study of a very minute, rare solitary potent egg parasitoid (*U. mukerjii* Mani) has been also revised. It is also a first time record from the North-eastern India as egg-parasitoid. These two are naturally occurring key parasitoids of bruchid pests.

The potentiatiality of using *D. vagabundus* and *U. mukerjii* as biological control agents have been explored in laboratory studies. Their biology has been studied during summer and winter seasons. Fecundity and percentage of parasitization were always higher in summer. It has also been observed that the parasitization percentage showed significant variation on different species of stored legume seeds infested by *C.chinensis*. It was maximum on cow pea (27.01) during summer followed by green gram, red gram and chick pea. The parasitization potentiality of *D. vagabundus* did not correspond to the high rate of reproduction but the capacity to penetrate the stored seeds and kill/paralyze the larva/pupa of *C.chinensis* by their modified strong ovipositor has distinguished this parasitoid from other hymenoptera parasitoids. Its larval-pupal diapauses (quiescent period) for 2-3 months during winter season has also been recorded. This diapause properly opens the scope of utilization of *D. vagabundus* as a bio-control agent for the management of stored pulses later on from the excessive damage by *C.chinensis*.

Uscana mukerjii was also found as naturally occurring solitary endo-parasitoid of *C.chinensis* eggs. It preferred to oviposit 0 to 48 hr. old bruchid eggs deposited on the surface of stored pulse seeds. Biology and potentiatiality of parasitization of *U. mukerjii* have been studied during winter, autumn, summer and rainy seasons in the laboratory. Total developmental period was longest during winter (15 days) and the shortest recorded during rainy seasons. The beneficial role of this parasitoid in regulating pest population and its use as bio-control agent is recognizable; Parasitization percentage has been maximum during summer (49.6) which was followed by rainy (48.9), autumn (39.5) and winter (35.2). Its growth and development varied significantly in different seasons and were influenced by temperature and relative humidity.

The philosophy and practices of I P M will continue to change and will remain dynamic simply because of its diverse nature and range of faunal appearance on the stored pulses. The effectiveness of easily available plant oils were used to test on adult *C. chinensis*. Present investigation also included to evaluate the efficacy of different plant oils and to find out more effective means of stored pulse managements that leaves no toxic residue, hazardous to health and environment. The indigenous plant oils are comparatively safer to man due to their biodegradable nature. Use of plant oils on botanicals is assumed to be an important approach to pest management. Insecticidal effect of different edible oils such as of rice bran *(Oryza sativa)*, sesame (*Sesamum indicum*), mustard (*Brassica juncea*), soybean (*Glycine max*), coconut (*Cocos nucifera*), niger (*Guizotia obyssinica*), safflower (*Carthamus tinctiorius*), palm (*Elaeis guineensis*), sunflower (*Helianthus annuus*) and non-edible oils such as of neem (*Azadirachta indica*), citronella (*Cymbopogon winterianus*), castor (*Ricinus communis*), clove (*Eugenia* sp.) and chaulmoogra (*Hydonocarpus kurzii*) were evaluated on the adult *C. chinensis*. It was evident that the non-edible oils were more effective to cause death of adult beetles. Among them, chaulmoogra oil was the most effective to cause death of adult at 24 hours of exposer. Other oils namely soybean, clove, safflower, citronella, neem and castor were also found promising to kill the adults.

Through the effective utilization of the finding under present investigation, the legume seeds can be stored at least up to a period of for four months using botanical oils as protectants against the bruchid to save food, seed, feed and sale. An adverse effect on oviposition of *C. chinensis* was observed which ultimately increased storage ability of seed. Gradual decline in egg laying was recorded with the rise of concentration (0.05 – 0.03% v/w) of all the oils. Among the different edible and non-edible oils, the persistency of toxicity was the longest (120 days) from chaulmoogra oil, followed by clove oil. Suppression of egg laying and adult emergence has been assessed on 30. 60, 90 and 120 days after treated with the oils. Interactions of different oils, their concentrations and days after applications were significantly different from the control (untreated seeds). The developmental period of *C. chinensis* was prolonged in the seeds treated with soybean, clove and chaulmoogra oils. All these plant oils are locally available and cheap, hence easily accessible to the poor farmers and also advantageous to stored pulses for commercial traders. Easy availability, higher biodegradable nature and non-hazardous properties as well as low cost of most of the oils as compared to synthetic pesticides once again focus attention to the use of the potentially promising plant oils as an alternative to the management of insect pests(*C.chinensis*) of stored pulses.

REFERENCES

REFERENCES

Abbott, W.S. (1925). A method of computing the effectiveness of an insectiside. *J. Econ. Ent.*, **18**(1):265-267.

Acharya, K.T. (1990). Oilseed and Oil Milling in India: A Cultural and Histotical Survey. Oxf. & IBH Pub. Co. Pvt. Ltd., New Delhi. PP. 104-311.

Agarwal, D.C., Deshpande, R.S. and Tipnis, H.P. (1973). Insecticidal activity of *Acorus calamus* on stored grain insects . *Pesticides*. **7**(4) :21.

Agarwal, K.C. (1999). Biodiversity. Agro Botanica, New Delhi. pp.1-1

Agarwal, N.S., Christensen, C.M. and Hodson, A.C. (1957). Grain storage fungi associated with the granary weevil. *J. Econ. Entomol.,* **50** : 659-663.

Agarwal, R.L. (1980). Moisture determination. In, *Hand Book of Seed Testing,*(ed. R.L. Agarwal),Oxford & IBH Pub. Com., New Delhi pp. 507-508.

Agarwal, S.C. (1989). Effect of stem inoculation of phytophthora stem blight on phenol contents in pegion pea. *Indian Journal of Pulses Research*. **2** (1) : 39-41.

Agrawal, P.K. (1993). Moisture determination.. *Hand Book of Seed Testing* (ed. Agrawal, P.K.) pp. 104-115.

Ahmed, K., Khalique, F., Khan., I.A, Afzal, M. and Malik, B.A. (1991). Studied on genetic resistance in chickpea (*Cicer arietinum*) to bruchid beetle (*C. chinensis*) attack. *Pakistan J. Sc. Ind. Res.*, **34** (2): 449 – 452.

Ahmed, K.N.; Nargis, A. and Husain, M.M. (1997) Parasitization of different stages of the host, *Callosobruchus maculatus* F. inferting different pulses by D*inarmus basalis* (Rond) (Hymenoptera:Pteromalidae).*Bangladesh J. Sci. Indus. Res.* **32**(1):35-38.

Ahmed, S.E., Kamel, A.H. and Wahab, A.E.A. (1981). A study of the duration of the different stages of *Callosobruchus chinensis* L. and *Callosobruchus maculatus* F. under constant conditions (Coleoptera, Bruchidae). *Agriculture Research Review*. **56** (1) : 151-154.

Akhtari, N., Sardar, M.K., Rahman, M.H., Abedin, S.M.Z. and Rahman, A.K.M.M. (1993). Feeding and ovipositional preference of pulse beetle, *Callosobruchus chinensis* L. on different genotypes of bean and its control. *Annals of Bangladesh Agriculture*. **3** (2) : 63-69.

Alam, M.Z. (1971). Pests of stored grains and other stored products and their control. *Agric. Inf. Ser.*,Dacca, pp. 61.

Alebeek, F.A., Van, A.A.(1994). A survey of bruchid pests and their parasitoids stored cowpea in Niger. *Proc. Selec. Exp. Appl. Ent.*, **5:** 145-150.

Al-Chalabi, B.M., Mahdi, M.T., Suhaily, I.A., Al-Bahadily, A.H. and Chalabi, B.M. Al.(1984) Effect of alfatoxins product in stored products on the biology of *Callosobruchus maculatus* F. *J. Bio. Sc. Res.*; **15**(2): 13 – 28

Ali, S.I., Sing,O.P. and Misra, U.S.(1983). Effectiveness of plant oils against pulse beetle, *Callosobruchus chinensis* . *Indian J. Ento.*, **45**(1): 6-9.

Amuti, K. and Larbi, M. (1981). Post-harvest losses in the bambara and geocarpa groundnut seeds stored under traditional conditions in Ghana. *Tropical Grain Legume Bulletin,* **23**: 20-22.

Anderson L.E. (1973). *The Encyclopedia of Microscopy and microtechniques.* Van Nostrand Reinhold Comp., New York. pp. 56-58.

Anderson, P.P. (2000).Insufficient Investment. In, *The Hindu Survey of Indian Agriculture.* pp. 21-23.

Antunes De Almeido, A.(1956).The insects of stored tobacco. *Estudos Ensaios Docum.,* **16**: 1-111 (In Portugese).

Archibald, R.D.; Maddison, P.A.(1988).A summary of stored product coleopteran in New Zealand and neighbouring Pacific countries. *New Zealand Ent.,* **11** : 1-6.

Arora, G.L. (1977). Bruchidae of Northern India oriental Insects (Supplement). *J. Systemic Ent., Geography of South and South East Asia.,* 1-116.

Arora, G.L. and Singh, T.(1970). The biology of *Callosobruchus chinensis* (Bruchidae: Coleoptera). *Res. Bull. Punjab Univ.* Punjab, India., 21 (1-11): 55-65.

Arora, R. (1999). Major Insect pests of rapeseed mustard and their management, In IPM System in Agriculture (ed) Aditya Books Pvt. Ltd., New Delhi India. *Oilseeds.,* **5**: 35 – 75.

Ashmead, W.H. (1904). Classification of the chalcid flies of the superfamily chalcidoidea, with descriptions of new species in the Carnegie Museum, collected in South America by Herbert H. Smith., *Mem.Carnegie Mus.,* **1**(4):1-9, 225-551.

Ashraf, M., Sohail, A., Akhtar, M. and Ali, A. (1991). Varietal resistance of pulses to dhora (*Callosobruchus chinensis* L.). *J. Agril. Res.,* **29** (1): 81-86.

Asthana, A.N. and Chaturvedi, S.K.(1999). A little impetus needed. *The Hindu Survey of Indian Agriculture.* pp. 61-65.

Atwal, A.S. (1968). Studies on the growth of population of *Trogoderma granarium* Everts and *Callosobruchus analis* Fabr., *Indian J. Ent.* **30** (3): 185 – 190

Aykroyd, C., Ramsastri, B.V. and Balasubramanian, S.C. (1977). Legumes in Human Nutrition., FAO International Studies No. 19.

Ayyar, P.N.K. (1934). A very destructive pest of stored products on South India *Corcyra cephalonica* Staint. (Lep). *Bull. Ent. Res.,* **25**: 155-169.

Babu, T.R., Reddy, V.S. and Hussaini, S.H. (1989). Effect of edible and non-edible oil on the development of the pulse beetle (*Callosobruchus chinensis*) and an viability and yield of mungbean (*Vigna radiata*). *Trop. Sci.,* **29**(3):215-220.

Bahr, J. (1980). Harmful occurrance of the bruchids *Callosobruchus chinensis; Acanthoscelides obtectus* Say and *Bruchus affinis* Frol. *Nachrichtenblatt fur den Pflanzenschutz in dir* DDR., **34** (9) : 195-196.

Baker, J.E., Weaver, D.K., Thorne, J.E. and Zettler,J.L.1995.Registance to protectant insecticides in two field strains of stored product insect parasitoid *Bracon hebetor* (Hymenoptera:Braconidae). *Journal of Economic Entomology.* **88(3)**:512-519.

Bato, M.S. and Sanchez, F.F. (1972). The biology and chemical control of *Callosobruchus chinensis* (Coleoptera: Bruchidae). *Philippine Ent.,* 2(3) :167-182.

Begum, A., Ahmed, M., Seal, D.R.(1984). Influence of temperature on population increase of pulse beetle *Callosobruchus analis* Fabricious (Coleoptera: Brachidae). *Bangladsh J. Zool.* **12** (1): 21-26.

Begum, A.; Rahman, M.S. and Seal, D.R. (1982). Comparative morphology of the larval instars of *Callosobruchus chinensis* L. and *C. analis* (Coleoptera: Bruchidae).*Bangladesh J. Zool.* ,**10** (1) : 67-79.

Begum, D.A., Taslima Khan, M.Z.A., Khatoon, N., Howlader, A.J. and Ahmed, M. (1987). The influence of mating on fecundity, fertility and adult longevity of pulse beetle, *Callosobruchus chinensis* L. *Annual Bangladesh Science Conference*, Dhaka, Bangladesh, 10-14 Jan, 1987.

Begum, D.A.; Taslima; Khan, M.Z.A.; Khatoon, N.; Howlader, A.J. and Ahmed, M. (1987). The influence of mating on fecundity, fertility and adult longevity of pulse beetle, *Callosobruchus chinensis* L. Annual Bangladesh Science Conference, Dhaka, Bangladesh, 10-14 Jan, 1987.

Begum, S. and Quiniones, A.C. (1990). Protection of stored mung bean seeds from bean weevil, *Callosobruchus chinensis* by vegetable oil application. *Bangladesh J. Zool.*, **18**(2):203-210.

Bhagwati, V.R., Bodhade, S.N., Aherkar, A.K. and Narsinghani, V.G. (1995). Laboratory studies on the relative susceptibility of same pea (*Pisum sativum* Linn.) genotype to pulse beetle (*Callosobruchus chinensis* L.). *Pestology.* **29**(11): 24-27.

Bhujbal, A.R., Bhole, S.R. and Karmakar, M.S. (2001). Effect of residual toxicity of some insecticides and neem oil as pigeon pea seed protection on loss in seed weight and germination of seed against *C. maculatus* Fab., *Pestology.***25** (2): 44-47.

Booker, R.H. (1967). Observations on three bruchid species associated with cowpea in Northern Nigeria. *J. Stored Prod. Res.* **3**: 1-15.

Borikar, P.S. and Pawar, V. M. (1996). Life fecundity tables for pulse beetle, *Callosobruchus chinensis* Linn. infesting mung bean, *Vigna radiata* (Wilezek). *J. Ento. Res.*, **20** (1): 59-65.

Borowick, L. (1980). Beetles Coleopteran. Bean weevils Bruchidae. *Klucze do Oznaczania Owadow Polski.*, **19** : 51-93.

Boshra, S.(1993). Effect of the different factors on the biology of *Callosobruchus chinensis* L. (Coleoptera: Bruchidae). *Bull. Ent. Soc. Egypt.* **71**: 163-171.

Boucek, Z., Subba Rao, B.R. and Farooqi, S.I. (1978). A preliminary review of Pteromalidae (Hymenoptera) of India and adjacent countries. *Oriental Ins.*, **12** (4): 433-468.

Boucek, Z., Subba Rao, B.R. and Farooqi, S.I. (1978). A preliminary review of Pteromalidae (Hymenoptera) of India and adjacent countries. *Oriental Insects.* **12** (4) : 433-468.

Boxell, R.A., Greenley, M., Tyagi, D.S., Lipton and Mand, N.J.(1977). The prevention of farm level food grain storage losses in India. *A Social Cost Benefit Analysis T.D.S. Res. Rep.*, pp.238.

Brewer, I.N and Horber, E. (1984). Evaluation resistances to *Callosobruchus chinensis* Linn. in different seed legumes.*Proceedings of the 3rd International Working Conference on Stored Product Entomology*, Oct. 23-28, Kansas State University, Manhattan, U.S.A. pp. 435 – 443.

Calderon, M. (1958). The Bruchidae (Col.) of Israel. *Ph.D. Thesis Submitted to the Senate of the Hebrew University*, Jerusalem (in Hebrew).

Cardona, C. and Flower, V.J.(1982). Levels to resistance to the Maxican bean weevil, *Zabrotes subfasciatus* Bohe. in cultivated and wild bean. *Columbiana de Entomologia* ., **7**: 41 – 45.

Casewell, G.H. (1973). The storage of cowpea., *Samaru Agric. Newsl.*,**15** (20) : 73-75.

Caswell, G.H. and Youdeowei, A. (1978). The stored grain legume. *Entomol. Soc. Nigeria.*, pp.131-142.

Chacraborty, A. (1997). Post Harvest Technology of Cereals, Pulses and Oilseeds. Oxford &IBH Publishing Co. Pvt. Ltd., N. Delhi.

Chandrakantha, J. and Mathavan, S.(1986). Changes in developmental rates and biomass energy in *Callosobruchus maculatus* F. (Coleoptera: Bruchidae) reared on different food and temperature; *J. Stored Pro. Res.*, **22** (2): 71-75.

Charjan, S.K.V. and Tarar, J.L. (1994). Viability, vigour and mycoflora changes in pulse beetle damaged seeds of green gram (*Vigna radiata* L. Wilczek). *Proceedings of the National Academy of Science, India, Section-B. Biological Science.* **64** (1): 95-98.

Chatterjee, B.N. and Bhattacharjee, K.K.(1986). Grain legumes in human nutrition, In *Principles and Practices of grain legumes Production*, Oxford & IBH Pub. Com. Ltd., New Delhi, pp. 407-429.

Chatterjee, S (1953). Biological notes on *Chactostrica mukherjii* (Mani) (Hymenoptera : Trichogrammatidae), an egg parasite of *Bruchus analis* Fabr. *Indian J.Ent.*, **15** : 382-383.

Chatterjee, S (1954). Biological notes on *Chaetostrica mukherjii* (Mani) (Hymenoptera : Trichogrammatidae), an egg parasite of *Bruchus analis* Fabr. *Indian J.Ent.*, **16** : 77.

Chaturvedi, S.K.and Ali, M.(2002). Poor man's meat needs fresh fillip. *The Hindu Survey of Indian Agriculture.* pp.63-69.

Chaudhuri, N.(2000). Insect pest constraints of tomato(*Lycopersica esculentum* Mill.) and their management under terai region of West Bengal. *Ph.D thesis.* University of North Bengal. West Bengal.

Chavan, P.D., Singh, Y. and Singh, S.P. (1997). Growth and development of *Callosobruchus chinensis* on cowpea lines. *Indian J. Ent.*, **59** (3):304-310.

Cheema, P.S. and Misra, J.N. (1962). *Curr. Sci.*, **31**: 21.

Chhabra, K.S. and Koner, B.S. (1998). Insect pest management in mung bean and blackgram status and strategies. *IPM System in Agriculture.* 4:233-310.

Chopra, I.C., Handa, K.L., Kapur, L.D. (1994). *Chopra's indigenous drugs of India.* Academic Publisher, Calcutta.

Chopra, R.N., Badhawar, R.L. and Ghosh, S.(1965). *Poisonous Plants of India.* Academic Publisher, Jaipur, India.

Choudhury and Pathak, S.C. (1989). Relative preference of *C. chinensis* for different varieties of Bengal gram. *Bull. Grain Tech.* **27** (3): 181-198.

Christensen, C.M. & Kanfman, H.H. (1969). The role of fungi in quality loss. In *Grain Storage.* Univ. Minnesota Press. Minn. U.S.A.pp. 153 .

Christensen, C.M. (1964). Effect of moisture content and length of storage period upto germination percentage of seed corn, wheat and barley free of storage fungi. *Phytopathol.*, **54** : 1464-1466.

Christensen, J.J. (1963). Corn smut caused by Ustilago Maydis Monog. *Amer. Phytopath. Soc.*, 2, 41 PPRMVM -7, 144, 1970.

Chung, S. H.; Choi, W. and Ryoo, M. (1995). Egg laying decision of adzuki bean weevil (Coleoptera : Bruchidae) effects of seed size and egg distribution pattern on seed. *Korean Journal of Entomology.* **25** (4) : 313-321.

Coombs, C.W., Billing, C.J. and Porter, J.E. (1977). The effect of yellow split peas (*Pisum sativum* L.) and other pulses on the productivity of certain strains of *Sitophilus oryzae* L. (Col. : Curculionidae) and ability of other strains to breed there on, *J. Stored Prod. Res.,* **13** : 53-58.

Cotton, R.T. (1920). Rice weevil *Calandra* (= *Sitophilus*) *oryzae* (L.)., *J. Agric. Res.,* **20** (6): 605-614.

Cotton, R.T. (1963). *Pest of Stored Grain and Grain Products.* Burgess Pub. Co., Minneapolis, U.S.A., pp. 85

Dabi, R.K., Gupta, H.C. and Sharma, S.K. (1979). Relative susceptibility of some cowpea varieties to pulse beetle, (*Callosobruchus maculatus* Fab.). *Indian Journal of Agricultural Science.* **49** (1): 48-50.

Das, G.P. (1986). Pesticidal efficacy of some indigenous plant oils against pulse beetle, *Callosobruchus Chinensis* (Coleoptera :Bruchidae)in black gram. *Bangladesh J. Zool.,* **14** (1):15-18.

Das, G.P. (1987).Effect of different concentration of neem oil on the adult mortality and oviposition of *Callosbruchus chinensis* Linn. (Bruchidae: Coleoptera). *Indian J. Agric. Sci.,* **50** (10):743-744.

De Luca, Y. (1965). Catalogue des Metazoaires Paradateurs de Bruchides (Coleoptera)., *J. Stored Prod. Res.* , **1**:51-98.

De Paula, D.C. (1994). Resistance to bruchids, fatty acid composition and grain texture in genotype of chickpea. *Bragantia.* **53** (1): 61 – 74

De Teledo, A.A. (1946). Control of the bean weevil with grassy substances. *Biologica.***12** : 149-156.

Deshpande, R.S., Adikari, P.R. and Tipnis, H.P. (1974). Stored grain pest control agents from *Nigella sativa* L. and *Pogostemon heyneanus* Benth. *Bull. Grain . Tech.,* **12**(3):232-234.

Dhanokmen, K.A.(2000).Phylogenetic relations between Palaearctic Pteromalidae (Hymenoptera : Chalcidoidae). *Zoologicheskii Zhurnal.,* **79** (5): 564-571.

Dhir, S.(1977).Further observations on oviposition of *Dinarmus vagabundus* Timb. (Pteromalidae : Hymenoptera). *Cur. Sci.,* **46** (1): 18.

Dias, C.A.R. and Yadav, T.D. (1988). Ovipositional preference of pulse beetle to four legume seed. *Indian J. Ent.,* **50** (4): 480-487.

Dina, S.O.(1971). The reaction of various types of pulses on the life process of bruchid, *Callosobruchus chinensis* L. And *C. maculatus* F. *M. Sc. Thesis, Post Graduate School, I.A.R.I.,* New Delhi.

Dwivedi, S.C. and Sharma, M.K. (1993). Extent of damage caused and host preference of *Callosobruchus chinensis* Linn. *Bioved.,* **4** (2) : 249-254.

Edward, G.; Jay, H.L. and Gorden, C.P. (1973). Damage to stored soybean by the cowpea weevil *Callosobruchus maculatus, J. Georgia Entomol. Soc.,* **8**: 164-167.

Edward, Y.S.J.T. and Gunathilagaraj, K. (1994). Relative susceptibility of green gram, black gram and cowpea cultivars to *Callosobruchus maculatus* (F.) in the field. *Madras Agril. J.,* **81** (10): 575-577.

El-Zemaity, M.S.; Zidan, A.A,. Salma, I., Zemaity-MS-EI (1985). The effect of successive infestation with bruchid beetes some physical properties and chemical constituents of stored lentils. *Lens Newsletter*, 12(2): 39 – 43.

Epino, P.B. and Morallo, R.B. (1982). Mechanism of resistance in mung bean (*Vigna radiata* L. Wilczek) to *Callosobruchus chineneis* (L.). *Philippine Entomologist.***5** (4) : 447-462.

Epino, P.B. and Morallo, R.B. (1983). Physio-chemical properties of mung bean (*Vigna radiata* (L.) Wilczek) seeds in relation to weevil resistance. *Philippine Entomoligist,* **6** (5) : 607-620.

Evans, T.B. P. (1939). Crop and insects problem of the Union of S. Africa. *Ann. Rept. of the Division of Plant Industry, Farm in S. Africa.* Report No. 10, Pretirier, 1939.

Fabres, G. and Reymenet, C. (1991). Maternal induction of larval diapauses in *Dinarmus acutus* (Hym. : Pteromalidae). *Entomophaga*, **36**(1):121-129.

Fam, E.Z.; Bushara, A.G.; Saxena, M.C.; Stewart, R.A. (1883). Insect pests. *Report on the first phase of the ICARDA-IFAD-Nile Valley Project (1979-82).* pp. 125-132..

Flanders, S.E. (1935). Host influence on the Prolificacy and size of Trichogramma. *Pan-Pacific Ent.*, **11**:175-177.

Fletcher, T.B and Ghosh, C.C. (1920). Stored Grain Pests, Rept. Proc. 3rd Ento. Meeting , 1919, Calcutta, 11,1920, pp. 712 – 761.

Fletcher, T.B. (1911). *Agric. J. India.* **6**: 333-334.

Gahukar, R.T. (1972). Pest Infestation Survey of Agricultural Commodities South India. *Bull. Grain Tech.,* **10** (3): 173-180.

Ghosal, T.K., Senapati, S.K. and Deb, D.C.(2003). Morphology with special emphasis to mouthparts, ovipositor apparatus and sexeual dimorphism of *Dinarmus vagabundus* (Timberlake) (Hymenoptera: Pteromalidae: Pteromalinae), a first report from Eastern India. *Proc. Zool. Soc. Calcutta,* **56(1)**:21-26.

Ghosh, C.C. (1937). The pulse beetles in Burma, *Indian J. Agril. Sci.,***7**(3) : 395-412.

Gijswijt, M.J. (1999). Four new species of *Pteromalus swederus* (Hymenoptera: Pteromalidae) and rediscriptions of three other species. *Zoolgische Mededelingen.* **73**: 165-175.

Girault, A.A. (1911). The Chalcidoid parasites of the coccid Karmes pubescenes Bogue, with descriptions of two new genera and three new species of Encyrtidae from Illinoiss. *Can. Ent.,* **43**: 168-178.

Girish, G.K., Singh, K. and Krishnamurty, K. (1974). Studies on the oviposition development of *Callosobruchus maculatus* (Fab.) on various stored pulses. *Bull. Grain Tech.,* **12** (2): 113-116.

Golab, P. and Kilminster, A.(1982). The biology and Control of *Zabrotes subtasciatus* Boheman (Coleoptera : Bruchidae) infesting red kidney beans., *J.Stored Prod. Res.*, **18**(3): 95-101

Gomez, K.A.and Gomez, A.A. (1976). *Statistical Procedures for Agricultural Research.* John Wiley & Sons, New York.

Goncalves, L.I. (1939). Ogorglho Japones , *Callosobruchus chinensis* (Linn. 1758) Pic. observacoes sove, a sua biologia, habitos, danus, causados e meios de combati. *Publ. Div. Def. Sanit, Veg.,* Rio de Jenero.**14** : 44.

Gopalan, C.; Ramasastri, B.V. and Balasubramaniam, S.C. (1977). *Nutritive value of Indian Foods,* compiled by Saini, R.S. Scientist, ICAR, New Delhi.

Govindan, R., Narayanaswamy, T.K., Ras, M.R.G. and Munirajappa, R. (1989). Relative susceptibility of wild mung and other pulses seeds for *C. chinensis. Environ. Eco.,* **7**(2): 469 –471.

Govindarajan, R. and Balasubramanian, M.(1983). Observation on the ovipositional behaviour of *Callosobruchus maculatus* F. and *C. chinensis* L. in relation to seed size. *J. Ent. Res.*, **5**(2): 177 – 179.

Govindarajan, R. and Balasubramanian, R.(1981).Observation on the ovipositional behaviour of *Callosobruchus maculatus* (F.) and *C. chinensis* (L.) in relation to seed size. *J. Ent. Res.,* **5** (2): 177-179.

Gupta, H.C., Gupta I.J. and Sharma, S.N.(1997). Parasitic wasps, *Dinarmus acutus* and *D. besalis* (Hymenoptera : Pteromalidae) parasitizing pulse beetle, *Callosobruchus maculatus. J. Bangladesh Cont.*, **11**(1):77-78.

Gupta, H.C., Kumawat, S.R., Saroha, A.P.S. and Chaturvedi, S.S. (1985). Comparative resistance of the seeds of green gram (*Vigna radiata*) varieties to pulse beetle (*Callosobruchus chinensis*). *Seed Res.,* **13** (2): 60-63.

Gupta, H.C.; Gupta, I. J. and Sharma S.N. (1998) Parasiticwasps, *Dinarmus acutus* (Thompson) and *D. basalis* (Rondani) (H;ym.:Pteromalidac) parasitizing pulse buthe *Callosobruchus maculatus* (Fabricius). *Seed Tech. Res.* **11(1-2)**:77-78.

Gupta, K.K. and Sehgal, S.S.(1987). Colour preference of *Callosobruchus maculatus* (fabr.) as elicited by its orientation and ovipositional behaviours. *Indian J. Ent.*, **49**(4): 544-546.

Gupta, S., Singhal, S.K. and Doharey, R.B.(1983). Studies on the chemical and nutritional changes in bengal gram (*Cicer arietinum*) during storage by the attack of pulse beetle (*Callosobruchus maculatus*)., *Bull. Grain.Tech.*,**19**(3): 185 – 190.

Gupta,H.C.,Gupta,I.J.andSharma,S.N.(1997).Parasiticwasps,*Dinarmus acutus* and *D. basalis* (Hymenoptera:Pteromalidae) parasitizing pulse beetle, *Callosobruchus maculates. J. Biol. Cont.*, **11(1)**:77-78.

Hagstrum, D.W. (1985). Post-harvest infestation of cowpea weevil (Coleoptera : Bruchidae) and population trends during storage in Florida. *J. Econ. Ent.,* **78** (2) : 358-361.

Han, E.D. and An, J.H. (1990). Studies on ecology and control of the azuki bean weevil, *Callosobruchus chinensis* (L.) in Korea. *Res. Rep.Rural Dev. Adm. Crop Prot.,* **32** (1): 24-59.

Haris, K.L. and Lindblad, C.J.(1978) *Post harvest grain loss assessment methods.* (Amer. Assoc. Cereal Chemists :St Paul, M.A.) pp.193.

Hawtin, G.; Webb, C.; Kamel, A.H. Hawtin, G.; Webb, C. (1982). Faba been pests in Egypt. *Proceedings of the Faba been Conference Held in Cairo, Egypt,* (March 7-11, 1981). pp. 271-275.

Hill, D.S. (1990). Pest : Class Insecta, In *Pests of stored products and their control.* CBS Publishers & Distributors, Delhi, pp. 41-172.

Hill, J. and Schoonhoven, A.V.(1981). Effectiveness of vegetable oil fractions in controlling the mexican bean weevil on stored bean. *J. Econ. Ent.,* **74** : 478-479.

Howe,R.W. and Currie, J.E. (1964). Some laboratory observations on the rate of development, mortality and oviposition of several species of Bruchidae breeding in stored pulses. *Bull. Ent. Res.,* **25** : 437-477..

Hu, W.T., Lan, Y.C. and Horng, S.B. (1995). Effects of bean size on larval competition and ovipositional preference of *Callosobruchus maculatus. Chinese Journal of Entomology.* **15** (4) : 321-332.

Huis A. V., Appiah, S.O. and Van H. A. (1995). *Uscana lariophaga,* West Africa egg parasitoid of the cowpea bruchid beetle *Callosobruchus maculatus* : photoperiod, parasitization and eclosion interactions. *Entomologia Experimentalis et Applicata,* **76**(1): 1-6.

Huis A.V., Schutte,C., Sagnia, S. and Van Huis A. (1998). The impact of the egg parasitoid ,*Uscana lariophaga* on *Callosobruchus maculatus* population and the damage to cowpea in a traditional storage system. *Entomologia Experimentalis et Applicata.*, **89** (3) : 289-295.

Huis, A.V., Kaasheok, N.k. and Mae, H.M. (1991). Biological control of bruchids (Col. : Bruchidae) in stores pulses by using egg parasitoids of the genus *Uscana* (Hym. : Trichogrammatidae) : a review. Fleurat-Lessard and P. Ducom (eds). In : *Proceedings of 5th International Working Conference on Stored Product Protection.*, 1:99-108. September 9-14, 1990, Bordeaux, France.

Huis, A.V., Wijkamp, M.G., Lammers, P.M., Klerin Goldewijk., C.G.M., Seeters, J.H. Van and Kaashoek, N.K. (1991). *Uscana Lariophaga* (Hymenoptera : Trichogrammatidae) , an egg parasitoid of bruchid beetle (Coleoptera : Bruchidae), storage pests in West Africa ; host age and host species selection. *Bull. Ent. Res.*, **81** : 65-75

HuisA.V.,Wijcamp,M.G.;Lammers,P.M., Klerin G.C.G., Seeters, J.N., Van J.H. and Kaashoek,N.K.(1991).*Uscana lariophaga* (Hymenoptera: Trichoqrammatidae), an egg parasitoid of bruchid beetle (Coleoptera : Bruchidae) storage pests in West Africa : host age and host species selection. *Bull. Ento. Res.*, **81**(1) : 65-75.

Hussain, T. (1994). The effect of parental age of progeny of *C. chinensis. Bangladesh J. Zool.*, **22**(1) 55-59.

~~*Insect-Science-and-its-Application* 15(3): 301 — 311.~~

Islam, M.N. (1991) Mating behaviour of the pulse beetle, *C. chinensis* (Coleoptera : Bruchidae). *Bangladesh J. Zool.* **1** : 59-67.

Islam, N. (1999). Evaluation of traditional methods for the management of the pulse beetle, *Callosobruchus chinensis* Linn (Coleoptera Bruchidae). *A thesis submitted to the University of Dhaka.* Dhaka , Bangladesh. .

Islam, W. (1992) Mating and egg-laying behaviour of Dinarmus basalis (Rondani) (hymnoptera : Pteromalidac), a larval – pupae parasitoid of *Callosobruchus chinensis.* (Lennacus). *Annals of Entomology.* **10(2)**: 13-16.

Islam, W. (1997) Host stage selection and preference for oviposition of the parasitiod *Dinarmus basalis* Rond . (Hym. : Pteromalidae) on Callosodruchus chinensis L. *Entomon.* **22(2)**:95-100.

Islam, w. (1998) Rearing and release of the pulse butle parasitoril *Dinarmus basalis* (Rond.) (Hymendptera : Pteromalidae). *Tropical Agril. Res. Extn.* **1(2)**:131-135.

Islam, W. and Kabir, S.M.H.(1995) Bio-control potential of *Dinarmus basalis* (Hymenoptera : Pteromalidae) , a larval –pupal Ectoparasitoid of the pulse beetle . *Crop Protc.*(Union Kingdom), **14**(6) :439-443.

Islam, W.(1995). Longevity and fecundity of *Dinarmus basalis* (Rondani) (Hymenoptera:Pteromalidae) a useful parasitoid of *Callosobruchus chinensis* (Coleoptera: Bruchidae).*Entomon.*, **20(1)**:19-21.

Jack, R.W. (1936). Annual report of the division of entomology for the 1935 – *Agriculture Rhodisia Agric.J.*, **35** (5) : 329-335. Salisburry, 1936.

JagadeeshBabu, C.S., Shivakumar, S., Savithamma, D.L., Viswanatha, K.P. and Rudraswamy, P. (2000). Factors affecting tolerance to pulse beetle (*Callosobruchus chinensis* (L.) on mung bean, *Vigna radiata* (L.). *Pestology.* **25**(6) : 37-39.

Jasper, G.W.(1978). Coconuts, production, processing products. Inc. AVI. Publ. Co. West Port Connecticut.pp. 307.

Jeswani, L.M. and Baldev, B.(1990). Advances in pulse production technology, Publication and Information Division, I.C.A.R.,N. Delhi.,pp190.

Jeswani, L.M. and Baldev, B.(1997). Advances in Pulse Production Technology, Publication and Information Division, I.C.A.R.,New Delhi.,pp190.

Joshi, M.S.(1977). Food legume crops improvement and production. In, FAO Plant Production and Protection. FAO,Rome,pp239.

Kailappan, R., Aleksha Kudos,S.K., Mohan, S. and Sreenarayan, V.V.(1999). Effect of field infestation on post-harvest losses in pulses. *Pestology.* **23**(8):9-10.

X — Kapila, R. and Agarwal, H.C. (1995) Biology of an egg parasite of *Callosobruchus maculatus* Fab. (Coleoptera : Bruchidae). *J. Stored Prod. Res.*, **31** (4): 335-341.

Kapila, R. and Agarwal, H.C. (1995) Biology of an egg parasite of *Callosobruchus maculatus* Fab. (Coleoptera : Bruchidae). *J. Stored Prod. Res.*, **31** (4) : 335-341.

Kapoor, K. N.; Gujrati, J. P. and Gangrada, G.A. (1972). Parasites of *Oberea brevis* (Coleoptera: Lamiidae). *Annals of the Entomological Society of America.*, **65** (3):755.

Karim, M.A.; Rahman, M.M. (1989). Status of insect and vertebrate pest management research on pulses in Bangladesh. *Proceedings of the 2nd National Workshop on pulses and advances in pulses research in Bangladesh.* Joydebpur, Bangladesh.pp. 135-138.

Katiyar, P.N. and Khare, B.P. (1984). Susceptibility of twenty lentil germplasms lines to pulse beetle, *Callosobruchus chinensis* (L.). *Legume Res.,* **5** (2): 105-110.

Katiyar, P.N. and Khare, B.P. (1985). Relative susceptibility of twenty germplasms of gram to pulse beetle *Callosobruchus chinensis* (L.). *Bulletin of Grain Technology,* **21** (1) : 31-36.

Khachare, B.V., Khaire, V.M. and Moti, U.N. (1994). Efficacy of different vegetable oil as seed treatment in increasing storage ability of pegeonpea seed against pulse beetle, *Callosobruchus chinensis* Linn. *Indian J. Ent.*, **56**(1):58-62.

Khaire, V.M, Kachare, B.V. and Patil, C.S. (1987). Effect of vegetable oils on pulse beetle (*Callosobruchus chinensis* L.). *Pigeonpea Current Res. Rep.*, **3**(2):53-58.

Khaire, V.M., Kachare, B.V. andMoti, U.N. (1992). Efficacy of different vegetable oils as gram protectants againet pulse beetle, *Callosobruchus chinensis* (L)in increasing storability of pigeon pea. *J. stored prod. Res.*, **28**(3):153-156.

Khare, B.P. (1994). Stored Grain pests and their management, In *Identification and Classification of Insects.* Kalyani Publishers, Ludhiana, India, pp. 17-94.

Khare, B.P. and Jhohari, R.K. (1983) Biology of *Callosobruchus chinensis* Linn. on whole grains and fractions of pegion peas (*Cajanus cajan* Linn.). *Agric. Sc. Digest.*, **3** (3/4): 137-138.

Khare, B.P.(1972) Insect pests of stored grain and their control in Uttar Pradesh. *Pantnagar Univ. College Agri. Tech.*, pp. 94-108.

Kumar, J.(2000). Towards a qualitative leap. *The Hindu Survey of Indian Agriculture*.pp.61-63.

Kundra, S. (1976). Some observations on the biology of *Dinarmus basalis* (Pteromalidae : Hymenoptera). *Bull. of Grain Technol.,* **14** (2) : 126-129.

Kundra, S. 1976. Some observation on the biology of *Dinarmus vegabundus* Timberlake (Pteromalidae : Hymenoptera). Bull Grain Tech. 14 (2) : 126-129.

Kunhi Kannan (1919). Pulse beetles (Stored Farms). *Bull. Dev. Agril.*, Mysore Entomological Service. **6**: 31

Labeyrie,V. (1981). The ecology of bruchids attacking legumes (pulses). *Entomologica.* **19** : 14-233.

Labeyrie,V.(1980).The ecology of bruchids attaching legumes (pulses). *Proceedings of the International Symposium held at Tours* (France), April 16-19, 1980.

Lakhanpal, G.C.; Kashyup, N.P. and Mehta , P.K. (1995) Evaluation of some edible oils as grains protectants against pulse beetle , *C. analis* in black gram, *Vigna mungo, J. Insect Sci.*, **8** (1) : 66-69.

Lambrides, C.J. and Imrie, B.C. (2000). Susceptibility of mung bean varieties to the bruchid species *Callosobruchus maculatus* (F.), *C. phaseoli* (Gyll.), *C. chinensis* (L.) and *Acanthoscelides obtectus* (Say.) (Coleoptera : Chrysomelidae). *Australian J. Agril. Res.,* **51** (1) : 85-89.

Lefroy, H.M. (1909). Indian Insect life: Thaker Spink, Calcutta, pp. 786.

Lienard, V. and Seck, D. 1994. Review of control methods against *C. maculatus* (Coleoptera: Bruchidae), a pest of grains of cowpea in tropical Africa.

Lima, A.D.F. (1942). *Bol. Soc. Brazil, Agron.,* **5** : 441.

Luca, Y.D. (1982). Products of vegetable origin that can be used against bruchids (Coleoptera, attractants, antifidants, lethal). *Res. Bull. Punjab Univ.* (Science). **2**:19-29.

Maiti, S.; Hedge, M.R. and Chattopadhya, S.B. (1988). Hand Book of Annual Oilseed Crops. Oxf. & IBH Pub. Co. Pvt. Ltd., New Delhi.

Majeet, I., Ahmed, I., Naqvi, S.N.H., Khan, A.R., Tabassum, R., Qureshi, I. (1994). Determination of toxicity of neem extracts (NFC and N-7) and coopex 25 EC (permethrin + bioallethrin) on pulse beetle, *C. analis. Proceedings of Pakistan Congress of Zoology.* **14**: 43 - 49.

Malick, C.P. and singh, M.B. (1980). *Plant enzymology and histoenzymology,* Kalyani Pub., New Delhi, p. 286.

Mani, M. S. (1935). First record of the Trichogrammatid Chalcid *Chaetostricha* Walker from India, with a description of a new species. *Rec. Indian Mus.* **37**: 337-338.

Mani, M.S. (1939). Description of new and records of some known chalcidoid and other hymenopterous parasites from India. *Indian J. Ent.,***1** : 69-99.

Mani, M.S. (1989). The Fauna of India and the Adjacent Countries (Chalcidoidea:Hymenoptera). Edited by the Director, *Zoological Survey of India,* Calcutta. **2**: 1364-1377.

Mani, M.S. (1989).The Fauna of India and the adjacent countries (Chalcidoidea:Hymenoptera). Edited by Director, Zoological Survey of India, Calcutta. **1**: 543-571. *Zoological Survey of India,* Calcutta.

Mannan, M.A. and Bhuiya, I.M.(1994) Studies on the oviposition preference of pulse beetle, *Callosobruchus maculatus* Fabr. On true and artificial seeds. *University J. Zool.*, Rajsahi University. **13**: 15-24.

Mannan, M.A. and Bhuiya, I.M.(1994) Studies on the oviposition preference of pulse beetle, *Callosobruchus maculatus* Fabr. On true and artificial seeds. *University J. Zool.*, Rajsahi University. **13**: 15-24.

Manohar, S.S. and Yadav, S.R.S. (1990). Laboratory observations on relative resistance and susceptibility of some cowpea cultivars to pulse beetle, *Callosobruchus maculatus* (Bruchidae: Coleoptera). *Indian J. Ent.,* **52** (2) : 180-186.

Misra, D.N., Misra, A.K., Tiwari, R and Upadhyaya, K.1989. Toxicity of some essential oils against pulse beetle, *Callosubruchus maculatus. Indian Perfumer.***33** (2): 137 - 141.

Miyaka, T. and Odera, S. (1939). Notes on the biology of Bruchidae. *Muji kairyo Shiryo N.,* **137**: 154-157, Tokyo.

Modgil, R. and Mehta, U. (1994). Effect of different levels of *Callosobruchus chinensis* L. infestation on proximate principle, true protein, methionine and uric acid contents of green gram and red gram. *Journal of Food Science and Technology.* **31** (2) : 135-139.

Modi, B.N.; Parsai, S.K.; Verma, R.S. and Singh, C.B. (1994). The reaction of pulse beetle, *Callosobruchus chinensis* Linn. on grains of 44 varieties of pigeon pea. *Bharatiya Krishi Anusandhan Patrika.* **9** (4) : 283-288.

Mookherjee, P.B.; Jotwani, M.G.; Yadav, T.D. and Sircar, P. (1970) Studies on incidence and extent of damage due to insect pests in stored seeds., *Indian J. Ent.* pp. 350-355.

Mookherjee, P.B.; Jotwani, M.G.; Yadav, T.D. and Sircar, P. (1970) Studies on incidence and extent of damage due to insect pests in stored seeds., *Indian J. Ent.* pp. 350-355.

Muhammad,H.; Roy, G.C. and Husain, M. (1997). Laboratory evaluation of some mung bean strains for susceptibility to pulse beetle, *Callosobruchus chinensis* (L.). *Bangladesh Journal of Entomology.* **7** (1-2) : 21-26.

Mukherji,D.D. and Bhuya, M.A.R. (1936). Life history of *Chacotostricha mukerjii* (Mani) (Trichogrammatidae: Hymenoptera). *Zool. Anz.*, **115**, F-8 : 209-212.

Mummigatti, S.G. and Ragunathan, A.N. (1977). Inhibitation of the multiplication of Callosobruchus chinensis by vegetable oils. *J. Food Sci. Tech.*, **14**(4):184-185.

Narendran,T.C.(2001). Parasitic Hymenoptera and Biological Control. Palani Paramount Pub., Palani, India.

needed. *The Hindu Survey of Indian Agriculture.*pp.61-65.

Negi, R.S., Srivastava, M. and Saxena, M.M. (1997). Egg laying and adult emergence of *Callosobruchus chinensis* on greengram (*Vigna radiata*) treated with pongam oil. *Indian J. Ent.*, **59**(2):170-172.

Oigiangbea, N.O. and Onigbinde, A.O. 1996. The association between some physio - chemical characteristics and susceptibility of cowpea (*Vigna unguiculata*) to *Callosobruchus marculatus. Journal of stored Product Research.* **32** (1): 7 – 11

Osuji, F.N.C. (1982).Radiographic studies of the development of *Callosobruchus masulatus* (Fabricius) in cowpea secds. *J. Stored Pro. Res.* **18(1)**:1-8.

Pajni, H.R. and Singh,T (1973). A note on the taxonomic position of *Uscana mukherjii* (Mani) an egg parasite of store – bruchids (Trichogramma: Hymemoptera). *Res. Bull. Punjab Univ.*, **24** (III – IV) : 163-164.

Pajni, H.R.; Seema S; Bharadwaj, N. and Sood, S. (1996) Biology of *Uscana murherjii* Mani, a potential parasitoid for the biocontrol of bruchid pests (Trichogrammatidae: Hymenoptera). *Res. Bull. Punjab Univ.*, **46** (1-4) : 77-87.

Pandey , G.P. , Doharey , R.B. and Verma, B.K. (1981). Efficacy of some vegetable oils for protecting greengram against the attack of *Callosobruchus maculatus* (fabr.). *Indian J. Agril. Sci.,* **51**(12):910-912.

Pandey, N.K. and Singh, S.C. 1997. Observation on the biology of the pulse beetle, *Callosobruchus chinensis* L. infesting stored pulses; *Uttar Pradesh Journal of Zoology.* **17 (1)** : 38-42.

Pandey, N.K. and Singh, S.C.(1997) Observation on the biology of the pulse beetle, *Callosobruchus chinensis* L. infesting stored pulses . *Uttar Pradesh J. Zool.*, **17** (1): 38-42.

Parajulee, M. N., Neupane, F.P., and Thapa, R.B. (1989). Life and seasonal histories, host preference and control of the pulse beetle, *Callosobruchus chinensis* (Coleptera : Poruchidae). *J. Ins. Agri. Ani. Sc.* **10**:1-6.

Paroda, R.S. (2000). Policy support essential. *The Hindu Survey of Indian Agriculture* . pp. 17-20.

Pathak, K.A. and Jha, A.N. (1999) .Toxicity of some insecticides against adults of *Sitophilus Oryzae, Sitophilus* sp *and Sototroga cereabella, Indian J.Ent.*, **61**(4) : 320-325.

Pereira, J. (1983). The effectiveness of six vegetable oils as protectants of cowpeas and bambara groundnuts against infestation by *Callosobruchus maculatus* (F) (Coleoptera: Bruchidae). *J. Stored Prod. Res.* **19**(2) : 57-62.

Prabhakar, G.S. (1979). Studies on Bruchid fauna infesting pulse crops of Karnataka with special emphasis on the bio-efficacy of *Callosobruchus chinensis* (Linnaeus) (Coleoptera: Bruchidae). *M.Sc. (Agril.) Thesis submitted to UAS, Bangalore.* 1-137.

Pruthi, H.S. and Singh, M.(1950). Pests of stored grain and their control. *Indian J. Agril. Sci.,* **18**(4) 1-87.

Qi,Y.T. and Burkholder, W.E. (1982) Sex pheromen biology and behavior of the Cowpea weevil, *Callosobruchus maculatus* (Coleoptera: Bruchidae). *J. Chem. Bio.*; **8**(2): 527 – 534.

Raghupati, A. and Rathnaswamy, R. (1970). Studies on comparative susceptibility of seeds of certain red gram (*Cajanus cajana*) varieties to pulse beetle. *Madras Agri.J.* **57** (2) : 106-109.

Rahman, K.A.; Sohi, G.S. and Sapro, A.N. (1942). Studies on stored grain pests in Punjab II. Biology of *Bruchus analis* Fab. And *B. chinensis* L. (Bruchidae : Coleoptera), *Indian J. Agric. Sci.* **12** : 851-864.

Raina, A.K. (1970). *Callosobruchus* sp. infesting stored pulse grain legumes in India and comparative study on their biology. *Indian Journal of Entomology.* **32** (4) : 303-310.

Raja, N., Albert, S., Ignacimuthu, S (2000). Effect of solvent residues of *Vitex negundo* and *Cassia fistula* on pulse beetle, *Callosobruchus maculatus* Fab. and its larval parasitoid, *Dinarmus vagabundus* (Timberlake). *Indian J. Exp. Bio.*, **38**(3):290-292.

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

Rajapakse, RH.S. and Senanayake, S.G.J.N. 1997. Effectiveness of seven vegtative oils against *C. chinensis* in pigeon pea, *Cajanus cajan. Entomon.* **22** (3-4): 179 - 183.

Rojas, R.D.; Eslami, J. and Periquet, G. (1988) Reproduction strategy of *Dinarmus vagabundus* (Timb.) (Hym. : Pteromalidae) : real sex ratio, sequence of emitting diploid and haploid eggs and effect of inbreeding on progeny . *J. Applied Ent..*, **106**(3):276-285.

Rojas, R.D.; kalmes, R.; Combescot, C.; Eslami, J.; Gomez, A.L.; Rousse, D.R. and Alvarez, L.G. (1988) Nutritional balance during the development of the gregarious ecto-parasite, *Dinarmus vagabundus* and the solitary *Dinarmus basalis*. *Eutomol. Exp. et Appl.*, **46**(1):63-70.

Ramzan, M. Chahal, B.S. and judge, B.K.(1990). Storage losses to some commonly used pulses caused by pulse beetle *Callosobruchus maculatus*. *J. Ins. Sci.,* 3(1): 106 - 108.

Rao,Y.P. (1974). A note on storage and preservation (unpublished), R.P.E.C., IIT, Kharagpur, India.

Raper, K.B. and Fennel, D. (1965). The genus *Aspergillus*. Williams and Williams Co, Baltimore,pp.686.

Raper, K.B. and Thorn, C. (1949). A manual of *Penicillia*. Williams and Williams Co., Baltimore.

Reymonet, C.; Fabres, G.and Labeyrie, V. (1987) Preliminary study of an external physiological maker of diapause in *Dinarmus acutus* (Hym:Pteromalidae), a parasite of *Bruchus affinis* (Col:brouchidae). *Annals de la Science Entomologique de France.*, **23**(3): 241-246.

Richa, E.M., Hashan, M.Y. and Rabie, M. 1993.Use of some essential oils as protectants against pulse beetle, *Callosobruchus chinensis*. *Bulletin of Entomological Society of Egypt.* **20**: 151 - 159.

Richards, O.W. and Davis, R.A. (1983). Imm's General Text Book of Entomology. (10^{th} Ed. Vol.II, Classification and Biology). Science paper back, Chapmen and Hall, London, New York: 421-1354

Roche, R.; Gonzalez, V.M.; Simanca, M.E. and Valenzuela, M.G. (1985) Life cycle of *Callosobruchus maculatus* (Coleoptera : Bruchidae), pest of stored seeds, *Ciencias de la Agricultura* ., **22** : 16-20.

Rojas, R.D., Kalmus, R., Combescot, C; Eslami, J., Gomez, A.L., Rojas, D.R. and Aluvarez, L.G. (1988). Nutritional balance during the development of the gregarious ectoparasite *Dinarmus vagabundus* and a solitary *Dinarmus basalis*. *Entomol. Exp. et Applicata.,* **46** (1) : 63-70.

Roy, S. and Roy, S. (1994). Ovipositional preference and development of *Callosobruchus maculatus* Fabricius on seeds of promising dry land legumes. *Agril. Sci. Digest,* Karnal,India. **14** (4): 177-180.

Rup, P.J. (1986). Mating and its attendant behaviour in *Callosobruchus maculatus* F. (Coleoptera : Bruchidae) reared on different food and temperature; *J. Stored Pro. Res.,* **22** (2) : 77-79.

Sadasivam, S. and Manickam, A.(1997) In : *Biochemical methods*, New Age International (P) Ltd, Publishers, New Delhi and Tamil Nadu Agricultural University, Coimbatore, p. 193.

Sadomov, E. (1984). Granivorous beetles. *Rastilelna Zashchita .,* **32** (6) : 32-34.

Sadomov, P. and Sunaryono, H. (1988). Seed storage of bushitao with several kinds of plants pesticide treatments., *Bull. Peneli. Horti.* **16**(1):24-28.

Saha, S.K.;Halder, S.K. and Biswas, S.(1995) State Fauna Series 3: Fauna of West Bengal., Zoological Survey of India , **6** (A) : 1- 51.

Saini, R.K.(1996). Survey and surveillance in insect-pests management. In, *Manual of advanced training course on insect pest management .ICAR Centre of Advance Studies,* CCS Hariyana Agricultural University. Hisar, Hariyana, India. pp.20-25.

Santhi, M., Krisnamurthi, M.M., Mayurvalli, V.V.I. and Reddy, G.P.V.(1990) Effect of certain synthetic pyredthroids on the biology of pulse beetle, *Callosobruchus maculatus* fab. and lesser grain borer, *Rhizopertha deminica* Fab., *Indian J. Ent.* **56**(3):94-98.

Saxena, R.C. (1989). Insecticide from Neem. In, Insecticide of Plant Origin. (eds. J.T. Arnason, B.J.R. Phylogene and P. Morand). American Chemical Society, Washington, pp. 110-135.

Saxena, S. and Saxena, R.(1997). Ovipositor apparatus in *Dinarmus basalis* (Hymenoptera : Pteromalidae). *Russian Entomological Journal.*, **6** : 73-81.

Schmutter, H. (1990). Properties and potential of natural pesticide from the neem tree, *Azadiracta indica. Ann. Rev. Ent.*, **35**: 271 – 297.

Schoonhovan, A.V. (1978). Use of vegetable oils to protect stored beans from bruchid attack. *J. Econ. Entomol.*, **71**:254-256.

Schoonhoven, A. V., Raper, K.B. and Thorn, C.(1949). A manual of *Penicillia.* Williams and Williams Co., Baltimore.

Seddiqui, P.M. (1972). Studies on longivity, oviposition, fecundity and development of *Callosobruchus chinensis* L. (Coleoptera : Bruchidae) *Zeitschrift fur Angewandte Entomologie.* **72** (1) : 66-72.

Sexena, R.C. (1995). Pests of stored products. In, *The Neem Tree, Azadiracta india A. Juss. and other Meliaceous Plants : Source of Unique Natural Product for Intergrated Pest Management, Medicine Industry and Other Purposes.* (Ed. H. Schmutterer). V.C.H., Weinheim, pp. 418-432

Sharma, M.K. and Dwevedi, S.C. (1996) Resistance of selected germplasms of bengal gram against *C. chinensis* L. (Coleoptera : Bruchidae). *Uttar Pradesh J. Zool.* **16**(2) : 79-82

Sharma, M.K., Dwivedi, S.C. and Dwivedi, N.S. (1997). Relative susceptibility of nine germplasms of cowpea against C. chinensis L.

Sheokand, S.S., Singal, S.K. and Verma, A.N.1993. Evaluation of some edible plant oils as protectants of chickpea against pulse beetle, *Callosobruchus chinensis. Journal of Insect Science.* **2** : 267 - 273.

Shinoda, K., Yoshida, T. and Okamoto, T. (1991) Two wild leguminous host plants of the azuki been weevil, *C. chinensis* (Coleoptera : Bruchidae). *Applied Entomology and Zoology.* **26**(1): 91-98.

Shivankar, V.J.; A.S. Tomer and P.S. Tomer (1989). Insect-pests of fodder crops, their control residual persistence of insecticides – A review. *Agricultural Review.* **10** (4) : 188-194.

Sing, D.P.; Sharma, S.S. and Thaper, V.K. (1982) Biochemical changes in stored moong and mash varieties due to infestation of *Callosobruchus maculatus* Fab. (Bruchidae: Coleoptera). *Journal of Research,* Punjab Agril. Univ., **19**(2): 130 – 135.

Singal, S.K. (1987a) Preliminary biological studies of pulse beetle *Callosobruchus chinensis* L. on corticated and decorticated fava beans, *Vicia faba* L., *FABIS Newsletter (ICARDA).* pp. 33-35.

Singal, S.K. (1987b) Toxonomic studies of genus *Sulcobruchus chujo* from India (Coleoptera : Bruchidae). *Entomon* ., **12**:219-221.

Singal, S.K.(1987c). Preliminary biological studies of pulse beetle *Callosobruchus chinensis* L. on corticated and decorticated fava beans, *Vicia faba* L., *FABIS Newsletter (ICARDA).* pp. 33-35.

Singal, S.K.(1996d). Management of insect-pests in stored grains. In , *Manual of Advanced Training Course on Insect- Pest Management . ICAR Centre of Advance Studies* , CCS Hariyana Agricultural University. Hariyana, Hariyana , India . pp.161-166.

Singh, D.P. and Sharma, S.S.(1982). Studies on grain damage and germination loss caused by *Callosobruchus maculatus* Fab. in different varieties of mung bean and mash during storage. *Bulletin of grain*

Singh, H. (1962). Biology of *Pachymerus chinensis* (L.) on different food materials. *Indian Journal of Entomology.* **24 (4):** 279-289.

Singh, O.P.and Singh, K.J.(1989). Effectiveness of soybean oil against pulse beetle, *Callosobruchus chinensis* on pigeon pea. *Farm Science Journal.* 4 (2): 144 - 147.

Singh, S.R. (1975) *Annual Report. International Institute of Tropical Agriculture.*, pp. 101.

Singh, T. (1981). A taxonomic study of the wing of Bruchidae (Coleoptera). *Oriental Insects.* **15** (2) : 221-225.

Singh, U. (1999). Changes in the quality of red gram under different storage systems. *Journal of Entomological Research.* **23** (2) : 157-159.

Singh, V.N. Pandey, N.D. and Singh, V.P. (1994). Effectiveness of vegetable oils on the development of *Callosobruchus chinensis* Linn. infecting stored gram. *Indian J. Ent.*, **56**(3):216-219.

Singh, V.N.; Pandey, N.D. and Singh, Y.P. (1995). Relative resistance of gram varieties to *Callosobruchus chinensis* Linn. on the basis of biochemical parameters. *Indian Journal of Entomology*, **57** (2) : 77-82.

Singh, Y.; Saxena, H.P. and Singh, K.M.(1980a). Exploration of resistance pulse beetles. I. Ovipositional preference of *C. chinensis* and *C. maculatus*. *Indian J. Ent.*, **42** (3) : 375-382.

Singh, Y.; Saxena, H.P. and Singh, K.M.(1980b). Exploration of resistance pulse beetles.II. Growth and development of *C. chinensis* and *C. maculatus*. *Indian J. Ent.*, **42** (3) : 383-389.

Singh, Y.; Saxena, H.P. and Singh, K.M.(1980c). Exploration of resistance pulse beetles.III. Growth and development of *C. maculatus* Fab. *Indian J. Ent.*, **42** (4) : 622-626.

Singh, Y.; Saxena, H.P. and Singh, K.M.(1980d). Exploration of resistance pulse beetles.IV. Influence of black gram flour on the growth and development of *C. chinensis* Linn.. *Indian J. Ent.*, **42** (4) : 690-695.

Singh, Y.; Saxena, H.P. and Singh, K.M.(1980e). Exploration of resistance pulse beetles.V. Influence of lentil flour on the growth and development of *C.maculatus* Fab. *Indian J. Ent.* **42** (4) : 696-700.

Singh, Y.; Saxena, H.P. and Singh, K.M.(1980f). Exploration of resistance pulse beetles.VI. Registance factor of *C. maculatus* Fab.. *Indian J. Ent.*, **42** (4) : 701-712.

Sison, M.L.J.; Adalla, C.B. and Mantala, J.P. (1996). Life history of *Callsobruchus chinensis* and new source of mung bean resistance to this storage pest. *Philippine Entomologist.* **10** (2) : 175-187.

Smith, J.H.; Okeeffe, L.E.; Muchbaner, F.J.(1982) Method of screening dry peas for resistance the pea weevil (Col : Bruchidae) variability in seed infestation level. *J Econ. Ent.*, **75(3):** 530 – 534.

Southgate, B.J. (1978) The importance of the Bruchidae as pests of grain legumes, their distribution and control., pp. 219-229. In : Singh, S.R.; Van Emden, H.F.; Taylor, A.T. (eds.). *Pests of Grain Legumes : Ecology and Control.* Academic Press, London.

Southgate, B.J. (1982). The importance of bruchids (Col : Bruchidae) as pests of pigeon pea (*Cajanus cajan*). *Tropical Grain Legume Bulletin.* **24** : 21-24.

Srinivasacharyulu, B.S. and Yadav, T.D. (1997). Olfactory and ovipositonal preference of two strains of *Callosobruchus chinensis. Indian J. Ent.,* **59**(2):193-197.

Srivastava, A.S. and Lal, J.(1967). Survey of stored product insects on various godowns in Kanpur , Azambagh, Mathura, Allahabad, Varanasi, Barailly, and Badaun., *Ladev J. Sci. Tech.*,**5**(2) :165-166.

Srivastava, B.K. and Bhatia, S.K. (1958). Development of *Callosobruchus chinensis* L. in certain vegetable seeds. *Madras Agric. J.*, **45** (10) ; 392 – 395

Srivastava, B.K. and Pant, J.C. (2000). Growth and developmental response of *Callosobruchus chinensis* Linn. to different pulses. *Indian J. Ento.*, **51**(2) : 196-199.

Srivastava, K.P. (1993). A Text Book of Applied Entomology. Kalyani Publishers, India. 1:3-126

Srivastava, M.K. and Gopal, K. (1984). Relalive toxicity of organophosphorus insecticides against stored grain pests. *J. Adv. Zool.,* **5**(1):23-27..

Srivastava, P.D. and Singh, R.P.)1997). Insect pest management, In An *Introduction to Entomology,* Concept Publising Company, New Delhi.,pp.203-230.

Staneva, E.(1982).Studies on the food-plants of the cowpea weevil, *Callosobruchus maculatus* F. (Coleoptera : Bruchidae). *Rasteniev-dni-Nauki.*, **19**(4): 111 – 119.

Stanislaw, I., Elbieta, P. and Marta, K. (1995). Compatibility of *Azadirachtin* with entomophilic nematode. Sternemema felliae (Filipjev), in controlling insect pests. *Neem Newsl.*, **12** (2) : 21-23.

Steffen, J.R. (1954). Note surle genre *Uscana* Girrlt. (Hym. : Trichogrammatidae) et descriptions d' especes nouvellas parasites de bruches. *Bull. Mus. Hist. Nat.* Paris. **26**:667-673.

Sujatha, A. and Punnaiah, K.C. (1985). Effect of coating stored seed on greengram with vegetable oils on the development of pulse beetle. *Indian J. Agric. Sci.,* **55**(7):475-477.

Takasugi, T. (1924). Stadies on Bruchus chinensis L. Insect Pest of Stored Products. Part. II. Plant Quarantine st. Yokohama, pp. 1-12.

Talekar, N.S. and Lin, C.L. (1992). Characterization of *Callosobruchus chinensis* (Coleoptera; Bruchidae) resistance to mung bean. *Journal of Economic Entomology.* **85** (4) : 1150-1153.

Talekar, N.S. and Lin, Y.H. (1981). Two sources with differing modes of resistance to *Callosobruchus chinensis* in mung bean. *Journal of Economic Entomology,* **74** (5) : 639-642.

Tauthong, P. and Wanleelag, N. 1983. Studies on the life history of the southern cowpea weevil (*Callosobruchus chinensis* L.) and its control; Pests of Stored Products. Proceedings of BIOTROP symposium on Pests of Stored Products, Bagor, Indonesia, pp. 87-98.

Thomson, C.G. (1878). Hymenoptera Scandinaviae *Pteromalus (Svederus), Continuatio,* 307.

Tikku, K., Koul, O., Saxena, B.P. (1981). Possible mode of action of vegetable oils to protect *Phaseolus aurens* Rozb. form bruchid attack. *Science and Culture.*, **47**(3):103-105.

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

Utida, S.(1942). Studies on the experimental population of the azuki bean weevil *Calloso bruchus chinensis* L. VI The relationship between the size of the environment and rate of population growth., *Mem. Coll. Agric.* Kyoto, **53** : 1 – 8.

Van Emden, F.I. (1946). Egg bursters in some families of polybhagus beetles and some general remarks on egg bursters. ,*Proc. Royl. Ent. Soc.*, London (A), **21**:89-97.

Verma, B.K. and panday, G.P. (1978). Treatment of stored greangram seed with edible oils for protection from *Collosobruchus maculatus* (Fab.). *Indian J. Agric. Sci.,* **48(2)**:72-75.

Verma, R. (1990). Host habitat olocation and host location by *Dinarmus basalis,* a parasite of bruchids of stored legumes. *Indian J. Exp. Bio.*, **28**:179-184.

Vir, S. (1982) Relative resistance of some cowpea varieties to the pulse beete, *Calloso bruchus maculatus* Fabricius., *Pestology,* **6**(7): 9 – 11.

Warni, C.M. (1984). Bruchid infestation of cowpea variety in the field. In *Insect Science and its Application.,* **5** (4) : 283-286.

Wasserman, S.S.(1981) Host- induced oviposition preferences and oviposition markers in the cowpea weevil, *Callosobruchus maculatus. Annals Euto. Soc. America.*, **74**(2): 242 – 245.

Wasserman, S.S.(1985) Oviposition behaviour and its disruption in the southern cowpea weevil, *Callosobruchus maculatus* F. (Coleoptera : Bruchidae). *J. Econ. Ento.,* **78**(1): 89 – 92.

Wightman, J.A.; Southgate, B.J. (1982). Egg morphology, host and probable regions of origin of the bruchids (Coleoptera : Bruchidae) that infest stored pulses – an identification aid. *New Zealand J. Exp. Agril.,* **10** (1) : 95-99.

Williams, J.O. (1980). Note on Bruchids associated with stored products in Nigeria. *Tropical Grain Legume Bulletin.* **21** : 5-10.

Xiao Hui.; Huang, D.; Xiao, H.; Huang, D.W.(2000). A taxonomic study of Pteromalidae (Hemenoptera) from Hainan ,China.; *Entomotaxonomia.,* **20** (2) : 140-149.

Xu Ying; Hong Jian; Hu Cui.; Xu, Y.; Hong, J. and Hu, C.(2000). Ultrastructural studies on the antennal sensilla of *Pteromalus puparum* L. (Hymenoptera : Pteromalidae). *J. Zhejiang. Univ. Agril. Life Sci.,* **26** (4) : 394-398.

Yadav, D.S. (1992).Pulse crops (Production Technology*).* Kalyani Publishers, New Delhi, pp 1-7.

Yadav, T.D. (1985). Antiovipositional and ovicidal toxicity of neem (*Azadirachta indica* A. Juss) oil against three species of *Callosobruchus. Neem Newsletter* ., **2**(1):5-6.

Zachir, F. (1930). Investigation on the morphology and biology of the seed beetles (Contribution to the knowledge of pests of stored Berhin products). *Arc. Richsamst.,* **18** (3) : 233-289.

Zaghloul, O.A. and Mourad, A.K. (1998). Studies on the egg parasitoid, *Uscana lariophaga* Steffan (Hymenoptera : Trichogrammatidae), with reference to its role in the assessment of cowpea losses due to *Callosobruchus maculatus* F. (Coleoptera : Bruchidae) in Egypt. *Proceedings : 50th International Symposium on Crop Protection,* Gent, Belgium., **63** (**26**) : 441-453.

Zakladnoi, G.A. and Ratanova, V.F.(1987). Stored Grain Pests and Their Control.,Oxonian Press Pvt. Ltd., N. Delhi,pp.20-82.

APPENDICES

Appendix I

Key to the identification of pests and parasitoids

A qualitative and quantitative survey that involves the identification of naturally occurred species present on stored pulses would be possible if a ready- reconer of species identification characters is made. The literature dealing with the species identification - key and taxonomy of insects is scattered in many journals and monographs published over many years. Many of these literatures are very difficult to obtain. The identification key was formulated as under based on the literature made by Arora (1977), Sing (1981), Mani (1989) and Khare (1994):

Species characters of the pests

Coleoptera : Bruchidae

Hind femur tooth on both sides, median basal thoracic lobe elevated, whitish ivory like spots, antennae long, pectinate and a pair of tubercles present at the base of third and fourth otries of each elytron in male; antennae short, sub-serrate and elytral tubercles absent in female. .... ***Callosobruchus chinensis*** Linnaeus

Hind femur tooth on both sides, median basal thoracie lobe slightly elevated and dark; densely covered with whitish hairs, male antennae larger than that of female; elytra dull coloured and female elytra with bright spots.. ***C. maculatus*** Fabricius

Body colour light in male, pygidium light-brown and wide median testaceous stripe (i.e. brownish yellow stripe or 'V' shaped area), body colour dark in female, pygidium black with white spots and narrow median testaccous stripe in female.......................... ....***C. analis*** Fabr.

Hind femur tooth on outer side, last segment of antennae coloured, first femur blackish, two blackish spots on the last abdominal segment ....***C. pisorum*** Linn.

Coleoptera : Curculionidae

Snout long and slender, elytra yellowish – uniformly polished markings absent, hindwings obsolete or rudimentary, punctures large on thorax. .... ***Sitophilus granarius*** Linn.

Lepidoptera : Galleriidae

Forewings greyish ochreous or light, lightly adpressed to the body, wings are held closely to the abdomen when rest, besal half of the forcewings silvery white, outer portion reddish bronze with irregular dark .... ***Corcyra cephalonica*** Stainton

Contd:

Species characters of the parasitoid of the bruchids

Hymenoptera: Chalcidoidea : Pteromalidae : Pteromalinae :Metaponini

Nucha will developed; body with metalic reflection; female antinnae with 3 and male antinnae with 2 annulli, marginal vein (*m*) alteest a little longer than stigmal vien(st) ……………………………………………………………………….**Genus-*Dinarmus***Thomson

Vein *pm* sub equal to vein *st*; both mandibles with 4 teeth…………………………………………………. ……………………………………………………………… … ……. ***Dinarmus vagabundus*** (Timberlake)

Chalcidoidea : Trichogrammtidae:Trichogrammatinae: Trichogrammatini

Antinnae with 7 segments; forewings with marginal fringe short and found all round... ……………………………………………………………………….. ***Uscana*** Girault

Brown, dnsely clothed with long fine setae; antennae 7 segmented – 1.1.1.1.3 mesonotum and scutellum smooth, vein *sm* about 2 times longer than *m* ……………………………………………………………………… ……………………………………………………………………… ***Uscana mukerjii*** (Mani)

Chalcidoidea : Pteromalidae : Cerocephalinae

Head subovate with a projection between antennae; antennae long and stout, 9 segmented, scape long, slender, club fused with funicle, shortly pointed, antennae in male adult with long hairs; mesonotum polished; scutellum flat; fore wing vein m long, fringe at apex long, pm and st veins short; legs stoupetiole hardly as wide as thick; abdomen shortly oval, first tergite largest…………………………………………….. … ***Cerocephala dinoderi*** Gahan

Hymenoptera : Ichneumonoidea : Braconidae

Minute or small; yellowish colour; forewings with 2 submarginal, 2 cubital and 1 discoidal cells. ……………………………………………………………………….***Bracon* sp.**

Appendix II

Pulses production in the four districts of Terai agro-ecological region

District / Pulse	YEAR	Coochbehar 1997-98	Coochbehar 1998-99	Jalpaiguri 1997-98	Jalpaiguri 1998-99	Darjeeling 1997-98	Darjeeling 1998-99	Uttar Dinajpur 1997-98	Uttar Dinajpur 1998-99
1. Bengal gram	A	NR	0.030	NR	0.042	NR	NR	1.081	0.257
	Y		677		677			611	467
	P		0.020		0.030			0.660	0.120
2. Red gram	A	0.012	0.151	0.008	NR	NR	NR	0.054	0.051
	Y	965	801	965				965	801
	P	0.010	0.120	0.010				0.050	0.040
3. Green gram	A	0.662	0.794	0.085	0.050	0.150	0.076	0.347	0.807
	Y	360	321	635	735	340	282	262	292
	P	0.238	0.255	0.054	0.037	0.051	0.020	0.091	0.236
4. Black gram	A	5.989	7.079	3.476	3.921	0.195	0.159	11.081	8.305
	Y	631	525	591	439	697	472	443	426
	P	3.77	3.720	2.056	1.720	0.136	0.075	4.904	3.534
5. Lentil	A	0.357	0.816	1.024	1.236	NR	NR	0.367	0.599
	Y	392	355	547	413			436	417
	P	0.140	0.290	0.560	0.510			0.160	0.250
6. Pea	A	0.013	0.048	0.551	0.182	0.924	0.876	NR	0.035
	Y	784	708	784	708	784	708		708
	P	0.010	0.030	0.430	0.130	0.720	0.620		0.020
7. Grass pea	A	0.824	2.873	1.451	0.421	NR	NR	0.775	0.285
	Y	835	438	834	451			835	438
	P	0.690	1.260	1.210	0.190			0.640	0.120
8. Horse gram	A	NR	0.010	0.099	0.100	NR	NR	0.992	0.580
	Y		400	540	550			401	360
	P		0.004	0.053	0.050			0.398	0.209
9. Soybean	A	NR	NR	NR	NR	0.533	0.533	NR	NR
	Y					652	655		
	P					0.348	0.349		
10. Other pulses	A	NR	NR	NR	NR	0.095	0.095	NR	NR
	Y					650	650		
	P					0.062	0.062		
Total pulses	A	7.857	11.801	6.694	5.952	1.897	1.739	14.697	10.919
	Y	619	483	653	448	694	647	470	415
	P	4.867	5.699	4.373	2.667	1.317	1.126	6.903	4.529
Report: Evaluation wing, Directorate of agriculture (Govt. of W. B.), India (2000)									

A = Area in '000 hectares.
Y = Yield rate in kg/hectares.
P = production in '000 tones.

NR= No report

Appendix III.

Climatic data (1971-2001) conditions of the Terai agro-Ecological Region of W.B.

Year	Temperature °C (Average)		Relative humility (%)			Rain fall (mm)
	Max.	Min.	Max.	Min.	Average	Average
	1	2	3	4	5	6
1971-81 (11 Years)	29.75	19.25	86.00	55.00	74.12	2537.90
1982 – 91 (10 Years)	29.07	18.02	87.30	60.38	76.06	2934.59
1992 – 2001 (10 Years)	28.59	17.79	88.75	63.77	79.09	3332.00
1971 – 2001 (31 Years)	29.13	18.35	87.35	59.71	76.42	2934.83
Normal (Average of 31 years)	**29.38**	**18.85**	**88.1**	**60.71**	**77.67**	**2936.33**

Source: NARP, IARI, New Delhi, India (1971-81)
Evaluation wing, Directorate of Agriculture (Govt. of W. B.), India (1982-2001)

Appendix IV.

Duration of seasons of Terai-region (1971-2001)

December and January are the coldest (12 ° C to 25 ° C); March to October is the highest (23°C to 32°C). The maximum and minimum temperature is stable during mid-April to mid- October. The extreme maximum temperature 32 to 35°C during May to October and extreme minimum temperature 7-10°C during January has been recorded. Humid and warm; September to November is autumn, November to February is winter (December to February); highest rainfall during June to September (Rainy season) and March to May is summer.

Season	Indian	Terai region of W. B., India
Summer	2nd week of April to 2nd week of June	1st week of March to last week of May
Rainy	2nd week of June to 3rd week of August	1st week of June to 3rd week of September
Spring	3rd week of August to 3rd week of October	-
Autumn	3rd week of October to 2nd week of December	3rd week of September to 2nd week of November
Winter	2nd week of December to 2nd week of February	2nd week of November to last week of February

Appendix V

Weekly temperature and relative humidity of the experimental during laboratory the period from January 1999 to July, 2002

Standard week	Year	Temperature °c			Relative humidity %		
		Min.	Max.	Average	Min.	Max.	Average
1.	1999	19.35	23.57	21.46	52	68	61.57
	2000	16.85	18.28	17.56	63	78	69.28
	2001	16.93	19.86	18.39	58	84	76.00
	2002	16.85	20.14	18.95	57	76	62.00
	Pooled	**17.49**	**20.46**	**19.09**	**57.50**	**76.50**	**67.21**
2.	1999	18.21	22.00	20.10	51	70	58.28
	2000	16.42	18.07	17.24	64	88	70.85
	2001	14.43	18.29	16.36	63	72	69.71
	2002	17.42	20.42	18.29	60	73	65.85
	Pooled	**16.62**	**19.69**	**17.99**	**59.50**	**75.75**	**66.17**
3	1999	18.78	22.35	20.56	54	82	62.57
	2000	18.35	19.85	19.10	63	79	68.00
	2001	16.43	19.71	18.07	63	72	69.71
	2002	18.28	19.91	19.9	67	79	78.57
	Pooled	**17.96**	**20.45**	**19.40**	**61.75**	**78.00**	**69.71**
4	1999	19.78	24.42	22.21	49	66	57.28
	2000	17.07	20.21	18.71	56	79	63.57
	2001	16.50	20.50	18.50	72	84	74.57
	2002	17.50	19.28	18.93	68	78	72.00
	Pooled	**17.71**	**21.10**	**19.58**	**61.25**	**76.75**	**66.85**
6.	1999	20.50	24.75	22.62	52	65	57.78
	2000	17.21	19.85	18.85	64	73	68.57
	2001	16.85	21.64	19.24	79	84	76.29
	2002	17.00	18.57	17.87	64	74	70.14
	Pooled	**17.89**	**21.20**	**19.64**	**64.75**	**74.00**	**68.19**
7.	1999	21.70	25.00	23.35	61	80	68.21
	2000	17.21	20.71	18.96	56	78	71.14
	2001	17.36	20.57	18.76	64	79	67.71
	2002	18.82	21.07	19.49	66	80	74.57
	Pooled	**18.77**	**21.83**	**20.14**	**61.75**	**79.25**	**70.40**
	1999	18.52	23.70	21.11	49	67	60.42
	2000	17.92	21.57	19.75	51	70	60.75
	2001	16.29	22.64	19.46	65	71	67.43
	2002	22.00	24.14	23.07	58	78	65.14
	Pooled	**18.68**	**23.01**	**20.84**	**55.75**	**71.50**	**63.43**
8.	1999	21.21	24.14	22.67	49	72	67.57
	2000	20.71	21.85	21.28	47	60	51.71
	2001	18.64	23.93	21.28	63	72	66.43
	2002	22.64	24.35	23.14	56	68	61.28
	Pooled	**20.80**	**23.56**	**22.09**	**53.75**	**68.00**	**61.74**
9.	1999	21.07	24.21	22.64	44	54	49.78
	2000	18.71	22.07	20.39	47	70	54.57
	2001	18.21	24.64	21.42	44	72	56.00
	2002	21.85	24.64	23.42	53	64	55.71
	Pooled	**19.96**	**23.89**	**21.96**	**47.00**	**65.00**	**54.01**
10.	1999	20.06	25.28	22.67	38	72	57.07
	2000	19.71	24.78	22.24	37	69	61.42
	2001	19.71	23.93	21.82	49	63	55.17
	2002	22.92	25.64	24.18	50	66	54.14
	Pooled	**20.60**	**24.90**	**22.72**	**43.50**	**67.50**	**56.95**
11.	1999	25.07	29.00	27.03	39	75	45.75
	2000	20.14	24.42	22.28	38	69	61.42
	2001	23.64	26.93	25.28	43	54	51.57
	2002	25.14	27.42	26.18	53	70	69.42
	Pooled	**23.49**	**26.94**	**25.19**	**43.25**	**67.00**	**57.04**
12.	1999	25.14	28.42	26.78	44	59	48.85
	2000	22.28	25.35	23.81	43	60	51.14
	2001	25.00	28.50	26.75	45	53	48.00
	2002	26.07	28.42	27.42	50	68	56.54
	Pooled	**24.62**	**27.67**	**26.19**	**45.50**	**60.00**	**51.13**
13.	1999	25.21	30.25	27.73	51	69	59.14
	2000	24.64	28.07	26.35	48	67	55.28
	2001	26.64	29.14	27.84	52	68	60.43
	2002	24.28	26.35	25.13	66	77	70.00
	Pooled	**25.19**	**28.45**	**26.76**	**54.25**	**70.25**	**61.21**
14.	1999	27.21	30.25	28.73	52	80	70.78
	2000	27.35	30.50	28.92	31	68	45.57

	2001	25.71	29.64	27.67	56	76	63.57
	2002	22.92	25.50	24.21	69	92	76.85
	Pooled	**25.79**	**28.97**	**27.38**	**52.00**	**79.00**	**64.19**
15.	1999	26.00	29.85	27.92	62	79	72.42
	2000	26.07	30.28	28.89	47	72	61.14
	2001	26.79	29.86	28.32	65	78	72.57
	2002	25.42	27.14	26.28	62	72	66.14
	Pooled	**26.07**	**29.28**	**27.85**	**59.00**	**75.25**	**68.06**
16.	1999	28.57	31.71	30.14	51	61	55.57
	2000	25.57	29.64	27.60	61	71	66.85
	2001	26.79	29.57	28.18	57	67	64.29
	2002	26.42	28.14	27.28	69	82	74.28
	Pooled	**26.83**	**29.76**	**28.30**	**59.50**	**70.25**	**65.24**
17.	1999	27.51	31.28	29.39	54	72	59.00
	2000	23.28	27.28	25.28	66	70	68.42
	2001	25.14	28.79	26.96	62	86	76.14
	2002	23.71	26.14	24.29	72	77	74.00
	Pooled	**24.91**	**28.37**	**26.48**	**63.50**	**76.25**	**69.39**
18.	1999	26.42	29.42	27.92	60	82	69.85
	2000	24.57	27.52	26.04	69	78	71.71
	2001	22.71	27.00	24.85	60	77	70.28
	2002	24.28	26.64	25.64	62	79	72.14
	Pooled	**24.49**	**27.64**	**26.11**	**62.75**	**79**	**70.99**
19.	1999	26.28	31.28	28.78	69	96	79.57
	2000	28.78	32.14	30.46	66	72	68.85
	2001	25.42	29.28	27.35	66	87	75.00
	2002	28.07	30.35	29.12	60	67	62.85
	Pooled	**27.13**	**30.76**	**28.92**	**65.25**	**80.5**	**71.56**
20.	1999	27.28	32.00	29.64	76	82	78.42
	2000	28.07	33.35	30.71	67	83	77.00
	2001	27.50	31.21	29.35	54	77	70.28
	2002	30.92	32.35	31.36	60	69	64.14
	Pooled	**28.44**	**32.22**	**30.26**	**64.25**	**77.75**	**72.46**
21.	1999	27.78	29.92	28.85	78	91	82.00
	2000	26.85	33.42	30.13	72	76	74.28
	2001	26.57	30.50	28.53	76	83	80.71
	2002	27.35	28.71	28.3	64	72	68.42
	Pooled	**27.13**	**30.63**	**28.95**	**72.50**	**80.5**	**76.35**
22.	1999	27.92	29.07	28.49	84	87	85.71
	2000	25.64	30.00	27.82	78	86	79.85
	2001	26.78	30.25	28.51	79	91	5.420
	2002	27.92	29.92	28.29	64	81	75.14
	Pooled	**27.06**	**29.81**	**28.27**	**76.25**	**86.25**	**61.53**
23.	1999	30.14	30.85	30.49	74	81	79.28
	2000	28.35	31.00	29.67	76	83	79.85
	2001	26.28	29.14	27.71	83	90	86.28
	2002	28.00	31.14	29.57	78	89	82.00
	Pooled	**28.19**	**30.53**	**29.36**	**77.75**	**85.75**	**81.85**
24.	1999	29.57	30.92	30.24	74	81	78.28
	2000	27.00	29.07	28.03	82	92	85.14
	2001	28.07	32.21	30.14	67	88	78.85
	2002	27.14	30.24	28.69	65	85	80.28
	Pooled	**27.94**	**30.61**	**29.27**	**72.00**	**86.5**	**80.63**
25.	1999	28.85	30.28	29.56	80	85	82.14
	2000	27.35	30.57	28.96	80	90	84.57
	2001	27.85	29.92	28.88	76	87	81.71
	2002	27.50	30.64	29.07	71	86	79.85
	Pooled	**27.88**	**30.35**	**29.11**	**76.75**	**87**	**82.06**
26.	1999	26.92	28.28	27.60	82	89	85.71
	2000	26.50	29.07	27.78	86	92	89.00
	2001	29.14	31.35	30.24	76	80	79.28
	2002	28.92	31.00	29.69	66	78	70.14
	Pooled	**27.87**	**29.92**	**28.82**	**77.50**	**84.75**	**81.03**
27.	1999	27.07	28.14	27.60	84	87	85.85
	2000	26.78	29.21	27.89	87	96	90.57
	2001	29.21	32.42	30.81	74	77	76.14
	2002	28.57	31.42	29.99	73	82	79.04
	Pooled	**27.90**	**30.29**	**29.07**	**79.50**	**85.5**	**82.90**
28.	1999	27.64	28.64	28.14	82	90	85.71
	2000	26.64	30.21	28.42	84	91	85.14
	2001	28.78	32.93	30.85	77	80	78.28
	2002	28.28	32.00	30.41	70	84	75.28
	Pooled	**27.83**	**30.94**	**29.45**	**78.25**	**86.25**	**81.10**
29.	1999	27.57	28.85	28.21	80	85	83.42
	2000	27.78	30.78	29.28	76	84	80.14
	2001	28.42	30.85	29.63	77	80	78.28
	2002	26.50	30.28	28.39	80	84	82.57
	Pooled	**27.56**	**30.19**	**28.87**	**78.25**	**83.25**	**81.10**
30.	1999	28.64	29.57	29.10	80	86	82.72
	2000	28.07	30.75	29.41	74	80	76.57
	2001	28.28	32.50	30.39	73	84	76.71
	2002	26.00	28.07	27.03	82	88	86.00
	Pooled	**27.74**	**30.22**	**28.98**	**77.25**	**84.50**	**80.50**
31.	1999	28.84	30.57	29.70	76	82	78.85
	2000	26.78	30.60	28.39	78	88	84.85
	2001	27.71	30.21	28.96	79	87	83.14
	Pooled	**27.77**	**30.46**	**29.01**	**77.66**	**85.66**	**82.28**
32.	1999	29.92	31.42	30.67	75	87	80.57
	2000	26.64	30.07	28.35	80	87	86.50
	2001	28.21	31.78	29.99	72	80	76.71
	Pooled	**28.25**	**31.09**	**29.67**	**75.66**	**84.66**	**81.26**

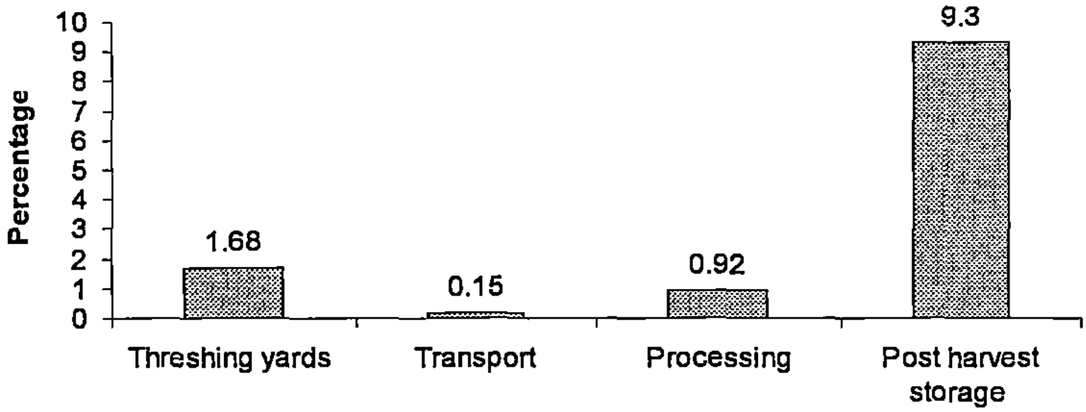
33.	1999	28.35	29.32	28.83	82	91	87.42
	2000	27.28	29.57	28.42	84	91	87.71
	2001	29.28	31.71	30.49	70	79	74.42
	Pooled	**28.30**	**30.20**	**29.24**	**78.66**	**87.00**	**83.18**
34.	1999	26.92	28.64	27.78	84	93	88.28
	2000	28.57	31.07	29.82	79	87	80.28
	2001	27.71	31.21	29.46	73	87	82.79
	Pooled	**27.73**	**30.30**	**29.02**	**78.66**	**89.00**	**83.78**
35.	1999	27.07	28.57	27.82	84	91	89.20
	2000	28.00	29.92	28.96	76	88	78.85
	2001	27.92	30.42	29.17	84	87	85.57
	Pooled	**27.66**	**29.63**	**28.65**	**81.33**	**88.66**	**84.54**
36.	1999	28.78	29.71	29.24	82	89	85.92
	2000	27.07	30.14	28.60	80	86	83.14
	2001	27.21	29.64	28.42	72	87	78.14
	Pooled	**27.68**	**29.83**	**28.75**	**78.00**	**87.33**	**82.4**
37.	1999	28.71	30.00	29.35	76	86	82.14
	2000	27.78	30.78	29.28	72	87	81.54
	2001	26.42	29.14	27.78	79	87	84.71
	Pooled	**27.63**	**29.97**	**28.80**	**75.66**	**86.66**	**82.79**
38.	1999	27.85	30.14	28.99	76	86	80.28
	2000	25.50	27.92	26.71	79	86	83.71
	2001	26.92	29.07	27.99	78	83	80.14
	Pooled	**26.75**	**29.04**	**27.89**	**77.66**	**85**	**81.37**
39.	1999	25.85	28.28	27.06	80	91	84.00
	2000	25.78	28.85	27.31	82	91	84.28
	2001	27.57	30.21	28.89	76	90	78.42
	Pooled	**26.40**	**29.11**	**27.75**	**79.33**	**90.66**	**82.23**
40.	1999	27.71	28.64	28.17	79	84	82.28
	2000	27.71	29.64	28.41	82	91	83.85
	2001	24.71	27.50	26.10	79	91	87.57
	Pooled	**26.71**	**28.59**	**27.56**	**80.00**	**88.66**	**84.56**
41.	1999	26.92	28.07	27.49	59	79	70.14
	2000	28.00	30.42	29.21	71	87	80.71
	2001	25.78	28.71	27.24	68	82	77.71
	Pooled	**26.90**	**29.06**	**27.98**	**66.00**	**82.66**	**76.18**
42.	1999	25.71	29.57	27.64	68	72	70.14
	2000	25.71	30.85	28.28	64	72	69.14
	2001	26.07	28.35	27.21	74	83	77.61
	Pooled	**25.83**	**29.59**	**27.71**	**68.66**	**75.66**	**72.29**
43.	1999	26.00	28.85	27.42	68	88	73.14
	2000	26.28	29.98	27.78	64	79	77.77
	2001	24.57	27.50	26.03	68	79	73.57
	Pooled	**25.61**	**28.77**	**27.07**	**66.66**	**82**	**74.82**
44.	1999	23.14	27.05	25.07	62	82	71.28
	2000	23.07	26.92	24.99	62	93	74.42
	2001	23.78	27.57	25.67	60	74	65.87
	Pooled	**23.33**	**27.18**	**25.24**	**61.33**	**83**	**70.52**
45	1999	21.42	24.85	23.13	65	75	71.14
	2000	23.92	26.92	25.42	59	78	70.00
	2001	23.00	26.57	24.78	58	79	69.57
	Pooled	**22.78**	**26.11**	**24.44**	**60.66**	**77.33**	**70.23**
46.	1999	21.71	24.21	22.96	68	73	70.28
	2000	21.5	24.57	23.03	60	77	69.28
	2001	21.28	24.85	23.06	62	78	68.29
	Pooled	**21.49**	**24.54**	**23.01**	**63.33**	**76**	**69.28**
47.	1999	21.14	24.00	22.57	67	72	69.00
	2000	22.64	25.35	23.99	60	72	64.71
	2001	21.71	24.85	23.28	59	73	67.42
	Pooled	**21.83**	**24.73**	**23.28**	**62.00**	**72.33**	**67.04**
48.	1999	22.50	24.14	23.32	56	69	62.28
	2000	21.21	23.85	22.53	53	67	57.85
	2001	20.28	23.57	21.92	50	65	59.00
	Pooled	**21.33**	**23.85**	**22.59**	**53.00**	**67**	**59.71**
49.	1999	21.35	23.57	22.46	52	58	55.71
	2000	18.28	21.57	20.07	52	65	60.85
	2001	18.92	21.71	20.85	53	74	70.57
	Pooled	**19.51**	**22.28**	**21.12**	**52.33**	**65.66**	**62.37**
50.	1999	21.21	22.58	21.89	60	68	62.14
	2000	18.42	21.37	19.89	65	80	73.57
	2001	18.50	21.07	19.96	57	79	82.53
	Pooled	**19.37**	**21.67**	**20.58**	**60.66**	**75.66**	**72.74**
51.	1999	19.85	21.57	20.71	57	71	64.85
	2000	18.47	21.35	19.91	66	79	73.85
	2001	18.75	21.21	19.98	51	78	63.14
	Pooled	**19.02**	**21.37**	**20.20**	**58.00**	**76**	**67.28**
52.	1999	19.12	20.14	19.63	58	69	63.51
	2000	18.17	20.61	19.39	62	77	69.55
	2001	18.49	21.01	19.75	54	74	64.00
	Pooled	**18.59**	**20.58**	**19.59**	**58**	**73.3**	**65.66**

Appendix VI

Monthly climatic data in the experimental laboratory during the period of investigation during 1999 to 2001 (January, 1999 to December, 2001)

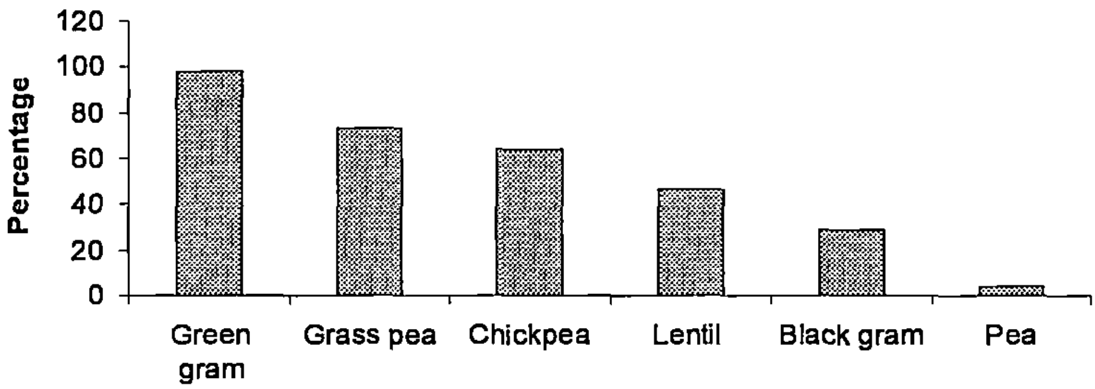
Year		Temperature (^{0}C)			Rainfall (mm)	Average relative humidity (%)
		Max.	Min.	Average		
January	1999	20.46	16.14	18.3	00.0	58.94
	2000	19.70	17.74	18.72	00.0	68.38
	2001	19.59	16.59	17.82	00.0	72.28
Pooled		20.13	16.90	18.45	00.0	65.96
February	1999	23.57	19.99	21.78	00.0	60.99
	2000	21.71	18.17	19.67	00.0	61.55
	2001	22.70	17.59	20.14	00.0	67.41
Pooled		22.55	18.97	20.94	01.00	60.23
March	1999	29.10	24.96	27.03	45.00	52.11
	2000	27.72	22.92	25.32	15.50	59.66
	2001	28.71	23.69	26.20	44.95	52.98
Pooled		28.28	23.96	26.12	55.38	54.31
April	1999	30.85	27.35	29.10	180.7	62.75
	2000	30.87	25.95	28.41	132.9	62.99
	2001	29.92	25.62	27.32	233.4	68.91
Pooled		30.55	26.47	28.39	189.25	65.03
May	1999	31.92	27.15	29.53	335.8	78.96
	2000	31.72	27.13	29.42	260.4	73.97
	2001	30.59	27.64	29.11	447.02	75.85
Pooled		31.62	27.68	29.65	335.80	74.57
June	1999	30.86	27.68	29.27	745.20	82.22
	2000	29.92	27.30	28.61	1009.80	84.64
	2001	29.48	27.41	28.44	493.50	81.69
Pooled		30.09	27.36	28.73	734.67	81.76
July	1999	29.14	27.98	28.56	862.60	83.73
	2000	30.26	27.25	28.75	777.48	83.28
	2001	30.73	28.53	30.13	314.03	78.85
Pooled		30.25	26.97	28.73	739.07	79.77
August	1999	29.48	28.22	28.56	1081.90	84.86
	2000	30.16	27.57	28.86	423.46	84.21
	2001	31.26	28.56	29.91	294.81	80.58
Pooled		30.42	27.18	28.72	698.76	81.72
September	1999	29.12	27.43	28.27	261.70	77.25
	2000	29.53	26.42	27.97	435.90	82.34
	2001	29.51	27.03	28.27	465.30	80.35
Pooled		29.59	26.25	27.92	520.57	80.87
October	1999	28.62	26.06	27.34	445.60	74.94
	2000	29.70	25.28	27.49	62.93	75.63
	2001	28.01	25.42	26.71	265.98	78.11
Pooled		28.66	25.57	27.11	254.40	74.04
November	1999	24.84	21.98	23.41	00.0	68.79
	2000	25.55	22.55	24.05	28.50	67.53
	2001	25.76	22.35	24.02	00.0	65.82
Pooled		25.30	22.96	24.13	07.12	65.53
December	1999	22.42	20.65	21.53	00.0	60.76
	2000	21.62	18.45	20.03	00.0	68.85
	2001	21.34	18.62	19.98	00.0	67.75
Pooled		21.84	19.43	20.63	00.0	65.59

Appendix-VIII. Storage loss of food grains



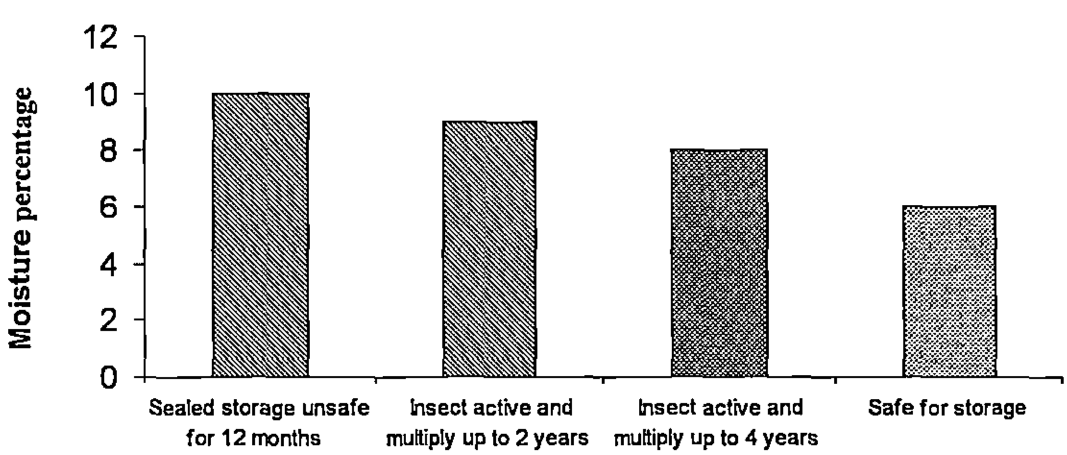
Report : Expert Committee, Govt. of India, Food Industry, 1978

Appendix IX. Loss of stored pulses in India by Bruchid pests (6-8 months of storage)



Source : Mookherjee *et al.,* 1970

Appendix-VII. Ecological control



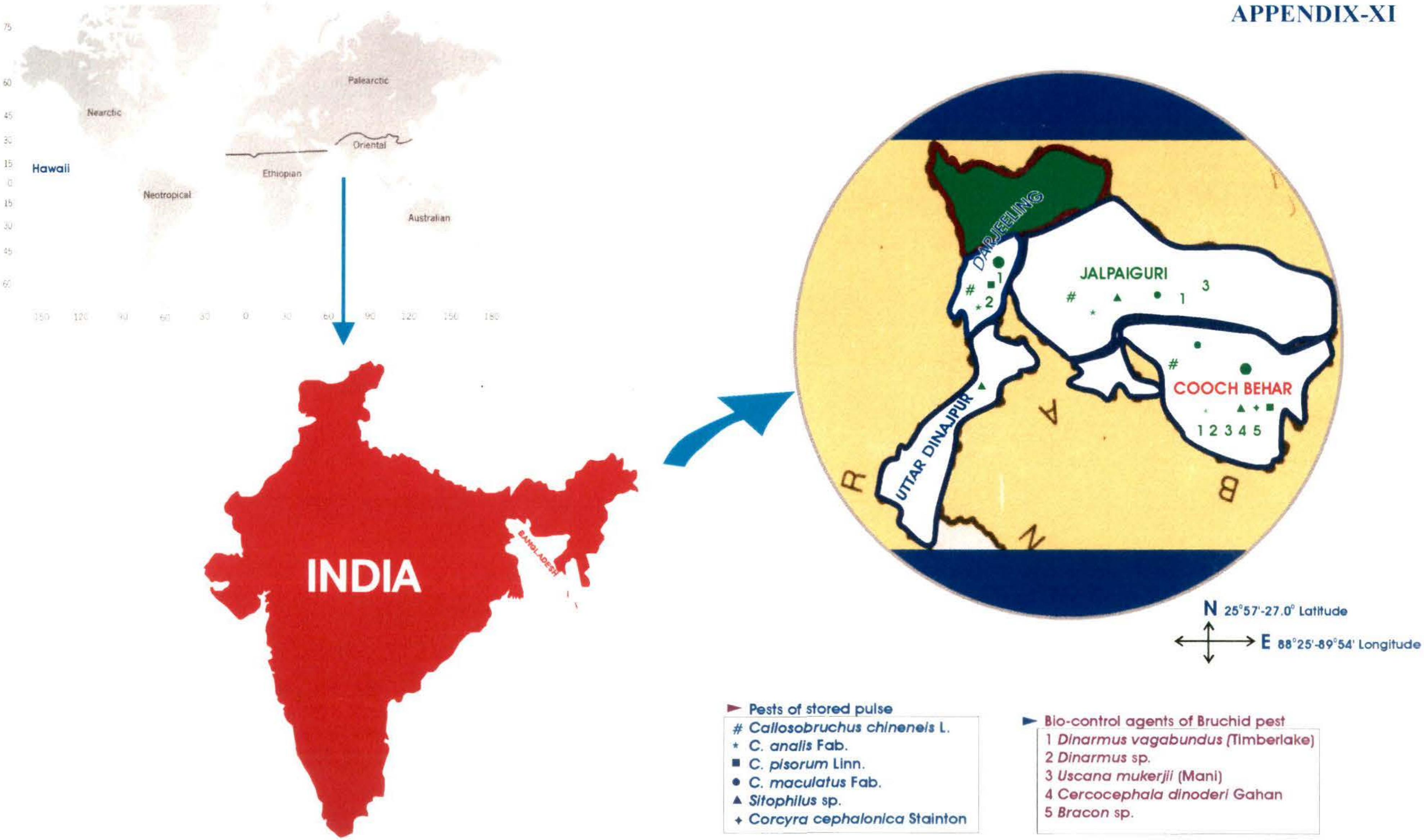
Source : Expert Committee, Govt. of India, Food Industry (1978)

Appendix X : Name of the oils and plant species, their families and bio-chemical components.

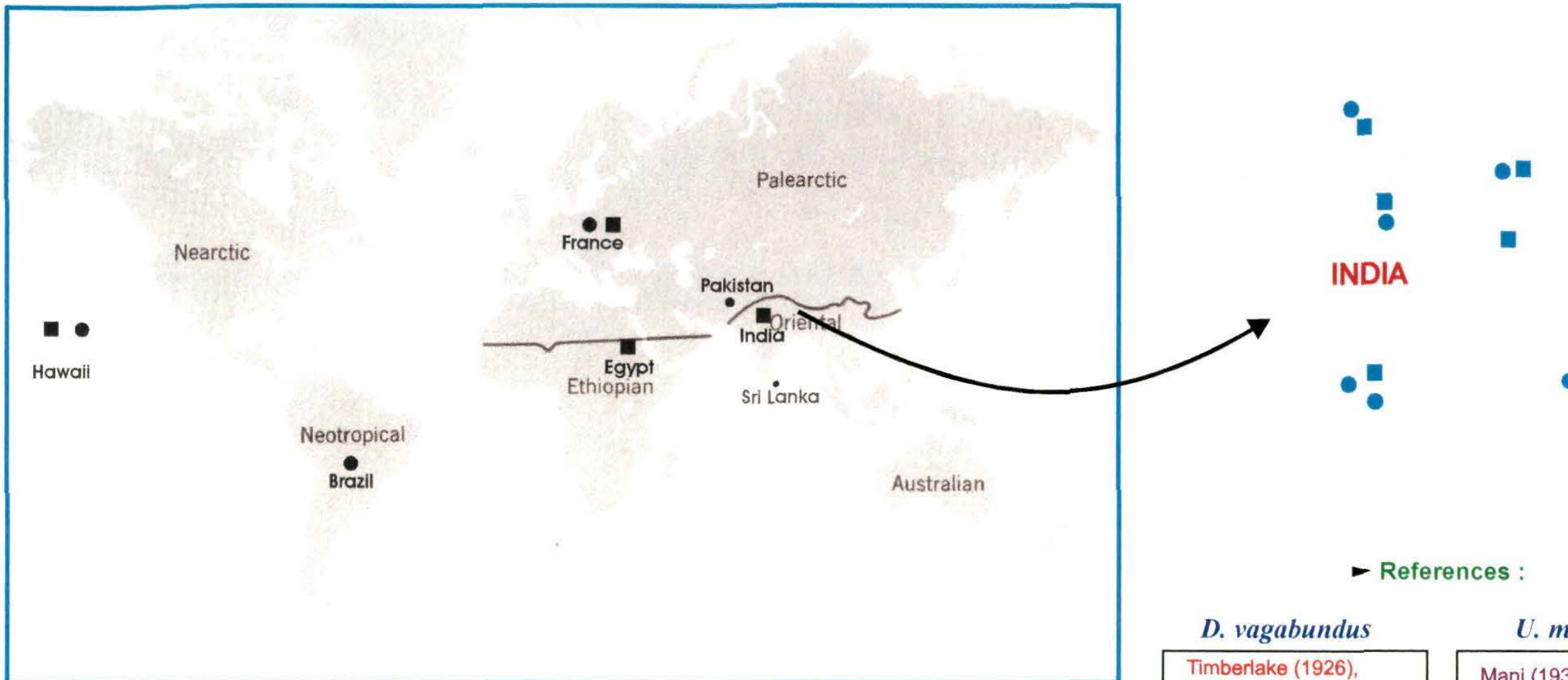
Common name & Scientific name	Family	Biologically active chemical Component (s) (ACID, *fatty acid*, ester & alcohol)
1. Mustard oil *Brassica juncea* Linn.	Cruciferae	*Oleic,linoleic,mysistic,lauric*
2. Soybean oil *Glycine max* (L.) Merrill	Fabaceae	Saponin (terpenoid), **pinitol,** OXALIC, HYDROCYANIC
3. Coconut oil *Cocos nucifera* Linn.	Palmaceae	*Caprolic, caprilic, lauric,* UNDECANOIC, *myristic*
4. **Neem oil** *Azadirachta indica* (A. Juss)	Meliaceae	Azadirachtin, limonoids, *palmitic, stearic,oleic, linoleic*
5. Niger oil *Guizotia obyssinica* Cass	Compositae	*Linoleic, myristic, palmitic,stearic, stearic, arachidic*
6. Safflower oil *Canthamus tinctiorius* Linn.	Compositae	*Palmitic, oleic, linoleic*
7. Palm oil *Elaeis guineensis* Jac.	Palmaceae	*Lauric, myristic, palmitic, oleic, linoleic*
8. Rice bran oil *Oryza sativa* Linn.	Graminae	*Ricinoleic, linoleic, oleic, stearic, palmitic*
9. Sesame *Sesamum indicum* Linn.	Cruciferae	*Stearic, oleic, linoleic*
10. Citronella oil *Cymbopogon winterianus*	Graminae	**Eugenol,**HYDROCYANIC **linalool, citranellol, citral, furfural,** *capriic,* **borneol**
11. Sunflower oil *Helianthus annuus* Linn.	Compositae	*Linoleic, myristic,* choline, Saponin(terpenoid), SUCCINIC, *oleic*
12. Castor oil *Ricinus communis* Linn.	Euphorbiaceae	*Ricinoleic,* formic, HYDROCYANIC, *linoleic, palmitic*
13. Chaulmoogra oil *Hydnocarpus kurzii*	Flacourtiaceae	*Hydnocarpic, chaulmoogric, gorlic*
14. Clove oil *Eugenia* sp.	Myrtaceae	**Cineole1-8, eugenol, geranoil, furfurol,** methyl selicylate, Saponin (terpenoid),TANNIC, **benzyl alcohol**

Sources: Duke (1985); Maity (1988); Acharya (1994); Chopra (1994); Dhaliwal and Arora (1998).

APPENDIX-XI



Appendix XI : Record of pests and their parasitoids on stored pulses in Terai Agro-Ecological region



► Bio-control agents of Bruchid pest

- ● *Dinarmus vagabundus* (Timberlake)
- ■ *Uscana mukerjii* (Mani)

► References :

D. vagabundus

Timberlake (1926),
Mani (1939),
Lima (1942),
Chatterjee (1954),
Cheema *et al.* (1962),
Dhir (1977),
Boucek *et al.* (1978),
Roja *et al.* (1988),
Mani (1989),
Alebeek *et al.* (1998),
Raja *et al.* (2000),
Ghosal *et al.* (2003)

U. mukerjii

Mani (1935),
Mukerji & Bhuya (1936),
Chatterjee (1953),
Steffan (1954),
De Luca (1965),
Pajni and Singh (1973),
Chatterjee (1954),
Mani (1989),
Kapila & Agarwal (1995)
Pajni *et al.* (1996),
Ghosal *et al.* (2003)

Appendix- XII : Global distribution of *Dianarmus vagabundus* & *Uscana mukerjii*

Appendix -XII1

Nutritive value and bio-chemical properties of pulses

Pulse	Proten (g)	Fat (g)	Carbohy-drate (g)	Fibre (g)	Ash (g)	Iron (mg)	Calci-um (mg)	Phosphorus (mg)	Carotene (mg)	Vitamin C (mg)	Vitamin D (mg)	Vitamin B_2 (mg)	Niacin (mg)	Thiamin (mg)	Riboflavin (mg)	Ascorbic and (mg)	Calories / 100 g	Mineral (g)
Chick pea	17.1	5.3	60.9	3.9	2.7	202.0	10.2	31.20	189	3.0	0.30	0.51	2.6	0.40	0.18	5.0	358	3.0
Cow pea	24.1	1.0	54.5	3.8	3.5	77.0	5.9	414.0	12	0.0	0.92	0.18	1.9	0.92	0.18	2.0	342	3.2
Green gram	24.0	1.3	56.7	4.1	3.4	124.0	7.3	326	94	0.0	0.47	0.39	2.1	0.47	0.39	5.0	348	3.5
Horse gram	22.0	0.5	57.2	5.3	0.9	287	8.4	311	71	1.0	0.42	0.20	2.5	0.40	0.15	T	338	3.2
Lentil	25.1	0.7	59.0	0.7	2.2	69	4.8	293	270	0.0	0.50	0.21	1.8	0.50	0.21	T	346	2.1
Moth bean	23.6	1.1	56.5	4.5	-	202	9.5	230	9.0	2.0	-	-	1.5	0.45	0.09	T	330	3.5
Pea	19.7	1.1	56.5	4.5	2.6	75	5.1	298	39	0.0	0.45	0.50	3.4	0.47	0.19	4.0	315	2.2
Kidney bean	22.9	1.3	60.0	4.2	3.8	260	5.8	410	-	-	0.54	0.18	2.1	0.54	0.18	3.0	341	3.2
Soy bean	43.2	19.5	20.9	3.7	4.7	240	11.5	690	426	-	-	-	2.1	1.03	0.30	T	335	4.6
Grass pea	25.0	1.0	61.0	4.6	3.1	92	5.6	317	38	0.0	0.45	0.41	1.8	0.10	0.40	T	298	2.3
Black gram	23.9	1.3	60.4	5.5	2.6	64	7.8	385	38	0.0	0.42	0.37	2.0	0.42	0.37	5.0	347	3.2
Red gram	20.9	1.7	62.9	8.0	3.5	73	5.8	304	132	0.0	0.52	0.14	2.3	0.50	0.14	4.0	343	-

Source: **1. Aykroyd and Doughty (1973)**
2. Gopalon *et al.*(1973)
3. Chatterjee and Bhatterjee (1986)