

**Bio-ecology and Management of Pulse
Beetle, *Callosobruchus chinensis* (Linn.)
on Mungbean, *Vigna radiata* (Linn.) Wilczek**

Thesis

**Submitted to the
Swami Keshwanand Rajasthan Agricultural
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for the degree of**

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**in the
Faculty of Agriculture
(Entomology)**

By

Rajendra Singh Bajiya

2009

**SWAMI KESHWANAND RAJASTHAN AGRICULTURAL UNIVERSITY,
BIKANER
S.K.N. COLLEGE OF AGRICULTURE, JOBNER**

CERTIFICATE - I

Dated : 2009

This is to certify that **Mr. Rajendra Singh Bajiya** has successfully completed the comprehensive examination held on 16th July 2004 as required under the regulation for **Ph.D. degree**.

(Ashok Sharma)

Head

Department of Agricultural
Zoology and Entomology
S.K.N. College of
Agriculture,
Jobner

**SWAMI KESHWANAND RAJASTHAN AGRICULTURAL UNIVERSITY,
BIKANER
S.K.N. COLLEGE OF AGRICULTURE, JOBNER**

CERTIFICATE - II

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This is to certify that the thesis entitled “**Bio-ecology and Management of Pulse Beetle, *Callosobruchus chinensis* (Linn.) on Mungbean, *Vigna radiata* (Linn.) Wilczek**” submitted for the degree of **Doctor of Philosophy** in the subject of **Entomology** embodies bonafide research work carried out by **Mr. Rajendra Singh Bajiya** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was also approved by advisory committee on 01.12.09.

(Ashok Sharma)
Head of the Department

(M.C. Bhargava)
Major Advisor

(G.L. Keshwa)
Singh)
Dean
S.K.N. College of Agriculture,
Jobner

(Swaroop
Co-Major Advisor

SWAMI KEWANAND RAJASTHAN AGRICULTURAL UNIVERSITY, BIKANER
S.K.N. COLLEGE OF AGRICULTURE, JOBNER

CERTIFICATE - III

Dated : 2009

This is to certify that the thesis entitled “**Bio-ecology and Management of Pulse Beetle, *Callosobruchus chinensis* (Linn.) on Mungbean, *Vigna radiata* (Linn.) Wilczek**” submitted by **Mr. Rajendra Singh Bajiya** to the Swami Keshwanand Rajasthan Agricultural University, Bikaner, in partial fulfillment of the requirement for the degree of **Doctor of Philosophy** in the subject of **Entomology**, after recommendation by the external examiner, was defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination on his thesis has been found satisfactory. We therefore, recommend that the thesis be approved.

(M.C. Bhargava)
Major Advisor

(Swaroop Singh)
Co-Advisor

(B.L. Jat)
Advisor

(S.C. Jain)
Advisor

(B.L. Kakralya)
Advisor

(Avdesh Chandra)
Dean, PGS Nominee

(Ashok Sharma)
Head of the Department

(_____)
External Examiner

Approved

(G.L. Keshwa)
Dean

DEAN,
POST GRADUATE STUDIES

SWAMI KESHWANAND RAJASTHAN AGRICULTURAL UNIVERSITY,
BIKANER
S.K.N. COLLEGE OF AGRICULTURE, JOBNER

CERTIFICATE - IV

Dated :

.....2009

This is to certify that **Mr. Rajendra Singh Bajiya** of the **Department of Agricultural Zoology and Entomology**, S.K.N. College of Agriculture, Jobner has made all corrections/ modifications in the thesis entitled “**Bio-ecology and Management of Pulse Beetle, *Callosobruchus chinensis* (Linn.) on Mungbean, *Vigna radiata* (Linn.) Wilczek**” which were suggested by the external examiner and the advisory committee in the oral examination held on _____. The final copies of the thesis duly bound and corrected were submitted on _____are enclosed herewith for approval.

**(M.C.
Bhargava)**
Major Advisor

(Ashok Sharma)
Head
Department of Agricultural
Zoology and Entomology

(G.L. Keshwa)
Dean
S.K.N. College of Agriculture,
Jobne

Approved
Dean, Post Graduate Studies
Swami Keshwanand Rajasthan Agricultural University,
Bikaner

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Place : Jobner

Dated :

(Rajendra Singh Bajiya)

**Bio-ecology and Management of Pulse Beetle,
Callosobruchus chinensis (Linn.) on Mungbean, *Vigna
radiata* (Linn.) Wilczek**

R.S. Bajiya*

**Dr. M.C.
Bhargava ****

Abstract

Investigations were carried out on “Bio-ecology and management of pulse beetle, *Callosobruchus chinensis* (Linn.) on mungbean [*Vigna radiata* (Linn.) Wilczek] “ during 2007-08 at ARS, Durgapura (Jaipur). During the survey, different type of storage structures viz., bag, loose, metal container, *kothi*, stone bin, *bhukhari*, earthen pot and pusa bin were observed in five *tehsils* (Chaksu, Dudu, Phagi, Phulera and Sanganer) of Jaipur district. None of the structures was found free from infestation except pusa bin. Maximum infestation was recorded in mud pot and *bhukhari* followed by loose, bag, *kothi*, stone and metal container.

The influence of different hosts viz., mungbean, gram, cowpea, *arhar*, moth and *urd* on biological parameters of *C. chinensis* was studied. The minimum developmental period was recorded in cowpea and mungbean (22.00 and 24.33 days) while maximum in *urd* (31.33 days). Maximum adult emergence, fecundity, grain damage, loss in weight and growth index were recorded in cowpea while minimum in *urd*. On the basis of different criteria, the suitability of host for test insect was in order of cowpea > mungbean > *arhar* > moth > gram > *urd*.

None of the mungbean varieties was found completely free from pulse beetles attack. By considering all the all the parameters, it was found that the pusa-105 and pusa bold were found to be least susceptible. The varieties RMG-492 and RMG-62 were found most susceptible, whereas, K-851, Ganga-8, Mum-2, Ganga-2, RMG-262, Pusa Vishal, RMG-344 and Pusa-9531 as moderately susceptible.

The growth and development of *C. chinensis* was studied under stored conditions on different temperature (20, 25, 30 and 35 °C) and humidity (60, 70, 80 and 90 %). The temperature and humidity have been shown to play a vital role in the growth and development of various stages of this pest. The ovipositional potential increased with

the increase in temperature from 20⁰ to 30⁰ C and decreased at 35⁰ C. The ovipositional incubation and developmental periods decreased with the increase of temperature and *vice-versa*. The adult emergence, grain damage and loss in weight increased upto 30⁰C and maximum at 30⁰C and 70 per cent relative humidity and less at 20⁰C and 90 per cent relative humidity. On the basis of various parameters, it can be concluded that for development of this pest, the optimum conditions were 30±1⁰C temperature and 70±5 per cent relative humidity.

* Ph.D. Student, Department of Agricultural Zoology and Entomology, S.K.N. College of Agriculture, Jobner.

** Thesis submitted for partial fulfillment of degree in Entomology under the supervision of **Dr. M.C. Bhargava**, Associate Professor, Department of Agricultural Zoology and Entomology, (Swami Keshwanand Rajasthan Agricultural University, Bikaner, Campus-Jobner).

Different concentrations (0.1, 0.5 and 1.0%) of plant oils (cotton seed, taramira, sunflower, groundnut, mustard, sesame, soybean) and one toxicant (malathion) were evaluated as seed coating against, *C. chinensis*. Malathion, cotton seed oil and taramira oil at 1.0 ml/100 g seed were found most effective in increasing the adult mortality and development period and decreasing adult emergence, adult longevity, grain damage and loss in weight.

The powders of different plant products *viz.*, neem kernel, dharak kernel, karanj kernel, datura leaf, tulsi leaf, aak leaf and citrus leaf powders when admixed with mungbean seeds @ 1.0, 2.5 and 5.0 g/100g seeds proved to be causing adult mortality and prolonged the developmental period and causing adverse effect of adult emergence, longevity of adults of *C. chinensis* and reduces the grain damage and weight loss by this pest.

Significant differences of incidence of *C. chinensis* were noticed in mungbean grain damage and loss in weight stored in different containers under artificial and natural conditions. Under artificial conditions higher dry mass loss (9.06%) and damaged grains (47.33%) was noticed in mud pot stored grains. The number of adults emerged varied from 10.00 in metal container to 21.53 in mud pot. Under natural condition, low dry mass loss and damaged grains were observed in mud pot followed by cloth bad, urea bag, polythene bag, gunny bag and metal container.

The exposure period of 24 hrs to solar energy in black and blue coloured bags was most effective to reduce cent per cent adult emergence and increase in the adult mortality of *C. chinensis*.

No adverse effect of tested oils and powders were noted on the germination of seeds upto 150 days of treatment.

Appendix – I

Name of the villages with *tehsils* from where infested grain samples were taken

S.No.	Tehsils	Surveyed village
1.	Chaksu	Chaksu, Badarampura, Shivdaspura, Palala, Kothun
2.	Dudu	Mozambad, Lordi, Meerapura, Datri, Kadvakabas
3.	Phagi	Choru, Gadduda, Konsale, Chakvada, Madhorajpura
4.	Phulera	Bheshlana, Gumanpura, Khatwadi, Surshinghpura, Banshipura
5.	Sanganer	Vatika, Renwal Mazi, Badi, Kumhariyawas, Munhana

Relative susceptibility of some promising mungbean, *Vigna radiata* (Linn) Wilczek varieties to *Callosobruchus chinensis* (Linn.) during storage

R.S. Bajiya, M.C. Bhargava* and Swaroop Singh

Department of Agricultural Zoology and Entomology
S.K.N. College of Agriculture, S.K. Rajasthan Agricultural
University

Campus : Jobner, 303 329 Rajasthan (India)

ABSTRACT

Twelve varieties of the mungbean tested under storage condition and none of the varieties was found completely free from the infestation of the pulse beetles, *Callosobruchus chinensis* (Linn.). It was found that the pusa-105 and pusa bold were least susceptible. The varieties RMG-492 and RMG-62 were most susceptible, whereas, K-851, Ganga-8, Mum-2, Ganga-2, RMG-262, Pusa Vishal, RMG-344 and Pusa-9531 were recorded as moderately susceptible.

Keywords : *Callosobruchus chinensis* (Linn.), susceptibility, mungbean varieties.

Among the important insect pest of stored grains the pulse beetle, *Callosobruchus chinensis* (Linn.) (Coleoptera : Bruchidae) is the most destructive pest of legumes during both pre and post harvest stages. The food constituents play a vital role in the survival and reproduction potential of the insects. The grain characters, which also interfere the normal physiology or feeding of the insect, affects adversely the biology of the pest and these a variety resistant to insect pest attack. The extent of damage by pulse beetle, *C. Chinensis* is influenced by the physico-chemical characters of the variety. Screening of less susceptible cultivars is a major components of IPM and is a continuous process. Keeping this in view the present investigations were carried out to assess the preferential response of different varieties of mung bean against *C. Chinensis* under storage conditions.

*** Email : drmbha@gmail.com**

Twelve mungbean varieties (RMG-62, RMG-262, RMG-344, RMG-492, MUM-2, K-851, Ganga-2, Ganga-8, Pusa Bold-1, Pusa Vishal, Pusa-9531 and Pusa-105) were obtained from the Pulse Breeder, Department of Plant Breeding and Genetics, Agriculture Research Station, Durgapura (Jaipur) for studying the varietal susceptibility. To maintain the stock culture of *C. chinensis*, the sound and healthy mungbean grains were cleaned and sieved to remove the fractions of grains or insects if any. The adults of *C. chinensis* were obtained from Department of Seed Technology, ARS, Durgapura (Jaipur), for mass rearing and reared on already conditioned grains of mungbean in plain glass jars of 2.5 litre capacity. These jars were kept at a temperature of $27\pm 2^{\circ}\text{C}$ and 65 ± 5 per cent relative humidity. The adults so emerged from the culture were used for further experimentation.

For determining the relative susceptibility of the different varieties, sound and healthy grains were selected after mechanical separation. The grains were sterilized in oven at $60\pm 5^{\circ}\text{C}$ for 8 hours to avoid any hidden infestations. Prior to the experiment, the grains of each variety were conditioned at least for a week in an incubator at $27\pm 2^{\circ}\text{C}$ and 65 ± 5 relative humidity in which the tests were carried out. All the varieties were inoculated simultaneously and were maintained in three replications. The experiment was conducted at $27\pm 2^{\circ}\text{C}$ temperature and 65 ± 5 per cent relative humidity. After storage period of three months the datas were recorded on ovipositional preference, developmental period, adult emergence, sex ratio, longevity of adults, grain damage and weight loss.

For the study of ovipositional preference, five pairs of freshly emerged adults were introduced in glass vials (15 x 5 cm) containing 50g grains separately on each variety for oviposition. For determination of growth and development, random sample of 40 seeds containing single egg (40 eggs) was placed in separate tube for each replication. From the day of emergence of fresh adults the dates and number of adults emerged were noted twice (morning and evening) daily to work out the total developmental period (egg to adult). Percent adult emergence was calculated on the basis of eggs placed in each specimen tube and identified for their sexes and the ratio of the male and female adults was calculated. The growth index was obtained by dividing percentage of adult emergence by total developmental period in days. The longevity of male and female beetles was determined by recording the dates of their emergence from pupae and dates of natural death. The damaged grains and weight loss were recorded after 90 days of the release of eggs. For this purpose, the sample of grains was spread upon a white sheet and damaged grains were counted and percentage of damaged grains were calculated (Chander, 2003). The loss in weight was obtained after removing all insect stages and frass. It was worked out by subtracting the final weight from the initial weight and converted into percentages.

Data contained in table 1 indicated that the respective mungbean varieties showed significant variation in egg laying of pulse beetle, *C. chinensis*. The maximum number of eggs were deposited on the mungbean variety RMG-492 (82.33) followed by RMG-62 (79.53),

Pusa-9531 (75.66), RMG-344 (69.44), Pusa Vishal (63.88), RMG-262 (62.44), Ganga-2 (60.99), Mum-2 (57.77), Ganga-8 (57.55), Pusa bold (53.55) and K-851 (52.88). The minimum number of eggs were observed on Pusa-105 (49.10) being unfavourable for oviposition. The present findings are in accordance to the findings of Gupta *et al.* (1985) who screened greengram varieties against *C. chinensis* and observed that variety RMG-62 to be had maximum number of eggs grain indicating its high susceptibility to the pulse beetle.

In present investigations, the developmental period of *C. chinensis* was greatly influenced by different mungbean varieties. The developmental period of pulse beetle varied from 23.33 to 32.66 days, being shortest on RMG-492 and longest on Pusa-105. The present findings corroborates the findings of Choudhary *et al.* (1982); Sachdeva and Seghal (1985) and Chavan *et al.* (1997b) who observed that the developmental period of *Callosobruchus* spp. was greatly influenced by respective pulse varieties. Similarly, Singh and Sharma (2003a) and Savita *et al.* (2008) reported that the developmental period was shorter in most susceptible varieties and reverse in less susceptible varieties of greengram.

Behaviour of different varieties towards successful emergence of adults differed significantly. Minimum numbers of beetles emerged from varieties Pusa-105 (48.33) followed by K-851 (54.16), while maximum in RMG-492 (83.33) followed of RMG-62 (80.00) and Pusa-9531 (73.33). The present findings in accordance with that of Jadhav *et al.* (1984) who observed that the per cent adult emergence ranged from 20.83 to 50.29, 48.15 to 87.92 and 64.00 to 96.00 in case of different varieties of chickpea, cowpea and pigeonpea, respectively. Similar to the present findings, Sachdeva *et al.* (1986) found variation in adult emergence of this pest on different varieties of cowpea.

The variation in sex ratio of *C. chinensis* on different varieties of mungbean ranged from 1:0.97 to 1:1.17 (male to female), minimum being in Pusa-105 and maximum in RMG-492. The number of female

was higher in each variety in comparison to male. Similar results were obtained by Singh and Sharma (2003a) in different varieties of greengram and reported that sex ratio varied from 1:0.98 (Pusa-105) to 1.087 (LGG-407). Singh and Sharma (2003b) obtained similar results in different varieties of cowpea and reported that sex ratio of pulse beetle varied who observed the sex ratio varied from 1:0.95 to 1:1.06 (M:F).

Significant difference was noticed in the longevity of male and female beetles on various varieties of mungbean. The longevity of male and female beetles varied from 5.00 to 8.33 days and 5.33 to 8.66 days on different varieties, respectively. It was observed that the female beetles survived longer than the male in each variety. The results of present findings finds support from the finding of Yadav and Bhargava (2005a) who reported significant difference in the longevity of male and female of *C. maculatus* on different varieties / genotypes of mothbean.

The percentage of damaged grains and loss in grain weight of different mungbean varieties due to infestation of pulse beetle varied from 31.33 to 44.06 and 5.96 to 15.98, respectively. Maximum damaged grains and weight loss was recorded in RMG-492 and minimum in Pusa-105 (Table1). Singh and Sharma (1981) and Singh and Khokhar (1991) also found significant variation in grain damage and loss in weight on different varieties of moong and pigeonpea, respectively. Similarly, Manohar and Yadav (1990) found that loss in weight varied from 16.55 to 44.97 per cent due to *C. maculatus* on different cowpea varieties.

Lower growth index values recorded on varieties Pusa-105 (1.47) and Pusa bold (1.78) denotes less susceptibility. The varieties RMG-492 (3.57) and RMG-62 (3.20) showed higher values of growth index indicating highly susceptibility varieties of mungbean against *C. chinensis*. The remaining varieties viz., K-851 (1.80), Ganga-8 (1.92), Mum-2 (2.00), Ganga-2 (2.20), RMG-262 (2.35), Pusa Vishal (2.38), RMG-344 (2.65) and Pusa-9531 (2.89) were intermediary in position

Table1). The varieties, having maximum growth index represented maximum number of population and higher infestation in term of per cent grain damage and weight loss which is in accordance with results of Chavan *et al.* (1997b) who reported that the growth index ranged from 1.656 to 2.112 in different less susceptible lines of cowpea against *C. chinensis*.

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1 Introduction

Pulses the “wonderful gift of nature” play an important role in Indian economy and diet both. Pulses are traditionally recognized as an indispensable constituent of Indian diet. In India where the population is predominantly vegetarian, pulses are important as they are rich source of protein and several amino acids. They are also rich source of energy, minerals and certain vitamins. India has the distinction of being world’s largest of grain legumes/pulses (Anonymous, 1988) sharing 34.35 and 23.24 per cent of world’s area and production, respectively (Anonymous, 1996). However, among the Indian states, Rajasthan stands at fourth position in pulse production. In Rajasthan, the total area under pulses was 20,28,329 hectares with the annual production of 5,02,521 lakh tonnes. Whereas, the total area under mungbean was 7,50,847 hectares with the total production of 2,71,112 tonnes (Anonymous, 2007).

In India 117 species of bruchids belonging to 11 genera have been recorded infesting different pulses (Arora, 1977). The genus *Callosobruchus* attacks grain legumes during both pre and post harvest stages all over the world. But in India *C. maculatus*, *C. analis* and *C. chinensis* are the predominate pest species of the genera (Dias, 1986). Among the grain insects spends its entire immature life in individual legume seeds, where they cause weight loss, decrease germination potential and diminish the market as well as nutritional value of the commodity. In India Gujar and Yadav (1978) recorded 32.2 to 55.7 per cent loss in seed weight and 17.0 to 53.5 per cent loss in protein content. In case of severe infestation cent per cent damage is caused by the pest (Pruthi and Singh, 1950).

The assessment of storage losses at farm level of villages has been an intricate problem since long. Though various estimates/gestimates, sporadic surveys has been made by various workers from time to time, the actual loss occurring in the villages in respect of per cent grain damage caused by various agencies still remains unanswered.

The development, population build-up and degree of infestation caused by insect pests depend on type of food. Unfortunately very little attention has been paid to this aspect of the relationship between the food and the insect development. The present investigations were, therefore, carried out with a view to study the suitability of several hosts in the development of this pest and extent of damage caused to different type of foods.

It is well known fact that food constituents play a vital role in the survival and reproduction potential of the insects. The grain characters, which also interfere the normal physiology or feeding of the insect, affects the biology of the pest adversely and these make a variety resistant to insect attack. Although grains of almost all the varieties of mungbean grown in the country are infested by stored grain pests but the extent of damage is influenced by the physico-chemical characters of the variety. The damage potential of this pest has been the subject of considerable research mainly on the relative preference in different stored products and among the varieties of the same product. Keeping this in view an attempt has been made to study the growth and development of this pest on some promising mungbean varieties.

Quantification of stored grain insect development rate on different commodities at range of temperature and relative humidity is an essential first step in understanding the population dynamics of pest

infesting different grains in storage. This will be helpful in developing and effective management strategy. In view, therefore, of the need of exact information on the biology of the pest and in respect of their relative behaviour under conditions of constant temperature and humidity, a comparative study of the beetles was undertaken.

It is well known fact that food constituents play a vital role in survival and reproduction potential of the insects. The grain characters, which also interfere the normal physiology or feeding of the insects, affects adversely the biology of the pest and these characters make a variety resistant to insect attack. Although almost all the varieties of mungbean grown in the country are infested by stored grain pests but the extent of damage is influenced by the physical and chemical characters of the variety. The damage potential of this pest has been the subject of considerable research mainly on the relative preference in different stored products and among the varieties of the same product. Keeping this in view an attempt has been made to study the growth and development of this pest on some promising mungbean varieties.

In order to develop economic and effective control measures for *C. chinensis* detailed and accurate knowledge of its bio-ecology is essential under variable macro and micro ecological conditions, which would be helpful in the possible prediction of population levels and study of the various mortality factors regulating pest abundance. This will be helpful in developing effective management strategy. These aspects need more intensive investigations, as abiotic factors such as temperature and relative humidity play a vital role in the pest infestation.

Success achieved, so far, in making the stored products free from pests has been largely dependant on pesticide alone. Pesticides are the most powerful tool available for pest control. They are highly effective, rapid in curative action, adaptable to most situations, flexible in meeting changing agronomic and ecological conditions and relatively economical. Despite these credentials, the long and indiscriminate use of pesticides has been found ecologically, unsound, associated with disadvantages like pest resistance, adverse effect on non-target organism, toxic residue in food grains, pollution of storage environment and direct hazards to the user. Although fumigation of stored food grains with toxic gases is effective but not applicable at the farm level because the storage structure are not airtight. This situation dictates the need for safe, locally available and less expensive materials for pest control in storage. There are encouraging reports on the use of certain indigenous plant products as grain protectants (Jotwani and Sircar, 1967; Jacob and Sheila, 1990; Sharma and Singh, 1993; Sundria *et al.*, 2001 and Bhargava and Meena, 2002).

India is among the foremost countries of the world receiving in exhaustible supply of solar radiation. The sun pours on energy square meter of land in India with about 6000 k. cal. of energy per day (Mathur and Patel, 1976). Solar heat is frequently used in most parts of our country for drying the seed without impairing their germination and sometimes to minimize the insect infestation in various types of stored products. The scope of harnessing the solar energy for disinfecting the stored products has ample potential in the country; some work on using bulky and costly, contraptions for the purpose has been done. However, more work, especially on smaller scale, using simpler techniques for trapping solar energy for post-harvest protection, need careful investigation (Anonymous, 1979).

Scope of the investigation

The above facts promoted to undertake the present investigation in order to find out some of the outstanding problems with the following objectives in view.

- (i) To survey the level of pulse beetle, *Callosobruchus chinensis* (Linn.) infestation on mungbean in Jaipur district.
- (ii) To study the host preference of *C. chinensis*.
- (iii) To screen the varietal susceptibility of mungbean against *C. chinensis*.
- (iv) To determine the effect of temperature and humidity levels on growth and development of *C. chinensis*.
- (v) To manage *C. chinensis* with plant products and physical component of environment.

2 Review of Literature

The present investigation aims to find out the host preference, varietal susceptibility and management techniques on the basis of bio-ecological factors (temperature, humidity and plant products etc.) against *Callosobruchus chinensis* Linn. In order to elucidate the situations with clarity, pertinent work done so far on the effect of host preference, physical factors on development, varietal susceptibility and management have been review in this chapter.

2.1 Survey

Fletcher and Ghosh (1921) reported the use of bag storage and mud bins and observed that there was more spoilage in mud bins than in open structures. Pruthi (1949) reviewed different storage structures prevalent with the farmers in India. Ramasivan *et al.* (1966) also discussed these storage structures in Punjab, the structures mentioned were *kohti*, *matka*, tin, *pacca* and *kachcha bukhari*, *kotha dheri*, *thaka*, *kup* and *bag* storage.

Zuthsi (1966) reported that in rural areas of Delhi, infestation and loss in weight of wheat, caused by insects, were maximum when stored loose in rooms, moderate in gunny and jute bags and least in metal bins. In villages around Hapur, the most common storage structures were jute bags, mud-pots and *kulthila*. Among all types of storage structure studied, metal drums proved the best in protecting the grains from spoilage. The average losses by insects were 2.0 per cent in metal drums, 2.3 per cent in bags, 7.6 per cent in *kulthila* and 9.5 per cent in *kachcha kothi*.

Ramasivan *et al.* (1968) reported that no structure was free from damage. In Gujarat, most common storage was used earthen jars, followed by jute bags, tin jars, wooden bins, heaps and pits (Patel, 1970). Srivastava *et al.* (1973) carried out surveys in two villages of western U.P. and observed that bag storage was most common method. Other structures were *kachcha* and *pucca kothies* and *drums*. Damage by insect was more in *kachcha* and *pucca kothies* than the drums.

Kharab (1981) collected samples of bengalgram from Haryana during different surveys and found five insect species, viz., *C. chinensis*, *T. granarium*, *T. castaneum*, *R. dominica* and *S. oryzae*. He further observed that four insect species namely *C. chinensis*, *T. granarium*, *T. castaneum* and *R. dominica* were almost equally prevalent in the state as a whole. He reported the storage structures used for storing bengalgram in Haryana and observed that 36 per cent farmers used bags and 64 per cent bulk storage. He divided bulk storage in to *bukhari*, separate storeroom, heaps in living room, *parchhati*, *kothi*, *kuthila* and *padkala*. Among the bulk storage *bukhari* was most common followed by separate storeroom and heaps in living room.

Awaknavar *et al.* (1989) studied five storage structures that could be used at farm level for the storage of pulses against the bruchid, *C. chinensis*. The performance of non-permeable structures such as metal bins and coaltar drums were better than other structures, so far as, deterioration, germination and weight loss was concerned. Percentage weight losses were 3.2, 4.2, 4.8, 6.3 and 5.0 for metal bin, coaltar drum, gunny bag, plywood bin and earthen pot storage, respectively.

Gupta (1990) studied the storage structures used for storing pulses in Rajasthan and observed that 24 per cent farmers used bags and 76 per cent bulk storage. He divided bulk storage into *bukhari* (33%), separate store room (32.4), heaps in living room (24.5%), *parchhati* (7.2%), *kothi* (1.4%) and *kuthila* (1.4%). He reported that the samples of cowpea, bengalgram and greengram from Rajasthan during different surveys and observed infestation by five insect species, viz., *C. chinensis*, *T. castaneum*, *T. granarium*, *R. dominica* and *S. oryzae*. He further observed that *C. chinensis* was most prevalent species and the infestation of *S. oryzae* was very low.

Sinha (1990) studied the multiplication rate of the stored product pest *C. chinensis* in the seeds of arhar (pigeonpea) in five types of containers in the laboratory, and reported the efficiency in decreasing order as, earthen *pucca* > tin > glass > earthen *kachcha* > plastic.

Singh and Sharma (2003a) reported that pulse storing system varied from district to district. Mainly bag (20.65%) and bulk (79.35%) were common and none of these structures was free from infestation. They further reported that grain stored in *kothi* and *kuthila* were found to have lesser grain damage (1.8 to 4.6%) as compared to separate store room and *bhukhari* which

has 2.6 to 22.2 per cent grain damage. In bag storage grain damage was found to 13.8 per cent.

Bhargava and Choudhary (2007) conducted survey in all districts of Rajasthan state during the year 2005-06. They reported that *Callosobruchus* spp. was associated with different pulses, viz., gram, mung and moth. Different storage structures, viz., bag, loose, metal container, kothi, bhukhari, earthen pot, stone bin and pusa bin was observed in different parts of Rajasthan. Maximum grain damage was recorded in loose storage while minimum in metal containers.

2.2 Host Preference of *C. chinensis*

Chittenden (1898) reported for the first time that *C. chinensis*, a specific pest of cowpea. On the other hand, Urich (1918) recorded it as the chief cause of damage to black eye peas. Later, Back (1922) reported its preference for cowpea over common pea, pigeonpea, lentil, chickpea, moong and white pea. Takasugi (1924) observed it to be the most injurious pest of stored peas in Japan. Later, he reported that among all the beans, it preferred *Phaseolus radiatus* and *P. vulgaris*.

Zaazou (1951) while studying the food preference of *C. chinensis* against cowpea, broadbean, stringbeans, and peas, observed that cowpea was preferred food for oviposition. Srivastava and Bhatia (1958) observed that cowpea and chickpea were preferred food for the pulse beetle, but gardenpea and broadbean were unsuitable for its development.

Gundurao and Majumdar (1964) listed the order of preference of food of this pulse beetle as greengram, cowpea, bengalgram, bean and pea. Gokhale (1973) observed that the growth and development of *C. maculatus* on 13 species of pulses. On the basis of growth index,

mothbean proved to be maximum food value to the insects, followed by green gram, pigeonpea, cowpea, bengal gram, chickpea, black gram, pea and hycianth bean in a descending order.

Singh *et al.* (1980) studied that the seven pulses, namely, greengram, cowpea, redgram, bengalgram, blackgram, pea and lentil and placed them in order of preference for the growth and development of *C. maculatus*. On lentil, the development period was increased, emergence, size and weight of the adults fecundity and longevity were reduced. The growth indices on whole, decorticated and autoclaved grains were 3.944, 3.518, 3.422 in greengram and 0.572, 0.662, 1.058 in case of lentil, respectively. Pea was categorized as poor food for the development of this beetle pest.

Jadhav *et al.* (1984) evaluated the effect of different varieties of cowpea, chickpea and pigeonpea on the growth and development of *C. maculatus* under the laboratory conditions and observed that the per cent adult emergence ranged from 20.83 to 50.29, 48.15. to 87.92 and 64.00 to 96.00 in case of different varieties of chickpea, cowpea and pigeonpea, respectively. The total period required for the completion of life cycle was more in case of chickpea (30.95 days) and less in case of cowpea (22.13 days).

Srivastava and Pant (1989) studied the growth and development of *C. maculatus* on different pulses and reported that green gram, black gram, red gram and cowpea were more susceptible pulses while bengal gram, pea and soybean were less susceptible.

Satyavir (1989) studied the multiplication of *C. maculatus*, infestation of seeds and loss in weight of mothbean and cowpea seeds at four levels of initial infestation viz., 1, 2, 3 and 5 pairs. He

reported that the population buildup was 510.50, 768.66, 996.00 and 1258.33 on mothbean seeds, and 417.33, 805.00, 912.33 and 1027.00 on cowpea seeds, after six months of storage from initial infestation of 1, 2, 3 and 5 pairs, respectively. The infestation of seeds varied from 31.66 to 81.60 per cent with a loss of 24.20 to 58.20 per cent in mothbean, and 35.00 to 68.90 per cent infestation with loss of 18.00 to 38.50 per cent in cowpea seeds after six months of storage.

Kumar *et al.* (2001) studied the ovipositional preference and development of *C. chinensis* on different pulses (green gram, black gram, cowpea, pea, soybean, pigeonpea and bengal gram) and reported that cowpea was most preferred by the bruchid for development as it took the minimum time (19.25 days) with a growth index of 5.025. The ovipositional preference showed no relationship with the development of the bruchid. Maximum adult emergence was observed for cowpea, whereas no adult emerged from black gram and soybean.

Bhargava *et al.* (2008) studied the biology and host preference of pulse beetle on different pulses and reported that the maximum fecundity, adult emergence, adult longevity of *C. chinensis* were recorded in cowpea while minimum in soybean. Larval, pupal and developmental period were shorter in cowpea, while maximum in soybean. On the basis of biological parameters and growth index, the suitability of host for the test insect was in order of cowpea > moong > moth > gram > pigeonpea > pea > soybean.

2.3 Varietal Susceptibility of Pulses Against *Callosobruchus* spp.

With regards to varietal susceptibility of *C. chinensis* on different mungbean varieties has been carried out in different part

of the country (Reddy and Singh, 1972; Choudhary *et al.*, 1982; Singal, 1986; Chavan *et al.*, 1997a & b and Savita *et al.*, 2008).

Teotia and Singh (1966) and Dabi *et al.* (1979) reported that *C. maculatus* did not show any ovipositional preference for the development of insects and eggs were laid invariably on all the varieties of test pulses. Reddy and Singh (1972) observed that gram varieties, 85-3/ 22 and T-2 were tolerant to pulse beetle, whereas, variety T-1 was very susceptible..

Studies on varietal resistant / susceptibility of different pulses against bruchid attack, viz., cowpea, lentil, redgram, greengram, bengalgram and pea (Singh *et al.*, 1980), mothbean (Satyavir, 1984), chickpea (Khare and Johari, 1984 and Ahmed *et al.*, 1991), fieldbean (Parsai and Rawat, 1987) have shown that all the varieties of pulses tested, except fieldbean, were more or less susceptible. Varieties of greengram losses caused by *C. maculatus* reported by Singh and Sharma (1980).

Singh and Sharma (1981) reported that the per cent loss in weight of different varieties of moong and mash increased with the progressive increase in population of pulse beetle over different storage periods. The loss in weight was observed to be 27.60, 22.53, 19.20, 8.83 and 3.73 per cent in shining moong No. 1, G-65, ML-5, Mash 1-1 and Mash T-9, respectively, after 5 months of initial infestation. The loss in weight was significantly higher in moong varieties than that in mash varieties which clearly showed moong served better host for the insect development than mash varieties.

Choudhary *et al.* (1982) worked on relative preference of *C. chinensis* to different varieties of green gram. They found that green gram with larger seed size and thinner testa was preferred more as compared to small seed with thicker testa. They also

reported the variety Kopergaon was the most susceptible and J-45 was the least susceptible and least preferred for the development and survival of *C. chinensis*.

Satayavir (1984) tested 24 varieties of cowpea, *Vigna unguiculata* for their relative susceptibility against *C. maculatus*. He found that the varieties viz., JS-5, 28/5/2/2, RS-9, GG-28 and Sel-1476 proved to be relatively resistant whereas, copusa-1, V-7, Copusa-2 24/4/1, Culture-2, 5259 and PTB-1 were found to be more susceptible, varieties JC-10-K-39, Culture-1, GG-11, V-37, GG-69, V-16, Copusa-3, PLS-382, HG-22, GG-55 showed an intermediate susceptibility and none was found immune to the attack of *C. maculatus*.

Sachdeva and Seghal (1985) investigated the ovipositional response and development of *C. maculatus* on four new varieties of green gram (*Vigna radiata*). They observed that the beetles laid eggs on all the varieties but the ovipositional preference was not related to the susceptibility of a particular variety for further development. The maximum growth was observed on the variety Pusa-103, whereas minimum growth on Pusa-105 which was recorded as the pest resistant variety on the basis of the ovipositional preference and the growth index.

Singal (1986) worked on 19 genotypes of pigeonpea against *C. chinensis* on the basis of different parameters and found the H-82-12 was preferred more for oviposition but was not suitable for further development. On the other hand H-81-1, H-80-74, H-77-216, H-79-2, H-79-10, Prabhat, T-21, H-80 and H-79 were highly susceptible. Singh *et al.* (1986) reported that undamaged seeds of 50 varieties of pigeonpea were preferred for oviposition by *C. chinensis*.

Manohar and Yadav (1990) tested ten commonly growth cultivars of cowpea to find out extent of damage and varietal resistance to pulse beetle, *C. maculatus*, Udaipur-2 variety suffered maximum loss of 44.97 per cent in apparent weight, while CO-1 variety had the least loss of 16.25 per cent. Conclusively CO-1 was relatively more resistant to *C. maculatus* as compared to other varieties.

Singh and Khokhar (1991) studied the comparative susceptibility of 33 genotypes of pigeonpea to pulse beetle in laboratory condition and reported that no variety has shown completely immune. On the basis of per cent damaged grains, genotypes IPCL-148 and IPCL-143 were found least susceptible and the genotypes H-79-4 was found most susceptible with 85.62 per cent damaged grain.

Haque *et al.* (1992) screened 150 genotypes of *Vigna mungo* for susceptibility to *C. maculatus* at 30⁰C and 70% R.H. and found that genotypes SBG No. 3 and UM-83-2 were least susceptible (3.0-3.5% weight loss), while PU-26 and UH82-46 were the most susceptible. They observed that smoothness and thinness of seed coat, size and mineral content of the seed were positively correlated with susceptibility, protein, crude fibre and phenolic contents imparted resistance. Hatchability of eggs, survival and growth indices were significantly greater in highly susceptible genotypes. The net reproductive rates and population increases per week on the genotypes UH82-46, PU-26, SBG No. 3 and UH 83-2 were 60.6, 46.3, 22.14 and 40.3 and 101, 87, 60 and 73 per cent, respectively. Males were heavier when reared on UH82-46 and PU-26 than on SBG No. 3 and UH 83-2.

Chavan *et al.* (1997a) studied ovipositional preference of *C. chinensis* on cowpea lines and observed that the beetles showed

a definite intra varietal response of ovipositional. The cowpea lines with rough seed surfaces were less preferred for ovipositional, where the percentage grams infested with eggs and the number of eggs laid per grain was lower as compared to the lines with smooth surface grains. No antibiosis effect in the viability of eggs on different cowpea lines could be noticed. The pulse beetle distributed egg uniformly on the grains of different cowpea lines and selected more grains for lesser number of eggs. The lines with brown, black, gray and red colour seeds are more preference for ovipositional over the with colored seeds.

Chavan *et al.* (1997b) tested various cowpea lines for their effect on growth and development on *C. chinensis* and observed the significant effect of these lines on growth indices, larval + pupal duration and the per cent adult emergence. On the basis of growth index the lines HLD-1, 258/85, EC- 340-10088, EC 59321, 597/85, V-70-3-3-1 and 109493/30 formed the less susceptible group where growth index ranged from 1.656 to 2.112. The development period increased by about 100 days between most preferred and least preferred cowpea lines.

Yadav and Bhargava (2005a) studied the development response of *C. maculatus* to different varieties / genotypes of mothbean and reported that none of the varieties / genotypes was found completely resistant to pest attack. The varieties *i.e.* Jadia and Jwala were less susceptible whereas, CMZ-12 and RMG-435 proved to be the most susceptible genotypes.

Savita *et al.* (2008) studied 10 varieties / genotypes of green gram viz., PS-16, PS-10, ML-137, Pusa-9331, RMG-344, RMG-192, Pusa-2032, S-8, K-851 and Pusa bold for their susceptibility of *C. maculatus*. They reported that none of the variety / genotypes was found completely free from its attack. The varieties / genotypes

PS-10 and PS-16 were found to be the most susceptible whereas S-8, Pusa-2032, RMG-492, Pusa-9531 and ML-137 as moderately susceptible. Singh and Sharma (2002) tested 12 varieties of greengram against *C. chinensis* and observed that the variety R-288-8 was the most preferred while the variety PS-16 was less preferred for the development of this pest.

2.4 Effect of Physical Factors on Growth and Development

As early as in 1922, in Australia, Winterbottom used high temperature to disinfest wheat grain infested with *C. chinensis*. He observed that infested wheat seeds when heated at a temperature range of 60-66 °C for 3 min. gave complete control against *C. chinensis*. This disinfestations operation was carried with continuous flow machine in which wheat was circulated over coils of steam pipes.

Nawrot (1981) determined the effects of temperature and relative humidity on the development and fecundity of *Ephestia cautella*. He observed that the duration of the development period decreased as relative humidity increased at each temperature tested. The duration of the incubation and pupation periods depended on temperature only, but at the low humidities many individuals did not complete their development. The eggs completed development at temperature in the range of 14-36°C and pupae in the range of 15-35°C. The time required for larval development was considerably affected by temperature and humidity. As temperature increased from 22° to 30°C the developmental time decreased exponentially and became less variable, but an increase from 30 to 32°C produced no further change. The adult life-span was longest at 18°C and 80 per cent R.H., and was shortened considerably by low humidities. Fecundity was adversely affected by high and low temperatures and by low humidity at all temperatures.

Tripathi and Hodson (1981) studied the productivity of the two species i.e. *S. oryzae* and *S. granarius* at the four temperature used 15, 20, 25 and 30 °C. At all four temperatures more eggs were deposited by *S. oryzae* though the difference at 30°C was not significant and also the number of eggs laid, was higher for *S. oryzae* in all cases.

Kim and Choi (1987) reported from Korea that in laboratory the bruchid, *C. chinensis* had 4 generations in a year, and the larvae overwintered within beans. The optimum temperature range for oviposition was found to be 25-30°C. Azukibean (*Vigna angularis*) was preferred for oviposition, followed by mungbean, (*V. radiata*), soybean, kidneybean (*Phaseolus vulgaris*), black soybean and pea. At the optimum temperature 25°C, the development of *C. chinensis* averaged 29, 31 and 49 days, respectively, on the first three food plants, and 46 and 34 days on the last two. Hatching and adult emergence rates were highest on *V. angularis* and *V. radiata*, and lowest on black soybean and *P. vulgaris* (no adult emergence). Lifespan at different temperatures was 4-5 days at 35°C, 5-7 days at 25-30°C, 10-15 days at 20°C and 9-24 days at 15°C. Azukibean damaged by *C. chinensis* did not germinate at all, and the germination rate for damaged black soybean and peas was 5 and 7 per cent, respectively.

Haque *et al.* (1996) studied the extent of grain damage, germination and viability caused by *S. oryzae*, infestation at different grain moisture and temperature levels under laboratory conditions. They reported that the grain damage was higher at 37 °C (0.873-1.963%) followed by 30 °C (1.083-1.393%) and room temperature 17-35 °C (0.219-1.09%) at any of the four moisture levels (10, 12, 14 and 16%) tested. The results also indicated that 30°C and room

temperature with high moisture level of 14 and 16 per cent were conducive to rice weevil damage.

Sharma *et al.* (1997) exposed the pupae of the stored products pests, *C. cephalonica*, *S. cerealella* and *S. oryzae* were exposed to temperatures of 35-45 °C for 24-72 h and reported that adult emergence was totally suppressed at 45 °C in all cases. A very high incidence of sterility was induced in the adults emerged from pupal exposures of *S. oryzae* and *C. cephalonica* at 40 °C, but the effect was less pronounced in *S. cerealella*.

2.5 Efficacy of Different Seed Protectants

Mixing the plant products (oils and powders) before the storage of grain of pulses is an age-old practice and still prevalent in most part of India. In recent past, a number of plant products have been used and scientifically evaluated against various stored product insects, which have been reviewed by many workers (Hewlett, 1947; Pruthi and Singh, 1950; Cotton, 1956; Bhatnagar *et al.*, 1974; Hewlett, 1975 and Saxena *et al.*, 1976).

Jotwani and Sircar (1967) found that the pulse grains could be effectively protected from the *C. maculatus* damage by mixing crushed neem seed @ 1.0-2.0 parts per 100 parts of seeds for 11 months without any adverse effect on germination of seeds.

Teotia and Tiwari (1971) tested dharak drupes and leaves as protectants on wheat seed against *Sitotroga cerealella* and found that the powdered drupes and leaves of dharak when mixed with wheat seed at the rate of 1 to 2 parts per 100 parts of seed and 4 to 8 parts per 100 parts of seed (w/w) respectively protected the damage of *S. cerealella*. They observed that build up of a adult population was prevented for at least 135 days.

It was reported (Anon, 1976a) from Nigeria, that *C. chinensis* infestation could be controlled by mixing groundnut oil with cowpea seeds at a rate of 5-10 ml/kg seed for more than six months. It was further reported that oil penetrated through minute opening in the surface of beetle eggs and prevented the larval hatching. In 1-2 days old egg, biological activity stops immediately, while in 3-5 days old egg partial larval development could be observed there after it died. The treated seeds germinated normally and this treatment did not affect taste or cooking time of the cowpea.

Pandey *et al.* (1976) studied the effect of powders of sweet flag, rhizomes, *kaner* drups, *adhatoda* and *sadabahr* leaves, for their repellent property against *C. chinensis* on gram seeds. *Kaner* drups powder, sweet flag rhizomes at 1 to 2 parts, and 8 parts of *sadabhar* leaf powder effectively protected gram seeds from damage by the bruchid for at least 135 days. No adverse effect of the treatment was observed on the germination of the seeds.

Sangappa (1977) tested the effectiveness of oils of mustard, sunflower, safflower, castor and neem against *Callosobruchus sp.* by treating red gram seeds and concluded that these oils act as surface protectants by checking the infestation of bruchids. Mustard oil was found to be most effective at 1.0 per cent concentration by reducing egg laying on the treated grain and 84 per cent of adult mortality.

Mummigatti and Raghunathan (1977) observed that castor, mustard and gingelly oil inhibited the multiplication of *C. chinensis* on green gram at 0.3 per cent, while coconut and groundnut oils at 0.5 per cent level, without affecting their viability.

Singh *et al.* (1978) found that groundnut oil at 5 ml/kg completely protected cowpea seeds in storage from *C. maculatus* up to 180 days. The treatment had no adverse effect on cooking time and on germination, even after six months of storage. The oil treatment also prevented emergence of adult progeny rather than affecting oviposition or mortality of the adult. It was further reported that groundnut oil entered in the eggs of *C. maculatus* through the micropyle in 1-2 days old eggs and protoplasm coagulated in 3-5 days old eggs, partially developed larvae were found dead. The larval death occurred within minutes of the entry of oil.

Verma and Pandey (1978) treated greengram seeds with different edible oil for the protection of *C. maculatus* attack. They observed that the fecundity of test insect was inhibited when the greengram seeds were treated with oil of coconut, mustard, groundnut, sesamum and sunflower at 0:3 parts of oil per 100 parts of seed (w/w). Ovipositional was completely inhibited when coconut and mustard oil were used, and very low eggs density was found in greengram seeds, when treated with groundnut, sesamum and sunflower oils. The development of the adult of pulse beetle was prevented at least for five months. The germination and viability of the seeds were not affected. It was reported that coconut oil was the best protectant followed by mustard, groundnut and sesamum oils.

Pandey *et al.* (1979) studied the organoleptic quantity and rancidity of blackgram and greengram seeds treated with edible oils. They suggested that mustard and coconut oil could safely be mixed with pulses without affecting the organoleptic qualities and without fear of rancidity.

Pathak (1980) used groundnut oil and coconut oil at the rate of 2, 5 and 8 ml / kg of seeds on four different pulses, viz, cowpea, greengram, blackgram and kidney bean. He observed that groundnut oil at 8 ml / kg have complete protection of cowpea seeds, while in greengram seeds there was no adult emergence of pulse beetles in all the three treatment dosages and for blackgram seeds treatment dosages of 5 and 8 ml/ kg of same oil were reported effective. Whereas, in case of coconut oil treatment dosages of 5 and 8 ml / kg gave complete protection of greengram and blackgram seeds. It was further reported that kidney beans could not be protected with both the oils against the infestation of *C. maculatus*.

Ghosh *et al.* (1981) studied the pesticidal efficacy of some ingenious plant products against *C. chinensis* in gram and found that the powder of neem seed kernel at the rate of 1.5 parts/ 100 parts of grain to be the more effective for the control of *C. chinensis* followed by *Chrysanthemum* and *Acorus calamus* powders.

Ali *et al.* (1983) tested the efficacy of different oils viz., coconut, mustard, neem, rape, mahua and palm at 0.5 and 1.0 ml/100g seeds of green gram against *C. chinensis*. All oil treatments at 0.5 ml/100g seeds were found less effective in comparison to 1.0 ml/100g against all stages of the pest. Neem coconut, mustard, palm and sesamum inflicted 100 per cent egg mortality at 1.0 ml/100g seeds.

Pereira (1983) reported that the plant products viz., neem kernel oil, kerite oil and groundnut oil showed the degree of ovicidal activity and reduced oviposition of *C. maculatus*. Bombara groundnut oil at 5 ml/kg cowpea seed gave good protection upto 6 months. Sowunmi and Akinnusi (1983) reported

that the powdered kernel of neem seed mixed in stored cowpea at the rate of 1.0 and 2.0 parts/100 parts of seed was effective for the control of *C. maculatus*.

Doharey *et al.* (1984) reported that some edible oils *viz.*, coconut, groundnut, mustard, sesame and taramira oil at 1.0 per cent concentration were effective against *C. chinensis* by reducing the seed damage.

Mathur *et al.* (1985) treated the black gram with neem seed powder at 1.50 parts, black pepper at 0.30 parts and turmeric at 1.75 parts per 100 parts of seed and found 79.54, 79.54 and 71.54 per cent mortality of *C. chinensis* after 5 days of treatment as compared to 10.23 per cent in untreated control. They concluded that mixing of neem seed powder at 1.50 parts and black pepper at 0.30 parts per 100 parts of black gram seeds could provided protection from the damage of *C. chinensis*.

Sujatha and Puhnaiah (1985) seeds of green gram treated with different oil *viz.*, sesamum, cotton seed, palm and coconut at 0.5 per cent were protected from the bruchid, *C. chinensis* attack.

Das (1986) studied the effect of different plant oils *viz.*, neem, coconut, sesame, mustard and soybean mixed with chickpea seeds at the rate of 10ml/kg seeds on mortality and fecundity of adult of *C. chinensis* and found that all adults died with in 4 days of release, while none died in untreated seeds. The treatments provided complete protection of seed against pulse beetle upto 3 months. The viability of the oil treated seeds remained unaffected.

Pandey *et al.* (1986) tested several plant extracts against the stored product pest, *C. chinensis*. Petroleum ether extract of neem (leaves and twings), *Lanthana camara* (leaves and flowers),

Ageratum conyzoides (leaves, flower and buds), *Thevetia neriifolia* (leaves, twigs and young branches) and *Ipomea carnea* (leaves) diluted in benzene and mixed with seeds of greengram at 0.5, 1.0 and 1.5 parts / 100 parts seed (w/w) were highly repellent to the pest, inhibiting oviposition and protecting against infestation.

Zewar (1986) studied the efficiency of five plant oils, castor, sesame, olive, maize, cotton and paraffin oils, in protecting cowpea (*Vigna unguiculata*) seeds against *C. chinensis* in laboratory at $27 \pm 1^{\circ}\text{C}$ and 75 ± 5 per cent R.H. As regards to treating infesting seeds with oils, it was found that oils were effective only in the case of seeds having the earlier stages of eggs. The germination of cowpea seeds treated with the oils at the different rates was not effected. Khaire *et al.* (1987) tested ten vegetable oils at 5-10 ml/kg seed against adult *C. chinensis* infesting pigeonpea (*Cajanus cajan*). They further reported that oil of neem and karanj (*Pongamia pinnata*) at the higher concentration were the most toxic to the beetle.

Babu *et al.* (1989) investigated the effect of pre-storage treatment of mungbean with neem, karanja, mustard, groundnut, castor oils at 2.5, 5.0 and 10.0 ml/kg seed, on by the bruchid *C. chinensis*. The treatment with karanja and castor oil (10 ml/kg effectively reduced oviposition by the bruchid, while maintaining a high level of germination for over 18 months of storage under ambient conditions. Singh and Singh (1989) studied in laboratory, the toxicity of refined and crude soybean oil to *C. chinensis*, at 0.1, 0.25 and 0.5 ml / 100 g of seed in pigeonpea. Crude oil was more toxic than refined oil and was more effective at higher dosages.

Begam and Quinones (1990) observed that efficacy of coconut, soybean, mustard and groundnut oil in protecting stored seeds of *Vigna radiata* against *C. chinensis*. At the dose of 3 ml / kg, the oil were effective in protecting *V. radiata* against bruchid infestation, and adversely affected oviposition, and had long residual effect, reducing oviposition and inducing egg mortality even after 4 months.

Choudhary (1990) reported that neem, groundnut, castor, soybean and sesame oils at 0.5 and 1.0 ml / 100 g of chickpea seed reduced damage by *C. chinensis*. Neem and groundnut oils were also effective at 0.25 ml / 100 g seed. Giga and Munetsi (1990) tested some locally available vegetable oils viz., maize, cotton seed, soybean, castor and citrus oil against *C. chinensis* in seed of *Vigna unguiculata*. It was found that the vegetable oils reduced oviposition and egg hatching of the bruchid more than the citrus oil and also reported that castor oil was most effective.

Jacob and Sheila (1990) reported that six oils viz., crude palm, sesamum, palmolein, neem, mustard and coconut oils at the rate of 0.5 and 1.0 ml/100g seeds caused more than 60 per cent mortality of *C. chinensis* after three days of release. Sesamum, palmolein and mustard oils at the rate of 1 ml/100 g seeds inhibited oviposition and prevented development of subsequent generation.

Kumari *et al.* (1990) evaluated that the efficacy of vegetable oils namely mustard, linseed, til, groundnut, neem and mahua as grain protectant against *C. chinensis*. They revealed that all the vegetable oils each at 1.0 per cent level proved equally effective for reduction in the percentage of damaged grains by number as well as by weight. Parsai *et al.* (1990) evaluated groundnut and mustard oil (0.25 to 1.0%) in urdbean against *C. chinensis*, the

number of egg laid and adult emergence of the pest and loss of grain weight decreased with the increasing oil concentration while the development period of the pest increased with increasing oil concentration.

Singal and Singh (1990) used different plant oils, viz., groundnut, coconut, mustard, sesamum, soybean and rapseed at 1, 3 and 5 ml/kg of seed against *C. chinensis* on chickpea which resulted in significant reduction in oviposition, adult emergence, hatching and development of embryos. Oil treatment did not adversely affect the seed germination potential.

Begum and Quiniones (1991) reported that coconut, soybean, mustard and groundnut oil applied to moong bean seeds infested by *C. chinensis* at 3 ml / kg reduced population more effectively over a 3 month period than seeds treated with same oils at 0.5 ml /kg.

Gupta *et al.* (1991) studied the efficacy of seed treatment of groundnut, neem, mustard, castor and karanj oils in greengram and chickpea against pulse beetle, *C. chinensis*, and their effect on seed germination. Oil treatment with 10 ml / kg gave complete protection from bruchid damage, at least up to one year of storage in both pulses. There was no adverse effect on germination in chickpea, while in greengram germination was adversely affected.

Choudhary (1992) tested different vegetable oil viz., groundnut, sesame, linseed, soybean, neem, castor, safflower and coconut @0.25, 0.50 and 1.0 ml/100 g seed against *C. chinensis* on chickpea. He found that all oil treatments showed significant reduction the number of eggs laid, adult emergence and seed damage due to *C. chinensis*. Oil effective increased with an increase in doses of all oils. Neem, groundnut, castor and sesame oil were most effective whereas linseed oil was least effective.

Khaire *et al.* (1992) evaluated the efficacy of ten vegetables oils, viz., sunflower, castor, mustard, safflower, palm, groundnut, sesame, neem, karanj and maize each applied at rates of 5, 7.5 and 10 ml / kg seed (0.5, 0.75 and 1.0% v / w) as grain protectants of pigeonpea against pulse beetle, *C. chinensis* ; effect of progeny emergence, loss in grain weight and germination upto 100 days after the treatment was measured. Adult emergence was completely prevented by karanj oil at 0.75 and 1 per cent and neem oil at all levels up to 100 days. No emergence of adults occurred upto 66 days with castor oil at the 0.75 and 1 per cent levels. Minimum grains loss was noted with castor, mustard and groundnut oils at 1 per cent levels upto 100 days after treatment. There was no adverse effect of the various oils on seed germination.

Shukla *et al.* (1992) reported that order of toxicity of the edible oils for *Rhizopertha dominica*, in ascending order was palm, soybean, groundnut, sesamum, mustard and corn. Dalda and coconut has no effect. Uvah and Ishaya (1992) conducted laboratory experiment to determine the effect of palm and groundnut oil on oviposition, emergence and longevity of adult of *C. maculatus* on cowpea and reported significant reduction in oviposition, progeny emergence and longevity by a single application of groundnut oil or palm oil at 2.5-3.0 ml/kg seed.

Ahmed *et al.* (1993) studied the efficacy of oils of neem, linseed, safflower and sesame against *C. chinensis* on moongbean seeds. All the doses (0.5 to 4%) of each oils significantly reduced oviposition and adult emergence of the pest.

Rao *et al.* (1993) evaluated the efficacy of sweet flag (*Acorus calamus*), ginger, Jamun (*Syzygium cumini*), neem and mango leaf powders, neem cake and sesamum, sunflower,

groundnut and palm oils and ordinary ash against *C. chinensis* on pigeonpea. *A. calamus* was the most effective followed by neem kernel powder, while neem cake and ash were the least effective.

Sharma and Singh (1993) tested six different plant oils viz., coconut, sesamum, rapeseed, cotton, mustard and groundnut at the rate of 1, 2 and 4 ml/kg of seed against *C. chinensis* on chickpea. They found that groundnut and mustard oils were effective for 8 months while coconut, sesame, rapeseed and cotton seed oil were effective for 12 months and none of the oils impaired seed quality and seedling vigour.

Singh *et al.* (1993) evaluated different edible oils against *C. chinensis* and found that the oil of taramira, coconut, sunflower and castor were most effective in inhibiting oviposition by the pest on gram seed at both dosages (1 and 3 ml/kg seed) as compared with the other oils. Adult emergence was the lowest in the seeds treated with castor, mustard, soybean, groundnut, coconut, taramira and rice bran oils at 1 ml/kg seed while at 3 ml there was no adult emergence. Seed treatment with oils usually delayed the developmental period of the insect by 6-14 days at both dosages.

Al-Hemyari (1994) tested some botanical products in the laboratory against stored products pest, *C. maculatus* and results obtained indicated that neem (*Azadirachta indica*) kernel powder mixed with feba bean seeds at the rate of 5g/100g seeds provided good protection and at the same rate neem leaf powder was barely effective.

Bhargava (1997) tested five plant extracts viz., neem seed extract neem oil, undi extract, karanj extract and lemongrass oil, 0.1, 0.5 and 1.0 ml/100 g seeds against *C. cephalonica*. He found that all the doses of different plant extracts reduced the fecundity but in case of lemongrass oil no egg laying took place and adult mortality occurred

within 6-8 hrs of their release. The reduction in egg viability varied from 24.63 to 59.63 per cent in different plant extracts. The longevity of male and female adults decreased when they were released in treated food.

Pandey and Singh (1997) studied the effect of neem bark powder on the population build up of *C. chinensis* in stored chickpea. It was observed that neem bark powder contained insect growth regulating and insecticidal properties and effectively controlled the increase of population of *C. chinensis* on chickpea in storage.

Sundria *et al.* (2001) tested six botanicals viz., ratanjot (*Euphorbia sp.*), garlic (*Allium sativa* L.), neem (*Azadirachta indica* A. Juss.) seed kernel suspension, neem seed kernel powder, neem leaf powder and black pepper (*Piper nigrum* L.) against the bruchid, *C. chinensis* in stored green gram. They reported that the black pepper seed powder proved to be the best protectant showing no damage even after four months of storage. The next best protectant was neem seed kernel powder at 20g/kg seed. Neem kernel powder suspension (20 ml), ratanjot and neem seed kernel powder also afforded effective protection against the bruchid damage for four months as compared to control. No adverse effect on seed viability was observed even after four months of storage.

Bhargava and Meena (2002) tested six vegetable oils viz., castor (*Ricinus communis*), mustard (*Brassica juncea*), groundnut (*Arachis hypogaea*), sesamum (*Sesamum indicum*), coconut (*Cocos nucifera*) and sunflower (*Helianthus annuus*) against *C. chinensis* in cowpea and found that castor oil @ 1.0 ml/100 g seed was the most effective in inhibiting the oviposition (26.6 eggs/ female) as against 79.4 eggs/ female in untreated seeds. At 1.0 ml/100 g seeds, castor oil caused maximum reduction in egg viability (61.7%) followed by

mustard oil (56.7%). The longevity of male and female adult decreased with the increase in doses of oil. The treatment of castor oil @ 1.0 ml/100 g seeds caused maximum reduction in adult emergence in F₁ generation (85.0%) followed by mustard oil (83.7%), groundnut oil (73.3%). No adverse effect of tested oils was observed on the germination of cowpea seed upto 150 days of treatments.

Singh and Sharma (2002) tested plant powders against *C. chinensis* and found that mixing of plant leaf powder viz., neem, tulsi, mehandi, podina and marigold @ 1.0, 2.5 and 5.0 parts (w/w) with green gram seed which causing inhibitory effect on oviposition and adult emergence.

Raghvani and Kapadia (2003) studied the efficacy of different vegetable oils on seed protectants of pigeonpea against *C. maculatus* and results indicated that neem and coconut oils @ 10 ml/ kg seed provided the complete control of grains against this bruchid for six months, followed by karanj, mustard and castor oils @ 10 ml / kg seed. Sesame and groundnut oils at 10 ml / kg seed and karanj oil @ 5 ml / kg seed gave more than 94 per cent protection upto 4 months of storage. The germination of pigeonpea seed not impaired due to different oil treatment.

Singh and Sharma (2003c) tested 9 plant oils against *C. chinensis* and found that significant protection against this pest. The oil @ of 2.5, 5.0 and 10 ml per kg seeds coating 4 to 6 hours after treatment gave complete protection while 3, 6 and 9 months after treatment gave partial to complete protection of seed of green gram against pulse beetle.

Khalequzzaman *et al.* (2007) tested seven vegetable oils viz., sunflower, mustard, groundnut, sesame, soybean olive and palm @ 5.0, 7.5 and 10 ml kg⁻¹ against *C. chinensis* on pigeonpea. They reported that adult emergence was completely prevented and the

minimum grain loss was achieved by groundnut oil at 10 ml kg⁻¹ upto 66 days after treatment.

2.6 EFFECT OF DIFFERENT STORAGE RECEPTACLES

Chander (2003) noted significantly higher dry mass loss (8.53%) and damaged grains (32.43%) due to *R. dominica* when stored in mud pot in artificial condition while under natural condition, low dry mass loss and damaged grains were recorded in urea bag followed by gunny bag, polythene bag, mud pot and cloth bag.

Meena and Bhargava (2003) studied the effect of different storage containers on the incidence of *C. cephalonica* in stored kernels of groundnut under both artificial and natural conditions and observed significant differences in damage on kernels stored in different containers under artificial and natural condition. Significantly higher dry mass loss (5.29%) and damage kernels (29.24%) was noticed in mud pot kernels. The number of adults varied from 2.33 in gunny bag to 4.00 in cloth bag. Under natural conditions, in low dry mass and damaged kernels were noticed in gunny bag followed by urea, cloth and polythene bags.

2.7 EFFECT OF SOLAR HEAT TREATMENT ON MUNGBEAN AGAINST PULSE BEETLE

Solar heat is frequently used in most parts of our country for drying the seeds without impairing their germination and some times to minimize the insect infestation in various types of stored products. The earlier findings on this aspect were reviewed by Dean (1911), Goodwin (1912) and Thomson (1915).

Begum *et al.* (1991) studied the effect of sunning on different pulse seed infested by *C. chinensis* by exposing the containers of lentils and black gram infested by *C. chinensis* to sunshine for 4 h (9.00

to 13.00) which inhibited the rate of insect multiplication and reduced the grain loss.

Krishnamurthy *et al.* (1991) used polythene pouches of different dimensions and capacity for controlling insect species with solar heat, viz., *S. oryzae* (sorghum, wheat), *R. dominica* (maida, groundnut seed), *T. castaneum* (wheat). These insect species showed 100 per cent mortality at all stages. According to them these pouches were safe, economical and effective solar heat disinfestations devices for homes and rural farms.

Saxena *et al.* (1992) observed the effect of exposing 1, 2 and 3 days old pupae of *T. granarium*, *T. castaneum* and *C. chinensis* to temperatures of 30°, 40° and 45°C for 24, 48 and 72 h. Observations on adult emergence and their progeny revealed that, although all temperatures were effective in causing sterility, exposure at 45°C was particularly effective in suppressing adult emergence of *T. castaneum* and *C. chinensis*; adult emergence was totally prevented by 48 h and 72 h exposures at 45°C.

Ghaffar and Chauhan (1999) studied the temperature and survival of *C. maculatus* in polythene bags containing pigeonpea seed when exposed to sun for a week and reported that maximum temperature in bags exposed to sunlight was 60°C and the beetles in these bags died without laying eggs.

Yadav *et al.* (2002) studied on the solar radiation as a means of eradicating *R. dominica* in wheat and reported that the mortality of test insect increased while seed germination decreased with the increase in duration of exposure to solar radiation and maximum infestation of *R. dominica* was eliminated by exposing the infected grains to solar radiation for 24 hrs in black polythene bag.

Singh and Sharma (2003e) observed the effect of solar energy vis-à-vis colour of the storage bags against *C. chinensis* on green gram and reported that black and blue colour were effective in harnessing the solar energy for beetle control. Only 16 hrs exposure was enough to cause egg mortality, for grub mortality and 24 hrs exposure was sufficient to causing adult mortality.

3 Materials and Methods

The present study “Bio-ecology and management of pulse beetle, *Callosobruchus chinensis* (Linn.) on mungbean [*Vigna radiata* (Linn.) Wilczek]” was conducted under laboratory conditions in the

Department of Entomology, ARS, Durgapura, Jaipur from May, 2007 to October, 2008. The details of the experimental treatments, materials used, techniques followed and criteria adopted for treatment evaluation during the course of present investigations are described in following text.

Experimental site and climatic conditions

The investigations were carried out at ARS, Durgapura which falls under agro-climatic zone III A, the “Semi-arid Eastern Plain Zone” of Rajasthan.

The climate of this area is typically semi-arid, characterized by extremes of temperature both in summer and winter with low rainfall and moderate humidity. Maximum temperature in summer reaches as high as 45⁰C while minimum temperature in winter some times falls down bellow 0⁰C. The average annual rainfall of locality varies from 400-500 mm occurring mostly from the last week of June to September. The weather conditions during the present investigations were, however, normal.

Maintenance of insect culture

To maintain the stock culture of *C. chinensis*, the sound and healthy mungbean grains were cleaned and sieved to remove the fractions of grains or insects if any. The grains were sterilized at 60±5⁰C for 8 hours in order to eliminate both apparent and hidden infestation of insects and mites, if any. These grains were conditioned at least for a week in an incubator maintaining 27±2⁰C and 65±5 per cent relative humidity to raise their moisture content. The adults of *C. chinensis* were obtained from Department of Seed Technology, ARS, Durgapura (Jaipur), for mass rearing and reared on already conditioned grains of mungbean in plain glass jars of 2.5 litre capacity. These jars were kept at a temperature of 27±2⁰C and 65±5 per cent

relative humidity. The adults so emerged from the culture were used for further experimentation.

Sexing of adults

Sexing of newly emerged adults were separated according to Halstead (1963). In case of male, the rostrum was distinctly shorter and wider while in female, it was distinctly longer and narrower. Sex differences were observed under hand lense in the laboratory throughout the course of investigations.

Experimental Details

3.1 Survey

Surveys were made in five major mungbean growing *tehsils* of Jaipur viz., Chaksu, Dudu, Phagi, Phulera and Sanganer. The samples of 500g of mungbean were collected randomly from five farmers from each villages in five *tehsils* of Jaipur and brought to the laboratory. The moisture content and level of infestation of grain samples were studies in laboratory. The moisture contents of grains were recorded with the help of moisture meter (Plate 1a and 1b).

3.2 Host Preference

The following six hosts viz., mungbean [*Vigna radiata* (Linn.) Wilczek], gram (*Cicer arietinum* L.), cowpea (*Vigna unguiculata* (L.) Walp.), arhar (*Cajanus cajan* L.), moth (*Vigna aconitifolia* (Jacq.) Marechal) and urd (*Vigna mungo* L.) were selected for the host preference studies. All the hosts offered which whole grains were sterilized in oven at $60\pm 5^{\circ}\text{C}$ for 8 hours to avoid any hidden infestation. Prior to the experiment, all the hosts were conditioned at least for a week in an incubator maintaining $27\pm 2^{\circ}\text{C}$ temperature and 65 ± 5 per cent relative humidity to raise their initial moisture content. The following observations were recorded.

- (i) Developmental period (eggs to adults)
- (ii) Adult emergence
- (iii) Fecundity
- (iv) Grain damage
- (v) Weight loss

The gravid females were released on the grains in specimen tubes for egg laying. After egg laying, a random sample of 40 seeds containing single eggs (40 eggs) was taken and placed in separate tube for development. The tubes were covered with muslin cloth and tightened with rubber bands. There were three replications for each host and all the hosts were inoculated simultaneously. From the day when fresh emergence started, the dates and number of adults emerged were noted twice (morning and evening) daily to work out the total developmental period (egg to adult) and per cent adult emergence.

For the determination of fecundity, three pairs of freshly emerged adults were introduced in specimen tubes having 10 g grains of each host for oviposition. Thereafter, the eggs were counted daily till all the females died in each replication. The grain damage and weight loss in each specimen tube were observed after 90 days of experiment. Suitability of host was assessed on the number of adults emerged and the length of the developmental period, *i.e.* on the basis of growth index obtained by dividing percentage of adult emergence by total developmental period in days.

3.3 Varietal Susceptibility

The following mungbean varieties were obtained from the Pulse Breeder, Department of Plant Breeding and Genetics, Agriculture

Research Station, Durgapura (Jaipur) for studying the varietal susceptibility.

- | | |
|------------|-----------------|
| 1. RMG-62 | 7. Ganga-2 |
| 2. RMG-262 | 8. Ganga-8 |
| 3. RMG-344 | 9. Pusa Bold-1 |
| 4. RMG-492 | 10. Pusa Vishal |
| 5. MUM-2 | 11. Pusa-9531 |
| 6. K-851 | 12. Pusa-105 |

Growth and Development

For determining the relative susceptibility of the different varieties, only sound and healthy grains were selected after mechanical separation. The grains were sterilized in oven at $60\pm5^{\circ}\text{C}$ for 8 hours to avoid any hidden infestations. Prior to the experiment, the grains of each variety were conditioned at least for a week in an incubator maintaining $27\pm2^{\circ}\text{C}$ and 65 ± 5 relative humidity in which the tests were carried out (Plate 2 and 3). All the varieties were inoculated simultaneously and there were three replications for each variety. The experiment was conducted at $27\pm2^{\circ}\text{C}$ temperature and 65 ± 5 per cent relative humidity. The following observations were recorded.

- (i) Ovipositional preference
- (ii) Developmental period (egg to adult stage)
- (iii) Adult emergence
- (iv) Sex ratio
- (v) Longevity of adults
- (vi) Grain damage
- (vii) Weight loss

For the study of ovipositional preference, five pairs of freshly emerged adults were released in glass vials (15 x 5 cm)

separately on each variety for oviposition. The total number of eggs laid by the female were counted daily till the death of females. For determination of growth and development, random sample of 40 seeds containing single egg (40 eggs) was placed in separate tube for each replication. From the day fresh emergence started, the dates and number of adults emerged were noted twice (morning and evening) daily to work out the total developmental period (egg to adult) and per cent adult emergence on the basis of eggs placed in each specimen tube and identified for their sexes and the ratio of the male and female adults was obtained. The growth index was obtained by dividing percentage of adult emergence by total developmental period in days. The longevity of male and female beetles was determined by recording the survival period. The damaged grains and weight loss were recorded after 90 days of the release of eggs. For this purpose, the sample of grains was spread upon a white sheet and damaged grains were counted. The percentage of damaged grains were calculated. The loss in weight was obtained after removing all insect stages and frass. It was worked out by subtracting the final weight from the initial weight and converted into percentage.

3.4 Effect of Physical Factors on Growth and Development of *C. chinensis*

Developmental studies of *C. chinensis* were undertaken in the laboratory at four different temperatures and humidity levels on mungbean grains in order to observe their effects on ovipositional potential, ovipositional period, incubation period, developmental period,

adult emergence, grain damage and weight loss of grain. The temperature levels of 20 ± 1 , 25 ± 1 , 30 ± 1 and 35 ± 1 and required humidity levels of 60, 70, 80 and 90 per cent were maintained by using digital environmental chamber.

Experimental Procedure

For the study of ovipositional potential, five pairs of freshly emerged beetles were released in glass vials for egg laying and oviposition period. The total number of eggs laid by the female were counted daily till death of females and oviposition periods were also recorded. A random sample of 40 seeds containing single eggs (40 eggs) was placed in separate tube for development. The specimen tubes were covered with pieces of muslin cloth and kept under each combination of temperature and relative humidity. There were three replications in each case. The observations were recorded on different aspect as described *vide supra* 3.3.

3.5 Management of *C. chinensis* Using Plant Products

3.5.1 Management Using Plant Oils

The bio-efficacy of different plant oils was evaluated against *C. chinensis*. The details of different plant oils used in the experiment are given in table 1.

Table : 1 Details of plant protactant (oils and toxicant) used

S. No.	Common name	Botanical Name	Dose (ml / 100 g of seeds)
1	Cotton seed oil	<i>Gossypium hirsutum</i> L.	0.1, 0.5, 1.0
2	Taramira oil	<i>Eruca sativa</i> Mill.	"
3	Sunflower oil	<i>Helianthus annuus</i> L.	"
4	Groundnut oil	<i>Arachis hypogaea</i> L.	"

5	Mustard oil	<i>Brassica juncea</i> L.	”
6	Sesame oil	<i>Sesamum indicum</i> L.	”
7	Soybean oil	<i>Glycine max</i> Merr.	”
8	Malathion	-	0.025, 0.05, 0.75%
9	Control	-	-

Treatments and their concentrations/doses

Ten ml solution of 1.0, 5.0 and 10.0 per cent concentration of test oils were mixed with 100 g seeds in such way to get a uniform coating which would give the doses of 0.1, 0.5 and 1.0 ml/100 g seeds. Control seeds were treated with acetone only.

Effect on adult mortality

To test the adult mortality 20 pairs of newly emerged adult were released in glass containing treated seeds with various doses of plant oils and toxicant to evaluate the effect of different compounds on the mortality of adult. The observation were recorded after three days of experiment.

Effect of treated seeds on *C. chinensis*

Ten pairs of newly emerged adults were released in glass vials containing 50 g mungbean grains treated with test compounds for egg laying. There were three replications for each treatment. A random sample of 40 seeds containing single eggs (40 eggs) was taken from each replication and placed in separate container to determine the growth, development and infestation of this pest. The duration of total life cycle (development period) was work out by recording the dates of

egg laying and dates of adult emergence on treated food with different doses of test oils. The per cent adult emergence was worked out on the basis of number of eggs placed in a specimen tube and number of adult emerged after completion of life cycle. The longevity of adults determined by recording the dates of their emergence and the dates of their natural death.

The weight loss and grain damage were also determined. The loss in weight was recorded after the end of experiment. Before weighing all insect stages and frass were removed. It was worked out by subtracting the final weight from the initial weight and converted into percentage. The per cent grain damage was calculated by counting the damaged and undamaged grains.

3.5.2 Management Using Plant Powders

The fine powders of different plant products (Table 2) were prepared by drying them in shade and then grinded in electric grinder. The powders were sieved through 60 mesh sieve and mixed with seeds @ 1.0, 2.5 and 5.0 g/100 g seeds.

For mixing the powder with seeds, 50 g seeds were placed in glass vial and desired doses of powder were added to each vial. The powders were mixed thoroughly with seeds by shaking the vials. Samples of seed from each treatment were transferred to specimen tubes. A control (untreated) was also kept simultaneously. The treatments were replicated three times. The further experimental procedure and observations recorded were the same as described under the heading, management with plant oil (3.5.1).

Table : 2 Details of powdered plant products used

S. No.	Common name	Botanical Name	Dose (parts per 100 parts
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			of seeds w/w)
1	Neem kernel powder	<i>Azadirachta indica</i> A. Juss	1.0, 2.5, 5.0
2	Dharak kernel powder	<i>Melia azadirach</i> L.	"
3	Karanj kernel powder	<i>Pongamia glabra</i> Vent.	"
4	Datura leaf powder	<i>Datura alba</i> Nees	"
5	Tulsi leaf powder	<i>Ocimum sanctum</i> L.	"
6	Aak leaf powder	<i>Callotropis procera</i> L.	"
7	Citrus leaf powder	<i>Citrus lemon</i> L.	"
8	Control (untreated)	-	

3.6 Effect of Different Storage Receptacle on *C. chinensis*

Different storage receptacles commonly used for storing the grains at village level, used included polythene bag (200 guage), urea bag, gunny bag, cloth bag, mud pot and metal container. Separate experiments were carried out under both artificial and natural conditions in completely randomized design (CRD) with three replications. Mungbean seeds containing 25 eggs were allowed for development on weighed and counted grains kept in different storage containers under artificial conditions. The grains were also kept without the inoculation of eggs under natural condition. Observations on adult emergence were recorded until all eggs became adults, while per cent dry mass loss and damage grains were obtained after 60 days of inoculation of eggs in each treatment. The per cent dry mass loss was worked out by count and weight method (Dick, 1987).

$$\text{Dry mass loss (\%)} = \frac{(U \text{ Nd}) - (D \text{ Nu})}{U (\text{Nd} + \text{Nu})} \times 100$$

Where,

Nu = Number of undamaged grains,

Nd	=	Number of damaged grains,
U	=	Dry mass of undamaged grains and
D	=	Dry mass of damaged grains.

3.7 Effect of Solar Treatment and Different Colours on *C. chinensis*

The experiment was designed to investigate the effect of solar heat energy and to evaluate the effect of different coloured storage bag (black, blue, green, red and yellow) for *C. chinensis* management in stored mungbean. Transparent plastic bags were used as control. To utilize full solar energy, the experiment was conducted in the month of June. For this purpose, 200 seeds after weighing were placed in each plastic bag (20 x 15 cm) and mungbean seeds containing 40 freshly laid eggs were released in each bag and then bags were exposed to sun for 8, 16 and 24 hours. An aliquot samples of 200 grains without releasing eggs were also kept in separate bags and exposed for the same period to test the effect of solar heat on germination of seeds. Three replications were taken for each treatment of coloured bags and solar period exposure treatment. The bags were put on the roof of Entomology building from 9.00 a.m. to 5 p.m. in such a manner that a thin layer of grains was formed inside the bag. For 8, 16 and 24 hrs. exposure periods, the bags were kept on the roof continuously for one, two and three days, respectively. After the solar exposure these seeds were placed in plastic containers and covered with muslin cloth, held tight with rubber bands. All observation regarding adult emergence was recorded after 45 days. Seed germination tests were carried out according to International Rules of Seed Testing (Anonymous, 1976b).

In another set of experiment, the effect of solar energy was evaluated on adult mortality of *C. chinensis*. For this purpose, 50 newly emerged adults from stock culture were released in each plastic bag

containing mungbean grains and bags exposed to solar energy for the period of 8, 16 and 24 hours by placing them on roof of building. The observations on mortality of adults were recorded in each exposure period of each treatment.

3.8 Effect of Plant Products on the Germination of Mungbean Seeds

In order to find out the effect of grain protectants on seed germination, different oils and powders were mixed with fresh and healthy mungbean grains. The observations on germination were observed just after the treatment and 150 days of treatment. All the treatments and control were replicated three times. The germination tests were carried out according to International Rules of Seeds Testing (Anonymous, 1976b). For assessing the germination of grains mixed with different materials and of untreated grains, a lot of 100 seeds were drawn from each replication and soaked in water for 24 hours and placed in petri dishes over a wet filter paper. These petri dishes were kept at a temperature of $28 \pm 2^{\circ}\text{C}$ and the numbers of germinated grains were counted upto one week and the percentages of germination were calculated.

$$\text{Germination per cent} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds kept for germination}} \times 100$$

Statistical analyses

The data obtained on various characters/parameters were subjected to analyses of variance technique applicable for completely randomized design. The level of significance used in 'F' test was $p = 0.05$ wherever, F calculated was significant, critical difference values were calculated for treatment comparisons. The values obtained in percentage were transformed into angular values and subjected to analyses.

4 Results

4.1 Survey

During survey the samples of mungbean was collected from five farmers of each five villages of five tehsils of Jaipur. Type of storage practices and protective measures were recorded. The samples were transferred in poly jars and brought to laboratory for analyses. Moisture content was taken using digital moisture meter. Incidence of pulse beetle was recorded from a sample and damaged *kernels* were

separated from undamaged. The results obtained during survey were given as follows :

A. Type and Efficacy of Rural Storage Structures (Table 3 and Fig. 1)

BAGS

The grains were filled in gunny or plastic or urea bags and they were staked in the room usually in corners or under shed. This practice was adopted by most of the farmers. Such practices was prevalent in big or small way of door grain storage throughout the surveyed area.

Table 3. Storage receptacles /structures in Jaipur district

S.No.	Storage receptacles/ structures	Number of users	Per cent prevalence
1.	Bag	47	37.60
2.	Loose	20	16.00
3.	Metal containers	18	14.40
4.	Kothi	9	7.80
5.	Stone bin	10	8.00
6.	Bhukhari	10	8.00
7.	Earthen pot	8	6.40
8.	Pusa bin	3	2.40

Loose storage

When the huge bulk of grain was received particularly just after harvest, it was not possible to store them in some structures and hence kept as such in the rooms / godowns. It was also one of the traditional bulk storage practices. If the grain not much, it was heaped in the corner of the room as loose as noticed during the survey. It was most prevalent in Phagi tehsil of Jaipur district.

Metal containers

Used oil or coltar drums of metal or the drum made up of galvanized iron sheet were also used for storing the mungbean grains by number of farmers. Such metal container vary in size and shape and their selection depends upon of the farmers. The usual capacity of

such metal containers was from one to three quintals but in the tehsil Sanganer, Chaksu and Phagi metal containers of capacity of 20 q were used. These containers may be provided with a small inlet hole in middle of top or with lid, half fixed or fully opened for putting in the grains. When such holes were closed, the structures becomes almost airtight. The inlet hole usually serve as exit hole also but in some improvised metal containers there may be an outlet hole at the bottom on the side.

Kothi

There were several different types of mud kothis observed with the farmers / villagers contacted during survey, varying in size, shape and capacity, usually with the individual farmer. Kothi is commonly made up of mud mixed with *bhusa* (straw) and cowdung and may be rectangular, square or circular in shape with the capacity ranging from 1-4 q. Kothi has an inlet hole of variable size at the top, while at the bottom on the side, with an outlet hole. After being filled with the grain both the holes (inlet and outlet) of the kothi are closed with the mud plaster. During survey kothi were found most common in all the tehsils except Phagi tehsil.

Stone bin

In the places where stone slabs were easily available, the grains were stored in structure made up of stone slab. Usually these structures were rectangular or cubical in shape. The structures were constructed in room where three existing walls of room were used and remaining part of the structures was constricted by stone slabs. At the top the structure remain opened to serve as inlet and outlet hole which was covered by a stone slab (lid). After filling up by grains the slab was placed on the opening and plastered with mud. The capacity varies from 10 to 50 q. There may be one or more compartment in a bin to

store more than one type of grain at same time and to withdrawal of grains without affecting others. This type of structure is very common in Sanganer, Dudu and Phulera tehsils.

Bhukhari

This was a structures, usually constructed with masonry material in the side or corner of a room. Their size, shape and capacity usually depend on the available space, which is used for constructing it, and may hold 10 to 100 q of grains. There may be one or more than one compartment in a bhukhari to facilitate storage and withdrawal of grains without affecting the other portion of the stored grain. This structure usually has an opening at the top for both inlet and outlet purposes but in some places an outlet is also provided on the side but close to the bottom. This structure is very common in Chaksu, Dudu and Phulera tehsils.

Earthen pots

Earthen pots of various sizes, shapes and capacity ranging from 5 to 20 kg were also used by some farmers of Chaksu and Phagi. Usually the earthen pot is made up of clay with single opening at top which works both as inlet and outlet hole. After filling up the grains an earthen lid was placed on the opening and plastered with mud.

BINS

Pusa bin improved storage structures easy to construct and with in a reach of an average farmers. It was made of unbrurnt bricks in which polythene film of 700 gauge was sandwiched, and inner wall was plastered with mud. An outlet for the grain in the from of a pipe with a screw cap was fitted on one side with adequate slope for the grain to flow out when required. The bin when filled to capacity and properly closed becomes an air tight, damp, proof structure, which is also poor in thermal conductivity. Only two Pusa Bin in Dudu and one in Phagi was observed during survey.

B. Infestation Relation to Storage Structures / Receptacles

The data obtained on samples collected during survey revealed that none of the structure was found free from infestation except pusa bin (Table 4 and Fig. 2). Maximum infestation was recorded in mud pot and bhukhari (100%), followed by loose (85.00%), bag (74.46%), kothi (66.66%), stone bin (50.00%) and metal container (38.88%).

C. Storage Practices and Receptacles

The prevalent storage practices and receptacles/ structures were examined at the spot and details regarding materials and method of their construction, size, shape, capacity, inlet and outlet holes, location, grain stored etc. were noticed. The names of the tehsils and villages were surveyed were presented in Appendix I. The storage practices and store receptacles / structures commonly observed in Jaipur districts were bag (37.60%), metal container (14.40%), loose (16.00%), kothi (7.80%), stone bin (8.00%), bhukhari (8.00%), earthen pot (6.40%) and pusa bin (2.40%) (Table 4 and Fig. 1).

The most commonly used storage practices for food grains was bag storage. Out of 25 villages surveyed 47 farmers (37.60%) were found to use bag storage from total samples. The next common receptacle for storage of food grains was metal containers made up of galvanized iron sheet, capacity from 2 to 40 q grains. Out of 125 users 18 users (14.40%) were found to use metal containers. These types of storage receptacles were common in Dudu tehsils. Storage of food grains as loose and kothi (capacity 1 to 40 q) were recorded from 20 (16%) and 9 (7.80%) farmers, respectively. Loose storage of food grains was found in almost all surveyed tehsils of Jaipur district. Phagi was recorded higher proportional use of loose storage as compare to rest of the tehsils. The maximum number of kothi was recorded in Chaksu followed by Dudu, Phulera and Sanganer. No kothi was observed in Phagi tehsil. Stone bin (capacity 5 to 20 q) were used by 10 (8.00%) farmers. Bhukhari constructed either kacchi or pucci (capacity varying from 10 to 100 q) were recorded from 10 users (8.00%). The higher percentage bhukhari was recorded from Dudu tehsil. The earthen pots of different shape, size and capacity (varies from 5 to 20 kg) are also used by farmers (6.40%) in the surveyed tehsils of Jaipur. There were only three pusa bins were recorded, two in Dudu and one in Phagi.

D. INFESTATION RELATION TO MOISTURE CONTENT OF SAMPLES

With regard to moisture content, out of 125 samples collected from 5 tehsils of Jaipur (Rajasthan) 98 samples having moisture content up to 10 per cent, 22 samples having 10.10 to 13.50 per cent, while only 5 samples having moisture content more than 13.60 per cent (Table 5).

TABLE 5. INFESTATION IN RELATION TO MOISTURE CONTENT OF SAMPLES

S.No.	Particulars	Moisture		
		Upto 10.00%	10.10 to 13.50%	More than 13.50%
1	Samples collected	98	22	5
2	Infested samples	66	18	4
3.	Per cent sample infested (%)	67.34	81.81	80.00

Out of 98 samples (moisture content up to 10.00 per cent), 66 samples (67.34%) were found infested with different insect pests. In the samples having moisture content between 10.10 to 13.50 per cent, 18 samples (81.81%) were infested out of 22 samples collected during survey while in 5 samples having moisture content more than 13.50 per cent, 4 samples were found infested (80.00%)

4.2 Host Preference of *C. chinensis*

4.2.1 Developmental period (Table 6 and Fig. 3)

The average number of days taken to complete the development of the beetles from egg to adult stage differed significantly on different hosts. The average developmental period of the pulse beetles progeny on cowpea (22.00 days) was significantly shortest then that on all other hosts. The average developmental period recorded on mungbean, arhar, moth and gram and urd were 24.33, 29.33, 29.66, 31.00 and 31.33 days, respectively, however, no significance different was observed between arhar and moth; and gram and urd.

4.2.2 Adult emergence (Table 6 and Fig. 3)

The adult emergence on different host grains varied from 70.83 to 84.16 per cent. The maximum percentage of adult emergence was recorded on cowpea 84.16 per cent which at par with mungbean 81.66 per cent followed by moth (78.33 %) and arhar (76.66 %). The minimum adult emergence was recorded on urd (70.83%) at par with gram (75.83%).

4.2.3 Fecundity (Table 7 and Fig. 3)

The results on fecundity presented in table indicated that the host on which they were bread, significantly affected the fecundity. The mean number of egg laid on different hosts ranged from 72.66 to 82.00. The maximum number of eggs (82.00) was laid on cowpea followed by mungbean (80.66), gram (76.33), moth (73.66) and urd (72.66). The minimum numbers of eggs per female (65.66) was laid on arhar (65.66).

4.2.4 Grain damage (Table 7 and Fig. 4)

A highly significant difference was recorded for grain damage in different hosts. The urd was the least damaged (33.53 %) while the cowpea was the highly damaged (43.13%). The extent of damage recorded on mungbean, moth, gram, arhar and urd was 42.13, 37.13, 36.60, 35.60 and 33.53 per cent, respectively. However, the damaged to grain in case of cowpea and mungbean did not differ significantly with each other. The extent of damaged caused by the test insect to cowpea and mungbean grains was significantly higher than that caused to grains of all other pulses.

4.2.5 Weight loss (Table 7 and Fig. 4)

Net weight loss due to feeding of test insect in various hosts grains differed significantly varying from as low as 6.87 per cent in urd to as high as 13.90 per cent in cowpea. The per cent weight loss recorded on mungbean, moth, gram and arhar were 11.29, 9.80, 9.22 and 8.41 per cent, respectively. However, no significant difference was observed between mungbean and moth.

4.2.6 Growth index (Table 7 and Fig. 4)

The growth index ranged from 2.25 to 3.82 in different hosts, being minimum urd (2.25) followed by gram (2.44), moth (2.52) and arhar (2.66), mungbean (3.31) and cowpea (3.82).

On the basis of growth index of test insect in different hosts, the order of suitability was : cowpea > mungbean > arhar > moth > gram > urd.

4.3 Varietal Susceptibility of Mungbean Against *C. chinensis*

4.3.1 Ovipositional preference (Table 8 and Fig. 5)

The Maximum numbers of eggs were deposited in RMG-492 (82.33) which was significantly different from the rest of the varieties. It was followed by RMG-62 (79.53), Pusa-9531 (75.66), RMG-344 (69.44), Pusa Vishal (63.88), RMG-262 (62.44), Ganga-2 (60.99), MUM-2 (57.77), Ganga-8 (57.55), Pusa Bold (53.55) and K-851 (52.88). Variety Pusa-105 had the minimum numbers of laid eggs (49.10).

4.3.2 Developmental period (Table 8 and Fig. 5)

The average developmental period of *C. chinensis* varied significantly on different mungbean varieties. The minimum developmental period was observed on RMG-492 (23.33 days) followed by RMG-62 (25.00 days), Pusa-9531 (25.33 days), RMG-344 (27.00 days), RMG-262 (28.00 days), Pusa Vishal (28.00 days), Ganga-2 (28.66 days), K-851 (30.00 days), Mum-2 (30.00 days), Pusa Bold (30.33 days), Ganga-8 (30.66 days) and Pusa-105 (32.66 days). However, no significant difference was observed between the varieties RMG-62 and Pusa-9531; RMG-344, RMG-262 and Pusa Vishal; Pusa Vishal and Ganga-2; Ganga-2, K-851 and Mum-2; and K-851, Mum-2, Pusa Bold and Ganga-8. The longest developmental period was recorded on Pusa-105 (32.66 days).

4.3.3 Adult emergence (Table 9 and Fig. 5)

The emergence of adult was significantly affected in mungbean varieties tested. The minimum number of adults emerged on the variety Pusa-105 (48.33%) which was significantly superior over rest of the treatments, while maximum number of adults emerged on RMG-492 (83.33%). However, no significant difference was observed between the treatment of K-851 (54.16%) and Pusa-Bold (54.16%); Ganga-8 (59.16%) and Mum-2 (60.00%); RMG-262 (65.83%) and Pusa Vishal (66.66%); and RMG-344 (71.66%) and Pusa-9531 (73.33%).

4.3.4 Sex ratio (Table 9)

The minimum sex ratio was obtained in varieties Pusa-105 (1:0.966) followed by Pusa Bold (1:0.969) while, it was maximum in RMG-492 (1:1.173) followed by Ganga-8 (1:1.088), RMG-62 (1:1.086). The rest of varieties were found intermediary in position which were Mum-2 (1:1.057), Ganga-8 (1:1.051), Pusa Vishal (1:1.051), RMG-344 (1:1.047), Pusa-9531 (1:1.046), K-851 (1:1.031) and RMG-262 (1:1.025). In general, the number of females was higher than the males in each variety except Pusa-105 and Pusa Bold where females were less than males.

4.3.5 Longevity of adults (Table 10 and Fig. 6)

The males lived for slightly shorter period as compared to females and the significant difference was recorded in the longevity of adult beetles of both sexes reared on different mungbean varieties. The male adult lasted for 5.00 to 8.33 days in different varieties being minimum on Pusa-105, while maximum on RMG-492 and RMG-62. The female longevity varied from 5.33 to 8.66 days in different varieties. Similarly, minimum longevity of females beetles was observed on Pusa-105, while maximum on RMG-492 and RMG-62.

4.3.6 Grain damage (Table 11 and Fig. 7)

A significant difference was observed between different mungbean varieties in term of per cent damaged grains due to the infestation of *C. chinensis*. The per cent damaged grain ranged from 31.33 to 44.06 in different mungbean varieties. Pusa-105 (31.33%), was the least damaged variety, while the most damaged variety was RMG-492 (44.06%) followed by RMG-62 (41.60%), Pusa-9531 (41.26%), RMG-344 (40.60%), Pusa Vishal (39.40%), RMG-260 (38.86%), Ganga-2 (37.06), Ganga-8 (36.86%), Mum-2 (36.66%), K-851 (35.53%) and Pusa Gold (34.73%).

4.3.7 Weight loss (Table 11 and Fig. 7)

The differences in per cent weight loss among different mungbean varieties were also significant. Lowest net weight loss (5.96%) was observed in Pusa-105 followed by Pusa Bold (7.93%). The highest net weight loss 15.18 per cent was observed in variety RMG-492. In remaining variety, it was ranged from 8.16 to 11.04 per cent.

4.3.8 Growth index (Table 11 and Fig. 7)

It was apparent from growth index as shown in table that the lower values were found in the varieties Pusa-105 (1.47), followed by Pusa bold (1.78), K-851 (1.80), Ganga-8 (1.92). The varieties RMG-492 and RMG-62 showed higher values of index of susceptibility, having 3.57 and 3.20, respectively. All the other varieties intermediately in position, which ranged from 2.00 to 2.89 values of it.

4.4 Effect of Physical Factors on Growth and Development of *C. chinensis*

4.4.1 Effect on ovipositional potential (Table 12 and Fig. 8)

The average number of eggs laid per female was found to be maximum (77.66) when insect were reared at 30°C and minimum number of eggs (21.16) was observed at 20°C. The number of eggs laid at 25°C and 35°C were 56.83 and 43.33, respectively. The data obtained on the effect of relative humidity clearly indicated that the most favourable relative humidity found for maximum egg laying was 70 per cent on which 52.57 eggs laid by a single female. The average number of egg laid per female in 60, 80 and 90 per cent relative humidity were 46.66, 50.33 and 49.41, respectively. The interaction of temperature and relative humidity revealed that most suitable combination for egg laying was 30°C and 70 per cent relative humidity on which maximum number of eggs (82.66 /female) were laid by female which was at par with 80.33 eggs laid by female at 30°C and 80 per cent relative humidity. The minimum fecundity (18.66 eggs /female) was recorded at 20°C and 60 per cent relative humidity.

4.4.2 Effect on oviposition period (Table 13 and Fig. 9)

The oviposition period of test insect was found varied significantly with the temperature levels. The maximum period (7.74 days) was recorded when the insect were reared at 20°C, whereas, minimum duration (3.49 days) was recorded at 35 °C. At 30°C the oviposition period was 4.33 days. The data obtained on the effect of relative humidity clearly indicated that the oviposition period (5.66 days) was higher at 80 and 90 per cent relative humidity while minimum 4.99 days at 70 per cent relative humidity. Regarding the combined effect of temperature and relative humidity on the oviposition period maximum duration (9.66 days) was recorded at 20°C and 90 per cent relative humidity against 2.66 days at 35°C and 90 per cent relative humidity.

4.4.3 Effect on incubation period (Table 14 and Fig. 10)

The data presented on incubation period at different levels of temperature indicated that there was a significant increase in the mean hatching period as temperature decreased. The mean egg period at 20, 25, 30 and 35°C were 10.07, 6.58, 5.08 and 4.16 days, respectively. The incubation period decreased with the increase in relative humidity. The maximum (7.24 days) incubation period occurred at 60 per cent relative humidity while minimum

(5.99 days) at 90 per cent relative humidity. The interaction between temperature and relative humidity, longest period (11.66 days) was observed at 20°C and 60 per cent relative humidity while shortest period of 3.66 days at 35°C and 90 per cent relative humidity.

4.4.4 Effect on developmental period (Table 15 and Fig. 11)

The complete developmental period (egg to adult) increased with the decreased in temperature. The developmental period was found to be maximum (49.41 days) when the insect were reared at 20°C and minimum duration (23.16 days) was observed at 35°C. At 30°C complete development took 29.74 days. The data obtained on the effect of relative humidity revealed that the test insect took minimum 31.91 days for completing their development at 70 per cent relative humidity. The pest took maximum time (38.24 days) in completing their development under 60 per cent relative humidity. The combined effect of both the factors revealed that the test insect took minimum time (22.00 days) in completing their development when reared at 35°C and 70 per cent relative humidity. The maximum developmental period of 55.33 days was recorded at 20°C and 60 per cent relative humidity.

4.4.5 Effect on adult emergence (Table 16 and Fig. 12)

The data clearly indicated that the maximum adult emergence (72.91%) was recorded when insect was developed at 30°C followed by 62.70, 52.49 and 27.70 per cent at 35°C, 25°C and 20°C, respectively. The most favourable humidity level for adult emergence was found 70 per cent, at which maximum adult emergence (58.12%) occurred. At 90 per cent humidity level only 51.03 per cent adult emergence was noticed. The combined effect of temperature and humidity indicated that the combination of 30°C and 70 per cent relative humidity was found best which resulted in 80.83 per cent adult emergence, whereas, the combination of 20°C and 90 per cent relative humidity only 25.00 per cent adult emerged.

4.4.6 Effect on grain damage (Table 17 and Fig. 13)

The data presented on grain damage at different levels of temperature indicated that the maximum grain damage was 37.19 per cent at 30 °C while minimum grain damage (13.09%) at 20°C. Regarding humidity levels, the maximum grain damage of 29.19 per cent was recorded in 70 per cent relative humidity. The minimum grain damage (25.26%) was recorded in 90 per cent relative humidity followed by 26.83 and 27.26 per cent at 60 and 80 per cent relative humidity, respectively. The combined effect of both the parameters revealed that the maximum grain damage (40.93%) was recorded at 30°C and 70 per cent relative humidity, while the minimum (9.86%) at 20°C and 90 per cent relative humidity.

4.4.7 Effect on weight loss (Table 18 and Fig. 14)

The data recorded on the effect of temperature indicated that the maximum weight loss (8.28%) was recorded at 30°C followed 7.26 per cent at 35°C while minimum weight loss (2.35%) at 20°C. The results obtained on the effect of relative humidity clearly indicated that the maximum weight loss 6.57 per cent was recorded at 70 per cent relative humidity. The minimum weight loss 4.94 per cent was observed under 90 per cent relative humidity, at par with 60 per cent relative humidity having 5.50 per cent weight loss. The combined effect of relative humidity and temperature showed that maximum grain weight loss (9.62%) recorded at 30°C and 70 per cent relative humidity while minimum weight loss (1.66%) at 20°C and 90 per cent relative humidity.

4.5 Management of *C. chinensis* Using Plant Products

4.5.1 Management Using Plant Oils and Toxicant

4.5.1.1 Effect on adult mortality (Table 19 and Fig. 15)

The percentage of adult mortality after 3 days of treatment was significantly superior in all doses of each treatment as compared to control. The percentage of adult mortality gradually increased with the increase in doses of each treatment. The mean adult mortality ranged from 47.70 to 75.20 per cent in different doses. Assessing the results obtained in different treatments it was observed that the maximum adult mortality of 69.44 per cent was recorded in malathion, which was at par with cotton seed oil (68.33%). It was followed by taramira oil (66.11 %), mustard oil (64.71%) and groundnut oil (59.72%). The next effective treatments were sunflower (56.38%) and sesame oil (55.55%). The minimum mortality was recorded in soybean oil (49.16%).

4.5.1.2 Effect on developmental period (Table 20 and Fig. 16)

All the dose level were found significantly superior in increasing the developmental period over control. The mean development period varied from 27.62 to 38.32 days in different doses. Comparing the results obtained in different treatments the mean duration of development ranged from 30.77 to 36.44 days, being maximum in malathion (36.44 days) at par with cotton seed oil (35.55 days). It was followed by mustard oil (34.10 days),

groundnut oil (32.88 days) and sunflower oil (32.55 days). The least effective treatment was found to be soybean oil (30.77 days) with minimum development period, which was at par with taramira oil (31.33 days) and sesame oil (32.10 days).

4.5.1.3 Effect on adult emergence (Table 21 and Fig. 17)

The data on per cent adult emergence from the grains treated with different doses of test oils and toxicant showed significant difference when compared with the control. The per cent adult emergence decreased with the increase in doses of all the treatments. The adult emergence ranged from 17.49 to 31.55 per cent at different dose levels as against 74.16 per cent in control. Considering the results obtained in different treatments the minimum adult emergence was recorded in grains treated with malathion (20.83%), which was at par with cotton seed oil (21.94%) followed by taramira oil (22.77%) and mustard oil (24.16%) while maximum recorded in grain treated with soybean (30.27%) as against control where 74.16 per cent adult emergence occurred.

4.5.1.4a Effect on longevity of male beetles (Table 22 and Fig. 18)

All the doses of plant oils and toxicant tested were found to be significantly superior in reducing the longevity of male beetles over control. The mean longevity of male beetles at different doses ranged from 5.78 to 8.87 days, while it was 9.33 days in control. The longevity of male beetle emerged from grains treated with malathion and cotton seed oil at the initial dose level was 8.66 days, which decreased to the 4.33 days at the highest dose level. Similar trends of reduction in longevity of male beetle was also observed in other treatments.

4.5.1.4b Effect on longevity of female beetles (Table 23 and Fig. 19)

The significant differences existed between the doses of plant oils and toxicant in reducing the longevity of female beetles. The longevity gradually decreased with the increase in dose level of each treatments. The mean longevity of female beetles at different dose levels ranged from 6.37 to 9.28 days whereas in control it was 9.66 days. In malathion and cotton seed oil the longevity of female beetle was 9.00 days at the initial dose level which decreased to the 5.00 days at the highest dose level. Similar trend of reduction in longevity of female beetles with the increase in dose level was observed in other treatments. The malathion and cotton seed oil at 1.0 ml/100 g seeds were found most effective while the soybean oil proved least effective in reducing the longevity of the female beetles.

4.5.1.5 Effect on grain damage (Table 24 and Fig. 20)

The per cent damaged grains in different treatments were significantly less than the per cent damage grains in control, however, different treatments exhibited different level of efficacy in terms of per cent grain damaged. The grain damage of treated grains progressively decreased with the increase in dose level of each treatment. The grain damage at different dose levels ranged from 6.71 to 34.24 per cent. The grain damage recorded in grains treated with malathion, cotton seed oil, taramira oil, mustard oil, groundnut oil, sesame oil, sunflower oil and soybean oil at the highest dose level of each treatment were 4.26, 4.60, 6.00, 6.26, 6.93, 7.80, 8.73 and 9.13 per cent, respectively, as compared to 43.20 per cent grain damage in the control.

Regarding different treatments, the mean per cent grain damage ranged from 19.95 to 26.93. Significantly less number of grain damage were found in grains treated with malathion and cotton seed oil as compared to other treatments. It was followed by taramira, mustard, groundnut, sesame, sunflower and soybean oils with 21.35, 21.77, 22.48, 24.02, 24.57 and 26.93 per cent grain damage, respectively. However, no significant difference between the treatments of malathion, cotton seed oil and taramira oil; cotton seed oil, taramira oil and mustard oil; taramira oil, mustard oil and groundnut oil; groundnut oil and sesame oil; and sesame oil and sunflower oil.

4.5.1.6 Effect on weight loss (Table 25 and Fig. 21)

All the doses were found significantly better in reducing the weight loss over control. The mean weight loss at different dose levels ranged from 2.57 to 9.29 per cent. The per cent weight loss gradually decreased with the increase in dose level of each treatment. In malathion, the net weight loss was 7.77 per cent at the initial

concentration (0.025%) which decreased to 1.10 per cent at the highest concentration (0.075%). Similar trend was also found in other treatments. Comparing the results obtained in difference treatments, the mean per cent weight loss varied from 5.11 to 8.66 per cent, being minimum in malathion and cotton seed oil and maximum in soybean oil treatment.

4.5.2 Management of *C. chinensis* With Plant Powders

4.5.2.1 Effect on adult mortality (Table 28 and Fig. 22)

The per cent adult mortality gradually increased with increase in dose level of each treatment. The mean mortality of adult in different doses varied from 41.78 to 65.71 per cent. In *neem kernel* powder, adult mortality was 51.66 per cent in dose level of 1.0 g / 100 g seeds which increased to 80.83% at the highest dose level of 5.0 g/100 g seeds. Similar trends of increase in mortality was also recorded in other treatments. The maximum adult mortality (65.83%) was observed in *neem kernel* powder which was significantly better over rest of the treatments. The next effective treatment was *karanj kernel* powder (61.94%) followed by *dharak kernel* powder (58.88%), *aak leaf* powder (54.16%), *datura leaf* powder (51.38%), *tulsi leaf* powder (44.71%) and *citrus leaf* powder (42.21%)

4.5.2.2 Effect on developmental period (Table 29 and Fig. 23)

All the treatments found significantly superior in increasing the developmental period of *C. chinensis* over control. The mean developmental period of beetles got progressively increased with the increase in dose level of test compounds. Considering the results obtained in different treatments, the mean duration of development ranged 30.44 to 36.44 days, being maximum in *neem kernel* powder (36.44 days), which was at par with *karanj kernel* powder (35.66 days). The next effective treatments were *dharak kernel* powder, *aak leaf* powder, *datura leaf* powder, *tulsi leaf* powder and *citrus leaf* powders having developmental period 35.22, 33.10, 32.55, 30.88 and 30.44 days, respectively while in control it was 24.66 days. However, no significance difference was observed between the treatment of *karanj kernel* powder and *dharak kernel* powder; *aak leaf* powder and *datura leaf* powder and *tulsi leaf* powder and *citrus leaf* powder.

4.5.2.3 Effect on adult emergence (Table 30 and Fig. 24)

The emergence of *C. chinensis* beetles from grains treated with different plant product powders @ 1.0, 2.5 and 5.0 g /100 g seeds showed significant difference as compared to control. The per cent adult emergence decreased with increase in dose level of the test compounds. The reduction in adult emergence at difference dose levels varied from 22.37 to 32.14 per cent as against 76.66 per cent in control. Adult emergence was 28.33 per cent at lowest dose level, which decrease to 16.66 per cent at highest dose level of *neem kernel* powder. Similar trend was also reported in other treatments.

Comparing the results obtained in various plant powders, it was found that *neem kernel* powder was most effective in which minimum percentage of adult emergence occurred and significantly superior to rest of the treatments. The next effective treatments of *karanj kernel* powder (24.72%), followed by *dharak leaf* powder (26.10%), *aak leaf* powder (26.38%), *datura leaf* powder (27.50%), *tulsi leaf* powder (30.83%) and *citrus leaf* powder (33.05%). However, no significant difference was noticed, between the treatment of *neem kernel* powder and *karanj kernel* powder; *karanj kernel* powder, *dharak kernel* powder and *aak leaf* powder; and *dharak kernel* powder, *aak leaf* powder and *datura leaf* powder.

4.5.2.4a Effect on longevity of male beetles (Table 31 and Fig. 25)

It is apparent from the data that all the doses of plant powders were found significantly superior in reducing the longevity of male beetles over control. The longevity of male beetles at different doses ranged from 5.56 days to 8.51 days, while it was 9.33 days in the control. The longevity of male beetles emerged from grains treated with

neem kernel powder 8.00 days, *karanj kernel* powder 8.33 days *dharak kernel* powder 8.66 days and aak leaf powder at the initial dose level, which decreased to the 4.33 days in *neem kernel* powder, 4.66 days in *karanj kernel* powder, 5.00 days in *dharak kernel* powder and 5.33 days in aak leaf powder at the highest dose level (5.0 g / 100 g seeds). Similar trend was also observed other treatments.. Comparing the results obtained in different treatments, *neem kernel* powder and *karanj kernel* powder were proved to be most effective in reducing the longevity of male beetles.

4.5.2.4b Effect on longevity of female beetles (Table 32 and Fig. 26)

The longevity of female beetles gradually decreased with the increase in dose levels of each treatment. The longevity of female beetles at different dose levels ranged from 6.14 days to 8.80 days whereas in control it was 9.66 days. The longevity of female beetles in the initial dose of *neem kernel* powder was 8.33 days which decreased to the 5.00 days at the higher dose level. Similar trend of reduction in longevity of female beetles was observed in other treatments. The *neem kernel* powder, *karanj kernel* powder and *dharak kernel* powder at 5.0 g/100 g seed were found most effective treatments in reducing the longevity of female beetles.

4.5.2.5 Effect on grain damage (Table 33 and Fig. 27)

The per cent of damaged grains in all the doses of different treatments were significantly less than the per cent of damaged grains in control. In *neem kernel* powder, the grain damage was 31.93 per cent at the initial dose level (1.0 g /100 g seeds), which reduced to 5.73 per cent at highest dose of 5.0 g /100 g seeds. Similar trends were recorded in other treatments. The mean grain damage at different dose levels ranged from 9.00 to 35.25 per cent. While assessing the results obtained in different plant powders, the average grain damage ranged from 21.04 to 28.04 per cent, being minimum in *neem kernel* powder and maximum in citrus leaf powder (28.04%).

4.5.2.6 Effect on weight loss (Table 34 and Fig. 28)

The relative efficacy of different treatments in per cent reduction in net weight of mungbean grains were found significant. The mean per cent weight in different doses ranged from 3.64 to 9.56 per cent, as against 12.58 per cent in control. Considering the results observed in different treatments, the minimum per cent weight loss (5.79%) was recorded in *neem kernel* powder, at par with *karanj kernel* powder (6.41%). It was followed by *dharak kernel* powder (6.65%), aak leaf powder (7.43%), *datura* leaf powder (7.87%), *tulsi* leaf powder (8.26%) and citrus leaf powder (8.63%). No significant difference was recorded between the treatments of *neem kernel* powder and *karanj kernel* powder; *karanj kernel* powder and *dharak kernel* powder; aak leaf powder and *datura* leaf powder; *datura* leaf powder and *tulsi* leaf powder; and *tulsi* leaf powder and citrus leaf powder.

4.6 Effect of Different Storage Containers on the Incidence of *C. chinensis* in Stored Grains of Mungbean

The investigation which was aim to findings out an effective and economical storage containers / receptacles was mainly confirmed to the usages of different types of containers which could profitably be employed by the villages. All types of containers that are commonly available viz., polythene bag, urea bag, gunny bag, cloth bag, mud pot and metal container were used in this study (Table 37 and Fig. 29).

The results indicated that the significant difference observed in grain damage and weight loss in different storage containers under artificial and natural conditions. Under artificial conditions maximum grain damage observed in mud pot (47.33%) which differed significantly from other containers. The minimum grain damage was recorded in metal container (24.93%). The maximum dry mass loss was recorded in mud pot (9.06%) which was at par with cloth bag (8.32%) and followed by urea bag (7.58%), polythene bag (7.22%) and gunny bag (5.92%). The minimum dry mass loss observed in metal container (4.25%). The significant number of adult emerged ranged from 10.00 in metal container to 21.33 in mud pot.

Under natural condition, minimum grain damage (1.53%) and dry mass loss (0.92%) were observed in metal container. The maximum grain damage (4.73%) and dry mass loss (2.03%) were recorded in mud pot followed by cloth bag (3.53% and 1.66%) urea bag (3.26% and 1.47%), polythene bag (2.80% and 1.11%), gunny bag (2.13 and 1.29). However, the damage was negligible in all receptacles.

4.7 Effect of Solar Treatment and Different Colours on *C. chinensis*

4.7.1 Eggs exposure

4.7.1.1 Effect on adult emergence (Table 38)

No adult emergence was found when the eggs were released in mungbean grains, exposed to sun in black, blue and red polythene bags for 24 hrs, however, poor adult emergence was recorded in other bags for the same exposure period. The mean number of adult emerged ranged from 0.11 to 2.77 in different colour bags. While comparing the results obtained in different time exposures, it was observed that the adult emergence decreased with the increase in solar time exposure. The mean number of adults emerged varied from 0.38 to 1.71 in different exposure periods.

4.7.1.2 Effect on seed germination (Table 39 and Fig. 30)

The maximum germination (91.66%) was observed in colourless polythene bag which differed significantly from coloured polythene bags. The mean per cent seed germination varied from 75.55 to 86.33 in different colour bags. Assessing the results of different exposure periods, it was clearly indicated that the per cent germination significantly decreased with the increase in solar time exposure. The mean seed germination ranged from 75.49 to 86.05 per cent in different exposure periods.

4.7.2 Adult exposure

In another set of experiment, 50 newly emerged adults from stock culture were introduced in each plastic bag containing

mungbean grains and bags exposed to solar heat. The mortality of adults was counted.

4.7.2.1 Effect on adult mortality (Table 40 and Fig. 31)

It is evident from the table that the maximum mortality of beetles (75.83%) occurred in black polythene bag, which was significantly higher as compared to other colour polythene bags exposed to sun for 8 hrs. A similar trend of beetles mortality was recorded in other exposure periods (16 and 24 hrs). The mean per cent mortality in different coloured bags ranged from 58.05 to 88.05. The treatment of black polythene bag proved most effective in causing the adult mortality which differed significantly and superior to rest of the treatments. It was followed by blue, red, yellow, green and colourless polythene bags with 84.16, 79.99, 74.99, 68.61 and 58.05 per cent mortality, respectively. However, the treatment of blue and red and red and yellow polythene bags were at par.

Assessing the results of different time exposures, it is clear from the data that the mortality of beetles increased significantly with the increase in solar exposure periods. The mean per cent mortality varied from 61.10 to 90.41 in different exposure periods, being maximum (90.41%) in 24 hrs exposure period which was significantly higher over rest of the exposure periods.

4.8 Effect of Plant Products on the Germination of Mungbean Seeds

The observations on germination of mungbean seeds at just after treatment and 150 days after treatment with different concentrations/ doses of test compounds used as protectant, showed no significant effect on the germination. The germination

percentage in different treatments ranged from 71.21 to 73.33 per cent (Table 26) in plant oils and 74.10 to 75.44 per cent (Table 35) in plant powders at just after the treatment. The germination percentage slightly decreased with the increases in dose levels of all test compounds, however, no significant differences was observed among themselves.

After 150 days of treatment, the germination ranged from 62.99 to 63.88 per cent (Table 27) in different plant oils and 65.44 to 66.77 per cent (Table 36) in different plant powders of treatment of mungbean seeds. However, no statistical differences existed among the treatments.

On the basis of above observations, it can safely be said that all the test compounds used as protectants had no adverse effects on the germination of mungbean seeds upto 150 days of treatments.

5 Discussion

5.1 Survey

In the present investigations survey of the pulse beetle, *Collosobruchus chinensis* Linn. in the stored mungbean in the five

tehsils of Jaipur and the type of storage structures used by the farmers at their swelling was undertaken.

It is reckoned that large quantity of mungbean are stored at farmer's level of purpose of their own use, i.e. for family and domestic animal consumption, and seed purpose. The mungbean produced were stored in different storage receptacles available with the farmers, ranging from very primitives types of structures made from mud in the form of backed and unbacked pots to modern bins.

The survey done in five tehsils of Jaipur revealed that 37.60 per cent farmers stored mungbean in bag, 16.00 per cent stored in loose, 14.40 per cent in metal containers, 7.80 per cent in kothi, 8.00 per cent in stone bin, 8.00 per cent in bhukhari, 6.40 per cent in mud pot and 2.40 per cent farmers stored mungbean in pusa bins. Gupta (1990) also reported bulk storage (76%) was more popular for pulse storage in Rajasthan as compared to bag storage (24%) which is in partially conformity with the present findings. He further reported that among the bulk storage structures, farmers adopted bhukhari (33%), separate store room (32.4%), kothi (1.4%) and kuthila (1.4%). Malik *et al.* (1994) who reported that maximum adoption of bag storage (77.67%) followed by pusa bin and metal bin upto 20.00 per cent in the villages but in present investigation, the adoption of metal bin was there but pusa bin was adopted by only few farmers (2.40%). Singh and Yadav (1995) also observed the similar type of structures and containers during survey in different part of Haryana. The present survey data is in conformity with observation of Fletcher and Ghosh (1921) and many other workers (Pruthi, 1949; Ramasivan *et al.*, 1968; Srivastava *et al.*, 1973; Gupta, 1990; Sinha, 1990, Singh and Sharma, 2003a and Yadav, 2007).

None of the structures was found free from infestation except pusa bin, which is also supported by Zuthsi (1966), Daliwal (1977), Dass (1977), Agarwal *et al.* (1981), Sinha (1990), Singh and Yadav (1995) and Singh and Sharma (2003a) who reported that infestation was maximum when stored in loose in room, moderate in gunny and jute bags and least in metal container partially conformity the present findings.

Moisture content of the grain plays an important role in deterioration of the stored produce. During the present study, it was found that storage structures play an important role in the retention or change in the moisture content of stored produce.

It is futile to grow more food, if what is grown is not stored properly to avoid post harvest losses. The present survey revealed that the storage structures used for storing the mungbean, however none of the structures are ideally suited for storing the pulses, which result in heavy loss to the producers, i.e. the farmers. Such post harvest losses have also been reported from different agro-climatic zones of India. The reason for such losses has been attributed to the lack of desired technical knowledge among the farmers (Birewar *et al.*, 1980). There is urgent need to modernize the storage facilities and methods in the country so that pest losses caused are minimized and the economically weak producer, the farmers, is strengthened.

5.2 Host Preference

The developmental period and adult emergence of pulse beetles were found to be significantly affected by different hosts. The developmental period and adult emergence varied from 22.00 to 31.33 days and 70.83 to 84.16 per cent, respectively on different hosts. The results obtained under this experiment are supported by the findings of Gokhale (1973) and Singh *et al.* (1980) who reported that rate of

development of pulse beetle varied with respect to the nutritive value of food stuff. The minimum developmental period of this pest was recorded on cowpea, followed by mungbean, *arhar*, moth, gram and *urd*. The cowpea and greengram were preferred food for growth and development of *Callosobruchus* spp. reported by several workers (Back, 1922; Zaazou, 1951; Gundurao and Majumdar, 1964; Gokhale, 1973; Srivastava and Pant, 1989; Roesli *et al.*, 1991; Kumar *et al.*, 2001 and Bhargava *et al.*, 2008) are in agreement with the present findings. In the present study, the maximum adult emergence was recorded on cowpea at par with mungbean. It was followed by moth, *arhar*, gram and *urd*. Kumar *et al.* (2001) observed that more adults of *C. chinensis* emerged from the cowpea than other pulses, support the present findings. Similarly, Bhargava *et al.* (2008) observed maximum number of F₁ progeny on cowpea as compared to other hosts.

The results showed that the beetle to oviposit was high when the seeds preferred for oviposition (namely cowpea and mungbean) were provided but was decreased on the less preferred hosts (gram, moth and *urd*) and was considerably less on *arhar* which was among the least preferred host for oviposition. The present findings corroborate the study of Srivastava and Bhatia (1958) who reported that the egg laying power increased when the preferred hosts were provided for oviposition. These studies also indicate that, in general, the development of the larvae was better on seeds which were preferred by the beetles for oviposition. Ueno (1955) also reported that greengram were preferred for oviposition, support the present findings. Similarly, Bhargava *et al.* (2008) also reported that maximum fecundity of *C. chinensis* on cowpea as compared to other hosts.

The maximum damaged grains and net weight loss was recorded in cowpea and mungbean, while minimum in *urd*. Thus, it can

be concluded that cowpea and mungbean were preferred host of *C. chinensis* over gram, moth, *arhar* and *urd*. These findings are in conformity with results of Satyavir (1989) who reported significant infestation with loss of 18.00 to 38.50 per cent in cowpea seeds after six month of storage. Srivastava and Bhatia (1958), Gundurao and Majumdar (1964), Singh *et al.* (1980), Kumar *et al.* (2001) and Bhargava *et al.* (2008) also observed that the percentage of infestation by this pest varied from host to host which is in agreement to the present findings.

The results of the studies on growth index ranged from 2.25 to 3.82 in different hosts. The minimum growth index was observed in *urd* followed by gram, moth, *arhar*, mungbean and cowpea. It was concluded that the preferred hosts produced higher growth index, while less preferred hosts showed lesser growth index. In the present study cowpea and mungbean found equally good with growth index of 3.82 and 3.31, respectively. Similar results were also reported by Kumar *et al.* (2001) and Bhargava *et al.* (2008).

From the forgoing results, it can be concluded that a gradation of nutritive values to this insect was exhibited by the commodities tested. A few were ideally nutritive, other less while remaining were of little or no food value. Many commodities could be made more or less efficient by altering their physical state but this is not applicable to others. On the basis of growth index of test insect in different hosts, the order of suitability was : cowpea > mungbean > *arhar* > moth > gram > *urd*.

5.3 Varietal Susceptibility of Mungbean Against *C. chinensis*

The respective mungbean varieties showed significantly variation in egg laying of pulse beetle. The maximum number of eggs

were deposited on the mungbean variety RMG-492 (82.33) followed by RMG-62 (79.53), Pusa-9531 (75.66), RMG-344 (69.44), Pusa Vishal (63.88), RMG-262 (62.44), Ganga-2 (60.99), Mum-2 (57.77), Ganga-8 (57.55), Pusa bold (53.55) and K-851 (52.88). The minimum number of eggs was observed on Pusa-105 (49.10) being unfavourable for oviposition. Gupta *et al.* (1985) screened greengram varieties against *C. chinensis* and observed variety RMG-62 to be had maximum egg laid grain indicating its high susceptibility to pest also support the present findings where RMG-62 have 79.53 eggs/female. Teotia and Singh (1966) and Dabi *et al.* (1979) reported that *C. maculatus* did not show any oviposition preference for the development of insect and eggs were laid invariably on all the varieties of test pulses partially conformity with the present findings. Similar type of work was also carried out by Chavan *et al.* (1997a) on cowpea against *C. chinensis* and reported that beetle showed a definite varietal response for oviposition.

In present investigations, the developmental period of *C. chinensis* was greatly influenced by different mungbean varieties. The developmental period of pulse beetle varied from 23.33 to 32.66 days, being shortest on RMG-492 and longest period on Pusa-105. The present findings corroborates the studies of Choudhary *et al.* (1982); Sachdeva and Seghal (1985), Haque *et al.* (1992) and Chavan *et al.* (1997b); who observed that the developmental period of *Callosobruchus* spp. was greatly influenced by respective pulse varieties. Similarly, Singh and Sharma (2003b) and Savita *et al.* (2008) reported that the developmental period was shorter in most susceptible varieties and reverse in less susceptible varieties of greengram. Yadav and Bhargava (2005a) reported significant difference in developmental period of *C. maculatus* on different varieties / genotypes of mothbean, support the present findings.

Behaviour of different varieties towards successful emergence of adults differed significantly. Minimum numbers of beetles were emerged from varieties Pusa-105 (48.33) followed by K-851 (54.16), while maximum in RMG-492 (83.33) followed of RMG-62 (80.00) and Pusa-9531 (73.33). The present findings in accordance with that of Jadhav *et al.* (1984) who observed that the per cent adult emergence ranged from 20.83 to 50.29, 48.15 to 87.92 and 64.00 to 96.00 in case of different varieties of chickpea, cowpea and pigeonpea, respectively. Similarly, Sachdeva *et al.* (1986) who found variation in adult emergence of this pest on different varieties of cowpea.

The variation in sex ratio of *C. chinensis* on different varieties of mungbean ranged from 1:0.97 to 1:1.17 (male to female), minimum being in Pusa-105 and maximum in RMG-492. In general, the number of female was higher in each variety in comparison to male. From the observations, it indicates that the number of female beetles were more in susceptible varieties, while less in least susceptible ones. Singh and Sharma (2003b) also noticed the sex ratio (male to female), varying from 1:0.98 (Pusa-105) to 1.087 (LGG-407) in different varieties of greengram to pulse beetle, support the present findings. Similar results were also observed by Singh and Sharma (2003d) who observed the sex ratio of pulse beetle in different varieties of cowpea.

Significant difference was noticed in the longevity of male and female beetles on various varieties of mungbean. The longevity of male and female beetles varied from 5.00 to 8.33 days and 5.33 to 8.66 days on different varieties, respectively. It was, thus, observed that the female beetles survived longer than the male in each variety. The results of Yadav and Bhargava (2005a) support the present findings, who reported significant difference in the longevity of male and female of *C. maculatus* on different varieties / genotypes of mothbean. Dhepe

et al. (1993) and Singh and Pandey (1994) reported that the longevity of both sexes was not significantly affected by different varieties of greengram and gram, respectively, contradicts the present observations.

The percentage of damaged grains and loss in weight of different mungbean varieties due to pulse beetle varied from 31.33 to 44.06 and 5.96 to 15.98, respectively, being maximum damaged grains and weight loss in RMG-492, while minimum in Pusa-105. Singh and Sharma (1981) and Singh and Khokhar (1991) found significant variation in grain damage and loss in weight on different varieties of moong and pigeonpea, respectively, support the present findings. Similarly, Manohar and Yadav (1990) found loss in weight from 16.55 to 44.97 per cent due to *C. maculatus* on different cowpea varieties.

It is apparent from the observations on growth index, which shows lower values on varieties Pusa-105 (1.47) and Pusa bold (1.78) denotes less susceptibility. The varieties RMG-492 (3.57) and RMG-62 (3.20) showed higher values of growth index indicating highly susceptibility varieties of mungbean against *C. chinensis*. The remaining varieties viz., K-851 (1.80), Ganga-8 (1.92), Mum-2 (2.00), Ganga-2 (2.20), RMG-262 (2.35), Pusa Vishal (2.38), RMG-344 (2.65) and Pusa-9531 (2.89) stood in intermediary in position. It is clear that the varieties, having maximum growth index represented maximum number of population and higher infestation in term of per cent grain damage and loss in weight which is in accordance with results of Chavan *et al.* (1997b) in different less susceptible lines of cowpea against *C. chinensis* the growth index ranged from 1.656 to 2.112.

5.4 Effect of Physical Factors on Growth and Development of *C. chinensis*

Mating takes place soon after emergence from grain, the time depending entirely upon temperature and humidity. The results under the present studies indicated that maximum ovipositional potential (77.66%) of the beetles was observed at 30⁰C. The maximum number of eggs laid per female (82.66 eggs/female) was observed at combinations of 30⁰C and 70 per cent relative humidity and 30⁰C and 80 per cent relative humidity (80.33 eggs/female). No work on the effect of temperature and humidity on the ovipositional potential of the pulse beetles is available, however Khare and Agrawal (1963) observed favourable temperature for oviposition was 30⁰C and 75 per cent relative humidity for growth and development of *S. oryzae* and *R. dominica*, support the present findings. Similarly, Singh *et al.* (1972) concluded that oviposition and developmental of *S. oryzae* was greater at 30⁰C and 75 per cent relative humidity and slower at 15⁰C. Tripathi and Hodson (1981) also reported that more eggs were deposited by *S. oryzae* at 30⁰C. Similar results were also observed by Nawrot (1981) on *Cadra cautella* who reported that fecundity of the pest adversely affected by high and low temperature and by low humidity at all temperatures, support the present findings.

The duration of oviposition period decreased with the increase in temperature. The oviposition period was longest at 20⁰C and 90 per cent relative humidity while shortest at 35⁰C and 90 per cent relative humidity. The work on the effect of different temperatures and relative humidity on the oviposition period of *C. chinensis* is not available,

however, the same type of work on other insect pests have been discussed. Simwat and Chahal (1970) and Chander (2003) found that the oviposition period of *T. castaneum* and *R. dominica*, respectively, was influenced by temperature, support the present findings. Similarly, Yadav *et al.* (2008) also reported that duration of the oviposition period of *S. oryzae* varied inversely with the temperature and relative humidity.

The results obtained on the incubation period at different levels of temperature showed that a significant increase in the mean hatching period as temperature decreased. The maximum egg period was 10.07 days at 20⁰C while minimum 4.16 days at 35⁰C temperature. The combined effect of temperature and humidity, the maximum incubation period (11.66 days) found at 20⁰C and 60 per cent relative humidity while minimum (3.66 days) at 35⁰C and 90 per cent relative humidity. These findings are partially agreement with the observations of Uniyal *et al.* (1972) and Nawrot (1981) who reported that duration of egg stage was significantly influenced by temperature but not by humidity. In the present investigation, the incubation period increased with the decrease of humidity level. But these results could not corroborate with the above workers who reported that incubation period was not affected by humidity. Uniyal *et al.* (1972) reported that temperature play a significantly role in incubation period of different stored insect, support the present findings.

In present investigation, the developmental period was affected by temperature and humidity. The complete development was found to be maximum (49.41 days) at 20⁰C, while minimum (23.66 days) at 35⁰C. The data obtained on the effect of relative humidity revealed that the beetle took minimum time (31.91 days) under 70 per cent relative humidity for completing their development. The findings are in

agreement with the results obtained by Kim and Choi (1987) who reported that developmental period of *C. chinensis* increased with the decrease of the temperature. Similarly, Singh *et al.* (1972) reported that the developmental period of *S. oryzae* was longer at low temperature and low humidity, while shorter at higher temperature and high humidity.

The maximum adult emergence (72.91%) was observed when insects developed at 30 °C. The data on humidity levels showed that the most favourable relative humidity for adult emergence was 70 per cent. The results on interaction of temperature and humidity revealed that the combination of 30°C and 70 per cent relative humidity resulted in maximum adult emergence (80.33%), whereas it was minimum (25.00%) at 20°C and 90 per cent relative humidity. The work on the effect of temperature and relative humidity on pulse beetle is not available, however, the same type of work on other insect pests have been discussed. Tripathi and Hodson (1981) recorded maximum adult emergence of *S. oryzae* at 30°C, support the present findings. These results also confirm the findings of Hugar *et al.* (1990) in *C. cephalonica*, Maity *et al.* (1999) in *S. cerealella* and Chander (2003) in *R. dominica*.

More loss in weight and higher grain infestation occurred when the grains were incubated at the optimum temperature and humidity for the insect. When the temperature and humidity were slightly less than the optimum, the insect activity decreased but not as much as it did when the temperature was more than the optimum by the same degree. During the present study, the grain infestation and loss in weight increased with the increasing in temperature from 20°C to 30°C. The optimum relative humidity for grain damage and loss in weight was 70 per cent, where 29.19 and 6.57 per cent damage and losses,

respectively were observed. The minimum loss in weight (4.94%) and grain damage (25.26%) observed at 90 per cent relative humidity. The higher grain damage (40.93%) and weight loss (9.62%) were recorded at 30°C and 70 per cent relative humidity while lower (9.86 and 1.66%) at 20°C and 90 per cent relative humidity. These findings are in agreement with the observations of Khokhar and Gupta (1974) who reported maximum grain infestation at optimum temperature. Similarly, Haque *et al.* (1996) reported that 30 °C and room temperature with high moisture level were conducive to rice weevil damage. On the basis of these results it may be concluded that temperature and humidity played a significant role in the growth and development of the insect.

The temperature and relative humidity are the two important components of the environment and the rate of metabolism, growth, development, reproduction, general behaviour and distribution of insect pests are largely controlled by it. Mallis (1960) reported that the rate of reproduction increased upto certain limits was directly proportion to temperature and moisture contents of the grains in which they are propagating. Later on Rose (1965) has found temperature, humidity, wind and moisture as some of the important factors for development of the insect. Fields (1992) proposed lethal, suboptimal and optimal temperature ranges for many stored product insects; 25-33°C is optimal for growth and reproduction, while 13-25°C or 33-35°C are sub-optimal ranges at which insects are able to complete their development and produce off springs and lastly at < 13 or > 35 °C insects eventually die, changes in metabolic rate caused by fluctuations of temperature have a direct bearing on two important aspects of insect life cycle; one is locomotion for performing crucial activities such as mating and feeding and the other is growth represented by development and

metamorphosis. Thus, temperature mediated physiological actions regulate population dynamic.

Similarly, the effect of humidity on the development of storage insect pests is almost intimately associated as temperature and operates indirectly through the moisture contents of grains.

It may be concluded that optimum conditions for the development of this pest were around a temperature of 30°C and relative humidity ranging between 70-80 per cent.

5.5 Management of *C. chinensis* Using Plant Products

Different plants were known to possess some insecticidal properties and as such they have been used in protecting the grains against the damage of number of stored grain pests in different parts of country according to local availability of such materials. In recent years, several plants products have been identified which can be used as safe and renewable sources of insecticides (Jotwani and Sircar, 1967; Ali *et al.*, 1983; Singh *et al.*, 1993; Bhargava and Meena, 2002; Raghvani and Kapadia, 2003; Meena and Bhargava, 2005 and Khalequzzaman *et al.*, 2007).

5.5.1 Management using plant oils

Pulse beetles infestation in pulses have been effectively control with the aid of neem, castor, soybean (Das, 1986; Chaudhary, 1990), Palm and sesamum oil (Islam, 1986; Jacob and Sheila, 1990); edible and non-edible oils (Gupta *et al.*, 1991; Ahmed *et al.*, 1993), vegetable oils (Khair *et al.*, 1992; Meena and Bhargava, 2002) and essential oils (Mishra *et al.*, 1989; Ansari and Mishra, 1990; Dixit *et al.*, 1992; Agarwal, 1994). Likewise, in the present investigation, seed coating of mungbean with plant oils gave a significant protection against *C. chinensis* as compared to control. Comparative efficacy of different oils

against pulse beetle, *C. chinensis* in mungbean during storage was investigated.

All the doses of test compounds was found to be significantly superior to cause adult mortality as compared to control. The adult mortality also increased with the increase in doses level of each treatment. The maximum mortality was caused by the malathion treatment, at par with cotton seed oil followed by taramira, mustard, groundnut, sunflower, sesame and soybean oils. The present finding are thus, similar to those of Srivastava and Dadhich (1973), Singh (1992), Savita (2001) and Yadav (2006) who reported that mixing of malathion with various pulses provided protection from the attack of pulse beetle. The treatment of different vegetable oils found effective against *Collosobruchus* spp. was reported by Sangappa (1977), Mummigatti and Raghunathan (1977), Verma and Pandey (1978), Pathak (1980), Ali *et al.* (1983), Doharey *et al.* (1984), Das (1986), Zewar (1986), Begum and Quiniones (1990), Rao *et al.* (1993), Sharma and Singh (1993), Bhargava and Meena (2002) and Khalequzzaman *et al.* (2007), support the present findings.

All the dose levels were found significantly superior in increasing development period over control. The developmental period increased with the increase in dose level of each treatment. The mean development period in different treatments varied from 30.77 to 36.44 days, while in control it was 25.00 days. The malathion and cotton seed oil were found equally superior in increasing the developmental period, followed by mustard oil, groundnut oil, sunflower oil, sesame oil, taramira oil and soybean oil. These findings are in accordance with the results obtained by Sujatha and Punnaiah (1985) and Parsai *et al.* (1990) who reported that seed treatment with different plant oils normally delayed the development of *C. chinensis*. Similarly, Naik and

Dumbre (1984), Singh *et al.* (1993) and Bhargava and Meena (2002) have also observed to prolonged the developmental period of *Callosobruchus* spp. by treatment with different plant oils. This increase in the developmental period is certainly due to antifeedant action of plant oils, that is why larvae fed slowly on treated grains and consequently developmental period was prolonged. The antifeedant response of plant products was also reported against *C. chinensis* (Girish and Jain, 1974) and *R. dominica*, (Tiwari, 1994).

The per cent adult emergence gradually decreased with the increases of dose levels of each treatments. In present investigation, the mean percentage of adult emergence was minimum in malathion, at par with cotton seed oil, followed by taramira, mustard, groundnut, sesame, sunflower and soybean oil. The present findings are conformity with Sharma and Singh (1993) who reported that cotton seed was found effective against *C. chinensis*. Similarly, Sujata and Punaiah (1985) who found significant reduction in adult emergence of *C. chinensis* by cotton seed, groundnut, palm and sesame oils at 0.50 and 0.75 per cent concentration. The reduction in adult emergence by other tested vegetables oils (taramira, sunflower, groundnut, mustard, sesame and soybean oils) in present investigation were also found effective in reducing the adult emergence. These results are in agreement with those of Mummigatti and Raghunathan (1977); Singh *et al.* (1978), Jacob and Sheila (1990), Bhargava and Meena (2002) and Khalequzzaman *et al.* (2007) who found significant reduction in adult emergence of *Callosobruchus* spp. by the treatment of different vegetable oils in various pulses. The reduction in adult emergence with different plant oils may be due to fact that oils influence early development or larval eclosion in addition to adult survival. Hewlett (1947) suggested that mortality caused by oils was due to interference with respiration.

The significant difference existed between the doses of test compounds in reducing the longevity to beetles of both sexes. The longevity gradually decreased with increase in dose level of test compounds. The maximum reduction in longevity of adults was observed in malathion, at par with cotton seed oil, followed by taramira, mustard, groundnut, sunflower, sesame and soybean oils. These findings are supported with the results of Uvah and Ishaya (1992) who reported significant reduction in longevity of adult of *C. maculatus* by a single application of groundnut oil and palm oil at 2.5-3.0 ml/kg seed. Bhargava and Meena (2002) also reported that significant reduction in adult longevity of *C. chinensis* with vegetable oils viz., castor, mustard, groundnut, sesame, coconut and sunflower @ 1.0 ml/100 g. Yadav and Bhargava (2005b) found significant reduction in longevity of both sexes by mustard oil which support the present findings.

All the test component used as grain protectant to the pulse beetle, found to be significantly more superior in reducing the grain damage and loss in weight in comparison to control. The efficacy of all treatments was observed after the end of experiment and grain damage and weight loss ranged from 6.71 to 34.24 and 2.57 to 9.29 per cent, respectively. The findings are supported with the results of Kumari *et al.* (1990) who observed that different vegetables oils namely mustard, linseed, til, groundnut, neem and mauha at 1.0 per cent level against *C. chinensis* proved effective for the reduction in percentage damaged grains by number as well as by weight. The vegetables oils were effective in reducing the grain damage and weight loss by *Callosobruchus* spp. was reported by Doharey *et al.* (1984), Choudhary (1990), Raghavani and Kapadia (2003) and Khalequzzaman *et al.* (2007), support the present findings. Thus, it may concluded that the tested plant oils were safer in minimizing the infestation of *C. chinensis* quite successfully in term of reduction in loss in grain weight.

5.5.2 Management Using Plant Powders

Various plant powders have been used since long for the control of various pests of stored grains. As early as, 1938. Coutinho Saraiva used neem leaves for the protection of greengram against *C. chinensis*. Thereafter, many workers (Pandey *et al.*, 1976; Chander and Ahmed, 1983; Pandey *et al.*, 1986; Bandara *et al.*, 1989; Prakash and Rao, 1989; Miah *et al.*, 1993; and Pandey and Singh, 1997) have used products from several plants species for the protection of stored grains insect pests.

In the present studies, all the doses of different plant powders were significantly superior in causing adult mortality in comparison to control. The mean mortality of adult in different doses varied from 41.78 to 65.71 per cent. The neem kernel powder was significantly superior in causing adult mortality (65.83%) which was followed by karanj kernel powder (61.94%), dharak kernel powder (58.88%), aak leaf powder (54.16%), datura leaf powder (51.38%), tulsi leaf powder (44.71%) and citrus leaf powder (42.21%). The present results confirm the study of Jotwani and Sircar (1967), Sowunmi and Akinnusisi (1983), Al-Hemyari (1994) and Sundria *et al.* (2001) who found that the neem kernel powder mixed with pulses @ 1.0 and 2.0 parts /100 parts of seed was found effective for the control of *Callosobruchus* spp. Similar observations was also observed by Ghosh *et al.* (1981), Mathur *et al.* (1985) and Rao *et al.* (1993) on *C. chinensis*. The treatment of karanj kernel powder and dharak kernel powder at 5.0 g/100g seed level ranked second and third in the present investigations caused 61.94 and 58.88 per cent adult mortality of *C. chinensis*, respectively. These observations are corroborates with the findings of Choudhary (2001) who observed 54.16 and 57.50 per cent adult mortality of *C. maculatus*

when karanj kernel powder and dharak kernel powder mixed at 8.0 g / 100 g seeds, respectively.

All the treatments were significantly superior in increasing the developmental period when compared with control. The mean developmental period in different treatments ranged from 30.44 to 36.44 days. The *neem* kernel powder treatment showed superiority over all other treatments to enhance the developmental period of the pest (43.33 days) which was at par with karanj kernel (42.00 days) followed by dharak kernel, aak leaf, datura leaf, tulsi leaf and citrus leaf powders. Singh and Sharma (2002) reported that the growth and development of the pulse beetles was affected by plant powder in treated seeds. Saxena and Singh (1994) reported that the duration of larval period of *R. dominica* prolonged when larvae fed on grains treated with *neem* kernel and dharak kernel powders, support the present findings. Similarly, Jhansi Rani (1984), Pandey *et al.* (1985 a and b), Chander and Ahmed (1986) and Khan and Thakare (1997 a and b) reported that the larval period of one week old *Corcyra* larvae was enhanced when fed on grains treated with *neem* seed powder at 10 per cent, support the present findings. This increase in the developmental period is certainly due to antifeedant effect of plant products (Girish and Jain, 1974 and Pandey *et al.* 1985 a and b).

As regard the adult emergence, the minimum percentage of adult emergence was recorded from grains admixed with *neem* kernel powder followed by karanj kernel powder, dharak kernel, aak leaf, dhatura leaf, tulsi leaf and citrus leaf powders. The present findings are in accordance with results of Singh and Sharma (2002) who reported significant reduction in adult emergence in seed treated with *neem* kernel powder. Similar observation was also reported by Ghosh *et al.* (1981), Rao *et al.* (1993) and Pandey and Singh (1997) on *C. chinensis*

when developed on various pulses. Similarly, Sharma *et al.* (1989) who reported significant reduction in adult emergence of *Rhizopertha dominica* and *Sitophilus oryzae* in wheat grain admixed with neem kernel powder @ 3.0 g/100 g grains. Similarly, Singh and Mall (1991) found that dharak leaf powder and neem, mustard and linseed cakes were found effective in reducing the emergence of *S. oryzae*. Teotia and Pandey (1978), Chander *et al.* (1991), Prakash *et al.* (1993) and Patel *et al.* (2004) were found significant reduction in adult emergence of *S. oryzae* from the grains treated with different plant powders which were tested in present investigations, support the present findings.

Regarding the longevity of male and female beetles, it was gradually decreased with the increase in dose level of each treatment. The neem kernel powder was the most effective in reducing the longevity of both sexes. Saxena and Singh (1994) observed that neem and dharek kernels and neem cake were found effective treatment to reduce the longevity of beetles of *R. dominica*, support the present findings. Similarly, Khan and Thakare (1997 a and b) and Jain and Kumar (2001) also found significant effect of neem kernel and leaf powders on the longevity of adults of *C. cephalonica*.

During present investigations, effect of some plant materials, as powder, has been tested against pulse beetle and results found to be significantly superior in reducing the grain damage and loss in weight in comparison to control. The damage and loss in weight by the pest was minimum in the grains treated with neem kernel powder followed by karanj kernel, dharak kernel, aak leaf, datura leaf, tulsi leaf and citrus leaf powders. Pandey *et al.* (1986), Ghosh *et al.* (1981), Mathur *et al.* (1985), Rao *et al.* (1993) and Sundria *et al.* (2007) found significant reduction in grains damage as well as loss in weight by *C. chinensis* with neem kernel powder, support the present findings. The treatment

of karanj kernel powder ranked second in the present investigation. These findings are corroborates with the findings of Choudahry (2001) who observed that karanj kernel powder @ 8.0 g/100 g seeds was effective against *C. maculatus*. Similarly, Chander (2003) observed significant reduction in grain and weight loss by *R. dominica* with karanj kernel powder treatment. Not much work is available on the effect of other plant powders on the grain damage and weight loss of *C. chinensis*, however, Yadav (2007) found significant reduction in grain damage and weight loss by *S. oryzae* with the treatment of dharak leaf, datura leaf and tulsi leaf powders @ 5.0 g /100 g seeds, support the present findings.

On the basis of adult mortality, adult emergence, damage and loss in weight of grains obtained due to treatment of various plants powders, it can be inferred that application of *neem* kernel, karanj seed, dharak, aak leaf and datura leaf powders proved to be more effective in reducing the loss by *C. chinensis*, while tulsi leaf and citrus leaf powders were less effective. Therefore, it may be concluded that plant powders being reasonable in cost and most effective can safely be used against *C. chinensis*.

5.6 Effect of Different Storage Containers on the Incidence of *C. chinensis* in Stored Grains of Mungbean

The role of different storage containers on the incidence of *C. chinensis* in stored mungbean was studied both under artificial and natural conditions. Significant differences were observed in grain damage stored in different storage containers under artificial and natural conditions. Under artificial condition, higher dry mass loss and damaged grains were observed in grains stored in mud pot. However, minimum dry mass loss and damaged grains were noticed in grains stored in metal container which was followed by gunny bag, polythene

bag, urea bag and cloth bag. The number of adults emerged varied from 10.00 in metal container to 21.33 in mud pot. Under natural condition, low dry mass loss and damage grains were observed in metal container followed by polythene bag, gunny bag, urea bag, cloth bag and mud pot. However, the damage was negligible in all containers. Not much work is done on the effect of different storage containers on the incidence of *C. chinensis*, however, Chander and Bhargava (2005) who reported that the maximum grain damage and weight loss due to *R. dominica* was recorded in grains stored in mud pot followed by cloth bag, urea bag, polythene bag and gunny bag, support the present findings. Similarly, Naga *et al.* (2007) also reported less damaged due to *T. castaneum* when wheat flour stored in metal bin which was accordance to the present findings. Awaknavar *et al.* (1989) reported that performance of metal bin and coltar drum was better than other structures as concerned with deterioration, germination and weight loss, support the present findings. Similarly, Bhargava and Choudhary (2007) reported that during survey conducted at different place of Rajasthan, the maximum grain damage was recorded in loose storage while minimum in metal container.

This study conclude that less damage in terms of per cent dry mass loss and damaged grains and low adult emergence were recorded in metal container which was followed by gunny bag, urea bag, polythene bag, cloth bag and mud pot and these containers can be used for storing the mungbean grains.

5.7 Effect of Solar Treatment and Different Colours on *C. chinensis*

The use of solar heat energy has long been practiced as one of the effective methods for minimizing pest infestation in stored grains (Thompson, 1915). The use of heat energy was first practiced in

Australia to disinfect wheat by exposing the grains for 3 minutes at a temperature range of 60⁰-66⁰ (Winterbottom, 1922). Mookherjee *et al.* (1968) recorded a solar heat temperature range of 45⁰-55⁰ to eliminate the infestation of *C. maculatus* in moong, pea and gram. In case of lentil, the temperature of 40⁰, 50⁰ and 60⁰C for the control of *Bruchus cryi* was recorded along with the exposure period of 5, 4 and 3 h, respectively. Dortbudak (1975) reported that exposing containers of lentil and blackgram infested with *C. chinensis* to sunshine for 4 h (from 9.00 to 13.00) inhibited the rate of pest multiplication and reduced grain loss.

In the present studies mungbean seed containing *C. chinensis* eggs (0-12 h old) and adult were exposed to solar energy in different colour polythene bags (black, blue, green, red, yellow and transparent) for 8, 16 and 24 h. In all the coloured bags solar heat exposure of 24 h was quite effective and fatal, inhibit the egg hatching and causes adult mortality in all the coloured polythene bags. The exposure period of 16 hrs was only effective in black and blue polythene bag, however, in rest of the coloured bag, lower infestation and adult emergence were noticed. The exposure period of 8 hrs was only effective in black polythene bag.

In another set of experiment, mungbean grains containing adults of *C. chinensis* were exposed to solar energy in different coloured polythene bags for 8, 16 and 24 hrs. to determine their effect on the mortality of beetles. The data revealed that mean per cent mortality of beetles in different coloured bags ranged from 58.05 to 88.05, being maximum in black polythene bags followed by blue, red, yellow, green and transparent polythene bags. In all colour bags, solar heat exposure of 24 hrs was quite effective and fetal, giving cent per cent adult mortality of *C. chinensis* in black while 95.83 per cent in blue polythene

bags. Ghaffar and Chauhan (1999) reported that per cent mortality of *C. maculatus* without lay eggs when polythene bags containing pigeonpea seeds exposed sun light for 7 days, support the present findings. These findings are also accordance with that of Singh and Sharma (2003d) who observed the similar results as in the present findings. Mookherjee *et al.* (1968) revealed that disinfest all the seeds of maize and *jowar* from *S. oryzae* by resorting to solar heating with the diurnal temperature varying from 37⁰C to 54⁰C, support the present findings. Krishnamurthy *et al.* (1991) used polythene pouches of different dimensions and capacity for controlling insect species with solar heat and showed cent per cent mortality at all the stages. Similarly, Mohammed-Dawd *et al.* (2001) also reported that hundred per cent adult mortality of *S. oryzae* and its variant was obtained with exposure to sun heat at different periods.

Higher mortality of eggs and adults after their exposure to sunshine was recorded in present observations. This could be due to the fact that they come in direct contact to solar heat generated by the absorption of different coloured polythene and the temperature, thus, heat generated within the bag was lethal to them. The higher temperature requirement for adult stage is understandable, since the insect is an internal feeder, as such the mass heat transfer from heated environment, *i.e.* within the bag the seed depends on many parameters *viz.*, (a) the moisture content of the grain as the thermal properties (specific heat, thermal conductivity diffusibility and latent heat) of grains are moisture dependent (Pandey, 1980). The physical properties of grains (size, shape, surface area, volume, particle density, bulk density and porosity) also play important role in the transfer of heat to the site of action where the test insect were located (Hussain *et al.* 1968; and Adhaoo *et al.*, 1976).

Mortality of insect as a result of exposure to heat is usually considered to be caused by the coagulation of the soluble proteins of the body tissue. However, death frequently occurs as a result of exposure to temperatures that are not high enough to cause coagulation of the proteins. In such cases death may be caused by desiccation or by injury to the enzymes of the body tissue. The activities of reductase, oxidases and catalases are injured in a greater or less degree by temperature below that needed to coagulate the proteins in insect tissue (Cotton, 1963). It was also known that at low humidities, insects die from the effects of desiccation (Chapman, 1982). Death at high temperature may result from various factors that insects have a limited physiological capacity to regulate their body temperature. Proteins may be denatured or the balance of metabolic process may be disturbed so that toxic products may accumulate (Chapman, 1982).

The seed germination decreased with the increase in solar time exposure. In black polythene bags for 24 hrs exposure, the seed germination was 75.49 per cent, whereas 81.00 per cent in transparent polythene bags. It appears that black coloured bags affected the seed germination, which was statistically inferior to germination in all exposure periods. Here again, adverse effect of solar radiation in black coloured polythene bags is due to higher temperature generated in them due to more heat absorption (Duffie and Backman, 1991) Blue colour was next in effectiveness in causing mortality of egg as heat absorption in this colour has been observed to be lesser than black (Duffie and Backman, 1991). These results are in agreement with the findings of Dortbudak (1975) who reported that lentil infested by *Bruchus eryi* when exposed to 40⁰, 50⁰ and 60⁰C for 5, 4 and 3 h, respectively resulted in reduction in seed germination. The present findings also get support from the observations of Yadav *et al.* (2002),

Singh and Sharma (2003e), Meena and Bhargava (2005) and Jakhar *et al.* (2006) who claimed that black and blue polythene bags for 24 hrs exposures to sun affected the seed germination. From the foregoing results it was concluded that different coloured polythene bags are safe, economical and effective solar heat disinfestation devices for home and rural forms.

5.8 Effect of Plant Products on the Germination of Seeds

Studies on germination of mungbean seeds at just after treatment and 150 days after treatment with different concentrations / doses of plant products used as protectant, revealed that plant products did not hamper seed viability. Non-significant variation in germination was recorded which varied from 62.99 to 75.44 per cent in different treatments. Similar results were also reported by Jotwani and Sircar (1967), Verma *et al.* (1983), Singal and Singh (1990), Gupta *et al.* (1988), Saxena and Singh (1994), Bhargava and Meena (2002) and Chander (2003) when they mixed the different plant products *viz.*, *neem* oil, castor oil, linseed oil, mustard oil, karanj oil, groundnut oil, sesame oil, cotton seed oil, palm oil, sunflower oil, eucalyptus oil, dharek leaf and kernel powders, *neem* leaf and kernel powders, karanj kernel powder, eucalyptus leaf powder, citrus leaf powder, aak leaf powder and dhatura leaf powder with wheat, maize, paddy, sorghum and pulses. The present results are in accordance with the investigation of above workers.

6 SUMMARY

Investigations on “Bio-ecology and management of pulse beetle, *Callosobruchus chinensis* (Linn.) on mungbean [*Vigna radiata* (Linn.) Wilczek]” were conducted at Agricultural Research Station, Durgapura during 2007-08, on the following parameters.

Survey

- Field surveys in five major mungbean growing *tehsils* of Jaipur were conducted to study the prevalence of *C. chinensis* in mungbean stored in different type of storage structures/ receptacles, its infestation and moisture content.
- The system of storing mungbean varied from village to village and farmers to farmers, however, types of storage structures and containers, were found in vogue in different villages. The maximum adoption of the bag storage was observed followed by loose, metal container, stone bin, *bhukhari*, *kothi*, earthen pot and pusa bins.
- The cent per cent infestation was recorded in samples collected from *bhukhari* and earthen pots followed by loose storage (85%), bags (74.46%), *kothies* (66.66%), stone bins (50.00%) and metal containers (38.88%). However, none of the sample taken from pusa bins was found infested.

Host Preference

- The pulse beetle, *C. chinensis* showed a very clear and distinct level of preference to different hosts in terms of time taken to complete the development from egg to adult, adult emergence, growth index, fecundity, grain damage and weight loss. The beetle produced significantly large number of progeny with shorter development period; higher growth index; maximum fecundity and the damaged grains and net weight loss were higher in highly preferred host and *vice-versa* on the least preferred. During present investigation, cowpea was the most preferred host followed by mungbean, *arhar*, moth and gram. *Urd* was the least preferred host.

Varietal Susceptibility

- None of the mungbean variety was found resistant to the test insect, varieties Pusa-105 and K-851 were found less susceptible, while Pusa Vishal, RMG-262, RMG-344, Ganga-2, Ganga-8, Mum-2 and Pusa Bold stood moderately susceptible, whereas, RMG-492, RMG-62 and Pusa-9531 were among the most susceptible varieties.

Effect of physical factors on growth and development

- The temperature and relative humidity played a vital role in the development of pulse beetle.
- The maximum and minimum eggs laid per female were 82.66 and 18.66 at 30⁰ and 20⁰C, respectively. The most suitable combination of both factors for egg laying was 30⁰C and 70 per cent relative humidity.
- The duration of oviposition period decreased with the increase in temperature. The oviposition was longest at 20⁰C

and 90 per cent relative humidity while shortest at 35⁰C and 90 per cent relative humidity.

- The incubation period was decreased with the increase in temperature and relative humidity.
- The longest developmental period was found to be 49.41 days under a combination of 20⁰C and 60 per cent relative humidity, while it was shortest (22.00 days) at 35⁰C and 70 per cent relative humidity.
- A combination of 30 ⁰C and 70 per cent relative humidity resulted in maximum adult emergence (80.83%), whereas it was minimum (25.00%) at 20⁰C and 90 per cent relative humidity.
- The grain damage (40.93%) and loss in weight (9.62 %) were observed at 30⁰C and 70 per cent relative humidity. while it was lower at 20 ⁰C and 90 per cent relative humidity. The grain infestation and loss in weight increased with the increase in temperature from 20⁰ to 30⁰C. Thereafter, it was slightly decreased at 35⁰C.

Evaluation of Plant Products on *C. chinensis*

Management Using Plant Oils

- The adult morality of the test insect increased with the increase in dose level of each tested compounds. The malathion and cotton seed oil were most effective while soybean oil proved least effective.
- All the dose levels were found significantly superior in increasing the developmental period over as compared to control. The mean developmental period in different treatments varied from 30.77 to 36.44 days, while in control, it was 25.00 days.

- The per cent adults emergence decreased with the increase in dose level. The malathion and cotton seed oil was proved most effective whereas soybean oil was remained least effective.
- The longevity of both sexes gradually decreased with the increase in dose level of the test compounds. The maximum reduction in longevity of adults was observed in malathion and cotton seed oil while minimum in soybean oil.
- The per cent grain damage and loss in weight were observed from 19.95 to 26.93 and 5.11 to 8.66 per cent, respectively, in different treatments, being minimum in malathion and cotton oil and maximum in soybean oil.

Management with Plant Powders

- All the treatments were significantly superior in causing adult mortality of test insect over control. The maximum adult mortality (65.83%) was observed in neem kernel powder while it was minimum (42.21%) in citrus leaf powder.
- All the doses of different plant powders were significantly superior in increasing the developmental period. With treatment *neem* kernel powder showed superiority over all other treatments to enhance the developmental period (36.44 days).
- The adult emergence decreased with the increase in dose level of treatment. The mean per cent adult emergence in different treatments ranged from 22.77 to 33.05, being minimum in *neem* kernel powder while maximum in citrus leaf powder treatment.
- The longevity of both sexes gradually decreased with the increase in dose levels of all the treatments. The *neem*

kernel powder was the most effective in reducing the longevity of both the sexes.

- The effect of some plant materials as powder were found to be significantly more superior in reducing the grain damage and loss in weight in comparison to control. Both grain damage and loss in weight were minimum in the grains treated with *neem* kernel powder.

Effect of Different Storage Receptacles

- Significant differences were obtained in grain damage stored in different containers under artificial and natural conditions. Higher dry mass loss (9.06%) and damaged grains (47.33%) were recorded in mud pot stored grains. The number of adults emerged varied from 10.00 in metal container to 21.33 in mud pot. Under natural condition, low dry mass loss and damaged grains were observed in metal container followed by urea bag, polythene bag gunny bag, urea bag, cloth bad and mud pot.

Effect of solar treatment and different colours

- The exposure period of 24 hrs to solar energy in black and blue coloured bags was most effective to reduced adult emergence and infestation and to cause adult mortality of *C. chinensis*. The seed germination was also decreased with the increase in solar time exposures.

Effect of plant products on germination

- No adverse effect of tested plant products was observed on the germination of mungbean seeds upto 150 days of treatment.

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