ABSTRACT

BI0-ECOLOGY AND MANAGEMENT OF GROUNDNUT BRUCHID, *Caryedon serratus* (Ol.) IN GROUNDNUT

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The period of February to April was most favored for egg laying (81.58 eggs) by bruchid, *C. serratus*. The total developmental period of bruchid varied from 40.54 to 78.35 days during different quarters of whole year. Female life span was longer than male life span, and found significant variation in her life span among different quarters.

Jaiphal was most preferred for egg laying by groundnut bruchid, *C. serratus* in free choice chamber test (124.27 eggs). The studies on development of bruchid on different host revealed that individually tamarind seeds, groundnut pod and groundnut kernel were preferred for egg laying with 67.73, 62.86, 59.41 eggs, respectively. Minimum and maximum time taken for hatching of eggs were observed on tamarind (6.05 days) and on cashewnut (8.80 days). Tamarind was found to be most suitable host for development of larva on which minimum time (20.48 days) required to reach pupal stage and also showed smallest pupal period among different test hosts. Oviposition preference had no relationship with the development of bruchid. Maximum percent adult emergence was observed on tamarind, whereas no adult emerged on dates, coconut and current. Tamarind was the most suitable host for the bruchid on which the total development period was minimum (41.36 days).

There was maximum number of eggs laid by *C. serratus* on ICGV-93133 in free choice chamber test (96.13 eggs). During developmental studies, no significant difference was observed in hatching and pupal period on different germplasm of groundnut, while maximum larval period was found on ICGV-93420 (34.54 days) and minimum on ICGV-92040 (21.12 days). ICGV-92040 was found to be most suitable germplasm of groundnut for the bruchid on which the developmental period was 39.82 days.

Pod damage was directly proportional to the population of bruchid development. The damage ranged from 29.53 to 71.33 per cent when groundnut stored for 3 to 9 months. An abrupt increase in damage was observed between three and six months of storage. Loss in weight after three, six and nine months of storage were found 2.23, 13.12 and 27.39 per cent, respectively. The total protein and carbohydrate content of stored groundnut after nine months

of storage decreased, while oil content was increased due to infestation of *C. serratus*. Among different storage receptacles tested, metal bin and earthen pots were found to be better than other receptacles.

Deltamethrin 10g/kg appeared to be the best protectant, showing no oviposition, and zero per cent adult emergence, weight loss and damage, even after nine months of storage. Deltamethrin 5 g/kg was the next treatment, while malathion 10 g/kg and black pepper powder 15 g/kg had also shown good effect to control the bruchid. It was found that with the increase in storage period, the effectiveness of all the treatments, except deltamethrin 10 g/kg decreased.

1. INTRODUCTION

Groundnut, *Arachis hypogea* (L.) is one of the major oilseed crops of India. It is popularly known as peanut, monkey nut and almond of poor men. It is a rich source of oil (40-54%) and protein (22-36%). Among edible oilseeds, the groundnut attains the most important status. The crop has very significant impact on Indian economy annually, 68.9 lakh tones of groundnut is produced which helps in 30 per cent of crop production of India (Anonymous, 2003). Amongst the various states, Rajasthan produces 2.89 per cent in total groundnut production of the country.

Various reasons including the ravages due to insect pests and inadequate storage management practices, significant deterioration in stored groundnut occurs and is more pronounced in the tropical parts of the world including India. On an average, 6-10 per cent of the stored groundnut gets damaged by various insect pests (Srivastava, 1970). Around 100 insect species have been reported to infest stored groundnut, *Caryedon serratus* (Olivier), *Tribolium castaneum* (Herbst), *Ephestia cautella* (Walker), *Oryzaephilus mercator* (Fawel), *Cryptolestes ferruginius* (Staphens), *Elasmolomus sordidus* (Fab.) are very important amongst them. However, *C. serratus* (Coleoptera: Bruchidae) is of utmost importance and potential threat to stored groundnut (Howe, 1952; Davey, 1958; Mital, 1969; Wightman *et al.*, 1987), tamarind and other leguminous seeds (Fletcher, 1914; Mital and Khanna, 1967; Pajni and Mann, 1979). *C. serratus* is also known as *C. fuscus* (Badel) and *C. gonagra* (F.) (Bridwell, 1946; Southgate and Pope, 1958; Southgate and Prevett, 1967 and Kingsolver, 1970). This bruchid is native to the tropics and subtropics of the Old World (Davey, 1958), and has been introduced into the different parts of New World (Prevett, 1967). In India, this bruchid is commonly present in stored groundnut in the states of Andhra Pradesh, Gujarat, Maharastra, Karnataka and some parts of Rajasthan adjoining Gujarat. The first record of infestation by *C. serratus* was reported on *Oryza sativa* (paddy) (Arora and Singal, 1978), followed by on *Acacia nilotica*, *A. tortilils* and *Prosopis cinereria* (Singal and Toky, 1988), on *Pongamia pinnata* (Singal and Toky, 1989), on *Bouhinia variegata* (Nilsion and Johnson, 1992) and *Cassia moschata* (Romero and Johnson, 2002). In 1957, this bruchid was reported to be attacked on stored groundnut, resulted in poor germination, leading to a serious set back to succeeding crop at Gambia (Green, 1959).

C. serratus is regarded as the only species that can penetrate into the pods infesting kernel by making galleries and thereby providing a base for secondary infestation by insects *viz., Tribolium confusum.* Insect infestation causes considerable quantitative and qualitative losses to the groundnut either stored in shell for seed purpose or unshelled for milling. As a result of feeding by this beetle, acidity of oil in nuts increases, ultimately deteriorating the quality of oil. Out of the total losses caused due to insect infestation, the loss due to this pest range from 19-60 per cent in India (Pal *et al.*, 2000).

Groundnuts are often stored for 6 to 9 months from harvest to next sowing season. Though efforts to impart safety to groundnut in storage are quite similar to cereals, but due to its higher oil content special attention is desired to prevent infestation and losses in storage. Various available techniques *viz.,* use of resistant varieties, various storage structures, naturally occurring plant materials having insecticidal properties can be used for effective management of this problem in stored groundnut. These are easily available and environmentally safe. Various powder of plants origin has been reported to possess insecticidal activities against bruchids.

A little work has been carried on *C. serratus* in Rajasthan on this pest of stored groundnut; therefore, the present study entitled "Bio-ecology and management of groundnut bruchid, *Caryedon serratus* (Ol.) in groundnut" has been undertaken to examine various aspects of stored groundnut. The objectives of the studies were as below: -

1. Studies on host range spectrum and biology of *Caryedon serratus* (Ol.).
2. Screening of groundnut germplasm against groundnut beetle for their relative resistance.
3. Estimation of the quantitative and biochemical changes inflicted by the bruchid during storage of groundnut.
4. Studies on the effect of different receptacles on the seed damage and weight loss caused by groundnut beetle.
5. Evaluation of plant products and dusts against groundnut beetle.

2. REVIEW OF LITERATURE

The large number of bruchid species has been reported from the tropical regions of Central and Southern Asia and Africa. A number of morphological characters of seeds *viz*., texture and hardness of seed coat, size and curvature of grains along with several organic food constituents have been identified to be responsible for different responses to the oviposition and development of storage insect pests. The present investigations were carried out on the biology, varietal preference, qualitative and quantitative losses inflicted by *C. serratus* and management of the bruchid in stored groundnut pods through plant products, dusts and storage structure. The literature pertaining only to these aspects have been critically abstracted under appropriate sub-heading.

2.1 BIOLOGY

Several workers have been conducted researches on biology and bionomics of groundnut bruchid. Appert (1956) made batches of 50 pairs of *C. serratus* and kept them at temperature of 27, 30, 33 or 36°C and relative humidity of 20,50,70,and 90 per cent and showed that the number of eggs laid per 50 females were highest (1093 & 1056) at 27°C temperature and 50 and 70 per cent RH. He found that the temperature in the range of 25-32°C favour the development of the bruchid, while high temperature adversely affect the development.

Davey (1958) studied the bionomics of *C. gonagra* (F.) and found that the development period at 70% RH was 42 days at 30°C and 91-98 days at 25°C. He indicated that most of the eggs are laid in the first 11 days of adult life and emergence of adults began six weeks after the beginning of oviposition and reached its peak 1-3 weeks later.

Sardesai (1961) investigated the effect of population density on oviposition of *C. gonagra* F. in groundnut pods. He made batches of 25-200 adults, irrespective of sex, were confined in a jars each containing 100 groundnut pods and found that number of eggs laid per female was about 29-50 and there was no relation with population density. Female from earlier generation laid more eggs than those from later one, indicating an unfavorable effect of inbreeding. Male and female lived for 11.72-14.47 days, with little difference between the sexes. Adult emergence reduced when more than six eggs were laid per pod.

Oviposition and the length of adult life of groundnut bruchid, *C. gonagra* F. were studied by Cancella Da Fornseca (1965). He observed that the temperature from 27.5-30^{o}C and 70-90% RH were optimum for oviposition and adult life span and found largest mean number of eggs (106-115) laid and adult life span (21 days). At 27.5 and 30^{o}C, the mean length of the oviposition period (9-13 days) was slightly influenced by RH, being slightly shorter at the lowest RH (50%). The number of eggs laid not influenced with absence of nuts but caused some irregularity in the oviposition pattern.

Calderon *et al.* (1967) showed that the *C. serratus* developed successfully on shelled groundnut at 25^{o}C and 70% RH. The females laid an average of 13.6 eggs each over a maximum period of 19 days and development in groundnut from oviposition to completion of the larval stage lasted 40-45 days. They found that most of adults emerged 25-30 days after the formation of the cocoon. The calculated period of development from egg to adult was 65-75 days, the range being 35-185 days. The female lived longer than the male.

Mital (1971) made studies to find a suitable food medium to prolong life of *C. gonagra*. He gave water, honey and saturated solutions of glucose, maltose, and D-mannose to newly emerged adults and obtained best results with D-mannose, on which adult males and females lived for 63 and 70 days, respectively, as compared with 19 and 24 days with no food.

Light was avoided by adults of *C. serratus* and mating took place by them at dusk and laid eggs usually in darkness (Pajni and Gill, 1974), while Belinsky and Kugler (1978) studied the biology of *C. serratus palestinicus* on the seeds of shrub, *Prosopis farcta* in the field and under laboratory conditions of 25^{o}C and 50% RH and 30^{o}C and 70% RH and found that the *C. s. palestinicus* always preferred the seeds of *P. farcta* and larval development was also shorter in seeds of shrub.

Pajni and Mann (1979) studied the biology of *C. serratus* on *Tamarindus indica* (Imli) at 30^{o}C and 70% RH. They found that it is a multi-brooded pest of stored imli and female laid on an average of 42 eggs with highest rate of oviposition of 6.3 eggs per day on the surface of the imli seed and larval instars grow within and consume the contents of the seeds. The fourth instar larva leaves the seeds and pupate inside the cocoon. The bruchid do not feed in the adult stage. They also found that adults show brisk activity during early morning and late evenings, remaining almost inactive at other times of the days. Adults also exhibit peculier habits of feigning death, cleaning their body parts and occupying the empty cocoon and used seeds.

Wightman and Southgate (1982) studied the eggs of the nine species of bruchid that are known to damage stored pulses and reported that they can be used as identification tool in the absence of adults. They found that the follicle cell pattern on the eggs of *C. serratus* is visible at about X 40 magnification. They further reported that the *Arachis*, *Acacia*, *Tamarindus* and *Cassia* were better host for *C. serratus*.

Conway (1983) found that insect commonly emerged from infested nuts as the fourth instar larva and migrated through bulk stored nuts and out of bag stacks before pupating. He found that adult emergence; mating and egg laying occurred at considerable depths of jute greatly restricted the movement of adults into and out of the bags.

Delobel (1989) made study on reproductive activity of *C. serratus* at 30^{o}C in groundnut and observed groundnut had no effect on mating and slight stimulation of oogenesis occurred due to presence of unshelled groundnut. In inseminated female, oocyte retention was very low, even in absence of groundnuts. The fecundity of inseminated and regularly pollen fed females was approximately 650 eggs. These females had a mean life span of approximately 3 months but some individuals survived almost 6 months with no sign of diapause.

Pierre and Huignard (1990) carried out studies on the biology of *C. serratus* on *Bauhinia rufescens*, and found that adults began to appear in traps in October, when females began to lay eggs on pods and number of insects increased during the dry season, reached peak in April-May when temperature increased. The onset of the rainy season caused reduction in the density of adult populations, even though pods remained available on the tree during this period. Larval and nymphal mortality was thought to explain the decrease in density of *C. serratus* during the rainy season.

Chaipou *et al*. (1993) conducted an experiment to find out the effect of age on female attractiveness and on male reactivity of *C. serratus*. The female of *C. serratus* release a sex pheromone from the beginning of the scotophase, which trigger a positive chemo-anemotaxy in males. They found that about 70.37% of males began to react to the sex pheromone within the first 24 hrs after emergence and on same age, only one female out of 31 was attractive.

While at 48 hrs, the percentage of attractive female was 38.7%. There was an inter- and intra-female variation found in sex pheromone production (beginning and regularity).

Patel and Koshiya (1994) made studies on life table and age specific fecundity for *C. serratus* on groundnut cv. GG-2 and they provided the information on the mean generation length, innate capacity for increase and finite rate of increase of this bruchid. While Kapadia (1995) conducted an experiment on biology of *C. serratus* on groundnut variety GAUG-10 and found that female glued its eggs on seeds and kernels. The incubation, larval and pupal periods of bruchid averaged 2.63, 18.88 and 12.88 days, respectively. He also noted that the sex ratio between female and male was 1: 1.78.

2.2 VARIETAL PREFERENCE / HOST PREFERENCE

Mital (1969) tested the seven varieties of groundnut to find out the relative resistance to the attack of *C. gonagra* and found that TMV-3 and TMV-2 showed minimum and maximum resistance, respectively, and none of these varieties was immune to the attack of this bruchid. *C. s. palestinicus* preferred the seeds of *P. farcta* than groundnut seeds for oviposition and larval development (Belinsky and Kugler, 1978).

Mukhtar and Sushil (1990) studied the ovipositional response of *C. serratus* in the laboratory using five seeds each of 52 tree species. They found that oviposition is independent with development as the maximum number of eggs (103) deposited on seeds of *Erythrina variegata*, in which adult did not develop. The next most preferred species for oviposition were *Cassia* sp. with 76, 74, 63 and 46 eggs laid on seeds of *C. grandis*, *C. roxburghii*, *C. fistula* and *C. nodusa*. Seeds of 23 species were rejected for oviposition. They suggested that the testa of the seed is an important factor, which provides the stimulus for egg laying. Seeds of *Acacia nilotica*, *A. planifrons, Bauhinia* sp. and *C. nodusa* were the best species for successful egg development to larval and pupal stages.

Mital (1991) also gave the extent of losses caused by the bruchid, *C. serratus* in the groundnut varieties *viz*., improved Spanish, RSB-87, TMV-3, Exotic-5, Samarellam, RS-1 and TM-2 under storage conditions.

Kapadia (1995) studied the four varieties of groundnut for varietal resistance against *C. serratus* (Ol.), and his results indicated that variety J-11 were least preferred and tolerated the development of this pest as compared to other three varieties *viz*., JL-24, GG-2 and GAUG-10.

Satya-vir *et al.* (1996) found that the *A. nilotica*, *Prosopis cineraria* and *P. juliflora* act as the secondary host for population build up of *C. serratus*, and from them it spread to its primary host, the groundnut (*A. hypogea*).

Sembene and Delobel (1996) reared the groundnut seed beetle, *C. serratus* on pods of five different host plants *viz*., *A. hypogea*, *B. rufescens*, *Cassia sieberiana*, *Piliostigma reticulatum* and *T. indicus* for using discriminated function analysis based on 22 morphological variables. They found that the body size was the main discriminating factors, which is indicated the analysis on the performations of raw data. *T. indicus* population had the largest body size, followed by *A. hypogea, P. reticulatum C. sieberiana* and *B. rufescens.*

Ghorpade *et al.* (1998) carried out studies on the relative susceptibility of seven groundnut cultivars to pod borer, *C. serratus* and found that per cent oviposition by this bruchid was lowest in cv. ICGS-11 and SB-11, while developmental period was also minimum (66.22 days) in cv. SB-11. They further found that the percentage of pods damaged varied from 64.40 (ICGS-11) to 92.82 (RVB-1) and pod weight loss in cv. ICGS-11 and SB-11 was 3.17 and 3.60%, respectively, compared with 22.93% in RVB-1.

On the basis of oviposition, pod damage, loss in pod weight and development period, cv. ICGS-11 and SB-11 was classified as least susceptible to *C. serratus.*

Haritha *et al.* (1999) evaluated the relative resistance of pods of groundnuts cv. ICGV-86325, ICGV-86590, ICGS-76, ICG (FDRS-10), ICGS-11, ICGS-5, ICGS-44, ICGS-37, ICGV-91117, K-134 and TMV-2 to attack of *C. serratus* under laboratory conditions. They were grouped the cultivars into the three categories as least susceptible, moderately susceptible and highly susceptible. The pods of cv. ICGS-11 and ICGS-76 exhibited low fecundity and high mean developmental period of the beetle with low index of susceptibility, weight loss and damage, and were grouped as least susceptible to *C. serratus*.

Devi and Rao (2000) reported that cultivars TCGS-61, TMV-2 and TPT-3, which had moderate reticulation, were less preferred by this bruchid for egg laying, while the varieties *viz*., TCGS-61 and TCGS-88 were least preferred host on the basis of per cent weight loss, damaged pods and kernels and per cent adult emerged. They found that the pod reticulation seems to be the major biophysical characters that influence the bruchid development.

Lale and Maina (2002) made studies to utilizing possible resistance in groundnut cultivars (*viz*., Jato, Yar Dakar, Yar Damboa and Kampala) and tamarind accession (*viz*., TAs, TA-I, TA-II, TA-III, TA-IV and TA-V) for the management of *C. serratus*. This bruchid considerably fewer eggs laid and fewer adult progeny developed on Jato seeds than on Yar Dakar or Yar Damboa seeds. Egg to adult development was also significantly longer in Jato than Yar Dakar or Yar Damboa. While fewer adult progeny of *C. serratus were* developed in TA-V than in TA-II or TA-IV.

2.3 EXTENT OF LOSSES

Hall (1954) found that 1.2 to 10.8 per cent of groundnut were damaged by insects (or possibly by fungi) before harvest, and 2.4 to 16 per cent by insect after harvest, with an average of 5 per cent in each case. Pre-harvest damage is thought to be caused by lepidopterous larvae and by hemiptera, but the most important single factor appeared to be post harvest damage by *Pachymerus (Caryedon) fuscus* (Goeze), which causes severe damage to the kernels. The larva destroys a kernel up to about 50 per cent. The damage of only one kernel leads to minimum loss whereas actual loss goes up to six per cent.

Fairchild *et al.* (1954) carried out an experiment with decorticated groundnut, which were artificially infested with *P. (C.) fuscus* (Goeze) to find out the effect on the amount and quality of oil and protein content. They found that the original infestation of adults of *P. fuscus* was same in all the samples, but duration of attack was varied from 9 to 21 weeks. In samples examined after 11 or 21 weeks contained less oil and protein than those examined after 9 weeks, but it appeared that the duration of infestation had little effect on the oil and protein content after an initial critical period of between 9 to 11 weeks. They found that the acidity of the extracted oil increased with the extent of infestation, the increase evidently associated with fragmentation by the insects. *Ehestia* (*Cadra*) *cautella* (Wlk.) also caused damage in stored groundnut (Mookherjee *et al.*, (1969). While Conway (1975) found that *C. serratus* caused heaviest attack in stored groundnut at bottom of sack, followed by the surface.

El- Atta (1983) collected the samples of seeds of *A. nilotica* from standing trees, the forest floor and in storage facilities in order to assess infestation by insect seed borer. He recorded the high rate of infestation of larvae of *C. serratus*. The larvae of this bruchid bore into the seeds via small holes and feed on the embryo and the endosperm, leaving all infested seeds non viable. Generally, the mean infestation rate was significantly higher in pods collected from on the forest floor than in pods from the standing trees. The mean infestation rate was 10.7 and 11.1% in pods collected from standing trees in gerf and maya, respectively, in Wad Dabkara forest.

Dick (1987) monitored the samples of unshelled groundnut at monthly intervals taken from oil mil warehouses and assessed the damage caused by insect populations to the kernels. After 5 months of storage, the total dry weight loss of the kernels was approximately 20%. The bruchid *C. serratus* was responsible for nearly all the damage. He gave the development of the insect populations and the accuracy of the loss measured.

Singh and Bhandari (1987) recorded the some insects pests of indigenous acacias and listed the insects pests of standing trees are the defoliators, *Cryplothelea crameri* (*Euneta crameri*) and a species of Baralade, the bark feeding caterpillar (*Inderbella qurdrinotata)*, the sap sucker (*Oxyrhachis tarandus*) and the pods and seeds pests, *Bruchidius spadiceus* and *C. gonagra*. *C. serratus* may causes 100 per cent loss of the seed crops.

Singal and Toky (1990) found that the bruchid, *C. serratus* caused 6.8 per cent damage in *A. nilotica* in the field in Harayana. The pods of *A. nilotica* gathered from the field for seed purposes were found to be infested in small number but the bruchid populations increased during storage.

Modgil and Mehta (1993) investigated the changes in the crude protein, true protein in three pulses, bengal gram, green gram and red gram caused by *Callosobruchus chinensis* at six different levels of infestation. Their results showed that increased value of crude protein and decreased true protein with increased infestation levels. Crude protein in *Vigna radiata* and pigeon peas increased about 44 and 42 per cent, respectively, at 60% per cent. At 60 % infestation, there was maximum true protein reduction in *V. radiata* (41%). Correlation coefficient of levels of infestation was significantly and positive with crude protein and negative with true protein. Similarly Khairnar *et al.* (1996) found that crude protein; ash and crude fat content of pigeon pea seeds were decreased due to infestation of pulse beetle, *C. chinensis* with increasing storage periods.

Dudu *et al.* (1996) assessed three physical forms (whole, broken and milled) of three oilseeds, *Irvingia gabonensis* (mango) *Citrullus lanatus* (melon) and *A. hypogea* (groundnut) for their relative susceptibility to infestation by *O. mercator* under laboratory conditions (25-30^{o}C and 77-90%) along with whole seeds of each commodity were also infested with adults of *O. mercator* and stored for 3, 6, and 9 months under identical conditions. They observed that moisture contents increased in oilseeds stored for nine months, where as protein contents of the seeds decreased during the same period. They also found that the oil content of groundnut generally increased with increasing storage time.

Satya-vir *et al.* (1996) made observations on the field infestation of *C. serratus* (Ol.) on seeds of *Acacia nilotica* and reported 10.3 to 30 per cent infestation and 1.2 to 1.3 per cent seed infestation. Insect infestation resulted in a loss of 22.51 per cent in seed weight and 1.18 per cent in seed biomass of the tree.

Chitra and Soundararajan (2001) conducted a survey in different locations in Tamil Nadu to study the percentage damage to *C. serratus* on stored tamarind seeds. They found 100 per cent damage in seeds samples collected from Coimbatore, Karaical and Podicheery, followed by 80% damage in samples collected from Vamban.

Cunninghum and Walsh (2002) assessed 40±8% (mean ± s.e) losses in seeds of *Cassia brewsteri* and *C. tomentelus* by *C. serratus*. This bruchid was detected in 72±8.6% of pods in 71±8.5% of trees were affected.

2.4 STORAGE STRUCTURE/ RECEPTACLES

Dhaliwal (1972) recorded maximum damage (6.67%) in bharoli and minimum in pucci kothi (1.03%), closely followed by metal bin (1.66%) after one month of storage. Daniel *et al*. (1977a) reported that in one kilogram of green gram, the population of *C. chinensis* multiplied to 14, 118, 233 and 295 insects per 100g after 1, 2, 3 and 4 months of initial infestation, respectively. Similarly, Daniel *et al*. (1977b) observed 6, 20 and 170 adults in 100g sample of chickpea after 1, 3 and 5 months of infestation when 5 pairs of adults were released per kilogram, under controlled laboratory conditions of 80±5^{o}F and 60±5 per cent relative humidity.

Khound and Borah (1984) reported 4.10 and 4.39% infestation after 3 and 6 months of storage of wheat in metal bin; 11.27 and 14.65 per cent in cement bin and 5.13 and 6.77% in juria duli for the same periods under Assam conditions. The average per cent loss in weight for metal bin, coaltar drum, gunny bag, plywood bin and earthen pot were 3.9, 4.2, 4.8, 6.3 and 15.0, respectively (Awaknawar *et al*., 1989).

Sinha (1990) carried out an experiment to find out the effect of quality of storage structure on multiplication behavior of *C. chinensis* in *Cajanus indicus* and found that the multiplication rate of this bruchid in descending order was Earthen Pucca > Tin > Glass> Earthen kaccha > Plastic.

Chaudhery *et al.* (1991) found that the maize seeds stored in polyethylene lined motka, improved tin containers, polyethylene lined jute bags, traditional tin and polyethylene lined dole containers had the lowest infestation rates of *Sitophilus* sp. and *Sitotroga cerealella* (0.46, 0.91, 1.14, 3.02 and 3.38%, respectively) compared with containers made from other materials. As a results of feeding by the pulse beetle (*C. maculatus*) the per cent losses estimated at 30, 60, 90 and 120 days after storage were 5.41, 23.17, 32.45 and 43.76 (metal bin); 5.3, 24.2, 32.46 and 45.34 (plastic container); 6.15, 22.09, 54.53 and 61.72 (gunny bag); 7.49, 21.23, 43.82 and 55.46 (earthen pot); and 7.46, 23.17, 36.15 and 43.75 (polyethylene bag)(Patel and Dadhich, 1992).

Kumari and Reddy (1997) kept *Cajanus cajan* cv. IPCL-87 seeds in clay pots or tins and than top layer covered with neem (*A. indica*) leaves, cow dung ash (1%) or mustard oils (0.5%) and stored for four months. After four months of storage they found that seed weight, density and bulk density were lowest in clay pot treated with cow dung ash. While treatment with mustard oil or neem leaves inhibited the pest infestation.

Shaw (1998) stored green gram seeds at 8, 12 and 16% moisture contents for up to180 days in polythene bags and jute bags. On the basis of moisture contents, insect (*C. chinensis*) damage, seed weight, protein contents and nitrogen solubility, polythene bags gave better seed preservation than jute bags.

Almeida *et al.* (1998) stored peanut seeds cv. Tatu in three types of containers under ambient conditions in two micro regions for 15 months. They found that the seed stored out of the kernel were more susceptible to pest attack and fungal infection and type of containers had an influence on incidence of insect pests and fungi.

2.5 MANAGEMENT

Green (1960) treated the surface of heaps of groundnuts against *C. gonagra*, with DDT @ 400 mg/sq. ft. and Y-BHC @ 20 mg/sq. ft., which gave complete protection during storage period of four months.

Jotwani and Sircar (1967) evaluated neem seed as a protectant against *Callsobruchus chinensis* infesting some leguminous seeds. Seeds of mung, bengal gram, cowpea and pea were effectively protected from damage by bruchid for about 8 to 11 months by mixing with crushed neem seed @ 1 and 2 parts per 100 parts of seeds (w/w).

Friendship (1973) indicated that the short exposure to dust of 1% malathion applied to the surface of heaps of groundnut was sufficient to kill the adults of *C. serratus* and found that currently recommended insecticide 0.5% gamma–BHC (Lindane) was less effective. While Conway (1975) found that malathion at 10 ppm in bulk stored groundnut and 20 ppm in bagged nuts gave a best results against the *C. serratus*.

Gupta *et al*. (1976) evaluated the nine insecticides in films for toxicity to adults of *C. serratus*. On the basis of LC_{50} values, the order of toxicity of insecticides against this bruchid was Labacid > Endosufan > Lindane > Malathion > Aldrin > Nuvan > Diptrex > BHC > Carbaryl. Powder prepared from seeds of custard apple afforded protection against *C. maculatus* to seeds of moong, when mixed with the stored product at 0.5-2.0 parts/100 parts preventing damage and controlling the build up of bruchid population (Pandey and Verma, 1977).

Sowunmi and Akinnusi (1983) reported the neem kernel powder at 0.5 parts per 100 parts of seeds was effective in controlling of *C. maculatus* up to 4 months, but thereafter, considerable damage occurred. They also observed that the treatment of neem kernel powder at 1.0 and 2.0 parts per 100 parts of seeds was effective for 8 months.

Mathur *et al.* (1985) evaluated the efficacy of black pepper, neem kernel powder, ash, turmeric, soth and adhatoda in comparison to malathion as against *C. chinensis* infesting black gram. Among plant products, black pepper was most toxic material, followed by neem kernel powder and ash, which were at par with malathion without adversely affecting viability of the seeds, whereas adhatoda was found least effective.

Delobel and Malonga (1987) gave an account of the effectiveness of *Tephrosia vogelii* and 5 other plants against stored pest, *C. serratus*. At application rates of 1: 40 (w/w), *Chenopodium ambrosioides* and *T. vogelii* affected the survival of *C. serratus* adults, 90.0 and 98.8% of them, respectively, dying within 13 days. Other plant materials had little or no effect on the different stages of the insect.

Mittal and Wightman (1989) found that an attapulgite base clay dust mixed with groundnut pods at 0.5 and 0.2%, respectively against *Callosobruchus analis* (F.). He reported that neem seed kernel paste suspension and neem seed kernel powder proved to be more effective as compared to neem leaf powder in reducing the pulse beetle damage.

Chiranjeevi (1991) tested the efficacy of seed powder of neem and leaf powder of neem, apamarga, kesarachetha, lantana, rhizome powder of sweet flag and ash of cow dung, acacias wood, neem wood and *Casuarina* against *C. chinensis* on the basis of percent grain damage, per cent protection over control and viability of treated seeds. He concluded that cow dung ash was most effective in reducing percent grain damage followed by neem seed kernel powder, sweet flag rhizome powder and neem leaf powder. No adverse effect of treatments was observed on the germination of the seeds.

Daglish *et al*. (1992) assessed the organophosphorus insecticides *viz*., malathion, fenitrothion, chlorpyriphos-methyl, pirimiphos-methyl and methacrifos, and the synthetic pyrethroid insecticides *viz*., bioresmethrin, deltamethrin, clophenothrin, fenvalerate and permethrin, and the insect growth regulator *viz*., methoprene, diflubenzuron and fenoxycarb against *T. casteneum* on peanut stored at 30^{o}C and 70% RH. They concluded that chlorpyriphos-methyl, methocrifos and deltamethrin, (all applied at 5 mg/kg), completely prevented the development of progeny. Deltamethrin was also highly toxic to adults while malathion had a low potency against both adults and progeny owing to resistance in the test insects.

Juneja and Patel (1994) indicated that the seed powder of custard apple and black pepper, leaves of mint (*Mentha piperata* L.) and peel of orange (*Citrus reticulata* Blanco) at 5 parts per 100 parts of green gram gave 100% adult mortality of the pulse beetle after 3 days of treatment and completely prevented the egg laying by female until 60 days after treatments. Furthermore, no population build up and grain damage were observed up to four months of storage, whereas seed kernel powder of neem (*A. indica*) gave protection only for three months.

Lafleur (1994) tested several control methods against *C. serratus* in stored groundnut. He found cyfluthrin, permethrin and deltamethrin were effective against this bruchid while oils, neem extracts and diatomite were ineffective. While seeds powder of custard apple (*A. squamosa*) and dried mint leaves (*Mentha spicata*) powder were found most effective against *Rhizopertha dominica* (Patel and Valand, 1994).

Shivanna *et al.* (1994) evaluated the efficacy of seed powder of neem (*A. indica*), honge (*Pongamia glabra* [*P. pinnata*]), soapnut (*Acacia sinuate*), custard apple (*A. squamosa*) and black pepper (*P. nigrum*); rhizome powder of turmeric (*Curcuma longa*) and sweet flag (*Acorus calamus*); and leaf powder of tulsi (*Ocimum basilicum*) and Eucalyptus, each at 0.5,1.5 and 2.5 g per 50 g of seeds of red gram (*C. cajan*) against *C. chinensis* on the basis of fecundity, adult emergence and per cent grain weight loss. Among the plant products, the sweet flag powder applied at all rates gave maximum protection against this bruchid, closely followed by custard apple, black pepper, turmeric and neem powder at the higher rate.

Khanna (1995) showed that black pepper (*P. nigrum*) powder at 500 ppm used along with mustard oil gave significantly greater protection of stored green gram (*Vigna radiata*) against *C. chinensis* and *C. analis* as compared with black pepper powder alone. While Pandey and Singh (1995) reported that the seeds of black gram (*vigna mungo*) could be protected against *C. chinensis* by treating seeds with dried neem leaf powder @ of 100-400 mg/ 50 g seeds and also observed that germination of treated seed was not impaired.

Prijona and Manuwot (1995) evaluated the seed extracts of 30 species of Annonaceae, Fabaceae and Meliaceae against *C. maculatus* females (1-2 days old in petri dishes and seed extracts of *A. squamosa* and *A. glabra*, amongst all Annonaceae, at 0.5% showed a good contact effect against *C. maculatus* (>90% mortality after 3 days and 100% after 5 days).

Senguttuvan *et al.* (1995) evaluated the plant products for efficacy in protecting stored groundnut against rice moth, *Corcyra cephalonica* Stainton. They found nochi leaf powder, neem leaf powder and neem oil were most effective followed by neem kernel powder against this moth.

Ghanekar *et al.* (1996) compared the effectiveness of dry formulations of three insecticides (chlorpyrifos, fenvalerate and carbaryl) against *C. serratus* and *C. cephalonica* in stored groundnut and pearl millet seeds. They found fenvalerate at 4 g/ kg seed showed quick action killed all the *Corcyra* eggs and *Caryedon* larvae and adults within 48 hrs. The chemicals tested had no adverse effect on seed viability of groundnut and pearl millet (*Pennicetum glauacum*) up to 180 days at ambient temperature during storage.

Rajapakse (1996) tested the potentiability of four plant products *viz.*, *P. nigrum* L., *A. reticulata* L, *Dillenia retursa* and O*cimum sanctim* L. against the cowpea bruchid *C. maculatus* (Bruchidae: Coleoptera) in Sri Lanka. He observed that the lower concentration of 5.3 percent powder obtained from fruit of *P. nigrum* significantly reduced the ovipositional and adult emergence, while 100% adult mortality was applied at a higher concentration of 42 per cent. Volatile oils obtained from some fruits of *P. nigrum* at 0.2 and 0.4 per cent concentration significantly caused adult mortality while oviposition was completely suppressed at 0.8 per cent and above.

Rouf *et al*. (1996) worked out the efficacy of leaf powder of neem (*A. indica*) nishinda (*vitex nergudunda*) or biskatali (*Poly hydropiper*) and combination of three plant materials against *C. chinensis* on lentil seeds and reported that biskatali leaf powder 4g/50g lentil seeds was most effective in reducing oviposition adult emergence and also the seed damage and weight loss followed by neem leaf powder alone. They further concluded that at the lower doses (1-2 g) all the plant materials applied either alone or in combination were less effective.

Bhatnagar and Sharma (1997) reported petroleum ether, chloroform, methanol and water extracts of neem (*A. indica*) leaf and water extracts of *A. squamosa* seeds, each at up to 20% concentration, effectively controlled *Chilo partellus* Swinhoe under laboratory conditions. Kumari and Singh (1998) found that black pepper powder, neem leaf dust and kalajira (*Nigella sativa* L.) powder were equally effective with respect to the number of eggs laid, number of adults that emerged and reduction in damage to grain by pulse beetle.

Rajapakse *et al.* (1998) carried out an experiment to find out the effectiveness of dried leaf powder of *P. nigrum, A. reticulata, A. indica* and *Capcicum annum* and dried peel of lemon (*Citrus limon*) on oviposition, adult emergence and adult mortality of *C. maculatus* in stored cowpea seeds under laboratory at 27-30°C and 60-80%RH. *A. indica* gave highest reduction in oviposition of *C. maculatus* (37.5%), followed by *A. reticulata* (39%). *A. indica* caused a significant reduction in adult emergence (20.3%).While lemon peel and *P. nigrum* gave mortality, 8.3 and 8.25%, respectively.

Murugesan *et al.* (1998) found that neem derivatives Fortune Aza 0.15% reduced oviposition and adult emergence and increased mortality in both seed pests, *C. serratus* and *Bruchidius* sp. The longevity of adults and the duration of pupal periods were drastically reduced following exposure of 75-100 ppm as compared to the untreated control.

Kumari *et al.* (1998) evaluated the plant powder (neem seed kernel powder, leaf powder of neem and *Lantana camara*) at 25 g / kg groundnut pods and two aromatic oils (Citronella and Pulmarosa) at 15 ml / kg pods, against the groundnut bruchid, *C. serratus*. They found that the Citronella and Palmarosa oils gave total protection to groundnut pods by inhibiting oviposition by the bruchid for 6 months with an efficacy equal to that of malathion dust (malathion 5D). Among the plant products, *L. camara* had a good oviposition deterrent activity, but lost effectiveness gradually after one month.

Cardet *et al.* (1998) tested the comparative efficacy of neem kernel oil, groundnut oil and a synthetic insecticide k-orthrine (deltamethrin) in protecting the leguminous seeds stocks against seed beetle under following insects/seeds combination models: - *Caryedon acaciae*/*Acacia nilotica*, *C. longispinosus*/*A. raddiana* and *C. serratus*/ *Tamaridus indica.* They found neem oil had pronounced adulticidal and ovipositional effect, which were maintained for 5 months and no significant fall in seed viability was observed except in the case of *C. acaciae*/*A. nilotica*. Deltamethrin had high adulticidal effect only at concentration of 25-100 mg / kg up to 5 months and observed no significant fall in seed viability.

Aku *et al.* (1998) studied the effect of *Annona senegalensis* root bark powder (@2.5% of seed weight) and its extracts (@ 2.5% concentration) with permethrin (Coopex 0.5% dust) on cowpea seed bruchid, *Callosobruchus maculatus* over short (45 days) and long (140 days) storage periods. *A. senegalensis* root bark powder significantly reduced oviposition (78.9-97.4%), number of progeny per female (to <1 from 45.0-79.5 in control), and weight loss (to 3.7% from 98.0% in control). While stem bark, leaf and seed powder and their extracts were less effective.

Oliveira *et al.* (1999) carried out a study on bean weevil, *Zabrotes subfsciatus* living on seeds of *Phasiolus vulgaris* and found that powder of black pepper (*P. nigrum*) and leaves of cinnamon (*Cinnamonum zeylanicum*) caused 100 and 98% mortality, respectively, and reduced oviposition of viable eggs and emergence of adults by 100% as compared with control. In another laboratory experiments conducted against larvae of *Spodoptera frugiperda* with ethanol extracts of seeds of *Annona crassiflora* (at 100463 and 7825 ug/ml), neem extract (at 18000 ug/ml) and chlorpyrifos (at 2000 ml) and found 100 per cent with all the treatment, except for one extract of *A. crassiflora* which gave 92.4% mortality (Prates *et al.*, 1999). While Sharma (1999) suggested that neem leaf powder (at 5%) protected the maize grain against *Sitophilus oryzae*, *Sitotroga cerealella*, *Rhizopertha dominica and Trogoderma granarium*.

Saxena and Saxena (1999) evaluated the efficacy of twelve extracts against cowpea weevil, *C. maculatus* at 1.0, 1.5 and 2.0 per cent concentration obtained by filter paper strip method. They observed the repellency at 2.0% concentration in descending order of black pepper (93.33%) > neem seed (88.00%) > garlic bulb (64.0%) > neem bark (57.33%) > turmeric rhizome (56.00%), while at 1.5%, 82.66 and 62.00% repellency was observed in black pepper and neem seed extract treatment, respectively. At 1.0% concentration black pepper extract showed only 52% repellency.

Sahayraj and Paulraj (2000) found leaf extract of *A. indica* was most effective against *Triboleum castaneum* in stored groundnut seeds, followed by those of *Vitex negundo*, onion and *Calotropis gigantean*.

Mishra (2000) used 3 per cent dried leaf powder of *V. neundo*, *Aegle marmelos*, *A. indica*, *Datura stramonium*, *Ocimum sanctum*, *L. camara*, *A. squamosa*, *Citrus limon* and fruit powder of *Capsicum annum*, and rhizome powder of *Acorus calamus* for control of *C. chinensis* in black gram seeds and found that all the treatments reduced the fecundity and seed weight loss caused by *C. chinensis* in stored black gram than the untreated control. However, *V. negundo*, *A. marmelos*, *A. indica* and *D. stramonium* treatments reduced fecundity more than the other powder treatments.

Tripathy *et al.* (2000) tested the residual toxicity of different insecticides *viz*., BPMC (Fanocarb), carbosulfon (each @ 20, 40,60 and 80 PPM) and fipronil (@10, 20, 30 and 40 PPM) against seed beetle, *C. serratus* infesting in stored groundnut. They indicated that the residual toxicity in the order of fipronil> carbosulfon >BPMC. F ipronil successfully checked the growth and multiplication of the beetle after one year of treatment. Third dose of each insecticides (60 PPM for BPMC and carbosulfon and 30 ppm fipronil) was found to be superior than lower two doses and as effective as the higher dose.

Ntonifor and Monah (2001) protected the stored maize with the help of up to 4 g of powdered black pepper (*P. nigrum*), bush onion (*Afrostyrax lepidophyllus*), dried leaves of *Basilicum* spp. and wood ash against *Sitophilus zeamais* and found very small number of adult emerged from grain treated with 4 g of pepper than other spices and 100% mortality were found in emerging adult with 2-4 days post emergence. Black pepper seed powder proved to be the best grain protectant showing no damage even after four months of storage, which was followed by neem seed kernel powder (20g/kg seeds). Neem and ratanjot seed kernel paste suspension (20ml/kg seeds) and neem leaf powder (20g/kg) also afforded effective protection against the bruchid damage for four months as compared to control (100% damage) with no adverse effect on seed viability (Sundria *et al.*, 2001).

3. MATERIALS AND METHODS

The experiments on different aspects of groundnut beetle were conducted in the storage laboratory, Department of Agricultural Zoology and Entomology, Rajasthan College of Agriculture, MPUAT, Udaipur and Stored Product Entomology Section, Division of Entomology, IARI, New Delhi during 2001-2003. For all the experiments, large numbers of insects are needed and rearing of the test insect was carried as follows.

Rearing of the insect

The test insect obtained from the trader's godown was identified as *Caryedon serratus* (Olivier) by Insect Taxonomy Section, Division of Entomology, IARI, New Delhi. The nucleus culture of this insect was maintained at Department of Agril. Zool. & Ento., RCA, Udaipur. Sex determination of the insect was done on the basis of characters as given below in the Table-1. This facilitated in the successful rearing of the insect.

Table 1. Sex determining characters of *C. serratus*

MALE	FEMALE
1. Length - 7.18 to 7.26 mm.	1. Length - 7.18 to 7.78 mm.
2. Pygidium -Black in colour with the apex dark brown, vertical and as long as broad.	2. Pygidium sub-vertical and longer than broad.
3. Pygidium or sixth visible tergite projects downwards, so that in dorsal view it is hidden by the elytra.	3. The Pygidium can be seen in dorsal view projecting beyond the elytra.
4. The fifth visible sternite is deeply incurved anteriorly so that the seventh tergite is often seen projecting between it and the pygidium.	4. The fifth sternite is fully extended, so that the vertical surface is more or less flat. The seventh tergite is not represented.

The culture of this bruchid was maintained on unshelled groundnut in the storage laboratory at room temperature. Groundnut pods, procured from college farm and market, were cleaned of inert material and then subjected to a temperture of 50±2 ^{o}C for an overnight to eliminate the hidden infestation, if any. The nucleus culture of *C. serratus* was obtained from a single pair and further multiplication was carried by releasing 30 pairs of one day old adults in rearing jars (25 cm X 10 cm dia.) containing 150 g pods for oviposition. The adults released were removed from glass jars after 5 days. The jars were covered with muslin cloth and tied with rubber band. Pupae formed in jars were separated from the culture and placed in petridish. In order to get a continuous supply of insects for experimentation, the culture was maintained releasing insects at a regular interval in number of jars. To avoid any kind of contamination, care was taken not to handle the pods and insects with naked hands. During experimentation, forcep, camel hairbrush and aspirator were used for transferring seeds and insects. Bio-agents may affect the culture, therefore hygiene was maintained and contaminated cultures were discarded occasionally, if any.

3.1 BIOLOGY AND HOST RANGE

3.1.1 Biology

The biology of bruchid, *C. serratus* was studied on groundnut pods throughout the year at room temperature (ambient conditions) in laboratory. The biology of this bruchid was studied at different ecological conditions prevailing during the year. The complete one year was divided into four quarters of three months each, starting with the month of February. Fifty pods of groundnut were taken in glass containers (12 X 5 cm.). One pair of 0-24 hrs old adults (male & female) was released in each container. The total number of eggs laid was counted till the death of adults. There were five replications. The pods having eggs laid on it were separated after one day and ten eggs per replication were confined to plastic vials (6 X 4.5 cm.) to determine the incubation, larval, pupal period and longevity of male and female. There were five replications for each treatment. Hatching date was determined by the formation of larva beneath the eggshell observing under the microscope. The larval period was counted from date of hatching to formation of pupa. The bruchids in general are internal feeders and the larval and pupal stages remain confined within the grain. But in case of *C. serratus*, the larva feeds within the kernel and before going into pupation moves out of the pod. The pupal formation is completed outside the kernel or sometimes half in and half out of the pods. Pupal period was worked out from the date of pupa formation to date of adult emergence. The developmental period of the insect was determined from the date of egg laying to adult emergence. Longevity of adults was also studied. Single male and female adults were placed separately in homeopathic vial (5.5 X 1.5 cm.) and observation on number of days till mortality were recorded. There were five replications, each containing ten, for each male and female adult individually.

3.1.2 Host range

3.1.2.1 Ovipositional preference

To study the ovipositional preference of the bruchid on ten hosts as mentioned in Table- 2, small compartments were made using drawing sheet strips in steel dish (22 cm dia.).

There were ten compartments, which were equal to the number of host taken, and all the compartments were of the same size. A compartment in the middle of the dish was left to release the insects. Test hosts were placed separately in different chamber of the dish. Ten pairs (male and female) of 0-24 hrs old adult groundnut bruchid were released in the central cavity of the dish giving beetles free chance to enter any compartments to oviposit. The dish was covered with a transparent glass plate. The dishes in four replications were placed at 29±3 ^{o}C temperature and 50±5 % RH. The number of eggs laid per host was counted after 10 days of release of beetles.

3.1.2.2 Development and adult emergence

To find out the development period of groundnut bruchid on different hosts as mentioned earlier, 25g of each host was taken in plastic container and one pair of newly emerged adults (male & female) of 0-24 hrs old was released. The test hosts with eggs laid on it were separated after one day and kept in vials to determine the incubation, larval and pupal periods as mentioned in the biology of the bruchid. Adult emergence was observed till it ceased. Percentage adult emergence was worked out on the basis of eggs laid.

Table 2. Hosts included studying the preferences of *C. serratus*

Hosts	Scientific name
1. Groundnut pod	*Arachis hypogea* L.
2. Cashewnut	*Anacardium occidentale* L.
3. Groundnut kernel	*Arachis hypogea* L
4. Coconut	*Cocos nucifera* L.
5. Currents	*Vitis vinifera* L.
6. Jaiphal	*Myristica fragrans* Houtt.
7. Almond	*Prunus amygdalus* Batsch
8. Tamarind	*Tamarindus indica* L.
9. Cardemon	*Elettaria Cardamomum*
10. Date palm	*Phoenix dactylifera* L.

3.2 GERMPLASM SCREENING

Twenty groundnut germ plasm (Table 3) were taken from regional center of All India Coordinated Research Project, Udaipur to work out the relative resistance against *C. serratus* on the basis of ovipositional preference, developmental preference and per cent weight loss.

3.2.1 Ovipositional Preference

To study the ovipositional preference of this bruchid on nineteen groundnut cultivars, compartments were made using drawing sheet strips in steel dish (28 cm dia.). The numbers of compartments were made equal to the number of germ plasm taken and all the compartments were same in size. A small area common to all the compartments was left in the center of the dish for releasing the groundnut bruchid. Ten sound and healthy pods of each germplasm were placed separately in different chambers of dish. Ten pairs of bruchid 0-24 hrs old were released in the central area of the dish leaving the beetles free to enter any compartments to oviposit and dish were covered with a transparent glass. The experiment was replicated three times with nineteen treatments in each replicate under control conditions of 29±3^{o}C temperature and 50±5 % RH. Total number of eggs laid per ten nuts of each cultivar was counted after 10 days of released bruchid in each replication.

Table 3. Germplasm of groundnut included studying the relative resistance to *C. serratus*

Serial number	Name of germ plasms
1.	ICGV-92015
2.	ICGV-93420
3.	ICGV-92028
4.	ICGV-93370
5.	ICGV-92222
6.	ICGV-93388
7.	ICGV-93128
8.	ICGV-92040
9.	ICGV-94361
10.	ICGV-92267
11.	ICGV-93133
12.	ICGV-92229
13.	ICGV-92218
14.	ICGV-93134
15.	ICGV-92022
16.	BAU-13
17.	GG-2
18.	TKG-19A
19.	ICGV-95136

3.2.2 Development Preference

To work out the developmental preference of *C. serratus* on different germplasm, 25 g nuts of each germplasm were taken in glass petridish (15 cm dia.) in three replications. One pair of newly emerged (0-24 hrs old) adults was released in each petridish. After ten days adult were drawn out from the petridish. For hatching period, ten eggs of same date were taken to find hatching date under microscope and subsequently larval and pupal period were observed as mentioned earlier in the study of the biology of this bruchid.

3.2.3 Per cent weight loss

Pods of germplasm weighing 50 g each on analytical balance were kept in plastic container (12 X 5 cm.). Two pairs of freshly emerged adult beetle were released in each container and were allowed to lay eggs for a period of 10 days, and removed. The plastic containers were kept at room condition. After the adult's emergence stopped, the adults were removed from the containers and weighing was done to work out the percentage weight loss.

3.3 QUANTITATIVE AND QUALITATIVE LOSSES

The extent of losses caused by this bruchid in stored groundnut pods was determined. The details are given as under.

Experimentation

The pods of groundnut were disinfected prior to start of experiment. Five hundred g of pods was taken in plastic containers of 2 kg capacity for observations on per cent damage and weight loss and for estimation of protein, oils and carbohydrate loss in stored groundnut. The jars were covered with plastic lid having small perforations. Five pairs of 0-24 hrs old adults of *C. serratus* were released in each container. Adults were allowed to lay eggs and multiply. There were separate jars to record observations after storage period of 3, 6 and 9 months. The jars were kept at room conditions. There were four replications for each treatment.

3.3.1 Quantitative losses

3.3.1.1 Damage

Fifty g groundnut pods were taken from each replication and counted. The damaged pods were separated out from the lot and percentage damage was worked out. The same procedure was adopted for observations to be taken after six and nine months of storage. The per cent damage was calculated as per formula given by Adams and Schulten (1978).

$$\text{Per cent damaged pods} = \frac{\text{Number of holed pods}}{\text{Total number of pods counted}} \times 100$$

3.3.1.2 Weight loss

After removing the adult beetles from each jar, the weight of pods was taken on a balance after three, six and nine months of storage. The per cent loss in weight was calculated as per formula given below.

$$\text{Per cent weight loss} = \frac{I - F}{I} \times 100$$

Where, I = Initial weight of pods

F = Final weight of pods

3.3.2 Qualitative Losses

To determine the qualitative changes taking place in the groundnut pods during storage, samples were dried first in the electric oven at 50 ^{o}C with a view to bring down the moisture content. The dried groundnut samples were then ground in micromill and sieved with 60-mesh. In order to avoid contamination, the micromill was thoroughly cleaned before each grinding. Protein, oil and carbohydrate (total soluble sugar) were determined as detailed below.

3.3.2.1 Protein content

The nitrogen content in the protein of the groundnut samples was determined by micro-kjeldahl method (A.O.A.C., 1970) using 0.2 g samples. Protein content was calculated by multiplying the percentage nitrogen figure by 5.46.

3.3.2.2 Oil content

The oil content was estimated by cold percolation method (Kartha and Sethi, 1957).

3.3.2.3 Carbohydrate (Total soluble sugar) content

Total sugar was estimated by the Anthrone method (Sadasivam and Manickam, 1992).

3.4 EFFECT OF RECEPTACLES/STRUCTURES

To study the effectiveness of receptacles, metal bin, mud pot, jute bag, high density poly ethylene bag and plastic container, were included. 500 g of groundnut pods were filled in each receptacle and five pairs of newly emerged male and female adults were released and kept at room conditions. After six months of storage, population build up, per cent weight loss and per cent pod damage was observed.

3.4.1 Population Build Up

After six months, the adult insects were removed from pods with the help of camel hairbrush. The half emerged adults but visible in the holes were also removed with the help of needle and forceps and total insects were counted.

3.4.2 Per cent Weight Loss

After removing the adult beetles from each replicate of different receptacles the weight of pods was taken separately on analytical balance after six months. The per cent loss in weight was calculated by the formula given earlier.

3.4.3 Per cent Damage

Hundred gram groundnut pods were taken from each replicate of different receptacles after six months. The damaged pods were separated from the total number of pods taken for observations in each replication. The data obtained was used for calculating the percentage of damaged pods. Per cent damage was determined by the formula given earlier.

3.5 MANAGEMENT OF *C. serratus*

With a view to determine relative efficacy of different plant materials and dusts against the seed beetle, *C. serratus* infesting stored groundnut pods, cylindrical plastic jars of 3 kg capacity were used. Seven Hundred g pods of groundnut were treated with different dosages of plant material and Insecticidal dusts as given below (Table-4).

The seeds of various plant materials were dried under the shade and then dried material was powdered in an electric grinder. The proper care was taken to clean the bowl of grinder before grinding each plant material for preparing the powder. The insecticidal dust procured from market.

Observations recorded:

To evaluating the effect of botanicals and dusts against this bruchid, 50 g pods were taken in three replicates from each jar and kept in small plastic containers .One pair adults was released in each small plastic container and then number of eggs laid by bruchid in each small plastic container counted after the adults died. The adult emergence was observed till it ceased. After the complete emergence, all the adults were removed from the plastic container and weight of pods was taken. Per cent seed damage was calculated by the formula as described earlier. The observations pertaining to oviposition, per cent adult emergence, per cent weight loss and per cent damage were recorded after 24 hrs, 3, 6 and 9 months of storage.

Table 4. Plant powders and insecticidal dusts used against *C. serratus* infesting groundnut pods

Common name	Scientific name	Family	Plant parts used	Dosages (g/kg)
A. Plant products				
Neem	*Azadirachta indica* (A.) Juss	Meliaceae	Seed powder	10 g 15 g 20 g
Black pepper	*Piper nigrum* L	Piperaceae	Drupe powder	5 g 10 g 15 g
Karanj	*Pongamia glabra* (L.)	Leguminasae	Seed powder	10 g 15 g 20 g
Custard apple	*Annona squamosa* (L.)	Annonaceae	Seed powder	10 g 15 g 20 g
B. Dusts				
Malathion 5 %				5 g 10 g
Deltamethrin 0.2 %				5 g 10 g

4. RESULTS

Investigations on the biology of *C. serratus* during whole year, and host preference on the different host and germ plasm of groundnut were carried out to gather basic information's pertaining to ovipositional and developmental period of the bruchid. The bio-efficacy of plant powders and insecticidal dusts were also evaluated against the bruchid under natural laboratory conditions. The experimental findings are mentioned below under different headings.

4.1 BIOLOGY AND HOST RANGE

4.1(A) Biology

(a) Number of eggs

The data on number of eggs laid by bruchid during whole year had showed significant variation with a maximum number of eggs (81.58) laid during February to April and minimum during May to July (47.66) (Table 5 & Fig.1). No significant different was observed between second and fourth quarters of the year. The eggs laid during third and fourth quarters were 66.57 and 53.08, respectively.

(b) Hatching period

The time taken by the egg to hatch out during a year varied from 4.12 to 13.04 days (Table 5 & Fig.1). The maximum time for hatching was taken during fourth quarter (13.04 days) and minimum during second quarter (4.12 days). There was no significant variation found during first (8.32 days) and third (7.01 days) quarters.

(c) Larval period

The observations of Table 5 & Fig.1 clearly depicted the larval period of first and third quarter of year were statistically at par showing 26.85 & 26.54 days, respectively. The bruchid took minimum period to reach pupal stage during May to July (21.40 days) and maximum during November to January (38.69 days).

(d) Pupal period

The maximum pupal period (26.33 days) was observed during fourth quarter and minimum (15.02 days) during second quarter. There was no significant variation observed between first and third and between second and third quarters (Table 5 & Fig.1).

Table 5. Biology of *Caryedon serratus* in different quarters of year

Quarters	No. of eggs laid*	Hatching period*	Larval period*	Pupal period*	Developmental period*	Adult life span*	
						Male	Female
February to April	81.58 (9.06)	8.32 $(2.97)^{a}$	26.85 $(5.23)^{a}$	19.75 $(4.50)^{a}$	54.85 $(7.44)^{a}$	16.15 $(4.08)^{ab}$	26.95 (5.24)
May to July	47.66 $(6.94)^{a}$	4.12 (2.15)	21.40 (4.68)	15.02 $(3.94)^{b}$	40.54 (6.41)	13.12 $(3.69)^{a}$	18.59 (4.37)
August to October	66.57 (8.19)	7.01 $(2.74)^{a}$	26.54 $(5.20)^{a}$	16.56 $(4.13)^{ab}$	50.05 $(7.12)^{a}$	18.86 $(4.40)^{b}$	31.31 (5.64)
November to December	53.08 $(7.32)^{a}$	13.04 (3.68)	38.69 (6.26)	26.33 (5.18)	78.35 (8.88)	28.44 (5.38)	39.06 (6.29)
SEm±	0.23	0.13	0.11	0.11	0.12	0.12	0.09
CD at 5%	0.69	0.38	0.33	0.33	0.35	0.35	0.27

*** Mean of five replications**

Figures in parentheses are √ n+0.5 transformation
Treatment mean with the letter in common are not significant

(e) Developmental period

The minimum and maximum development period were found during second (40.54 days) and fourth (78.35 days) quarters. The developmental period of bruchid was 54.85 and 50.05 days during first and third quarters, respectively and statistically at par.

(f) Adult life span

The observations on life span of male and female of bruchid manifested that female had longer life span in comparison to male during whole year. The male life span varied from 13.12 to 28.44 days, whereas female life span ranged from 18.59 to 39.06 days (Table 5 & Fig.1). The adult male and female bruchid had maximum life span during fourth quarter 28.44 and 39.06 days, respectively, while during second quarter, it was minimum 13.12 and 18.59 days, respectively. However, there was significant variation observed in female life span among different quarters.

4.1(B) Host preference

(i) Ovipositional preference

The data on ovipositional preference of the groundnut bruchid on different test host showed significant difference (Table 6 & Fig.2). Jaiphal was most preferred for egg laying with maximum number of eggs laid on it (124.27), followed by tamarind (111.14 eggs). The least preferred test host was cardamom on which only 4.17 eggs were laid. The remaining test hosts showed intermediate response to egg laying, ranging from 6.95 to 102.73 eggs. The ovipositional preference was in a descending order as jaiphal > tamarind > groundnut pods > groundnut kernel > almond > dates > cashewnut > currents > coconut > cardamom.

Table 6. Ovipositional preferences of *C. serratus* on different test hosts

Test hosts	Mean no. of eggs laid*/host
Almond	48.36
	(6.99)
Cardamom	4.17
	(2.16)[c]
Cashewnut	12.82
	(3.65)
Groundnut pods	102.73
	(10.16)
Coconut	6.95
	(2.73)[bc]
Dates	27.17
	(5.26)
Groundnut kernel	79.42
	(8.94)
Currents	7.97
	(2.91)[b]
Tamarind	111.14
	(10.80)[a]
Jaiphal	124.27
	(11.17)[a]
SEm±	0.22
CD at 5%	0.62

*** Mean of four replications**

Figures in parentheses are √ n+0.5 transformation

Treatment mean with the letter in common are at par

(ii) Developmental preference

(a) Number of eggs

The observation on number of eggs laid by the bruchid on individual test hosts had shown significant difference with a maximum number of eggs (67.73) laid on tamarind and minimum on currents (11.06). No significant variation was found in number of eggs laid among tamarind, groundnut pods and groundnut kernel. The eggs laid on almond (47.39), cardamom (39.19) and dates (43.19) were also statistically at par (Table 7 & Fig.4).

(b) Incubation period

There were no significant variations observed in the time taken by the eggs to hatch out among almond, cardamom, groundnut pod, dates, groundnut kernel and jaiphal (Table 7 & Fig.3). The maximum time for hatching was taken on cashewnut (8.80 days), followed by jaiphal (8.38 days) and dates (8.20 days). The minimum incubation was observed on tamarind (6.05 days). There was no hatching observed in coconut and currents.

(c) Larval period

The data from Table 7 & Fig.3 showed the inability of larvae to develop on dates, as no larval emergence had taken place in this test host. The larval period on remaining test hosts varied from 20.84 to 62.23 days. Jaiphal was least preferred host for development of larvae (62.23 days), which is statistically at par with cashewnut (57.72 days). The larvae took minimum period to reach pupal stage on tamarind (20.84 days), followed by groundnut pods (24.60 days).

(d) Pupal period

As seen from the Table 7 & Fig.3 the minimum pupal period was observed on tamarind (13.94 days), followed by groundnut pods (14.02 days). There were maximum pupal period was found on jaiphal (18.60 days) which was statistically at par with cardamom (17.82 days), almond (16.56 days) and cashewnut (16.39 days).

(e) Developmental period

The development period ranged from 41.36 to 89.18 days excluding coconut and currents where eggs failed to hatch and on dates where larvae failed to complete its development (Table 7 & Fig.3). The bruchid least preferred jaiphal for its development as the adults completed life cycle in 89.18 days, followed by cashewnut (82.86 days). The development period of beetle was 46.29, 48.64, 57.87 and 63.34 days on groundnut pods, groundnut kernels, almond and cardamom, respectively, while on groundnut pods and groundnut kernels showing no significant variation. Tamarind was found to be the most preferred food for the bruchid showing development period of 41.36 days.

(f) Adult emergence

A notable variation in adult emergence on ten test hosts has been manifested in Table 7 & Fig.4. The data revealed that the bruchid failed to develop as adults on coconut, currents and dates. The percent adult emergence varied from 3.20 to 48.79 per cent. The maximum adult emergence was recorded on tamarind (48.79%), followed by groundnut pods (41.27 per cent) and groundnut kernel (37.67 per cent). The lowest adult emergence observed on jaiphal (3.20%) that was at par with cashewnut (4.50 per cent).

Table 7. Biology of bruchid, *Caryedon serratus* on different test hosts

Test hosts	No. of eggs laid*	Hatching period*	Larval period*	Pupal period*	Developmental period*	Per cent Adult emergence*

Almond	47.39 (6.92)[cd]	7.57 (2.84)[ab]	33.84 (5.86)	16.56 (4.13)[ab]	57.87 (7.64)	23.64 (29.13)[#]
Cardamom	39.19 (6.30)[d]	7.51 (2.83)[ab]	38.44 (6.24)	17.82 (4.28)[a]	63.34 (7.99)	15.16 (22.95)
Cashewnut	18.68 (4.38)	8.80 (3.05)[a]	57.72 (7.63)[a]	16.39 (4.11)[ab]	82.86 (9.13)	4.50 (12.32)[b]
Groundnut Pods	62.86 (7.96)[a]	7.23 (2.78)[ab]	24.60 (5.01)[b]	14.02 (3.81)[b]	46.29 (6.84)[a]	41.27 (40.00)[a]
Coconut	26.64 (5.21)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)[c]	0.00 (0.71)	0.00 (1.28)
Dates	43.19 (6.61)[cd]	8.20 (2.95)[a]	0.00 (0.71)	0.00 (0.71)[c]	0.00 (0.71)	0.00 (1.28)
Groundnut kernel	59.41 (7.74)[ab]	7.68 (2.86)[ab]	25.41 (5.09)[b]	15.02 (3.94)[ab]	48.64 (7.01)[a]	37.67 (37.89)[a]
Currents	11.06 (3.40)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)[c]	0.00 (0.71)	0.00 (1.28)
Tamarind	67.73 (8.26)[a]	6.05 (2.56)[b]	20.84 (4.62)	13.94 (3.80)[b]	41.36 (6.47)	48.79 (44.34)
Jaiphal	49.34 (7.06)[bc]	8.38 (2.98)[a]	62.23 (7.92)[a]	18.60 (4.37)[a]	89.18 (9.47)	3.20 (10.30)[b]
SEm±	0.23	0.12	0.11	0.11	0.07	0.77
CD at 5%	0.68	0.35	0.32	0.32	0.20	2.22

*** Mean of four replications**

Figures in parentheses are √ n+0.5 transformation

Treatment mean with the letter in common are not significant

 # Figures in parentheses are arc sine value

4.2 VARIETAL PREFERENCE

(i) Ovipositional preference

As seen from the Table 8 & Fig.5, highest oviposition of 96.13 eggs from *C. serratus* was received on ICGV-93133, followed by ICGV-92267 (76.06 eggs). The least preferred germ plasm was BAU-13 on which only 0.89 eggs were laid. The remaining germ plasm showed intermediate preference to oviposition, ranging from 4.16 to 51.63 eggs. The oviposition preference was in an ascending order as BAU-13 >TKG-19A >ICGV-93388 >ICGV-92022 >ICGV-92040 >ICGV-94361 >ICGV-92218 >ICGV-92015 >ICGV-93134 >ICGV-93370 >ICGV-93420 >ICGV-92229 >GG-2 >ICGV-95136 >ICGV-93128 >ICGV-92028 >ICGV-92222 >ICGV-92267 >ICGV-93133.

(ii) Developmental preference

(a) Number of egg laid

The observations on number of eggs laid by the bruchid on individual germ plasm had shown significant variation with a maximum number of eggs (92.04) laid on ICGV-92040 and minimum on BAU-13 (4.43 eggs) (Table 9). No significant difference was observed in number of eggs laid on ICGV-92028, ICGV-94361, ICGV-92218, ICGV-92022 and ICGV-93370, which showing 27.17, 29.09, 28.12, 31.20 and 36.10 eggs, respectively. The germ plasm, CHICO (49.48 eggs), ICGV-92015 (47.80 eggs), ICGV-92267 (50.48 eggs), ICGV-92222 (47.52 eggs), ICGV-92229 (43.59 eggs), ICGV-95136 (45.20 eggs) and TKG-19A (40.46 eggs) were also at par in receiving of eggs from *C. serratus.*

(b) Hatching period

The time taken by the eggs to hatch on all the germ plasm of groundnut did not exhibit significantly difference, but varied from 4.56 to 8.56 days (Table 9). The maximum time for hatching was taken on ICGV-92222 and ICGV-93420 showing 8.56 days on each, followed by ICGV-93134 (8.26 days). The minimum incubation period was observed on ICGV-93388 (4.56 days).

(c) Larval period

The data from Table 9 clearly depicted that the bruchid larva least preferred the germ plasm ICGV-93420 for its development (34.54 days). The larval period of bruchid was, 23.90, 24.20, 24.50, 24.80, 24.90, 25.21, 25.82, 26.13, 26.54, 27.17, 28.12, 28.55, 29.31, 29.53, and 30.19 days on ICGV-94361, ICGV-93380, ICGV-92028, BAU-13, ICGV-92022, ICGV-92015, ICGV-92222, ICGV-93134, TKG-19A, ICGV-93128, CHICO, ICGV-93370, ICGV-95136, ICGV-92218 and ICGV-92229, respectively, showing no significant variation. ICGV-92040 was found to be most preferred for larva development (21.12 days), followed by ICGV-93133 (23.22 days).

(d) Pupal period

There was no significant variation recorded in pupal period among different germ plasm of groundnut. The maximum pupal period was found on ICGV-93420 (16.48 days), followed by ICGV-93133 (16.23 days). The pupal period varied from 12.17 to 16.48 days. The bruchid took minimum period to reach adult stage on ICGV-93370 (12.17 days).

(e) Developmental period

The development period ranged from 39.82 to 59.72 days was recorded (Table 9). The bruchid least preferred ICGV-93420 for its development as the adults completed life cycle in 59.72 days. The development period of bruchid was recorded significantly at par on ICGV-92015, BAU-13, TKG-19A, ICGV-93370, ICGV-93128, ICGV-93133, ICGV-92028, ICGV-93134, ICGV-92222, ICGV-92218, CHICO, ICGV-92229, ICGV-95136 and ICGV-92267 (45.33, 46.01, 46.15, 46.70, 46.97, 47.25, 47.52, 48.22, 49.20, 49.63, 49.34, 50.77, 50.91 and 55.30

days, respectively). The minimum time was taken to complete its development on ICGV-92040 (39.82 days).

(iii) Per cent weight loss

As seen from Table 9, data revealed that significant variation was observed due to feeding of *C. serratus* among different germ plasm of groundnut. The maximum per cent damage was found on ICGV-92040 (18.17 per cent), followed by ICGV-95136 (14.39 per cent). The minimum weight loss was observed on ICGV-93420 (0.07 per cent), followed by ICGV-92267 (0.16 per cent). The remaining germ plasm exhibited intermediate responses to weight loss due to feeding of feeding, ranging from 2.06 to 13.05 per cent.

4.3 Extent of damage

The quantitative and qualitative losses caused by *C. serratus* in stored groundnut pods were determined by releasing five pairs of adults in the groundnut pods. The observations on damage, weight loss, protein, oil and carbohydrate (total sugar) were recorded and have been presented under.

(i) Quantitative losses

(a) Per cent damage

The results of pod damage (Table 10 & Fig.6) depicted that the insect infestation caused 29.53 per cent damage after three months of release which increased with the storage duration resulting 96.02 per cent after nine months of storage. All the observations were found highly significant to each other. A substantial increase in damage was observed after six months (71.33 per cent).

(b) Per cent weight loss

The per cent loss in weight of groundnut pods increased with the advancement of storage period because of relative increase in the population of insect. The results (Table 10 & Fig.6) revealed that 2.23, 13.12 and 27.39 per cent weight loss of pods inflicted after three, six and nine months of insect infestation, respectively. Intensity of weight loss between six and nine months was maximum 14.27 per cent than between three and six months *i.e*. 10.89 per cent. A highly significant variation was observed in weight loss after three, six and nine months of storage.

Table 10. Effect of *C. serratus* infestation after different storage period on per cent damage and weight loss in groundnut.

Storage period (months)	Per cent damage*	Per cent weight loss*
Three	29.53 (32.92)	2.23 (8.59)
Six	71.34 (57.63)	13.12 (21.24)
Nine	96.02 (78.50)	27.39 (31.56)
SEm ±	1.07	1.16
CD at 5%	3.42	3.71

*** Mean of four replications,**

Figures in parenthesis are arc sine value

(ii) Qualitative losses

(a) Protein content

As seen from Table 11 and Fig.7 the value of protein content was observed 25.57 per cent initially, which reached 28.42 per cent after three months of storage. After that slight decrease in protein content (27.81 per cent) was observed after six months but it was more than initially protein content. Ultimately a slight decrease was seen after nine months of storage (24.29 per cent) to initially content of protein.

Table 11. Effect of *C. serratus* infestation after different storage period on per cent protein, oil and carbohydrate (total sugar) in groundnut

Storage period (months)	Per cent Protein*	% Oil Content*	% Carbohydrate (total soluble sugar)*
Initial	25.57 (30.38)[bc]	42.79 (40.86)[b]	13.22 (21.32)[a]
Three	28.42 (32.22)[a]	46.30 (42.88)[a]	13.08 (21.21)[a]
Six	27.18 (31.42)[ab]	47.26 (43.43)[a]	12.83 (20.99)[ab]
Nine	24.29 (29.53)[c]	44.76 (41.99)[ab]	12.36 (20.59)[b]
SEm ±	0.51	0.55	0.19
CD at 5%	1.57	1.69	0.58

*** Mean of four replications**

Figures in parenthesis are arc sine value

(b) Oil content

The oil content following cold percolation procedure was found to be 42.79 per cent (initially). Some increase (46.30 per cent) was noted in the oil content after three months of storage. It was continuously increased up to six months showing 47.26 per cent. After that slight decrease in oil content (44.76 per cent) was observed after nine months of storage but it was greater than initially oil content.

(c) Carbohydrate content (Total soluble sugar)

As seen from Table 11 and Fig.7 data revealed that significant variation was shown in carbohydrate due to feeding of *C. serratus* in stored groundnut. There was significant variation observed in carbohydrate after 9 months of storage but it was decreased continuously from 13.22 to 12.83 per cent. After 9 months significant decrease was observed in carbohydrate (12.36 per cent).

(D) Effect of storage receptacles

(a) Population build up

As seen from Table 12 the population build up of *C. serratus* was lowest when groundnut pods stored in the metal bins (340.27), followed by that in earthen pots (471.69) and the maximum population build up of the bruchid was in the control (1056.40). The remaining storage structures showed intermediate effect on population build up ranging from 732.28 to 803.79. While, jute bags (803.79), HDP bag (753.00) and plastic containers (732.28) were found significantly at par in population build up.

Table 12. Effect of storage receptacles on the population build up of bruchid, *C. serratus* and the loss manifested to stored groundnut

Storage structures	**Population build up***	**Per cent weight loss***	**Per cent damage***
Earthen pots	471.69 (21.73)[#]	8.86 (17.32)[b]	76.72 (61.15)[a]
Metal bins	340.27 (18.46)	6.45 (14.72)	52.18 (46.25)
Jute bags	803.79 (28.36)[a]	11.88 (20.16)[a]	86.79 (68.69)
HDPE bags	753.00 (27.45)[a]	11.13 (19.49)[a]	80.78 (64.00)[a]
Plastic containers	732.28	9.87	78.10

	(27.07)[a]	(18.31)[ab]	(62.10)[a]
Control	1056.40 (32.51)[a]	16.68 (24.11)	93.61 (75.36)
SEm±	1.07	0.70	1.32
CD at 5%	3.19	2.09	3.91

*** Mean of four replications**

Figures in parentheses are arc sine value

 # Figures in parentheses are √ n+0.5 transformation

Treatment mean with the letter in common are at par

(b) Per cent weight loss

The observations on weight loss (per cent) after six months in different storage receptacles showed minimum weight loss that in metal bins (6.45%), followed by that in earthen pots (8.86%) and the maximum loss was in control (24.11%). The weight loss was statistically at par when groundnut pods stored in plastic containers (9.87%), HDPE bags (11.13%) and jute bags (11.88%).

(c) Per cent damage

There was significant variation observed in damage when groundnut stored in storage structures and control. The pod damage was varied from 52.18 to 93.61 per cent. The minimum per cent damage was in metal bins (52.18%). The per cent damage was in a ascending order as metal bins > earthen pots > plastic containers > HDPE bags > jute bags > control.

(E) Effect of plant powders and insecticidal dusts

The plant powders and insecticidal dusts were tested for their effectiveness as protectant against groundnut bruchid, *C. serratus* (Ol.) infesting groundnut for different storage periods (after 24 hrs, 3, 6 and 9 months) on the basis of oviposition, per cent adult emergence, per cent weight loss and per cent damage and the findings are mentioned here under.

(a) Oviposition

As seen from Table 13 and Fig.8 after 24 hrs of treatment application, no oviposition was observed at both the doses of deltamethrin and malathion and 10 and 15 g/kg black pepper drupe powder treatment. Excluding the above treatments, the minimum oviposition was in black pepper 5g/kg (1.93 eggs), followed by NSKP 20 g/kg (2.96 eggs). The maximum oviposition was in control (65.76 eggs) that was at par with KSP 10, 15 and 20 g/kg (61.12, 63.66 and 60.65 eggs, respectively). In other treatments, oviposition was varied from 5.60 to 34.31 eggs.

When beetles were released after three months of storage of groundnut, zero oviposition was again observed in deltamethrin (5 & 10 g/kg), malathion (10 g/kg) and BPP (10 & 15 g/kg). The minimum egg laying was recorded in malathion 5 g/kg (13.26 eggs), followed by BPP 5 g/kg (18.77 eggs) that was at par with NSKP 20 g/kg (19.21 eggs). The maximum oviposition was recorded in the KSP 15 g/kg (68.39 eggs) that was at par with control (66.90 eggs). The treatments CASP10 g/kg, KSP 20 g/kg and KSP 10 g/kg were found at par where oviposition of 56.65, 60.96 and 62.23 eggs, respectively, was observed after three months of storage. NSKP 10 g/kg (41.36 eggs) and CASP 20 g/kg (46.97 eggs) were also found significantly at par.

Deltamethrin (5 & 10 g/kg) and BPP (15 g/kg) continued to give best protection to groundnut by checking the oviposition of *C. serratus* even when beetles were released after six months. Malathion 5 & 10 g/kg, BPP 5 & 10 g/kg and NSKP 20 g/kg checked the oviposition effectively showing 29.64, 9.23, 31.65, 19.93 and 35.26 eggs, respectively. The treatments, NSKP 15 g/kg and CASP 20 g/kg pods, were found statistically at par in checking oviposition. The maximum oviposition was observed in KSP 15 g/kg (66.58 eggs), which was statistically at par with control and KSP 10 and 20 g/kg, CASP 10 & 15 g/kg and NSKP 10 g/kg exhibiting 63.98, 64.62, 61.91, 60.97, 60.03 and 59.25 eggs, respectively.

Deltamethrin 10 g/kg continued its superiority even after nine months of storage of groundnut. Deltamethrin 5 g/kg proved to the second best treatment in keeping a check on oviposition (14.25 eggs), followed by malathion 10 g/kg (17.48 eggs). BPP 10 & 15 g/kg and malathion 5 g/kg had also shown good effect (32.91, 21.87 and 42.27 eggs, respectively) in controlling the oviposition. The oviposition in KSP, CASP and NSKP (all @ 10, 15 & 20 g/kg) was ranging from 57.26 to 68.89 eggs and statistically at par with control (64.62 eggs).

(b) Per cent adult emergence

The data pertaining to treatment in which beetles were released after 24 hours of mixing plant power (Table 14 and Fig.9) indicated that all the doses of deltamethrin, malathion, BPP and NSKP (@15&20 g/kg) showing no adult emergence and were significantly superior over all other treatments. The minimum adult emergence was in NSKP 10 g/kg (7.29 per cent). The remaining treatments exhibited maximum adult emergence in KSP 10 g/kg (40.17 per cent) that was at par with control (41.96 per cent) and KSP 5 &10 g/kg showing 37.61 and 39.73 per cent, respectively.

When beetles were released after three months of storage deltamethrin, malathion, BPP at all doses and NSKP@ 20 g/kg continued to check cent percent adult emergence in groundnut. All the treatments maintained its superiority over control (46.55 per cent) in reducing per cent adult emergence except KSP 10, 15 and 20 g/kg (42.51, 48.36 and 44.69 per cent, respectively) and found at par with control. NSKP 15 g/kg was found to be the second best treatment to check the adult emergence (14.59 per cent). NSKP 10 g/kg and CASP 15 & 20 g/kg were found at par where adult emergence of 27.93, 30.12 and 26.53 per cent, respectively.

As seen from Table 14, deltamethrin (5 & 10 g/kg), malathion (10 g/kg) and black pepper (15 g/kg) checked hundred per cent adult emergence even after six months. Malathion at 5 g/kg pods ceased the insect population effectively showing adult emergence of 13.56 per cent. The treatments CASP 20 g/kg, KSP 15 g/kg, CASP 15 g/kg, CASP 10 g/kg, KSP 20 g/kg and KSP 10 g/kg exhibiting adult emergence of 38.92, 40.31, 40.59, 41.25, 42.14 and 47.64 per cent, respectively, and found significantly at par with control (42.92 per cent). In remaining treatments, adult emergence was varied from 21.98 to 36.14 per cent.

Deltamethrin @10 g/kg continued its superiority even after nine months of storage. Deltamethrin 5 g/kg pods found to be second best treatment in keeping check on per cent adult emergence (7.02 per cent) and found significantly at par with BPP 15 g/kg (8.78 per cent). There was no significant variation recorded in adult emergence among NSKP 10 g/kg (39.22%), NSKP 15 g/kg (37.61%), CASP 10 g/kg (40.40%), CASP 15 g/kg (39.35 %), CASP 20 g/kg (37.31%), KSP 10 g/kg (40.67%), KSP 15 g/kg (41.43%), KSP 20 g/kg (39.59%) and control (40.89%) after nine months of storage.

(c) Per cent weight loss

The observations in Table 15 and Fig.10 depicted that after 24 hrs of treatment application, zero per cent weight loss was observed in stored groundnut treated with deltamethrin (5 & 10 g/kg), malathion (5 & 10 g/kg), BPP (5, 10 & 15 g/kg) and NSKP (15 & 20 g/kg). The maximum per cent weight loss was observed in control (4.29 per cent) and found at par with KSP 10, 15 & 20 g/kg pods (3.80, 3.69 and 3.78 per cent, respectively). Among different doses of CASP, per cent weight loss was varied from 0.59 to 1.54 per cent. In remaining treatments NSKP 10 g/kg gave minimum weight loss of 0.15 per cent.

After three months of storage all the doses of deltamethrin, malathion, BPP and NSKP 20 g/kg gave full protection as no weight loss was observed in groundnut. The per cent weight loss in remaining treatments were varied from 0.53 to 4.93 per cent. All the plant powders were found significantly superior over control (4.68 per cent) except KSP 10, 15 & 20 g/kg (4.17, 4.93 and 4.21 per cent, respectively). The minimum weight loss was observed in NSKP 15 g/kg (0.53 per cent), which was at par with NSKP 10 g/kg (0.90 per cent).

Similarly, after six months of storage no weight loss was observed in treatments deltamethrin (5 & 10 g/kg), malathion (10 g/kg) and BPP (15 g/kg). When the above treatments were not taken into consideration, the minimum weight loss was recorded in malathion 5 g/kg (0.61%), followed by BPP 10 g/kg (0.68%). There was no significant difference found among malathion 5 g/kg, BPP 5 & 10 g/kg, NSKP 20 g/kg. The treatments NSKP 10 g/kg, CASP 10 & 15 g/kg, KSP 10, 15 & 20 g/kg, were found significant at par where weight loss of 3.68, 3.89, 3.68, 4.78, 4.04 and 4.20 per cent, respectively, and all the treatments were at par with control (4.49 per cent).

As seen from Table 15, deltamethrin 10 g/kg continued to show no per cent weight loss event after nine months of storage. Deltamethrin 5 g/kg was proved to be second best treatment in keeping a check on per cent weight loss (0.14 per cent), followed by BPP 15 g/kg (0.24 per cent). The remaining treatments, per cent weight loss was ranged between 0.40 to 4.49 per cent. No significant difference in per cent weight loss was found among control (4.03 per cent) and KSP 10 g/kg (3.94%), KSP 15 g/kg (4.49%), KSP 20 g/kg (4.04%), CASP 10 g/kg (3.95%), CASP 15 g/kg (3.81%), CASP 20 g/kg (3.44%), NSKP 10 g/kg (3.80 %), NSKP 15g/kg (3.63 %), NSKP 20 g/kg (3.10 %) and BPP 5g/kg (2.72%).

(d) Per cent damage

The observations from Table 16 and Fig.11 indicated that after 24 hrs of treatments application, all the doses of deltamethrin, malathion, BPP and NSKP 15 & 20 g/kg completely protected groundnut showing zero per cent damage against *C. serratus* and found significantly superior over all other treatments. The per cent damage after 24 hrs in all the treatments varied from 0.00 to 48.61 per cent. All the plant materials and dusts were found significantly superior over control (47.72 per cent) except KSP 10, 15 &20 g/kg (48.61, 45.54 and 46.53 per cent, respectively). The treatment NSKP 10 g/kg was found to be second best treatment as the damage of pods was 2.66 per cent.

After three months of storage deltamethrin, malathion and black pepper at all the doses and NSKP 20 g/kg continued to give full protection as no damage was observed in groundnut. All the treatments maintained their superiority over control (55.52 per cent) in reducing the per cent damage except KSP 10, 15 and 20 g/kg (52.00, 58.08 and 53.75 per cent, respectively). The order of effectiveness of treatments in the descending order was: deltamethrin 5 & 10 g/kg = malathion 5 & 10 g/kg = BPP 5, 10 & 15 g/kg = NSKP 20 g/kg >NSKP 15 g/kg > NSKP 10 g/kg > CASP 20 g/kg > CASP 15g/kg > CASP 10 g/kg > KSP 10 g/kg >KSP 20 g/kg > KSP 15 g/kg.

Deltamethrin (5 & 10 g/kg), malathion (10 g/kg) and BPP (15 g/kg) continued to give best protection even after six months. Malathion 5 g/kg and BPP 10 g/kg checked the insect population effectively exhibiting damage of 7.96 and 8.82 per cent, respectively. The treatments BPP 5 g/kg and NSKP 20 g/kg pods were found statistically at par in checking the per cent damage. The effectiveness of treatments CASP 10, 15 & 20 g/kg and NSKP 10 & 15 g/kg had reduced after six months of storage as per cent damage increased to 50.37, 48.19, 39.76, 46.36 and 29.69 per cent, respectively. KSP 10, 15 and 20 g/kg were found to be least effective treatments giving damage of 54.36, 54.03 and 51.62 per cent, respectively.

Deltamethrin 10 g/kg continued its superiority even after nine months of storage of groundnut and were significantly superior over all other treatments. Deltamethrin 5 g/kg proved to be second best treatment in keeping a check on per cent damage (1.54 per cent), followed by BPP 15 g/kg (3.64 per cent). Malathion 5 & 10 g/kg, BPP 5 & 10 g/kg and NSKP 20 g/kg had also shown good effect in controlling the insect infestation. The treatments NSKP 10 & 15 g/kg KSP 10, 15 & 20 g/kg, CASP 10, 15 & 20 g/ kg lost their effectiveness giving 50.43, 48.39, 50.46, 54.86, 52.34, 51.07, 49.16 and 47.28 per cent damage, respectively, and all treatments were significantly at par with control (52.43 per cent).

5. DISCUSSION

With a view to have information on biology of bruchid during whole year, oviposition & developmental preference of bruchid on different test host and germplasm of groundnut and relative bio-efficacy of different plant powders and insecticidal dusts against the groundnut bruchid, *C. serratus*, the investigations were conducted.

5.1 BIOLOGY

Significant differences were recorded in number of eggs laid by the bruchid during different quarters of whole year. The first and third quarters of year *i.e.* from February to April and August to October were favoring for egg laying with 81.58 and 66.57 eggs, respectively. While, minimum eggs were laid (47.66 eggs) during second quarter of year. Appert (1956) recorded the maximum number of 1093 and 1056 eggs laid by fifty females of *C. serratus* at 27°C and 50 and 70 per cent RH, respectively. Sardesai (1961) found that average number of eggs laid per female was from 29 to 50, whereas Cancela Da Fornseca (1965) observed highest mean member of eggs (106-115) at 27.5–30^{o}C and 70 -90 per cent RH. Prevett (1953 & 1954) also recorded wide range of eggs laid from 6–99 and 2-153, respectively.

The time taken for hatching eggs was varied from 4.12 to 13.04 days among different quarters. However, the maximum and minimum time taken for hatching was observed 13.04 and 4.12 days, respectively during fourth (when temperature reach approximately below 10^{o}C) and second (when temperature reach approximately above 36^{o}C), respectively. Similar findings were reported by Mookherjee and Chawla (1964) in *C. maculatus* during whole year. Moreover, Kapadia (1995) found the incubation period of *C. serratus* on groundnut from 2-5 days with an average of 2.63 days.

The observations on larval period indicated that the duration was minimum (21.40 days) during second quarters of year, and there was no significantly variations observed in larval periods of first (26.85 days) and third (26.54 days) quarters. Mookherjee and Chawla (1964) found periods of March to May and September to November to be very much congenial for the development of *C. maculatus*. Kapadia (1995) and Calderon *et al.* (1967) found that mean larval period of *C. serratus* was 18.88 and 40-45 days (inclining oviposition), respectively.

It is evident from data that maximum and minimum pupal period were 26.33 and 15.02 days, respectively during fourth and second quarters, respectively. Caldaron *et al.* (1967) reported the pupal period to be 25-30 days. Kapadia (1995) observed mean pupal period of 12.88 days, ranging from 10-22 days. The developmental period of *C. serratus* was varied from 40.54 days to 78.35 days. There was 54.85 and 50.05 days of development period observed during first and third quarters of years and found statistically at par. Similar results were also observed in *C. maculatus* by Casewell (1956) in which the adult development period was 23-25 days after oviposition in March, November and February and 30-31 days during July to August. Kapadia (1995) and Calderon *et al.* (1967) reported that the pest completed its life cycle (egg to adult) within 82 and 65-75 days, respectively. The minimum durations of development from egg to adult was 41 days recorded at 33^0C and 90 % RH by Appert (1956). Moreover, Davey (1958) recorded the development period of *C. serratus* was 42 days at 30^0C and 91-98 days at 25^0C at 70% RH.

It is clearly depicted from data, the female life span was longer than male, and significantly varied in duration during different quarters of year. Male and female lived maximum (28.44 and 39.06 days, respectively) during fourth and minimum (13.12 and 18.59 days, respectively) during second quarter. Similarly, Kapadia (1995) also observed female life span was longer than male *i.e.* 42.20 and 27.70 days, respectively with the range of 11-69 and 12-45 days, respectively. While, Cancella Da Fornseca (1965) observed adult life span on different combination of temperatures and minimum and maximum life span of male and female was 3 and 4 days, respectively at 45^0C and 70 per cent RH and 18 and 21 days, respectively at 27.5^0 C and 75 per cent RH. Delobel (1989) reported female had a mean life span of 3 months but some individual survived up to 6 months.

5.2 HOST PREFERENCE

5.2.1 Ovipositional Preference

Investigation on ovipositional preference in free choice chamber test revealed that jaiphal was most preferred by *C. serratus* for egg laying as received maximum number of eggs (124.27), followed by tamarind (111.14 eggs). Cardamom showed least preference for egg laying, bearing only 4.17 eggs. Jaiphal was preferred due to present of maximum crevices on its surfaces. However, the surface structure and tests host play an important role for stimulating the egg laying. Similarly, Avidov *et al.* (1965) reported that the difference is the number of eggs laid might be due to ovipositional behavior of insects. Mukhtar and Sushil (1990) found that among seeds of 52 tree species, *Erythrina variegata* seeds received maximum eggs (103), while seeds of 23 species were rejected for oviposition by *C. serratus*.

5.2.2 Developmental Preference

There was significant variation observed in number of eggs laid by groundnut on different test host in separate containers. Tamarind, groundnut pod and groundnut kernel were most preferred for egg laying with 67.73, 62.86 and 59.41 eggs, respectively. While, on currents, minimum eggs were laid (11.06). Similarly, Belinsky and Kugler (1978) reported *C. serratus* preferred the seeds of *P. farcta* than groundnut seeds for oviposition.

It is evident from observation that no hatching of eggs was observed on coconut and currents, whereas maximum and minimum duration were taken on cashewnut (8.80 days) and tamarind (6.05) days, respectively. Moreover, Pandey and Singh (1997) and Raina (1970) observed in incubation period in *C. chinensis* on urd and cowpea and on green gram from 4 to 5 days and 3.5 days, respectively.

The observation on larval period indicated that the time taken for larva to reach pupal stage was maximum on jaiphal (62.23 days) and minimum on tamarind (20.84 days), showing later to be the most preferred host for *C. serratus*. No larval development was found on dates. Similar findings were obtained by Mital and Khanna (1967). Moreover, Mukhtar and Sushil (1990) found egg laying on *Erythrina variegata*, in which adult did not develop.

As seen from data, minimum pupal period was observed on tamarind (13.94 days) and maximum on jaiphal (18.60 days). The developmental period of *C. serratus* ranged from 41.36 to 89.18 days, with maximum period of 89.18 days on jaiphal and minimum period of 41.36 days on tamarind. This supports the view that tamarind was the most preferred food for the development. It was observed that the oviposition preference had no relation with the development of the insect. Lale and Maina (2002) reported that large adult progeny of *C. serratus* were develop on tamarind (TA-II and TA-IV).

The result indicated maximum adult emergence on tamarind (48.79 %), while minimum on jaiphal (3.20 per cent). On coconut and currents eggs were not hatch, while on dates, larvae unable to complete its development, so they were found completely unfit for development of the beetle as no adult emergence. It is suggested that chemical composition of host play a vital role to complete its life cycle for development. Mukhtar and Sushil (1990) found that no adult emergence on *Erythrina variegata,* while its got maximum number of eggs. Devi and Rao (2000) observed 3 to 22 per cent adult emergence of *C. serratus*.

5.3 VARIETAL PREFERENCE

5.3.1 Ovipositional Preference

Highest ovipostion of 96.13 eggs from *C. serratus* was received on ICGV-93133, while minimum on BAU-13 (0.89 eggs). The remaining germplasm showed intermediate preference to oviposition, ranging from 4.16 to 51.63 eggs in free choice chamber test. Similarly Mital (1969) showed that maximum number of eggs laid by *C. gonagra* on improved Spanish. While ICGV-92040 was most preferred for egg laying with 92.04 eggs and minimum number of eggs on BAU-13 (4.43 eggs), among different germplasm of groundnut, when experiment conducted in separate container. Devi and Rao (2000) found that significantly higher number of eggs was laid on TCGS-91 followed by ICGS-11. Ghorpade *et al.* (1998) recorded minimum number of eggs laid by *C. serratus* on ICGS-11 and maximum on JL – 24.

5.3.2 Developmental Preference

The time taken for hatching of eggs varied from 4.56 to 8.56 days on different germplasm with no significant variation. However, the maximum time taken for hatching was observed ICGV-92222 and ICGV-93420 showing 8.56 days on each and minimum on ICGV-93388 (4.56 days). Kapadia (1995) observed 2.63 days of incubation period of *C. serratus* on groundnut germplasm.

It is manifested from data that the bruchid larvae least preferred the germplasm ICGV-93420 (34.54 days), while ICGV-92040 was most preferred for larval development (21.12 days). Mital (1969) observed maximum larval period of 60.25 days on TMV-3 and minimum on TMV-2 (33.50) days. While Kapadia (1995) found maximum larval period on J-11 (30.94 days) and minimum on GG-2 (26.78 days). He recorded no significant variation in pupal period among different germplasm of groundnut. The maximum period was found on ICGV-93420 (16.48 days) and minimum on ICGV-93370 (12.17 days). Kapadia (1995) found minimum pupal period of JL-11 (15.82 days), and there was no significant variation observed in pupal period on JL-24, GG-2 and GAUG-10.

The developmental period of *C. serratus* varied from 39.82 days to 59.72 days with maximum period of 59.72 days on ICGV-93420 and minimum periods of 39.82 days on ICGV-92040. This supports the view that ICGV-92040 was the most favorable germplasm for development. Gorphade *et al*. (1998) found that every development period of *C. serratus* was minimum in SB-11 (62.22 days), while it was maximum on RVB-1 (98.17 days). Shiwalingaswamy and Balasubramanium (1992) reported that development of *C. serratus* was 45.22 and 46.70 days on ICGS-11 and JL-24, cultivars, respectively. The pod reticulation seems to be the major biophysical character that influences the bruchid development beside other parameter of the host (Devi and Rao, 2000).

The observations on per cent weight loss revealed that it was maximum on ICGV-92040 (18.17 %) and minimum on ICGV-93420 (0.07 %). The ICGV-92040 was observed susceptible germplasm on the basis of egg laying, developmental period and percent weight loss caused by *C. serratus* on its. Mital (1969) found that maximum per cent weight loss on TMV-2 (7.36 per cent) and minimum on RS-1 (0.26 per cent). Similarly, Gorphade *et al.* (1998) observed maximum and minimum loss on RVB-1 (22.93 per cent) and ICGS-11 (3.17 per cent), respectively. While Devi and Rao (2000) exhibited that TCGS-88 got minimum weight loss (0.57 per cent) and TPT-4 got maximum weight loss (8.51%).

5.4 EXTENT OF DAMAGE

Heavy damage caused by bruchid species in storage. The extent of losses caused by a particular species varies from host to host depending upon the host suitability of oviposition and development. The density of insects ultimately reflects in the quantum losses both quantitative and qualitative.

5.4.1 Quantitative Losses

5.4.1.1 Per cent damages

Damages to the pods, which the ultimate effect of the bruchid infestation was more or less parallel to the population of the bruchid, *C. serratus* in groundnut pod. The findings revealed that the initial damage after 3 month was 29.53 per cent, which increased abruptly in the six month of storage (71.33 per cent) due to fast population build up of bruchid. After nine month of storage (96.02 per cent) damage was observed. Singh and Bhandari (1987) recorded 100% loss of the seed crops of acacias due to *C. serratus*, while Singh and Toky (1990) revealed that 6.8 per cent damage in *A. nilotica*. Doharey *et al.* (1987) also observed that same trend in seed loss caused by *C. chinensis* with an initial loss of 1.35 per cent, gradually increasing to 99.91% after 120 days of storage period.

5.4.1.2 Percent weight loss

The grubs of the bruchid feeding inside the groundnut pods cause the loss in weight. The weight loss was initially 2.23 per cent after three month of storage. However, due to fast multiplication of the bruchid population in subsequent storage period upto nine month, the loss to groundnut pods increased tremendously reaching 27.39 per cent. Earlier Hall (1954) found 2.4 to 16 per cent loss in stored groundnut. Dick (1987) found that *C. serratus* was responsible to caused approximately 20% weight loss in groundnut kernel after five month of storage.

5.4.2 Qualitative Losses

5.4.2.1 Protein content

Various reports are found in literature with respects to the changes in various seed constituents in the oil and protein fractions are of greater metabolic significance, due to their functional properties. Decrease in protein content has been reported in seeds of peanut (Jiang and Sung, 1994; Dudu *et al.*, 1996), Sunflower (Dadlani *et al.*, 1995). In the present study upto six month increased in protein content was found. However, the increase was more profound due to *C. serratus* infestation and accelerate aging. The initial protein content was 25.57 per cent, which was reached 24.29 per cent after nine month of storage with slight decrease.

5.4.2.2 Oil content

It is evident from values that a slight increase was observed in oil content after periods of nine month. There was initially 42.79 per cent oil content present, which increased up to 44.76 per cent in groundnut after nine month of storage. Similar findings were obtained by Dudu *et al.* (1996) and Fairchild *et al.* (1954). They found that the oil content of groundnut generally increased with increasing storage time and quality of oil seeds deteriorate due to insect infestation.

5.4.2.3 Carbohydrate content

It is evident from data, that significant variation was observed in per cent carbohydrate content of groundnut after 9 months of storage. Reduction in carbohydrate was observed from 13.22 to 12.36 per cent after 9 months of storage. Similar finding was observed by Vijay (2000). He found some decrease in total soluble sugar content in maize and soybean after 15 months of storage. The above results are in line with the investigation made by Singh and Yadav (1987) and found that the amount of total sugar was decrease.

5.5 STORAGE STRUCTURES

After six month of storage, based on the three parameters, the lowest damage was recorded when groundnut was stored in metal bin (51.18 per cent) whereas the maximum damage was in the control (93.61 per cent). Observation on weight loss after six month in different storage receptacle showed that the loss was minimum in metal bin (6.45 per cent) and maximum in the control (24.11 per cent). Much alike, the population build up was minimum in metal bin (340.27). Earlier various reports on the estimation of losses showed minimum damage in metal container due to insect infestation. Zutsi (1966) reported 2 per cent loss to wheat, stored in metal bin. Dhaliwal (1972) reported 1.66 percent after a month of storage of wheat and Sonelal *et al.* (1987) reported 6 per cent weight loss of wheat stored in metal container. Daniel *et al* (1977a) reported that the population of *C. chinensis* multiplied to 14, 118, 233 and 295 insects per 100 g after 1, 2, 3 and 4 months of initially infestation.

5.6 EFFECT OF PLANT POWDERS AND INSECTICIDAL DUSTS

The effect of different plant products and insecticidal dusts against *C. serratus* on oviposition, adult emergence (%), weight loss (%) and damage (%) in groundnut for different periods indicated that there was no oviposition, adult emergence, weight loss and damage observed after 24 hrs, 3, 6 and nine months when deltamethrin (10g/kg) was used. Deltamethrin 5 g/kg, malathion 10 g/kg and black pepper powder (10 and 15 g/kg) afforded effective to check oviposition, adult emergence, weight loss and damage caused by *C. serratus* even after nine months. While CASP (10 &15 g/kg) and NSKP (10 g/kg) was found ineffective after six months of storage. The treatments NSKP (15 & 20 g/kg), CASP (20 g/kg) were found to be ineffective after nine months of storage and was at par with control (except adult emergence and damage per cent). Karanj seed powder (10, 15, and 20 g/kg) was found ineffective even after 24 hrs of treatment application, besides this, it also observed that the oviposition, adult emergence, weight loss and damage were higher than control. Earlier workers reported plant powders and insecticidal dusts to be effective in the management of groundnut bruchid. Deltamethrin provided complete protection of groundnut (Lafleur, 1994) and found highly toxic to adults (Daglish *et al.,* 1992). Similarly synthetic pyrethroid, fenvelerate at 4 g/kg showed quick action and killed *Caryedon* larva and adults and gave protection to groundnut upto 180 days (Ghanekar *et.al*., 1996 and Cardet *et al.,*1998). Similarly, Kumari *et al*., (1998) found that malathion (15 g/kg) was effective to give 100 percent protection to groundnut upto four months and observed that NSKP at 25 g/kg was ineffective to check *C. serratus*. Custard apple seed powder provided complete protection to gram (Pandey and Verma, 1997). Similarly working on plant products (Juneja and Patel, 1994) reported that black pepper and custard apple at 5 part/100 parts of green gram (w/w) gave 100 % adult mortality and completely prevented female from egg laying. Sundria *et al.,* (2001) demonstrated that black pepper powder was the best grain protectant showing zero percent damage even after four months of storage, which was followed by NSKP (20 g/kg).

6. SUMMARY

Finding on the investigation entitled "Bio-ecology and management of groundnut bruchid, *Caryedon serratus* (Ol.) in groundnut" are summarized as under.

The duration of February to April was most favorable for egg laying of *C. serratus*, at which it laid maximum number of eggs (81.58), while minimum 47.66 eggs were laid during May to July. The studies on development of bruchid, revealed that maximum time (13.04 days) taken for hatching was observed during November to January and minimum (4.12 days) during May to July. The bruchid larvae took maximum period to reach pupal stage during November to January (38.69 days) and there was no significant difference observed in larval period during first (26.85 days) and third (26.54 days) quarters. The pupal period was recorded maximum (26.33 days) and minimum (15.02 days) during fourth and second quarters of whole year, respectively. The total developmental of bruchid varied from 40.54 to 78.35 days and there was no significant variation found during first (54.85 days) and third (50.95 days) quarters. Maximum life span of male and female was recorded during November to January, which was 28.44 and 39.06 days, respectively, where as minimum during second quarters (13.12 & 18.59 days, respectively). There was significant variation observed in female life span among different quarters of whole year.

Jaiphal was most preferred by bruchid for eggs laying (124.27), while the least preferred test host was cardamom (4.17 eggs). During studies on developmental preferences of bruchid, exhibited that individually tamarind, groundnut pods and groundnut kernel were preferred for egg laying with 67.73, 62.86 and 59.41 eggs, respectively. Minimum time taken for hatching was observed on tamarind (6.05 days). However, no hatching was observed in eggs laid on coconut and currants. On jaiphal, larva took 62.23 days to reach the pupal stage, which was maximum time taken on any of the test host. It is evident that pupal period was minimum on tamarind (13.94 days) and maximum on jaiphal (18.60 days). The total developmental period for bruchid ranged from 41.36 to 89.18 days with maximum time taken on jaiphal and minimum on tamarind, depicting the tamarind was the most suitable host for the development. It was also observed that the oviposition preference had no relation with development of the bruchid. The adult emergence was maximum on tamarind (48.79 per cent) and minimum on jaiphal (3.20 per cent). No adult emerged on coconut, current and dates, which showed that they were completely unfit for development of the bruchid.

ICGV- 93133 was received maximum eggs (96.13) in free choice chamber tests, while the least preferred germplasm was BAU-13 (4.43 eggs). In developmental studies, ICGV-92040, ICGV-93133, ICGV-93134 and ICGV-93388 were preferred for egg laying with 92.04, 67.23, 64.79 and 62.07 eggs, respectively. Maximum incubation period was recorded on ICGV-92222 and ICGV-93420 showing 8.56 days on each. However, there was no significant difference observed in the hatching period on germplasm of groundnut. On ICGV-92040, the larva took 21.12 days to reach the pupal stage, which was minimum time taken on any of the germplasm. There was no significant variation observed in pupal period on different germplasm of groundnut. The developmental period was varied from 39.86 to 59.72 days with maximum time upon ICGV-93420 and minimum on ICGV-92040, manifested that the ICGV-93420 was relatively less susceptible to damage of bruchid. Similarly, maximum weight loss (18.17 per cent) was observed on ICGV-92040 and minimum on ICGV-93420 (0.07 per cent).

The studies made regarding to quantitative and qualitative damage caused by *C. serratus* to groundnut depicted that damage was directly proportional to population of bruchid. After three months, the damage was low *i.e*. 29.53 per cent, which increased abruptly up to 96.02 per cent after nine months of storage. The weight of stored groundnut was reduced 2.23 and 27.39 per cent after three and nine months of storage, respectively. The studies made on the effect of infestation of this bruchid on the protein, oil and carbohydrate showed that the total protein content was decreased from 25.57 to 24.29 per cent, whereas overall increase observed in oil content (42.79 to 44.76 per cent) after nine months of storage. Carbohydrate content was continuously decreased after three months (13.22 per cent) to nine months (12.36 per cent) of storage.

Among different storage receptacles, population build up, per cent damage and per cent weight loss was recorded minimum (340.27 adults, 52.18 & 6.45 per cent, respectively) when groundnut was stored in the metal bin, whereas, the corresponding values were maximum in the control after six months of storage.

Efficacy of plant powders and insecticidal dusts in protecting groundnut from *C. serratus*, showed that after 24 hrs of treatment application, deltamethrin (5 & 10 g/kg), malathion (5 & 10 g/kg) and BPP (10 & 15 g/kg) were the best protectants and there was no eggs laying observed. At 15& 20 g/ kg of NSKP including above said treatments were showing zero per cent adults emergence, weight loss and damage after 24 hrs of treatment application. Deltamethrin (5 & 10 g/kg), malathion (10 g/kg) and BPP (10 & 15 g/kg) were equally effective after three months of storage except malathion (5 g/kg). At all the doses of deltamethrin, malathion, BPP and NSKP (20 g/kg) continued to gave full protection as no adult emergence, weight loss and damage were observed in stored groundnut. Excluding above treatments, minimum adult emergence, weight loss and damage were found in NSKP at 15 g/kg (14.59, 0.53 & 6.68 per cent, respectively). Even after six months of storage period, the groundnut pods treated with deltamethrin (5 & 10 g/kg) and BPP (15g/kg) showed no oviposition, while there was no per cent adult emergence, weight loss and damage observed on groundnut pods when treated with malathion (10 g/kg) and above said treatments. BPP 10 g/kg, malathion 5 g/kg, BPP 5 g/kg and NSKP 20g/kg pods followed these treatments. Nine months after storage deltamethrin (10 g/kg) was the only treatment to retain its effectiveness (no oviposition, zero per cent adult emergence, weight loss and damage). Deltamethrin 5 g/kg was next to deltamethrin 10 g/kg in protecting groundnut, followed by BPP 15 g/kg and malathion 10 g/kg. The treatments NSKP 20 g/kg, BPP 5 & 10 g/kg afforded effective protection against the bruchid damage after nine months as compared to control which showing 64.62 eggs, 40.89, 4.03 and 52.43 per cent, oviposition, adult emergence, weight loss and damage, respectively.

Table 8. Ovipositional preference of bruchid, *C. serratus* among different groundnut germplasm

Germplasm	*Mean number of eggs laid* /* **10 pods of groundnut germplasm**
ICGV-92015	23.31 (4.88)^{ef}
ICGV-93420	31.65 (5.67)^{cdef}
ICGV-92028	47.94 (6.96)^{ab}
ICGV-93370	27.27 (5.27)^{def}
ICGV-92222	51.63 (7.22)^{a}
ICGV-93388	5.55 (2.46)^{j}
ICGV-93128	42.27 (6.54)^{abc}
ICGV-92040	11.13 (3.41)^{hi}
ICGV-94361	14.63 (3.89)^{gh}
ICGV-92267	76.06 (8.75)
ICGV-93133	96.13 (9.83)
ICGV-92229	32.56 (5.75)^{cde}
ICGV-92218	21.97 (4.74)^{fg}
ICGV-93134	24.20 (4.97)^{ef}
ICGV-92022	8.20 (2.95)^{ij}
BAU-13	0.89 (1.18)
GG-2	34.66 (5.93)^{cd}
TKG-19A	4.16 (2.16)^{j}
ICGV-95136	36.47 (6.08)^{bcd}

SEm±	0.24
CD at 5%	0.68

*** Mean of three replications**

Figures in parentheses are √ n+0.5 transformation

Treatment mean with the letter in common are at par

Table 9. Biology of bruchid, *Caryedon serratus* on different germplasm of groundnut

Germplasm	No. of eggs laid*	Hatching period*	Larval period*	Pupal period*	Developmental period*	Per cent weight loss*
ICGV-92015	47.80 (6.95)^{cd}	5.80 (2.51)	25.21 (5.07)^{cde}	14.17 (3.83)	45.33 (6.77)^{bcd}	5.67 (13.78)^{h}
CHICO	49.48 (7.07)^{c}	5.55 (2.46)	28.12 (5.35)^{abcd}	15.58 (4.01)	49.34 (7.06)^{abcd}	12.63 (20.82)^{bcd}
ICGV-92028	27.17 (5.26)^{hi}	7.91 (2.9)	24.50 (5.00)^{cde}	14.79 (3.91)	47.52 (6.93)^{bcd}	10.72 (19.11)^{bcdef}
ICGV-93370	36.10 (6.05)^{efgh}	5.90 (2.53)	28.55 (5.39)^{abcd}	12.17 (3.56)	46.70 (6.87)^{bcd}	11.14 (19.5)^{bcde}
ICGV-92040	92.04 (9.62)	5.26 (2.4)	21.12 (4.65)^{e}	13.26 (3.71)	39.82 (6.35)^{d}	18.17 (25.23)^{a}
ICGV-93388	62.07 (7.91)^{ab}	4.56 (2.25)	24.20 (4.97)^{cde}	13.49 (3.74)	42.40 (6.55)^{cd}	8.80 (17.26)^{efg}
ICGV-93128	38.44 (6.24)^{defg}	6.79 (2.70)	27.17 (5.26)^{abcde}	12.82 (3.65)	46.97 (6.89)^{bcd}	6.03 (14.21)^{gh}
ICGV-92222	47.52 (6.93)^{cd}	8.56 (3.01)	25.82 (5.13)^{cde}	14.55 (3.88)	49.20 (7.05)^{abcd}	7.73 (16.14)^{fgh}
ICGV-94361	29.09 (5.44)^{gh}	6.21 (2.59)	23.90 (4.94)^{cde}	13.19 (3.70)	43.59 (6.64)^{cd}	4.98 (12.9)^{h}
ICGV-92267	50.48 (7.14)^{bc}	6.47 (2.64)	33.26 (5.81)^{ab}	15.26 (3.97)	55.30 (7.47)^{ab}	0.16 (2.34)^{i}
ICGV-93133	67.23 (8.23)^{a}	7.57 (2.84)	23.22 (4.87)^{de}	16.23 (4.09)	47.25 (6.91)^{bcd}	9.33 (17.78)^{def}

ICGV-92229	43.59 (6.64)^{cde}	5.55 (2.46)	30.19 (5.54)^{abc}	14.87 (3.92)	50.77 (7.16)^{abc}	9.00 (17.46)^{efg}
ICGV-92218	28.12 (5.35)^{h}	5.45 (2.44)	29.53 (5.48)^{abcd}	14.25 (3.84)	49.63 (7.08)^{abcd}	12.15 (20.4)^{bcde}
ICGV-93134	64.79 (8.08)^{a}	8.26 (2.96)	26.13 (5.16)^{bcde}	13.56 (3.75)	48.22 (6.98)^{bcd}	10.23 (18.65)^{cdef}
ICGV-92022	31.20 (5.63)^{fgh}	4.56 (2.25)	24.90 (5.04)^{cde}	13.86 (3.79)	43.46 (6.63)^{cd}	12.37 (20.59)^{bcde}
ICGV-93420	19.93 (4.52)^{i}	8.56 (3.01)	34.54 (5.92)^{a}	16.48 (4.12)	59.72 (7.76)^{a}	0.07 (1.55)^{i}
GG-2	51.20 (7.19)^{ab}	4.98 (2.34)	23.22 (4.87)^{de}	15.02 (3.94)	43.59 (6.64)^{cd}	2.06 (8.26)
TKG-19A	40.46 (6.40)^{cdef}	5.26 (2.40)	26.54 (5.20)^{bcde}	14.25 (3.84)	46.15 (6.83)^{bcd}	13.05 (21.18)^{bc}
ICGV-95136	45.20 (6.76)^{cde}	8.14 (2.94)	29.31 (5.46)^{abcd}	13.04 (3.68)	50.91 (7.17)^{abc}	14.39 (22.29)^{ab}
BAU-13	4.43 (2.22)	6.56 (2.66)	24.80 (5.03)^{cde}	14.48 (3.87)	46.01 (6.82)^{bcd}	9.00 (17.46)^{efg}
SEm± CD at 5%	0.28 0.81	0.23 NS	0.23 0.66	0.24 NS	0.26 0.73	1.17 3.34

*** Mean of three replications**

Figures in parentheses are √ n+0.5 transformation

 # Figures in parentheses are arc sine value

Treatment mean with the letter in common are at par

Table 13. Effect of plant powders and insecticidal dust on the oviposition of bruchid, *C. serratus* at different storage periods

Treatments	After 24 hrs*	After Three months*	After six months*	After nine months*
NSKP 10 g	13.64 (3.76)	41.36 (6.47)[f]	60.03 (7.78)[b]	61.91 (7.90)[ab]
NSKP 15 g	5.60 (2.47)	23.22 (4.87)[g]	49.63 (7.08)[c]	61.59 (7.88)[ab]
NSKP 20 g	2.96 (1.86)[b]	19.21 (4.44)[gh]	35.26 (5.98)[d]	57.26 (7.60)[bc]
BPP 5 g	1.93 (1.56)[b]	18.77 (4.39)[h]	31.65 (5.67)[de]	51.34 (7.20)[c]
BPP 10 g	0.00 (0.71)	0.00 (0.71)	19.93 (4.52)	32.91 (5.78)
BPP 15 g	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	21.87 (4.73)[d]
KSP 10 g	61.12 (7.85)[a]	62.23 (7.92)[abc]	64.62 (8.07)[a]	62.54 (7.94)[ab]
KSP 15 g	63.66 (8.01)[a]	68.39 (8.30)[a]	66.58 (8.19)[a]	68.89 (8.33)[a]
KSP 20 g	60.65 (7.82)[a]	60.96 (7.84)[bc]	61.91 (7.90)[ab]	64.95 (8.09)[ab]
CASP 10 g	34.31 (5.90)	56.65 (7.56)[cd]	60.97 (7.84)[b]	63.98 (8.03)[ab]
CASP 15 g	23.90 (4.94)	51.34 (7.20)[de]	59.25 (7.73)[b]	60.34 (7.80)[b]

CASP 20 g	18.25 (4.33)	46.97 (6.89)[ef]	51.34 (7.20)[c]	58.64 (7.69)[bc]
Malathion 5 g	0.00 (0.71)	13.26 (3.71)	29.64 (5.49)[e]	42.27 (6.54)
Malathion 10 g	0.00 (0.71)	0.00 (0.71)	9.23 (3.12)	17.48 (4.24)[de]
Deltamethrin 5 g	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	14.25 (3.84)[e]
Deltamethrin 10 g	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
Control	65.76 (8.14)[a]	66.90 (8.21)[ab]	63.98 (8.03)[ab]	64.62 (8.07)[ab]
SEm ± CD at 5%	0.12 0.33	0.15 0.44	0.12 0.33	0.17 0.49

*** Mean of three replications**

Figures in parentheses are √ n+0.5 transformation

Treatment mean with the letter in common are at par

Table 14. Effect of plant powders and insecticidal dust on adult emergence (%) of bruchid, *C. serratus* at different storage periods

Treatments	**After 24**	**After Three**	After six months*	**After nine**

	hrs*	months*		months*
NSKP 10 g	7.29 (15.73)	27.93 (31.93)^{c}	36.14 (36.98)^{c}	39.32 (38.86)^{a}
NSKP 15 g	0.00 (1.28)	14.59 (22.49)	30.08 (33.29)^{d}	37.61 (37.85)^{ab}
NSKP 20 g	0.00 (1.28)	0.00 (1.28)	22.67 (28.46)^{e}	34.50 (35.99)^{b}
BPP 5 g	0.00 (1.28).	0.00 (1.28)	22.57 (31.71)^{d}	34.16 (35.79)^{b}
BPP 10 g	0.00 (1.28)	0.00 (1.28)	21.98 (27.99)^{e}	26.30 (30.88)
BPP 15 g	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	8.78 (17.28)^{c}
KSP 10 g	40.17 (39.36)^{a}	42.51 (40.72)^{b}	47.64 (43.67)^{a}	40.67 (39.62)^{a}
KSP 15 g	37.61 (37.86)^{a}	48.36 (44.09)^{a}	40.31 (39.44)^{bc}	41.43 (40.07)^{a}
KSP 20 g	39.73 (39.11)^{a}	44.69 (41.98)^{ab}	42.14 (40.51)^{b}	39.59 (39.02)^{a}
CASP 10 g	29.35 (32.83)	34.70 (36.12)	41.25 (39.99)^{b}	40.40 (39.49)^{a}
CASP 15 g	23.59 (29.09)^{b}	30.13 (33.32)^{c}	40.59 (39.61)^{bc}	39.35 (38.87)^{a}
CASP 20 g	21.08 (27.36)^{b}	26.53 (31.04)^{c}	38.92 (38.63)^{bc}	37.31 (37.67)^{ab}
Malathion 5 g	0.00	0.00	13.56	21.70

	(1.28)	(1.28)	(21.65)	(27.76)
Malathion 10 g	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	15.24 (23.02)
Deltamethrin 5 g	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	7.02 (15.36)[c]
Deltamethrin 10 g	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)
Control	41.96 (40.41)[a]	46.55 (43.05)[ab]	42.92 (40.96)[ab]	40.89 (39.75)[a]
SEm ± CD at 5%	1.29 2.63	1.25 2.54	1.37 2.78	1.23 2.51

*** Mean of three replications**

Figures in parentheses are arc sine value
Treatment mean with the letter in common are at par

Table 15. Effect of plant powders and insecticidal dust against bruchid, *C. serratus* on weight loss (%) in stored groundnut at different storage periods

Treatments	**After 24 hrs***	**After Three months***	After six months*	**After nine months***

NSKP 10 g	0.15 (2.58)	0.90 $(5.59)^{cd}$	3.68 $(11.06)^{abc}$	3.80 $(11.31)^{ab}$
NSKP 15 g	0.00 (1.28)	0.53 $(4.36)^{d}$	2.32 $(8.86)^{cd}$	3.63 $(11.05)^{ab}$
NSKP 20 g	0.00 (1.28)	0.00 (1.28)	1.24 $(6.51)^{ef}$	3.10 $(10.22)^{ab}$
BPP 5 g	0.00 (1.28)	0.00 (1.28)	1.33 $(6.75)^{def}$	2.72 $(9.59)^{b}$
BPP 10 g	0.00 (1.28)	0.00 (1.28)	0.68 $(4.92)^{f}$	1.33 $(6.76)^{c}$
BPP 15 g	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	0.24 $(3.09)^{de}$
KSP 10 g	3.80 $(11.32)^{a}$	4.17 $(11.86)^{a}$	4.78 $(12.70)^{a}$	3.94 $(11.52)^{ab}$
KSP 15 g	3.69 $(11.15)^{a}$	4.93 $(12.89)^{a}$	4.04 $(11.66)^{ab}$	4.49 $(12.30)^{a}$
KSP 20 g	3.78 $(11.29)^{a}$	4.21 $(11.91)^{a}$	4.20 $(11.90)^{a}$	4.04 $(11.67)^{ab}$
CASP 10 g	1.54 (7.24)	2.52 $(9.22)^{b}$	3.89 $(11.45)^{ab}$	3.95 $(11.53)^{ab}$
CASP 15 g	0.89 $(5.56)^{b}$	1.98 $(8.19)^{b}$	3.68 $(11.14)^{abc}$	3.81 $(11.33)^{ab}$
CASP 20 g	0.59 $(4.59)^{b}$	0.97 $(5.80)^{c}$	2.66 $(9.47)^{bc}$	3.44 $(10.77)^{ab}$
Malathion 5 g	0.00 (1.28)	0.00 (1.28)	0.61 $(4.66)^{f}$	1.40 $(6.91)^{c}$
Malathion 10 g	0.00	0.00	0.00	0.40

	(1.28)	(1.28)	(1.28)	(3.86)[cd]
Deltamethrin 5 g	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	0.14 (2.46)[de]
Deltamethrin 10 g	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)[e]
Control	4.29 (12.02)[a]	4.68 (12.57)[a]	4.49 (12.31)[a]	4.03 (11.65)[ab]
SEm ± CD at 5%	0.63 1.28	0.63 1.25	1.13 2.29	1.12 2.27

*** Mean of three replications**

Figures in parentheses are arc sine value

Treatment mean with the letter in common are at par

Table 16. Effect of plant powders and insecticidal dust against bruchid, *C. serratus* on damage (%) in stored groundnut at different storage periods

Treatments	After 24 hrs*	After Three months*	After six months*	After nine months
NSKP 10 g	2.66 (9.48)	15.22 (23.22)	46.36 (42.94)^{b}	50.43 (45.28)^{ab}
NSKP 15 g	0.00 (1.28)	6.68 (15.04)	29.69 (33.05)	48.39 (44.11)^{ab}
NSKP 20 g	0.00 (1.28)	0.00 (1.28)	15.91 (23.55)^{c}	40.59 (39.61)^{cd}
BPP 5 g	0.00 (1.28)	0.00 (1.28)	17.45 (24.73)^{c}	34.96 (36.28)^{d}
BPP 10 g	0.00 (1.28)	0.00 (1.28)	8.82 (17.33)^{d}	18.31 (25.37)^{e}
BPP 15 g	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	3.64 (11.07)^{fg}
KSP 10 g	48.61 (44.23)^{a}	52.00 (46.29)^{b}	54.36 (47.53)^{a}	50.46 (45.29)^{ab}
KSP 15 g	45.54 (42.47)^{b}	58.20 (49.75)^{a}	54.03 (47.34)^{a}	54.86 (47.82)^{a}
KSP 20 g	46.53 (43.04)^{ab}	53.75 (47.15)^{b}	51.62 (45.96)^{ab}	52.34 (46.37)^{ab}
CASP 10 g	19.75 (26.42)	38.58 (38.43)	50.37 (45.24)^{ab}	51.07 (45.64)^{ab}
CASP 15 g	11.31	28.64	48.19	49.16

	(19.70)	(32.39)	(43.99)[ab]	(44.55)[ab]
CASP 20 g	8.67 (17.18)	22.31 (28.22)	39.76 (39.09)	47.28 (43.47)[bc]
Malathion 5 g	0.00 (1.28)	0.00 (1.28)	7.96 (16.45)[d]	18.10 (25.22)[e]
Malathion 10 g	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	5.34 (13.43)[f]
Deltamethrin 5 g	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	1.54 (7.25)[g]
Deltamethrin 10 g	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)	0.00 (1.28)
Control	47.72 (43.72)[ab]	55.52 (48.20)[ab]	52.32 (46.36)[ab]	52.43 (46.42)[ab]
SEm ±	0.63	1.06	1.79	1.99
CD at 5%	1.28	2.14	3.64	4.05

*** Mean of three replications**

Figures in parentheses are arc sine value

Treatment mean with the letter in common are at par

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