Chapter-II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

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

2.1.1. Occurrence

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

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

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

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

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

2.1.2. Nature of infestation

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

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

2.1.3. Occurrence of parasitoids of *Callosobruchus* spp.

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

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

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

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

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

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

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

2.4. Host preference and relative susceptibility of pulses to bruchids

2.4.1. Host preference of C. *chinensis*

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

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

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

Srivastava and Pant (1990) studied the growth and development of *C. chinensis* on seeds of 11 legumes. The preferred legumes were lentil, green gram *(V. radiata),* red gram *(Cajanus cajan),* bengal gram (*Cicer arietinum*) and cowpea (*V. unguiculata).* Pea and grass pea (*Lathyrus sativus)* was less preferred. Bhut (black-seeded soybean), soybean, black gram *(V. mungo)* and kidney bean (*Phaseolus vulgaris*) were unsuitable for growth and development of the pest. In a laboratory observation made by Dwivedi and Sharma (1993) on 7 different pulses where cowpea and soybeans were the most and least preferred food of *C. chinensis* respectively. Ahmed *et al.* (1991) studied genetic resistance in chickpeas (*Cicer arietinum) to C. chinensis* attack. Grain of 47 varieties was evaluated for number of damaged seeds, number of emergence holes and seed coat texture after exposed to the bruchid beetle using a free choice test. Varieties with a rough, hard, wrinkled and thick seed coat showed less seed damaged and were therefore, more resistance than varieties with small, soft and thin seed coats. Correlation between the 2 damage parameters was positive and highly significant. Oviposition and development of *C. maculatus* on 9 legume seeds was studied during survey and storage conditions in the Bundelkhand Region of Madhya Pradesh. Bengal gram was most preferred both under no choice conditions, bruchids developed in green gram, cowpeas, lentils and red gram only. The survey results also showed similar trends. (Roy and Roy,1994). Bhagwati *et al.,* (1995) reported that the development period of *C. chinensis* varied from 19 to 22.67 days in different genotypes of pea. Sison *et al.* (1996) reported that the total developmental period (egg to adult emergence) for the bruchid ranged from 21 to 30 days. Pupation took place in a cell inside the seed and the adults emerged through the entrance hole made by the larva. Pandey (1997) studied the biology of *C. chinensis* on black gram (*V. mungo*) and chickpea (*Cicer arientinum*) seeds at 28 ± 2^0C and 70±5% r.h. The incubation period was found to be lasted for 4-5 days and the larval-pupal period varied from 20 to 28 days. The mortality during the development from egg to adult stage was 24% while working on the life history of *C. chinensis* on mung bean .Pandey and Singh (1997) studied the biology of the *C. chinensis* infesting stored pulses like Urd (*V. mungo)* and chickpea (*Cicer arietinum*) seeds at 28 ± 2^0C and 70±5% r.h. An average of 70 eggs was laid by each female, incubation period lasted for 4–5 days and combined larval-pupal period lasted for 20-28 days. Mortality during development from egg to adult stages was 24%, with most mortality occurring during egg laying and early larval stages. Srinivasacharyulu and Yadav (1997) studied the olfactory and ovipositional preference of two strains of *C. chinensis.* A soybean strain of *C. chinensis* and a local IARI strain were tested for olfactory attraction, oviposition, adult emergence, mean development period and growth index parameters of 4 legumes (Soybeans, cowpeas, chickpeas and pigeon peas). Choice and no-choice tests were conducted. The local strain failed to damage soybean.

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

2.4.2. Host preference of *C. analis*

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

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

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

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

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

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

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

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

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

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

2.5. Morphological studies on a pteromalid and a trichogrammatid parasitoid

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

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

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

2.6. Biology and per cent parasitization of egg parasitoids

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

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

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

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

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

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

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

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

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

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

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

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

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

2.8.1. Bio-chemical properties of plant oils

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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