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Bruchid Research in Bangladesh

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Abstract: The use of chemical pesticides against storage pests by farmers in developing countries like Bangladesh is inadequately docummented. The holistic view of pest control technology is required to evaluate its impact on net social welfare, the simultaneous determination of optimal storage operations, consumption and production over time and optimal pest management. To make these variables operational the collaboration of biologists (especially pest management expert), economists, systems analysts, extension workers and social scientists are very much to be solicited. It is apparent that our basic understanding of bruchid pests is still far from being adequate. Therefore, intensive studies of their, biology, ecology and effects on foodstuffs are needed to be vigorously persued. Chemical pesticides are expected to play a major role in pest management programmes. However, the development of alternative pest management strategies involving non-chemical methods should vigorously pursued. There is no single answer to pest problems. The development of an integrated pest management system incorporating the principles, methods and techniques advanced by various disciplines into a coherent and comprehensive programme seems to be the answer.

Key words: Bruchids, biology, control, Bangladesh

Introduction

There are approximately 1300 described species of Bruchidae in the world and about as many again to be described (Johnson and Kistler, 1987). Bruchid larvae extensively feed on seeds and 33 families of plants have been reported as their hosts (Kinslover, 1979; Johnson, 1981). About 84 percent of the known hosts of bruchids are in the Leguminosae (Johnson, 1970).

Bruchids are distributed throughout the world except Antarctica and the largest number of species occur in the tropical regions of Asia, Africa and Central and South America (Southgate, 1979).

Significant annual losses of pulses due to bruchid infestations are reported from many countries including Bangladesh (Bangladesh Agricutural Research Institute, 1984) have led entomologists to make concerted efforts for developing control methods against them.

Pulses are heavily damaged under storage by several species of Bruchidae. Of these, *Callosobruchus chinensis* (L.) and *C. analis* (F.) have been recorded as major pests of pulse seeds in Bangladesh. Begum and Bahman (1974) observed that *C. analis* causes 94.96, 73.18 and 22.08 percent damage to moong (Phaseolus aureus Roxb.), chickpea (*Cicer arietinum* L.) and pea (*Pisum sativum* L.) respectively after 60 days of infestation under laboratory conditions. Begum *et al*. (1984a) recorded 96.42, 67.88 and 61.34 percent damage by *C. analis* to red lentil, (*Lens culinaris*), kheshari (*Lathyrus sative*) and mash (*Vigna mungo*) respectively.

The present review deals with the research works so far done on bruchid beetles in Bangladesh.

Biology of Bruchidae: The biology of C. *analis* has been studied by Begum and Bahman (1974) under Bangladesh conditions. Mating of the beetles occurred immediately after their emergence. The preoviposition period was 1-4 hours. The female laid an average of 69.39 eggs in her life at the rate of 1-25 eggs per day. The oviposition period lasted for 6-8 days. The development from egg-adult took 32.50, 39.00 and 48.50 days in *V. radiata, C. arietinum* and *P. sativum* respectively. The growth of the insects was the maximum on *V. radiata.* The sex-ratio was approximately 1:1.

Bhuiyan and Peyara (1978) studied the biology of *C. chinensis* on stored pulses (*V. aureus*) in Bangladsh. Just after hatching, the larvae bored into the seeds and began to consume the seed contents causing great damage. Both the larvae and pupae remained completely hidden within the seeds. The adult beetles mated a few hours after emergence and started egglaying within 24 hours. The life-cycle of *C. chinensis* was completed in 30-32, 22-23 and 44-46 days during early summer, mid-summer and winter seasons respectively. There were 10 generations of the beetle under laboratory conditions.

Morphology and anatomy of Bruchidae: Begum *at al.* (1982) described and compared the morphology of the larval instars of *C. chinensis* and *C. analis.* The main differences recorded were in the size and in the distribution of bristles. In *C. chinensis* the first larval instar was differentiated from the successive ones chiefly by the presence of frontal suture which disappeared in the 2nd instar. The 2nd instar larva was similar to the 3rd instar except for size and shape. The labrum of the 4th instar larva was chitinized basally and had 33 long and short spines at the distal extremity. However, in the earlier instars, the basal part remain non-chitinized except for a narrow part bearing 12 long and short bristles. The stipes of the 4th instar larva bore 19 long bristles instead of three in the earlier instars. The morphological characters of the larval instars of *C. analis* are very much similar to those of *C. chinensis* but differ only by the teeth of the prothoracic region, bristles of the labrum, subfacial region and abdomen. The marking difference between the two species of the genus was noted by the teeth of the 'X'-shaped thoracic plate. The maximum affinity of this type has also been supported by Prevett (1971).

Rahman and Ameen (1986) gave a detail account of the anatomy of the larval alimentary canal of *C. analis* and *C. chinensis.* They pointed out the metamorphic changes of the alimentary canal during the larval stage only. The larval gut consists of a short and strong foregut, distinguishable into pharynx, oesophagus and proventriculs (only in the late larva) long and wide midgut divisible into an anterior and posterior midgut and a narrow convoluted hindgut, differentiated into a short pylorus, a characteristically convoluted ileum, a cryptonephridia-invested colon and a short rectum. During larval development, the proventriculus is formed in the foregut and the midgut is elongated considerably.

Rahman and Ameen (1988) described in details the anatomy of the alimentary canal of larvae, pupae and adults of *C. analis* and *C. chinensis* and its metamorphic changes. In all the stages of the beetles the foregut can be differentiated into the pharynx, oesophagus and proventriculus; midgut into anterior and posterior midgut; and the hindgut into pylorus, ileum, colon and rectum. The foregut is very short as compared to mid- and hindgut. The midgut appears as a. very long, tubular structure in the mature larva. The ileocolon is characteristically 'S'-shaped and the colon is invested by cryptonephridial system. During metamorphosis the midgut becomes very short and ultimately becomes slightly saccular in the adults. Cryptonephridia-invested colon persists throughout metamorphosis. The anatomical details and metamorphic changes of the alimentary canal of *C. chinensis* is very much similar to those of *C. analis.*

The anatomy and histology of the Malpighian tubules of the various life stages and their metamorphic changes in *C. analis* and *C. chinensis* have been studied in details by Rahman and Ameen (1990). There are six Malpighian tubules in the beetles: two are short which extend posteriorly and four are long which extend cephalad. The distribution of these tubules is similar in pupae and adults but is different in larvae. The Malpighian tubules shorten and attenuate in the pupae but widen again in the adults. The epithelium of the free tubules is formed of cuboidal cells with large nuclei and a district brush-boarder. During metamorphosis, some of the epithelial cells of the larval Malpighian, tubules degenerate and new epithelium is formed by the growth and differentiation of the "imaginal cells". No major change occurs in the cryptonephridial system during metamorphosis.

The histology of the gut of adult *C. analis* and *C. chinensis* has been given by Rahman and Ameen (1991). The intima of the foregut of the beetles is variously modified as "pharyngeal spines", "oesophageal spines" and "proventricular needles" in the pharynx, oesophagus and proventriculus, respectively. A distinct proventricular valve is present in the proventricular invagination. The cells of the foregut epithelium are short, cuboidal but not isodiametric. The midgut epithelium consists of short evaginations of the gut wall known as the "crypts". The midgut epithelium contains tall columnar cells except the crypts. The regenerative cells remain in the "crypts". The ileal intima is very thin and uniform as thickness and the epithelium consists of cuboidal cells which are not iso-diametric. The intima of the colon is variable in thickness and the epithelium consists of cuboidal cells, irregularly arranged, approximately iso-diametric and slightly wider than tall. The rectum is clearly divisible into anterior "rectal pad" and posterior "rectal papillae" that bear "rectal spines".

Ecology: The importance of population development of pest insects and the interactions between two or more species under natural conditions, is of great interest. Moreover, recent interest in non-chemical pest control methods necessitates the prediction of population development in presence of other insects. The mixed species or interspecies studies are covered primarily with the analysis of competitive (or cooperative) relations established within a population, when several species with essentially similar ecological requirements live together. Kabir and Begum (1990) studied the populatidn development and interactions of *C. chinensis* and *C. analis* in the laboratory under controlled conditions of food and space limitations using six pulses, *L. stivus, L. culinaris, V. radiate, V. mungo, C. arietinum* and *P. sativum* at 28-31±1°C and 75-85 percent rh. In single species cultures, *C. analis* developed the highest population level in *V. radiata* on the 80th day. *C. arietinum* did not support *C. analis* while *L. sativus, L. culinaris* and *P. sativum* showed low pest population buildup. *C. chinensis* produced almost comparable populations in chickpea, mung and red lentil on the 80th day. Black gram failed to support *C. chinensis* and the beetle died out soon. In interspecific cultures, the interactions between *C. analis* and *C. chinensis* adversely affected the population growth of the latter in mung.

Begum *et al.* (1984a) studied the effects of food, temperature and humidity of *C. analis.* Foods affected the fecundity and adult emergence of the bruchid. The females laid maximum number of eggs at a temperature above 30°C and at a relative humidity above 82 percent. *L. esculenta* was very suitable for their growth, producing 9.14 generations in a year, followed by *L. sativus* (7.88) and *P. mungo* (5.32). The total day degrees required for the beetles to complete their life-cycle was 432.45, 619.15 and 890.96 in *L. esculenta, L. sativus* and *P. mungo* respectively. *P. mungo* produced heavier individuals. *C. analis* is a serious pest, generally found in stored pulses, in Bangladesh. It occurs throughout the year and cause much damage to economy. It has been observed that there is a great plopulation fluctuation of the bruchid at different times of the year in Bangladesh-the population goes down in winter and builds up during summer. The age-specific survival rates (ln) and fecundity rates (mx) of *C. analis* at different temperatures, viz. 20.0, 22.5, 25.0, 30.0, 32.5 and 35.0°C have been studied to estimate the temperature dependence of the intrinsic rate of natural increase (rm) by Begum *et al.* (1984b). The pulse beetle populations attained their optimum intrinsic rate at 32.5°C, at which the doubling time, the mean generation time (T) and the developmental period were the minimum. The fecundity of the females was the maximum at 35°C.

Rahman *et al.* (1978) studied the effect of variable temperatures (20±0.5, 25±0.5 and 30±0.50°C) at a constant relative humidity (75%) on the oviposition of *C. chinensis* and *C. analis.* The mean oviposition were 44.10±6.80, 56.40±7.30 and 71.0±8.90 and 57.40±21.10, 89.50±13.70 and 100.30±17.10 by *C. chinensis* and *C. analis* respectively at these tempertaures. Thus, egglaying was the maximum at 30°C for both the species.

Control of Bruchidae

Physical Control Methods: "The shortcomings of agricultural pesticides (usable on grains) has renewed interest in the application of physics to control insect pests", said Watters (1972) about three decades ago and this is still true today. Physical means of insect disinfestation can avoid many of the noxious effects of the immoderate application of chemical agents.

Inert substances: The protection of stored commodities with inert materials is an age-old and traditional method in tropical parts of the world. In this method the epicuticular lipid layer which protects insects from dessication is removed by sorption or abrasion (Ebeling, 1971).

Nasiruddin (1988) used six inert substances, e.g. ash, sand, sawdust, rice husk, wheat husk and rice straw as top surface covering to protect *P. mungo* and *L. sativus* against *C. chinensis.* The rate of infestation was 0.0, 0.0, 12.6, 21.8, 34.6 and 73.5 percent as against 78.1 percent infestation is control when *P. mungo* seeds were covered with ash, sand, saw dust, rice husk, wheat husk and rice straw respectively. In *L. sativa,* the highest infestation (90.1%) occured in seeds covered with rice straw while it was 0.0 percent in ash and sand. The rate of infestation in ascending order was 48.7, 71.5 and 81.2 percent when the seeds were covered with saw dust, rice husk and wheat husk respectively as against 99.1 percent in control.

Temperature, moisture and food requirements directly affect the development of storage insects (Cotton, 1960). If the water content in the stored products is low, the number of pests may not increase despite infestation (Zakladoni and Ratanova, 1987).

It is observed that sunning significantly reduced the infestation of *C. chinensis* on *L. esculenta, C. arietinum* and *V. mungo* seeds.

Begum *et al.* (1984a) studied the age-specific survival rates (ix) and fecundity rates (mx) of *C. analis* at various temperatures, viz. 20.0, 22.5, 25.0, 30.0, 32.5 and 35.00°C, to estimate the temperature dependence of the intrinsic rate of increase (r-). The beetle population attained their optimum intrinsic rate of increase at 32.5°C, at which the doubling time, the mean generation time (T) and the developmental period became minimum. The fecundity of the bruchid was the maximum at 350°C. Begum *et al.* (1984b) in another exepriment noted that *C. analis* laid the maximum number of eggs at a temperature <30°C and <82.0% r.h.

Chemical Control: In Bangladesh, various chemical pesticides have been tried against bruchid pests. Sultana and Ahmed (1978) determined the protective efficacy of three insecticides, e.g. Dichlorvos, Sumithion and Malathion used as external surface applicants of gunny bags for storing *V. mungo.* They observed that the pulse grains in the bags impregnated with Dichlorvos remained completely free from infestation up to two months after which a low infestation (1.6%) was recorded at the end of three months. However, seeds stored in bags impregnated with Malathion and Sumithion remained free from infestation up to one moth only; at the end of two months Sumithion and Malathion treated bags had 1.1 and 1.5 percent infestation as against 6.9 percent in control bags. Deltamethrin at 3.0 ppm and Sevin at 50.0 ppm caused 100 percent mortality of *C. chinensis* adults but Fenitrothion was moderatley toxic (Rahman, 1990). Deltamethrin inhibited oviposition of the beetle completely at dose as low as 3.0 ppm.

Miah *et al.* (1992) noted that the oviposition, adult emergence and damage by *C. chinensis* were significantly reduced on *L. sativus* and cowpea (*V. unguiculata)* seeds treated with nishinda (*Vitex negundo* L.) leaf powder. Islam and Karim (1995) tested the efficacy of naphthalene balls on the mortality of the developmental stages of *C. chinensis. C. arietinum* seeds with freshly laid eggs of the beetle showed no adult emergence after 24 h exposure to naphthalene in closed containers. No adult emergence occurred from the exposed pulses with hidden larvae or pupae after an exposure period of 144 h for *L. culinaris* or 192 h for *C. arietinum.* It was noted that naphthalene produced no adverse effects on the germination of the seeds up to 60 days.

Islam and Sarker (1996) evaluated the toxicity of Malathion, Cymbush and Nogos against *C. chinensis* adults. The LD50 values of males and females after 12-, 24 and 36-h postexposure were 1.668, 0.0063 and 0.0808 and 84.047, 20.060 and 0.0860 ppm for Malathion; 0.829, 0.0063 and 0.00064 and 0.260, 0.0024 and 0.00001 ppm for Cymbush and 2.136, 0.276 and 0.0118 and 0.560, 0.0194 and 0.0006 ppm for Nogos, respectively. The order of toxicity was Cymbush>Malathion>Nogos.

The oviposition, adult emergence and weight loss of *C. arietinum* by *C. chinensis* on *V. negundo,* Amoora ruhituka Wright and Am. and *A. indica* leaf powders and oils of neem, linseed and sesame treated *C. arietinum* seeds have been determined (Miah *et al.* 1993) and found that nishinda leaf powder was more effective to reduce infestation and weight loss than the others. Nasiruddin (1986) evaluated the efficacy of some edible oils namely linseed (*Linum usitatissimum*), til (*Sesamum indicum*) and soybean *(Glycine max*) at the rate of 10 ml/kg seeds as protectants of *V. mungo* against *C. chinensis.* The infestations of the beetles were 4.48, 12.44, 20.08 and 78.54 percent for tishi, til, soybean oil and control respectively after nine months of storage. Das (1985,1986) recorded 100 percent mortality in *C. chinensis* adults following neem and sesame oils treatments. In another study, Das and Karim (1986) reported that neem and sesame oils were effective to reduce oviposition, adult emergence and weight loss by pulse beetle on chickpea.

It has been observed that storage time had a profound effect on the oviposition of *C. chinensis* on neem *(Azadirachta indica* A. Juss)-treated *C. arietinum* seeds (Das, 1989). In all the cases from introducing adults immediately after treating seeds with neem oil to the introduction of adults into the treated seeds stored for 1, 2, 4 and 6 months oviposition was either zero or negligible as compared to the untreated control seeds. Neem oil could be used as an effective surface protectant against the bruchids in stored legumes.

Ahmed *et al.* (1993) conducted laboratory experiments to determine the efficacy of oils of neem, *L. usitatissimum*;

Safflower, *Carthanamus tintorius* L.; Sunflower, *Helianthus annus* L and *S. indicum* against *C. chinensis* on *V. radiata* All the concentrations (e.g. 0.5, 1.0, 2.0 and 4% v/v) of each oil significantly reduced the oviposition and adult emergence of the beetle. The effects were dose-dependent that increased with increasing concentrations of the oils. Neem oil was the best protectant of pulse seeds against *C. chinensis.*

The efficacy of *A. indica,* castor *(Ricinus communis* L.) and mustard (*Brassica* sp.) oils on the infestation by *C. chinensis* of *L. esculentus* has been determined (Islam and Mondal, 1994). Oil treatments of the lentil reduced the rate of infestation, egg laying and population buildup of the bruchid. The effects of the oils was in the order Neem > castor > mustard > 0 (control). In another study Islam (1997b) evaluate efficacy of some plant oils e.g., *A. indica, A. hypogea, Brassica* spp., *S. indicum, R. communis* and *L. usitatissum* against *C. maculatus on V. mungo.* All the three concentrations (5.0, 12.5 and 25.0 ppm) of each oil reduced percent of infestation, weight loss of grains and adult emergence in *C. maculatus.* Neem and groundnut oils at 25.0 ppm completely protected the mash seeds from the attack of *C. maculatus* while only 0.28, 0.48, 0.56 and 1.28 percent of weight loss were recorded at the same concentration of mustard, sesame, castor and linseed oils respectively compared to 38.0 percent in controls. The effectiveness of oils increased with the increase of the concentrations in all the cases. Among the oils tested neem oil was the best protectant of mash seeds against *C. maculates.*

Nishinda leaf powder significantly reduced oviposition, adult emergence and the weight loss of the lentil, *L. culinaris* by *C. chinensis* (Miah *at al.,* 1996). Linseed, neem and seame oils were slightly effective as a protectant against lentil.

The leaf powder of *A. indica, V. negundo* and bishkanthali *(Polygonum hydropiper)* and their combinations were tested against *C. chinensis* on *L. esculenta* seeds. Bishkanthali leaf powder at 4 g/50 g lentil seeds was most effective in reducing oviposition and adult emergence of the pulse beetle and its rate of damage and weight loss to lentil seeds. The combination of neem + bishkanthali leaf powder ranked second and only neem leaf powder ranked third. Apparent, the lower doses of the plant materials were less effective against *C. chinensis.* Gremination of lentil seeds was not affected following *P. hydropiper* treatments.

Storage performance of *V. radiata* seeds for a period of nine months against *C. chinensis* infestation using gamma irradiation, heat and sun-drying on grains and their combined treatment with plant products, viz. neem seed, fresh leaf and leaf dust extracts, tobacco leaf dust extract and leaf dust, neem seed coast dust and jute seed dust, on packages was evaluated (Shahjahan and Saha, 1997). Products from neem and tobacco leaves checked reinfestation but jute seed products were unable to check reinfestation. Irradiation and heat treated pulses could be stored pest free up to nine months when the packages were treated with 2-5 percent neem dust or 2-6 percent neem spray or 1-5 percent tobacco dust or 1-6 percent tobacco sparay.

Biological Control: Non-chemical methods of pest control have received much recent attention due to the hazards produced by chemical pesticides through their indiscriminate application. Biological control of pests is a popular option. The term is used to denote one of the major ecological forces of nature, the regulation of plant and animal numbers by natural enemies. In generally the term "Biological control" has been restricted to the utilization of predators, parasites/parasitoids and pathogens for the control of pest populations.

Haines (1984), Van Huis (1991) and Khan and Selman (1995) have reviewed the status of research on the role of parasites/parasitoids and predators in the management of pests. The major priorities for future research in this line include (Haines, 1984):

(i) observations on the prey/host range of many of the natural enemies for which such data are not available and surveys of their distribution and occurrence;
(ii) ecological and behavioural srudies, under relevant environmental conditions, on species that appear to have potential as control agents;
(iii) increased emphasis on the use of field trials to evaluate the efficacy of potential biocontrol agents.

Bruchidae are attacked by parasitoids belonging to 10 families of Hymenoptera and 1 of Diptera (Southgate, 1979). *Anisopteromalus calandrae* (Howard) and *Dinarrnus basalis* (Rondani) are two important pteromalid hymenopteran parasitoids attacking pulse beetles. Considerable works have been conducted on them in Bangladesh. The morphology of *A. calandrae* has been studied by Islam *et al*. (1983) and that of *D. basalt's* by Islam and Ahmed (1985).

Islam and Ahmed (1984) described the mating and egg laying behaviour of *A. calandrae.* Males mate 5-7 times that are preceeded by courtship. In mating males took initiative role. *A. calandrae* prefers to lay eggs in 3rd and 4th instar *C*. chinensis larvae, pre-pupae or pupae compared to 2nd instar pest larvae. No oviposition took place in the first instar larvae. The female usually failed to determine wheather the seeds contained parasitized host or not and super-parasitism was frequently recorded. Begum (1995) also recorded the mating and oviposition behaviour of this parasite.

The biology of *A. calandrae* has been studied by Islam (1993a). The eggs are hymenopteriform, translucent and dirty white in colour and measure (0.40 ± 0.004) x (0.13 ± 0.0001) mm. There were three larval instars with spines and setae. The pupae are exartae. The developmental time from egg to adult emergence was 237.6 ± 1.83 h for males and 260.57 ± 0.78 h for females at 30 ± 1°C and 70 ± 0.5 percent r.h. Males are polygamous but females are monandrous.

Islam and Nargis (1993) noted that both the longevity and fecundity of *A. calandrae* differed significantly when fed on different larval instars/stages of the host, *C. chinensis.* The highest longevity and fecundity of *A. calandrae* were observed on the 4th instar host larvae and the lowest on the 2nd instar.

The age of the host has significant effects on the oviposition and development of parasitoids (Vinson and

Iwantsch, 1980) because the nutritional status and accessibility of the host change with age. The rate of development, number of mature oocytes at emergence and size of head-capsule of *A. calandare* was the maximum when the parasite was reared on 4th instar *C. chinensis* larvae (Islam and Nargis, 1994b).

Host recognition is a key step in successful parasitism (Cave *et al.,* 1987) and this is specially true for parasitoids that show a high degree of host specificity.

Begum (1994) studied the host selection behaviour of *A. calandrae. A. calandrae* showed a high degree of discrimination during the selection of their host, *C. chinensis.* Its host selection behaviour may be divided into three major stages: host finding, host acceptance and host suitability. The parasite preferred the 3rd or 4th instar larvae and pre-pupae and early pupae of the host for oviposition, occasionally oviposited on the first instar host larvae.

The effects of temperature (18-35°C) and relative humidity (30-90%) for development and progeny production of *A. calandrae* on *C. chinensis* have been studied by Islam and Kabir (1991). In all the cases males emerged 1-2 days before than females. Developmental time and progeny production was minimum at 18°C and 30 percent rh, while, complete development and maximum progeny production occurred at 31°C and 70 percent rh.

Islam and Nargis (1992) gave a mass rearing technique for *A. calandrae* following which 44838 parasites were produced per week from 1000 parasites on *C. chinensis.* According to them it was essential to provide young adults with abundant hosts to maintain high rate of their reproductive potential.

Islam and Nargis (1994a) determined the efficacy of *A. calandrae* in suppressing *C. chinensis* populations breeding on red lentil debris in simulated warehouse rooms. The parasites were released at six levels (5, 10, 20, 30, 40 and 50 pairs) in a 500 ft^2 room. The lowest levels (5-10 pairs) controlled the pest population to 56-69 percent, 20-30 pairs gave 80-88 percent control whereas the highest levels (40-50 pairs) gave control exceeding 98 percent. In progeny production, the lower levels of parasite introduction (5 pairs) produced more progeny (65.36%) that at the higher level of 50 pairs (8.85%). This investigation indicated that *A. calandrae* has the potential for suppressing *chinensis* in large storage areas. The authors opined that although restrictions may prohibit insect introductions into commercial storages, one area in which *A. calandare* might currently be used effectively against *C. chinensis* is in small farm storages, especially where pulses are not stored for prolonged periods.In such cases *A. calandrae* could be released shortly before or just after the pulse is introduced to destroy the relatively small residual populations of the beetles or related pests. Given the rapid rate of dispersal and high reproductive potential of the parasite, it may be possible to attain an acceptable level of pest suppression without repeated parasite introductions.

D. bases is a larval-pupal parasitoid of *C. chinensis.* Maswood and Kabir (1990) studied the host selection, courtship and oviposition behaviour of the parasitoid. The 3rd and 4th larval instars and the prepupal stage of the host served as the most preferred stages of the parasitoid females for oviposition. The adult females were monogamous and they mated only once in their life time, although they exibited courtship behaviour with more than one males. The males are polygamous and they mated 5-7 times with different females and each time they exibited elaborate courtship behaviour. Prior to or in-between oviposition, the female parasitoids construct a feeding tube with their ovipositor to feed on the host's body fluid. Islam (1992) recorded the mating and egg-laying behaviour of *D. basalis.* Mating took place immediately after the virgin females was introduced to the male. The male's overtures to the female are expressed in a series of movements like chasing of the female, sudden stopping and wobbling from side to side, fluttering of the wings and contacting the female with outstretched antennae. Courtship takes about 12 secs and copulation lasts for about 22 secs. Males are polygamous but females are uninuptial. *D. basalis* lays eggs on the surface of mature larvae, pre-pupae and pupae of *C. chinensis* and oviposition period lasts for about 21 minutes. The biology of *D. basalis* at 30±1°C and 70 percent rh has been given by Islam (1995a). The deposited egg is typically hymenopteriform, dirty white, smooth, elongate and rounded at both ends. The incubation period was 24.75±0.9 h. A solitary larva develops to suck the hosts's body fluids. The mean duration of the larval instars were 66.35±0.96, 103.14±0.89 and 132.33±1.13 h. The pre-pupal stage lasted for 143.70±0.9 h and the pupal stage for 284.0±1.41 and 308.14±1.02 h for males and females respectively.

Developmental stages of *C. chinensis* affected longevity and fecundity of *D. basalis* significantly (Islam, 1995c). Both longevity and fecundity of the parasitoids were the highest on 4th instar host larvae and the lowest on 2nd instar. This was primarily due to the intrinsic differences in food quality of the stages of the hosts supplied.

Islam (1994a) determined the effect of host age on the rate of development of *D. basalis.* Development time for the parasitoid was shorter on 4th instar larvae and pre-pupae than on 2nd and 3rd instar larvae of *C. chinensis.* Developmental time and progeny production was significantly different between the two sexes. The maximum number of males emerged from 2nd or 3rd instar larvae but females from 4th instar larvae or pre-pupae. The sex-ratio of the parasitoid was strongly female-biased. The female parasitoids when developing from 4th instar *C. chinensis* larvae were bigger.

Host-age significantly affected the offspring production in *D. basalis* on *C. chinensis* (Islam, 1995b). The offspring production was in the order 4th instar larvae > pre-pupae > pupae > 3rd instar larvae > 2nd instar larvae. More males emerged from 2nd and 3rd instar host larvae. Host-age also affected pupal size of the female parasitoids.

The fluctuation of *C. chinensis* populations took place depending upon the fluctuations in storage temperature and the population of *D. basalis* (Malek and Ahmed, 1990). During June-September, when temperature ranged between 32-33°C, the population of both the parasitoid and pest increased and again, during October-February; when temperature ranged between 32-24°C, the populations of both of them declined. However, in March when the storage temperature raised to 27°C both the parasitoid and pest populations increased. The parasitoid attacks the host larvae and pupae to a greater rate and as a result the pest population declines in October .

Islam (1993b) assessed the effects of temperature (18-350°C) and relative humidity (30-90%) on the development and progeny production of *D. basalis* on *C. chinensis.* Poor development and small progeny production of the parasitoid took place at 18°C and 30 percent rh, while successful development and maximum progeny production occured at 31°C and 70 percent rh. Male *D. basalis* emerged 1-2 days earlier than females.

The selection of the host stages for oviposition of *D. basalis* for different developmental stages of *C. chinensis* showed that the parasitoid deposited eggs on 2nd, 3rd and 4th instar larvae, pre-pupae and pupae but 4th instar larvae were the most preferred (Islam, 1997a). Host selection by *D. basalis* is made by antennae and ovipositor.

It has been noted that *D. basalis* was able to discriminate between unparasitized and parasitized *C. chinensis* and avoided oviposition in the latter (Islam, 1994b). Rejection of a parasitized host took place after the parasitoid examined the hosts with her antennae and then with the ovipositor. *D. basalis* left the site of infestation when most of the seeds *(L. esculenta)* were parasitized.

Islam and Kabir (1993) reported the occurrence of superparasitism of *D. basalis* on *C. chinensis.* The parasitoid laid more than one eggs on a single host at higher parasitoid densities. Superparasitism did not affect the duration of developmental periods and size of adults but the percentage of female progeny was somewhat reduced at higher parasitoid densities.

Islam and Kabir (1992) gave an account of the mass culture and production of *D. basalis on* C. *chinensis.* The total number of F_1 offspring produced from 1000 parasitoids was 30,627 in a week. It was essential to provide young parasitoids with abundant hosts to maintain a high rate of their reproductive potential. Nutrition and adequate provision for oviposition of newly emerged adult females apparently influence their subsequent behaviour and productivity.

D. basalis was introduced to suppress residual populations of ca 60°C. chinensis breeding in red lentil debris in a 46.24 m^2 room (Islam and Kabir, 1995). The parasitoid was released at six densities, e.g. 5, 10, 20, 30, 40 and 50 pairs. The highest parasitoid density, i.e. 50 pairs, suppressed the *C. chinensis* population 100 percent during April-May but during July-August, 30 pairs could achieve this result. More progeny per female parasitoid were produced at the lower parasitoid density than at the higher levels. In another experiment, ca 500 pulse beetles per 275 g of lentils, kept separately in each of three types of bags, viz. amemian, jute and polypropylene were exposed in the room to 50 pairs of parasitoids. The highest percentage of parasitism and suppression occurred in amemian bags and the lowest in polypropylene bags when a single release of 50 pairs of *D. basalis* were made during both the periods. The results amply advocate the suitability and efficiency of *D. basalis* to check the population of *C. chinensis* in 'empty' granaries as well as in bagged beans. Mass rearing technique of *D. basalis* and release of this parasitoid in an experimental room to determine its potential as a biological control agent against *C. maculatus* has *been* described by Islam (1998). He observed that 1000 parasitoids produced more than 35000 parasitoids per week. *D. basalis* suppressed about 85 percent *C. maculatus* at the introduction level of 50 and about 45 percent at the introduction levels of 5 pairs only. The number of progeny produced when introducing 50 pairs was 9.01 per female and it was 35.5 per female with 5 pairs. *Uscana mukerjii* (Mani) (Hymenoptera:Trichogrammatidae) is another important solitary egg parasitoid of *C. chinensis.* Islam *et al.* (1985a) reported the occurrence of the parasitoid in Bangladesh. The biology and parasitism of *U. mukerjii* in *C. chinensis* have been studied by Islam *et al*. (1985b). Mating occurs within an hour of emergence. The parasitoid usually lays one and rarely two eggs at a time in the same host. One-day old eggs are preferred for oviposition. The incubation period varies from 18 to 24 hours. The latval and pupal periods range between 4-5 and 3-4 days respectively. The life-cycle is completed in 8-10 days at 30.1°C and 70 percent rh. *U. mukerjii* lived for 3-4 days without food. Its rate of parasitization of *C. chinensis* was 32 percent on stored *L. esculenta* and 27 percent on *C. arietinum.*

Islam *et al.* (1991) noted the influence of host age on the progeny production by *U. mukerjii.* The parasitoid preferred one day old host eggs for oviposition but eggs up to three-day old were parasitized. Consequently, higher number of progeny were produced from one-day old host eggs and progeny production significantly declined as the age of the host eggs increased. More females were produced than males. Decreased nutritional quality, hardness of the egg-shell, change in pH and above all, behaviour of the ovipositing female to make adequate provision for development of egg, all may be responsible for this.

Effect of Radiation: The effects of irradiation with gamma rays on the immature stages and adults of *C. analis* have been studied (Rahman *et al.,* 1975). It was observed that 0.5 kr showed outright kill of the developing stages of the eggs and no larvae developed into adults at <2 kr. Pupae irradiated with 30 kr produced no adults and all the pupae died at 25 kr within 7 days. Adult beetles were highly radioresistant.

Begum *et al.* (1985) irradiated *C. analis* with 0-60 Gy gamma radiations to determine their effects on the reproductive potential, longevity and sex-ratio of the beetles. Irradiation significantly reduced the oviposition and adult emergence of the bruchid. Irradiated males lived longer than the unirradiated males. However, irradiation had no effcts on the longevity of the females. The female progeny predominated the males.

Various types of electromagnetic energy are technically available for use in the disinfestation of foodstuffs including stored commodities. Watters (1972) confirms a useful review of possible applications for radio-frequency heating, infra-red, ultraviolet and ionizing radiation. But the use of these techniques for storage pest control is still limited by the basic problems of capital cost, running costs and other aspects of practical feasibility (Banks, 1976, McFarlane, 1989). Further irradiation confers no protection against irradiation procedures their inclusion in the IPM systems will depend primarily, as with the use of other techniques, upon their relative cost efficiency.

Pheromones: A pheromone is a chemical or a mixture of chemicals that is released to the exterior by an organism and that causes one or more specific reactions in a receiving organism of the same species (Shorey, 1977). They are effective in minute amounts and act as chemical messengers between individuals. Pheromones are essential to the survival of many species. The vital functions mediated by pheromones include sexual behaviour and maturation, trail following, alarm and individual or colony recognition. The culture medium of an insect is said to be 'conditioned' when individuals of species have lived in the medium for some time. The medium which is thus conditioned involves at least three factors: (a) deplition of the nutritive value of the medium; (b) accumulation of exuvia, dead animals and other debris and (c) most remarkably, the accumulation of any secretion (s) left behind by the insects that is taken up by the medium (Ghent, 1963; Sokoloff, 1972). There are many reports on the attractive and/or repellent effect of Tribolium conditioned medium on the conspecific and interspecific larvae as well as adults (Ghent, 1963; Ogden, 1969; Ryan and O'ceallachain, 1976; O'ceallachain and Ryan, 1977; Hughes, 1982; Mondal, 1985). The conditioninig of seeds during creeping by adult *C. maculates* has been reported (Yoshida, 1961; Umeya, 1966). Khan *et al. (1994a)* tested the oviposition preference of *C. chinensis* females between fresh mungbean (*V. radiate)* grains and grains conditioned by conspecific virgin males, virgin females, mated males, mated females and both sexes together. A highly significant effect was recorded in the deposition of eggs and subsequent adult emergence for each type of conditioned grain. The maximum reduction in adult emergence was obtained from grains conditioned by virgin females. The conditioning capacity of the beetles decreased with age. The highest and lowest reduction in adult emergence were 42.0 and 90.0 percent from 0.24 hr old male and 48-72 hr old females respectively. In another experiment Khan *et al.* (1994b) tried to isolate oviposition deterrent factors(s) from the adult bodies of *C. chinensis.* Various solvents, e.g., methanol, ethyl alcohol, water, actone, di-ethyl ether, petroleum ether, di-chloromethane and hexane were utilized for extraction, Among these, acetone extract of the female beetles showed higher percentage (81.17%) of deterrence. Dosimetric study of acetone extract was also found to show a linear relationship between the dose and deterrent activity. The results suggest the presence of strong oviposition deterrent factor(s) in *C. chinensis* females. The isolation and charactreization and subsequent chemical synthesis of such factor(s) may be of immense value in pest management.

Guidelines for Future Research: Bruchid research in Bangladesh is far from being sufficent. Some immediately feasible points are indicated below. Feasibility nevertheless depends upon the reduction or elimination of various identifiable constrains. Long-term possibilities rely more heavily upon the progress of socio-economic developments, especially in agriculture, marketing and agro-industry and these, in term, obviously, are dependent upon sound and progressive development policies.

- Bangladesh has a rich flora with several species with high insecticidal properties. Concepted research should be carried out for the potential utilization of plant extracts with pest control properties.
- Studies should be undertaken to identify and establish the degree of influence of different socioeconomics and technical factors affecting the adoption of pest control technologies. Strategies can then be developed and pilot programmes tested to effect more widespread adoption of the technology.
- Bruchid systematics in Bangladesh should be comprehensively studied.
- Much emphasis should be directed towards the design and maintenance of grain storage systems. To this end, the modification and improvement of the existing storage structures to make them more suitable for holding produce must be persued.
- Proper measures are needed to reduce the residual pest populations through sanitation.
- A strong extension service with specialists in postharvest systems could alleviate most of the pesticide problems.
- The relative susceptibilities or toterances of different locally grown varieties and accession lines to major pests should be evaluated. The data, thus generated, should be included as a factor in influencing national and local recommendations for the use of new varieties and active selection by plant breeders to produce new varieties with high tolerance to pests.
- Intensive training, workshops and seminars for farmers, warehousemen,traders,processors, extension workers, pest control technicians and quarantine officers on storage and pest management principles and techniques should be provided. For promoting exchange of information, regional and international seminars should be arranged and there should be exchange of experts at regional and international levels as well.
- Clearly, in Bangladesh a good amount research has been done on storage bruchids. Future research works are solicited on bruchids attacking crops and trees.

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