BIOLOGY, MORPHOLOGY, NATURE OF ATTACK AND DISPERSAL OF *Cyrtobagous salviniae* CALDER & SANDS (CURCULIONIDAE: COLEOPTERA)

By

LEENA K. T.

THESIS

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DECLARATION

I hereby declare that this thesis entitled "Biology, morphology, nature of attack and dispersal of *Cyrtobagous salviniae* Calder & Sands (Coleoptera : Curculionidae)" is a bonafide record of work done by me during the course of research work and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara,
29-a-1988.

LEENA, K.T.

CERTIFICATE

Certified that this thesis entitled "Biology, morphology, nature of attack and dispersal of *Cyrtobagous salviniae* Calder & Sands (Coleoptera : Curculionidae)" is a record of research work done independently by Smt.Leena, K.T. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellanikkara,
29-3-1988.

Dr.P.J.JOY,
Chairman,
Advisory Committee,
(Associate Professor of Agrl. Entomology)

CERTIFICATE

We, the undersigned members of the Advisory Committee of Smt.Leena, K.T., a candidate for the degree of Master of Science in Agriculture with major in Agricultural Entomology, agree that the thesis entitled "Biology, morphology, nature of attack and dispersal of *Cyrtobagous salviniae* Calder & Sands (Coleoptera : Curculionidae)" may be submitted by her in partial fulfilment of the requirement for the degree.

Dr.P.J.JOY,
Chairman,
Advisory Committee.

Dr.C.C. ABRAHAM,
Member

Dr.P.VARADARAJAN NAIR,
Member

Sri.V.K.G.UNNITHAN,
Member

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Introduction

INTRODUCTION

The aquatic weevil Cyrtobagous salviniae Calder & Sands is now being used in Australia, Papua New Guinea and Sri Lanka as a very successful agent for the bio-control of the troublesome aquatic fern weed Salvinia sp. In India, this weevil is being used with spectacular success in the Kuttanad tract of the Alleppey district to control the most troublesome floating weed Salvinia molesta Mitchell. Trial releases of the Australian strain of this weevil were started in 1984 and their impact became perceptible from 1986 by which time an area of nearly 1000 sq.km of water bodies was cleared of the weed mat (Plate.1).

The aquatic fern S.molesta is indigenous to South East Brazil. It has spread over many tropical and sub-tropical countries of the world including Africa, India, Ceylon, Indonesia and Australia. In Kerala, its occurrence as a serious weed was recorded for the first time in 1964, possibly as an introduction from Ceylon. The rapid proliferation and spread of the weed in fresh water bodies especially in the paddy fields, canals and irrigation systems of the Ernakulam, Kottayam, Alleppey,

PLATE-1

a

b

Quilon and Trivandrum districts have been causing serious problems to agriculture, aquaculture and navigation. Its spread to reservoirs and ponds has caused excessive loss of water by evapotranspiration.

Among the various methods such as biological, mechanical, physical and herbicidal, the bio-control methods were found to be the most economic, durable and the safest to aquatic ecosystems. Attempts on biological control of S.molesta were initiated by the Commonwealth Institute of Biological Control in Nineteen sixtees and continued in the Nineteen seventees. In 1978, CSIRO Australia commenced a programme aimed at the biological control of S.molesta. In South America, the curculionid Cyrtobagous sp., the pyralid Samea multiplicalis and the paulinild Paulinia acuminata have been reported to feed on this weed, of which Cyrtobagous sp. and S.multipliealis were found to be remarkably host specific (Forno, 1981). The first release of C.salviniae in Australia was spectacularly successful (Room et al., 1981) and this has opened up possibilities for successful bio-control.

Detailed information on the life-cycle, nature of dispersal and nature of damage of Cyrtobagous salviniae is necessary to plan release programmes. The present studies were taken up to generate basic information on these aspects.

Review of Literature

REVIEW OF LITERATURE

1.Distribution of and extent of damage by *Salvinia* spp.

The weed genus *Salvinia* was erected by Herzog in 1935. He isolated the species as *S.auriculata* on the basis of hairs on the leaf papillae.

Records show the spread of this weed in Botanic Gardens at Rio de Janeiro, South America since 1941.

Hira (1969) found that the presence of floating weed masses of *S.auriculata* along the sea shore line of lake Kariba was responsible for reduction of turbulence in inlets and this favoured the multiplication of the vector-snails at the lake.

Mitchell (1970) identified the specimens from Rhodesia and Trinidad to be different from the ones from South America (*S.auriculata*). He described the new species as *S.molesta* (1972).

In Kerala living Salvinia bio-mass was observed in water ways, ponds, tanks and flooded paddy fields along the main road from Kottayam to Ernakulam (Simmonds, 1971). In a particular locality along this route he observed extensive paddy fields, where cultivation was totally abandoned due to the weed menace.

Mitchell (1971 a) concluded that the loss of water by evapo-transpiration through the plants has been much higher than the loss of water by evaporation alone from an open water surface. According to Mitchell (1971 b) this weed competes for nutrients in reservoirs thereby adversly affecting the lake ecosystem.

A considerable reduction in tiller production of rice was reported in a field infested by Salvinia by Soetono (1971).

Cook and Gut (1971) considered Salvinia as a major weed in Kerala and found that since 1964, it has choked the rivers, canals, lakes and lagoons of the coastal plains besides the Kakki reservoir.

Mitchell and Thomas (1972) studied the Salvinia problem in South America.

Salvinia was reported from Kariba lake in 1959. Within six months the weed completely covered the dam (Mitchell, 1973).

According to George (1976) this weed was brought to Trivandrum from Bangalore for botanical studies. George (1977) reported that Salvinia has spread to nearly 19000 ha of paddy cultivated wet land areas of Kerala.

S.molesta was reported for the first time from South America by Forno and Harley (1979). They found that its distribution was limited to Southern Brazil.

The presence of this fern was noted as a noxious weed in 1956 at Veli near Trivandrum (Thomas, 1979).

Pillai et al. (1981) described the short and long term effects of Salvinia deposits in inshore areas of Cochin. They observed the weed deposit immediately after the onset of monsoon.

2.2.Chemical control

Chemical methods of weed control have been applied against aquatic weeds in many areas of the world. However, it is often expensive and wide spread use of chemicals cannot be recommended safely since it creates problems of water pollution.

Sculthorpe (1967) reported the use of simazine, diquat, paraquat and PCP against Salvinia.

In 1970, Wild and Mitchell found that bayluscide at 0.5 and 1.0 ppm affected the budding of Salvinia thereby giving 50 per cent control.

Paraquat at a rate of 2 pints in 150 gal water per acre was recommended to control Salvinia (Usher, 1971). Similar results were also obtained by Kleinschmidt (1973). A check was obtained over S.auriculata by using paraquat at 2-4 pints in 100-150 gal water per acre.

While evaluating amytryne at 0.4 to 1.6 ppm, a reduction in the growth of S.molesta for the lower concentrations was reported by Bambang (1975).

George (1976) reported that paraquat at 5 kg in 650 lit per ha was lethal to Salvinia.

During the months of April and June, 1977, Edwards and Thomas (1977) reported a considerable success with aerial spraying operation with paraquat on the open river and lakes of northern Botswana and Eastern Caprivi area.

3.Mechanical control

Mechanical removal of the weed is the most widely practised method of weed control. The other techniques

include drying out the water sources, but this can be practiced only in habitats that can be easily drained. The risk of incomplete coverage, the chance of reinfestation and the need for frequent repetition of the treatment are some of the handicaps of this method.

Sculthorpe (1967) has pointed out the drawbacks of mechanical control.

Cook (1976) described the mechanical elimination from Kakki reservoir. The spread of the weed to about 200 ha was destroyed in 3 months by keeping wire retaining nets at the inlets and outlets of water canals and periodical removal of the weed thus collected was recommended as a method of control (Thomas, 1976).

Samuel and Jacob (1977) proposed a novel fluidisation technique for harvesting Salvinia.

The possibilities of mechanical control of Salvinia was investigated by Sri.M.R.Sankaranarayanan, College of Horticulture, in 1981. The studies were on the development and evaluation of a prototype Salvinia harvesting machine.

The performance of a Salvinia harvester having clog free high capacity ejector system was evaluated in 1987 by Sri.M.S.Hajilal, College of Horticulture, Vellanikkara for the control of Salvinia.

4.Biological control

4.1.Natural enemies of Salvinia

4.1.1. Fishes

Singh et al. (1969) used grass carps to control Salvinia.

The grass carp, Ctenopharyngodon idella was considered as one of the promising bio-control means in reducing the growth of weed (Pheang et al., 1975).

The herbivorous fish Puntius gonionatus was found to feed on Salvinia by Charoenpong 1978.

4.1.2. Snails

Seaman and Porterfield (1964) found that Salvinia rotundifolia was effectively controlled by the snail Marisa cornuarietis.

Black Burn and Andres (1968) reported that M.cornuarietis can effectively control Salvinia as they feed on the floating leaves.

In Kerala, three species of snails viz., Lymnaea luteola, Indoplanorbis exustus and Pila globosa were recorded by Thomas (1975). He found that, of these P.globosa feed voraciously on Salvinia but not on paddy.

4..3. Pathogenic organisms

Loveless (1969) isolated two fungi a saprophytic Alternaria sp and a parasitic Spicariopsis sp from degenerating mats of Salvinia auriculata.

4.1.4. Competitive plants

Silva and Premadasa (1984) observed in a mixed culture, S.molesta was suppressed by the vigorous growth of Eichhornia crassipes during the first four weeks.

4.1.5. Insects

Nymphula responsalis Walker (Pyralidae : Lepidoptera)

Nandayani and Syed (1976) gave an account of the life history of Nymphula responsalis. Host specificity tests showed that the larvae fed and developed on Salvinia spp, Marsilea crenata, Lemna purpusilla, Monochoria vulgaris, Spirodela polyrhiza, Azolla pinnata and Pistia stratiotes.

Verghis (1976) reported N.responsalis as a pest of Salvinia from Kerala.

Mitchell (1981) made a mass release of the moth N.responsalis for controlling Salvinia.

Rhopalosiphum nymphaeae Linn. (Aphididae : Homoptera)

The feeding behaviour and the nature of attack of the aphid, R.nymphaeae were studied under laboratory and restricted field conditions in Trivandrum by John and Nair (1982).

Samea multiplicalis Guinee. (Pyralidae : Lepidoptera)

Bennett (1970) observed S.multiplicalis on S.auriculata.

Bennett (1972) discussed the problems caused by the weed Salvinia and its possible control using the agent S.multiplicalis.

Forno and Bourne (1974) reported this moth as a bio-control agent for S.molesta from Brazil.

S.multiplicalis was found sufficiently host or habitat restricted when introduced into areas outside America for controlling S.molesta (Bennett, 1978).

A preliminary field evaluation conducted at the Biological Control Unit of the Division of Entomology, Brazil indicates that, the moth S.multiplicalis substantially reduced the growth of S.molesta in 1979-80.

According to Julien et al. (1984) S.multiplicalis was not an efficient controlling agent, although its multiplication and spread was very rapid in Australia.

Room et al. (1984) attempted to control Salvinia using S.multiplicalis. Their studies showed that the moth spread over an area of 170 km in 20 months in Australia.

Sands and Kassulka (1984) studied the biology and host specificity of S.multiplicalis in quarantine conditions. They found that the immature stages of these insects could thrive on Salvinia and some other aquatic plants, but were unable to complete its life-cycle on the alternate hosts.

Whiteman and Room (1985) estimated the population density of larvae of this moth using Berlese funnel and recovery of the larvae from plants at different luminosities of the light source was determined.

Forno and Bourne (1986) discussed the effect of S.multiplicalis on the growth of Salvinia in relation to temperature.

Paulinia acuminata De Geer. (Acrididae : Orthoptera)

Sankaran et al. (1966) noted a grass hopper, P.acuminata feeding on Salvinia sp in Amazon region.

According to Greathead (1970-'71) the low recovery of this insect in Kenya was due to reduced mating in cooler climates.

Studies conducted at Zambia, Ministry of Rural Development, Department of Agriculture, showed the recovery of P.acuminata on S.molesta at released sites (1971-'72).

Irving (1972), Forno and Bourne (1974) and Bennett (1978) investigated the possibilities of using P.acuminata as a bio-control agent for Salvinia.

Chisholm (1979) gave a detailed account of the feeding rate of nymphs of P.acuminata on S.molesta under laboratory conditions and found that each of the successive instars ate more of plant tissues.

In Lake Kariba control of Salvinia was reported by the introduction of P.acuminata (Mitchell and Rose, 1979).

In Brazil, studies conducted by the Commonwealth Scientific and Industrial Research Organisation, Division of Entomology revealed that the wingless grass hopper, P.acuminata substantially reduced the growth of S.molesta (1979-'80)

Thomas (1980) gave a detailed account of his observation on life history and effect of this insect on S.molesta under constant temperature.

Joy et al. (1981) studied the biology and host range of P.acuminata with a view to control S.molesta. Their studies revealed that the female larvae devoured 0.59 g of plant material per day while the males consumed only 0.25 g per day. According to them, the field releases of this insect in Mannuthy and Moncompu was a failure.

Mitchell (1981) investigated the use of P.acuminata as a bio-control agent for S.molesta.

In Brazil, the effect of P.acuminata on the growth of S.molesta was assessed. Forno and Bourne (1986) found the growth of S.molesta reduced by this insect, causing more damage as temperature increased.

Sands and Kassulke (1986) studied the biology and host specificity of P.acuminata in quarantine in Australia. They pointed out that the adults and nymphs fed on the leaves of S.molesta. Host specificity tests of adults and nymphs were conducted on fifty three plants and the results showed that only seventeen were attacked by the adults and nearby nymphs in presence of S.molesta.

Cyrtobagous singularis Hustache/C.salviniae Calder and Sands (Curculionidae : Coleoptera)

Bennett (1966) briefly described the life history, type of damage, host specificity and extent of damage caused by C.singularis to Salvinia and recorded its widespread occurrence in South America.

Kissinger (1966) considered the genus Cyrtobagous Hustache to be monotypic, containing only C.singularis. He also recorded that the weevils were positively phototropic.

Bennett (1972) recommended C.singularis for the control of Salvinia sp. with an aim to clear the navigation canals and fishing areas.

The potentialities of the weevil as a bio-control agent was studied by Irving (1972).

Sankaran and Ramaseshiah (1973) conducted host specificity tests of C.singularis on several hosts including Allium cepa L., Beta vulgaris L., Brassica oleracea L., Canna sp, Dacus carata L., Lactaca sativa L. and Hevea brasiliensis and found that they did not oviposit and feed on any of these test plants except on Salvinia.

Forno and Bourne (1974) studied the insects and mites associated with Salvinia auriculata. In their field studies Cyrtobagous sp was found to be a promising bio-control agent.

In Botswana, C.singularis collected from S.auriculata Aublet failed to establish when released for biological control of S.molesta Mitchell (Bennett, 1975).

Bennett (1976) reported C.singularis as highly host specific and found them always confined to an aquatic environment.

Mitchell (1981) rated C.singularis as a potential controlling agent of Salvinia.

Room et al. (1981) considered C.singularis as a successful agent for controlling S.auriculata.

In Australia, rapid control of S.molesta was obtained by the introduction of closely related species of Cyrtobagous (Room et al., 1981).

Cardo et al. (1982) reported that the weevil C.singularis found in South America fed exclusively on S.auriculata.

Population densities of Cyrtobagous sp. was estimated by extracting from weed bio-mass using Berlese funnels (Boland and Room, 1983).

Forno et al. (1983) studied the distribution, biology and host specificity of C.singularis. Host specificity studies showed that the immature stages were found only on S.molesta. Minor leaf scarring occurred on sweet potato when it was held contact with water. Adults fed, but failed to reproduce on Pistia stratiotes.

Sands (1983) reported that the weevil introduced to Australia for biological control of S.molesta Mitchell, represents a species different from C.singularis.

Sands et al. (1983) reported that the newly emerged larvae of Salvinia weevil browsed on the roots prior to the tunnelling into the rhizome of the host plant for 1 to 4 days, while the scraping period in the buds of the host plant extended upto nine days.

Joy et al. (1984) reported that the weevil is a very potential bio-control agent against Salvinia in Kerala. Their studies however, revealed that the dispersal habit of the weevil was very slow.

According to Room (1984) the weevil successfully controlled the S.molesta in Australia. He also described the interaction of environment with the biological control agent, so as to increase the chances of achieving control in other countries.

Room et al. (1984) found that, out of eight released sites, Cyrtobagous sp established at seven. In these sites, the air temperature ranged from less than 0°C to more than 45°C and mean concentration of nitrogen in S.molesta ranged from 1.18 to 1.82 per cent of dry weight. According to them the shortest time required for extensive damage of the weed was four months. In undamaged Salvinia, the weevil dispersed at a rate of four meters per month.

Calder and Sands (1985) described C.salviniae and compared it with C.singularis. Distribution and the host ranges of both species have been furnished and discussed.

Forno and Bourne (1985) gave a detailed account of feeding by adult C.salviniae on S.molesta under different levels of temperature and nitrogen content . They pointed out that the nitrogen concentration in buds of Salvinia had no influence on feeding by adult C.salviniae, but the time spent feeding on a bud was dependent on temperature and rate of bud development.

According to Joy et al. (1985 a) C.salviniae was an effective bio-agent against S.molesta as it established in many of released sites of Kerala.

Results of studies conducted by Joy et al. (1985 b) showed that yellowing started after four to six months of release of weevil and decaying and sinking of Salvinia occurred within 10 to 12 months.

Room and Thomas (1985) released 570 beetles on S.molesta in field cages, where the population declined to 4.5 in a period of seven months and eleven months later, when weekly application of urea was given in another field cage with 592 beetles, an increase of population upto 3000 was recorded.

Schlettwein (1985) evaluated the distribution and population leavels of C.singularis at Eastern Caprivi Zipfel.

Thomas (1985) suggested this weevil as a permanent controlling agent against S.molesta.

The damage of S.molesta by C.salvinia in relation to temperature was studied in two sites, in canal with running water and in lagoon with still water (Forno and Bourne, 1986). They found that the insect reduced the growth of S.molesta over a mean leaf temperature range of 16 to 30°C, causing more damage as temperature increased.

Host specificity of C.salviniae was studied by Jayanth and Sudha Nagarkatti (1986). They found that, out of 75 species tested the weevil did not attack on 67 species and on the remaining there was only slight attack.

May and Sands (1986) described the biology of C.singularis in Zimbabwe, Southern Africa and C.salviniae in Queensland, Australia.

Room (1986) reported C.salviniae as a successful agent against S.molesta.

The intrinsic rates of increase (rm) of Cyrtobagous salviniae from Brazil and C.singularis from Trinidad were determined in the laboratory at 23°C, 27°C and 31°C on the weed S.molesta (Sands et al., 1986). Their studies revealed that, the variation in oviposition and immature survivorship differed between species in rm values. At all temperatures, C.salviniae laid seven times as many eggs as C.singularis, while at 31°C oviposition was reduced in both the species accompanied by a reduction in egg hatch.

Thomas and Room (1986) suggested the use of the bio-control agent C.salviniae against Salvinia as it provides cost effective environmentally sound and apparently permanent control of the weed.

Studies conducted by Forno (1987) at North Eastern Australia showed that the weevil is effective in reducing Salvinia density both at coastal and elevated sites.

Jayanth (1987) reported the successful control of the weed in a lily pond at Bangalore by C.salviniae.

Material and Methods

MATERIALS AND METHODS

1.Biology studies

Biology studies on C.salviniae were carried out under laboratory conditions. Rearing was done in Reinforced Concrete Cement aquaria of the Project Centre of the AICRP on Bio-control of Crop Pests and Weeds at Vellanikkara. The tertiary growth stage of Salvinia was used for rearing the weevils.

1.1.Egg period

Adult weevils were collected from culture tanks and males and females were separated. A pair of weevils were then released into fresh Salvinia kept in plastic basins (18 x 8 cm) containing water. The eggs deposited on leaf base and rhizome scars were then transferred to moistered filter paper kept in paired petridishes for determining the incubation period.

1.2.Larval period

Newly hatched larvae were carefully transferred to Salvinia buds placed in glass containers (8 cm diameter) and the larval duration was recorded.

1.3.Pupal period

After pupation, the pupae along with plant parts were placed in plastic containers (18 x 8 cm) and kept until the adults emerged.

1.4.Adult longevity

The newly emerged adults were maintained on Salvinia kept in cement tanks (0.4 m diameter) containing water. Water level in the tank was maintained steadily. The Salvinia used for rearing was changed every week.

1.5.Mating and ovipositional capacity

For studying the mating and ovipositional capacity, pupae were collected from culture tanks. When the adults emerged, they were sexed into males and females. One pair of weevils were then introduced into the Salvinia in the tanks filled with water. The pre-ovipositional period, number of eggs laid and mating capability were determined.

2.Morphology

Morphological observations were made using stereomicroscope. For this, measurement of adult weevils, pupae, and different instars of larvae as well as eggs were taken and permanent slides of legs, antennae, mouth parts, wings and genetalia were prepared.

2.1.Preparation of slides

Various parts of the insect were dissected out and transferred into a glasstube of size 75 x 15 mm to which 5 per cent Potassium hydroxide was poured and boiled for five minutes over a spirit lamp. Using a fine needle, the tissues were removed and transferred to acetic acid. After 3 minutes they were transferred to Carbol-xylol (1:3) and kept there over night. These were transferred to xylol for dehydration. Staining was done in the case of mouth parts and genetatia. Canada balsam was used as the mountant. The slides were later labelled and stored in slide trays.

2.2.Measurements

The length of the adult was measured from the anterior margin of the snout to the apex of elytra along the mid-dorsal line and the body width across the indest area of the closed elytra.

Maximum length of rostrum was measured from the base to the apex of the rostrum. Length of thorax was measured from the base of rostrum to the anterior margin of elytra and width across the middle line of thorax.

Length of elytra was noted from the apex to the base of elytra and width across the one third distance from the anterior margin.

Measurements of the length of legs were made from coxa to the distal end of claw.

Length of antenna was taken from the base of scape to the apex of club.

Measurements of length and width of each instar of larva was taken. The length was measured from anterior margin of the head to the apex of the anal region and the maximum width across the middle region of larva.

Measurements of the size of mandible was made from the proximal to the distal end.

Maximum width of head capsule was measured across the middle portion.

3.Nature of attack

Experiments on the feeding damage were conducted in the RCC tanks using Completely Randomised Design. For this, five replications were maintained. Two hundred grammes of Salvinia mass was weighed and put into each tank. Weevils were released into the tanks at 4, 8, 12 and 16 numbers per tank. Five insect-free control tanks

were kept as checks. The records on reduction in weight and percentage damage to Salvinia were made at fortnightly intervals. Measurements on leaf area and root length were taken at monthly intervals by taking ten samples randomly from each treatment.

3.1.Feeding damage by adults

Two separate experiments were conducted to assess feeding damage to lamina and the feeding damage to buds. These experiments were carried out in laboratory using circular plastic containers of size 13 cm in diameter and 7 cm depth with water. For this, leaves of size ranging from 4 cm^2 to 5 cm^2 and buds of size varying from 1.5 cm^2 to 2 cm^2 were used. There were four replications for each sex and treatments and treatments were given as one, two, three and four numbers of insects. The area consumed was measured by placing leaves/buds on graph paper and counting the number of squares until the leaves/ buds were completely damaged.

3.2.Effect of adults on plant growth

The tertiary growth of plants with first three main stems and connecting rhizomes were used for this experiment. Two pairs of adults were placed on the apical bud of each of 10 plants and another 10 insect

free controls were also placed in a circular container of size 13 cm in diameter 7 cm depth half filled with water. The water in the containers was changed every third day. The relationship of side branches to main stems, the number of buds and leaves formed were recorded.

4.Dispersal studies

Dispersal studies were conducted in plastic pools of 3 m diameter each. Tertiary stages of Salvinia were used for this study. The plastic pools were filled with water and completely covered with Salvinia. Adults were then released into a particular marked point. The plant bits around the released point was daily examined. The distance travelled and direction of movement were recorded. The phototropism of the weevil was studied using a light trap.

5.Statistical analysis

For comparison of treatments with respect to the weight of Salvinia, root length, leaf area reduction and feeding damage to leaf/bud at different population loads, the Analysis of variance technique was made use of.

Equality of variance of the male and female insects was first tested using the F ratio ie., the ratio of the larger mean square to the smaller. Then the 't' statistics was calculated as follows.

$$t = (\overline{x_1} - \overline{x_2}) \Big/ \sqrt{(s_1^2 + s_2^2)/n}$$

where $\overline{x_1}$ = mean for male insects

$\overline{x_2}$ = mean for the female insects

s_1^2 = mean square for male insects

s_2^2 = mean square for female insects

n = common sample size. This being 10 numbers in all the cases.

The calculated value of 't' was compared to the critical values of students 't' with 2 (n - 1) degrees of freedom if the variance did not differ significantly and with n - 1 degrees of freedom otherwise.

Paired 't' test was used for comparison of different parts of the same insect.

RESULTS

1.Biology (Fig. 1)

1.1.Eggs

Eggs are inserted singly either within the base of leaves (75 per cent) or in scars of rhizome (25 per cent). Freshly laid eggs are pale yellow in colour which gradually darkened during the course of development. The incubation period varied from 6 to 9 days, the average being 7.9 days (temperature 31°C and RH 86%). Hatching took place during day or night time and the process was completed in about 30 to 40 minutes. During hatching, the larva pushes the operculum and comes out.

1.2.Larva

On hatching, the first instar larva remains outside for a while scraping on the tender plant tissues. After about 3 to 4 days they tunnell into the leaf base (50 per cent) or the nodal region of the rhizome (50 per cent), and complete the three instars in about 9 to 10, 8 to 10 and 7 to 10 days respectively. The total life span varied from 21 to 28 days. (Table 1)

1.3.Pupa

The last instar larva stops feeding and comes out of the plant parts. Then it pupates within a spun cocoon. Plant parts are used for spinning the cocoon which is attached ventrally on leaf base (40 per cent) or rhizome (40 per cent) or on root mass (20 per cent). At times, cocoons are found attached to the rachis at the root base. The pupal duration extends over 9 to 13 days with an average of 11.3 days. Pupa has a very high percentage survival of about 85 per cent.

1.4.Adult

Adult comes out of the cocoon, using its mouth parts. Freshly emerged adults are metallic brown in colour and gradually the colour turns to dark brown. Within 4 to 5 days the adults attain black colour. These sub-aquatic adults which adhered beneath the fresh growth usually, feed on leaf buds and immature leaves. Occasionally, they are found to be gathering near the root region for feeding. The legs are armed with water repellant adhesive hairs which helps the insect to float on water surface. Females are relatively larger than males. Adult lives for a period of 172 to 279 days ($\bar{x}$ = 211.9 days).

Table-1. Life cycle of *C.salviniae* under laboratory conditions.

Sl. No.	Egg period	Larval period	Pupal period	Adult period
1	8	22	12	198
2	6	21	11	172
3	9	28	12	227
4	7	23	11	220
5	8	28	12	279
6	8	23	9	209
7	8	22	11	190
8	9	23	13	208
9	8	23	12	205
10	8	22	10	211
Mean days	7.9	23.5	11.3	211.9

LIFE STAGES OF *C. salviniae* IN RELATION TO HOST

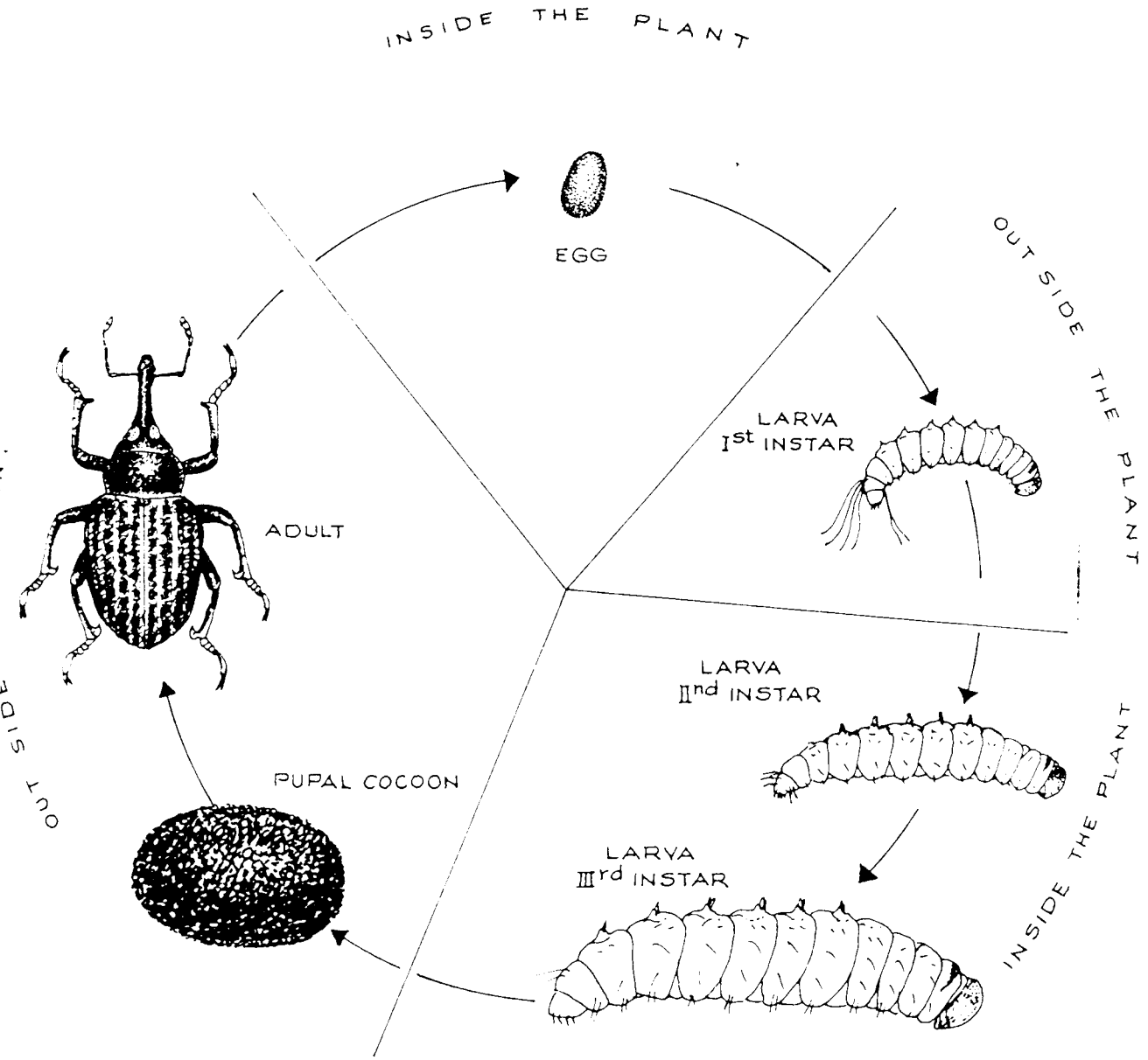


FIGURE. 1

1.5. Mating and ovipositional capacity.

Mating takes place 4 to 5 days after emergence. Mating occurs periodically within leaves or near leaf base on rhizome. A pre-ovipositional period of 5 to 10 days was recorded.

2. Morphology

2.1. Egg

Eggs are ovocylindrical with slightly thickened operculum, length being 0.56 mm and width 0.25 mm (Fig.2 A). Body segmentation of the first instar larva could be observed in a mature egg.

Table-2 a. Average size of immature stages of C.salviniae (mm)

	Egg	Larva			Pupa
		I instar	II instar	III instar	
Length	0.56	1.80	2.75	3.48	2.88
Width	0.25	0.38	0.69	0.98	1.72

2.2.First instar larva

Freshly emerged larvae are creamy-white in colour, gently curved along the longitudinal areas and tapering towards both ends. They possess a well developed head and a distinct pronotum. Body segmentation is not quite distinct. They possess three thoracic and ten abdominal segments. The retractile spiracles are clearly visible from the dorsal side. The body is covered with long and short setae. The setae on the ventral side are hook-shaped and curved backwards. They are distributed on all the segments, except the ninth. The setae are forwardly directed in the anal segment. The elongated trailing setae are found on ninth segment. Fine setae are observed on the lateral and dorsal sides of the segments (Fig.3.A). The length of first instar larvae varied from 1.65 to 1.89 mm ($\bar{x}$ = 1.80 mm) and width from 0.35 to 0.41 mm ($\bar{x}$ = 0.38 mm) (Table 2 a). The head capsule on an average, measured 0.19 mm in width. The reddish brown bilobed mandibles has a length of 0.05 mm.

2.3.Second instar larva

They are stout and relatively more active, compared to the first instar. They are yellowish-white in colour

and crescent shaped (Fig.3.B). The trailing setae on ninth segment are much reduced both in their length and in number. The length, width, head capsule width and mandible length of the second instar larvae are 2.45 to 2.97 mm, ($\bar{x}$ = 2.79 mm), 0.63 to 0.79 mm ($\bar{x}$ = 0.60 mm), 0.24 mm and 0.07 mm respectively

2.4.Third instar larva

But for the sluggish nature, the third instar larva resembles the second except that the trailing setae in the former are very much reduced or absent (Fig.3.C). Their body length varied from 3.46 to 3.50 mm ($\bar{x}$ = 3.48 mm) and width from 0.97 to 0.99 mm ($\bar{x}$ = 0.98 mm). Head capsule width is 0.28 mm, the mandible length being 0.09 mm.

Table-2 b. Measurements of head width and mandible length of C.salviniae.

	Head capsule width (mm)	Mandible length (mm)
First instar	0.19	0.05
Second instar	0.24	0.07
Third instar	0.28	0.09

Analysis of observations revealed that head capsule width of first (0.19 mm) and second (0.24 mm) second and third (0.28 mm) and first and third instars significantly varied (Table 2 b).

Measurements on mandible length were taken and the analysis showed conspicuous difference in the three instars.

2.5.Pupa

Pupa is broadly oval in shape and is concolorous to plant parts when freshly formed (Fig.2.B). By about 6 to 8 days the colour changes to brown. Pupa measured about 2.72 x 2.88 mm in size.

2.6.Adult

Freshly emerged adults are of varying shades of brown. They turn black during the course of development. Length of male varied from 2.01 to 2.25 mm ($\bar{x}$ = 2.12 mm) and width from 0.75 to 1.10 mm ($\bar{x}$ = 0.95 mm). Female length varied from 2.52 to 3.11 mm ($\bar{x}$ = 2.92 mm) and width 0.96 to 1.22 mm ($\bar{x}$ = 1.05 mm).

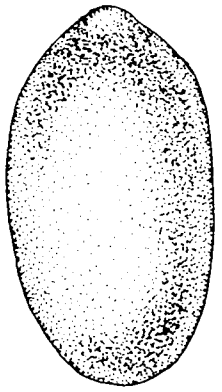
Table-2 C. Average size of adult C.salviniae

	Length (mm)	Width (mm)
Male	2.12	0.95
Female	2.92	1.05

Fig. 2

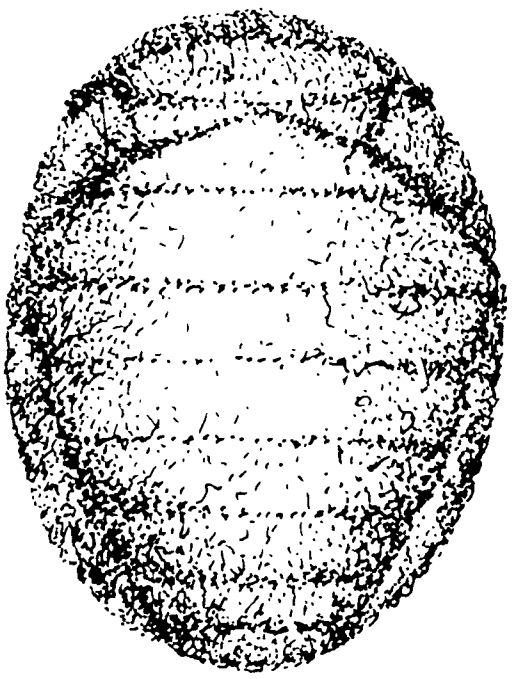
A. Egg of C.salviniae.

B. Pupal cocoon of C.salviniae.



A

0·1mm



B

1mm

FIGURE . 2

Fig. 3

Larval instars of C.salviniae

A. First instar

B. Second instar

C. Third instar

ADB - Abdominal segment

AS - Anal setae

DS - Dorsal setae

PS - Pleural setae

THR - Thoracic segment

TS - Trailing setae

VS - Ventral setae

S1 - Spiracle

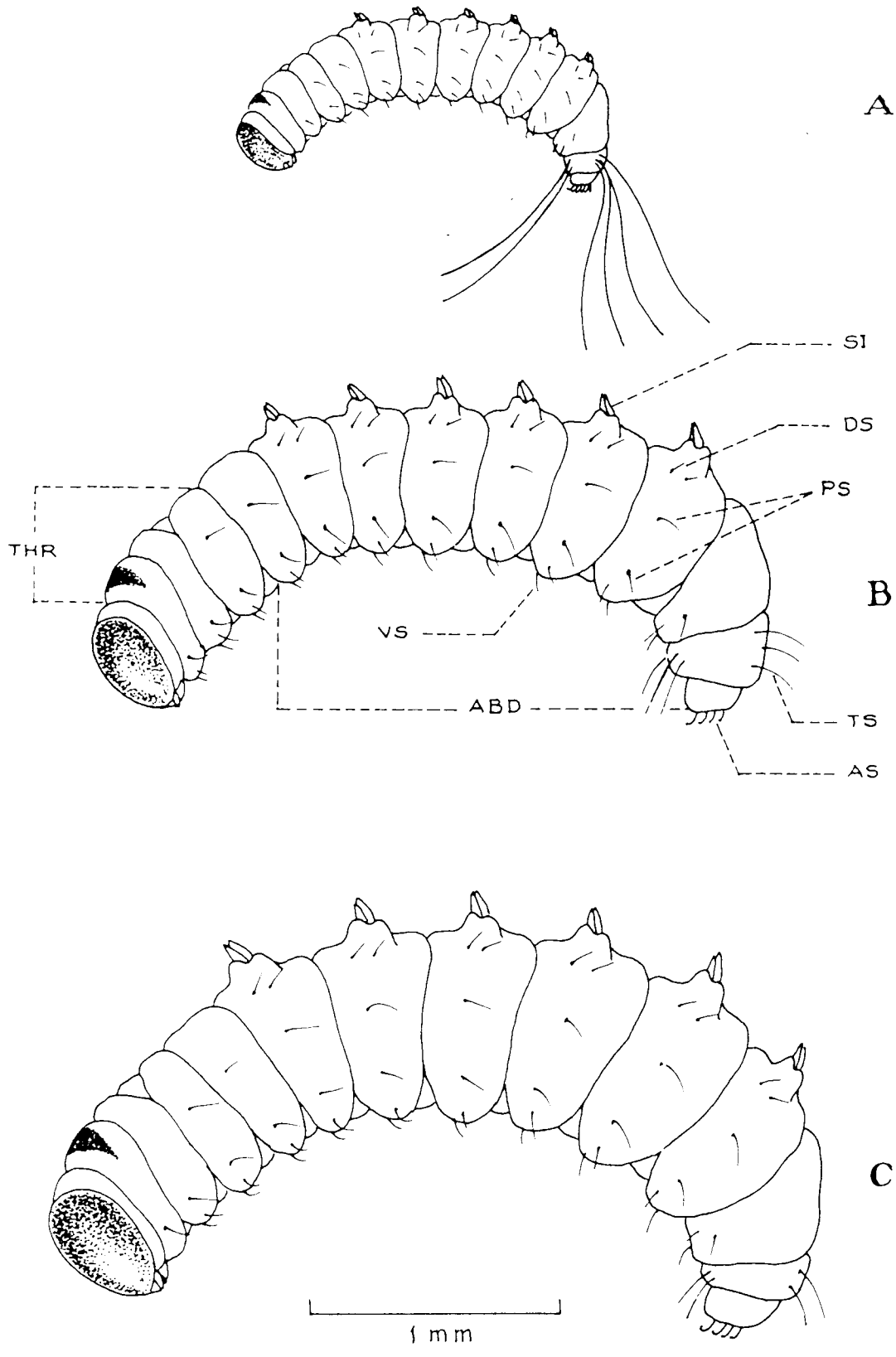


FIGURE . 3

It was found that females were distinctly longer (Fig.4.B) than the males (Fig.4.A). Significant differences with regard to female width and male width was also observed (Table 2 d).

2.6.1.Rostrum

The rostrum is elongate and slender being slightly convex towards the apex. The scrobe is well marked on either sides. The dorsal surface of the rostrum shows shallow irregular depression.

The female rostrum is significantly longer (1.22 mm) as compared to males (1.03 mm). The width also showed significant difference between male (0.35 mm) and female (0.46 mm).

2.6.2.Head

Sub-globular, and is set well into prothoracic cavity. The eyes are slightly oval and is situated towards the base of the rostrum.

Mouth parts

Mouth parts are enclosed in the terminal aperture and are much reduced in size. Only mandibles are visible from outside.

Fig. 4

Adult *C.salviniae*

A. Male

B. Female

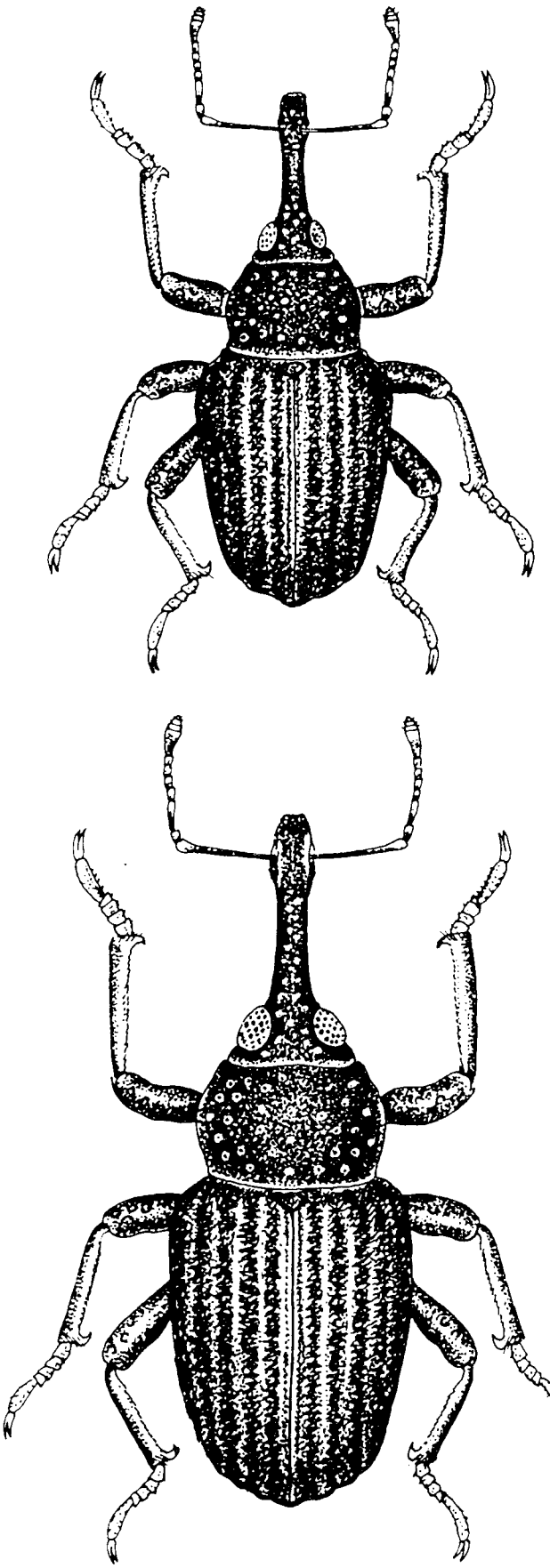


FIGURE. 4

Mandible: Hard and reddish brown in colour. Length 1.16 mm, width 0.87 mm, with three curved denticles, the inner one being the smallest (Fig.5.A).

Maxilla: Three lobed. Cardo, short. Stipes with prominent notch having a massy palpus. Palpus three segmented. Apical two are smaller as compared to the basal. Lacinia possess a short tooth like process (Fig.5.C).

Labium: Sub-mentum broad holding a 'U' shaped mentum, bearing a filament like process at its middle. Palpi distinct with two lobe-like processes on either side (Fig.5.B).

2.6.3.Antenna

Reddish-brown in colour, situated at sub-apical region of the rostrum at one-third distance from the apex.

Scape: Elongate (0.45 mm) and slender towards the base and swollen apically.

Funiculus: Six segmented. Basal segment swollen (0.09 mm). Second being slender and elongate (0.12 mm). Segment 2 to 6 with apex having a cone shaped depression into which the basal region of the succeeding segment fits snugly. The segments 3 to 6 are more or less equal in length (0.04 to 0.05 mm).

Fig. 5

Mouth parts of *C.salviniae*

A - Mandible

B - Labrum

ME - Mentum

SU - Submentum

C - Maxilla

CA - Cardo

LAC - Lacinia

PAL - Palpus

PR - Palpifer

ST - Stipes

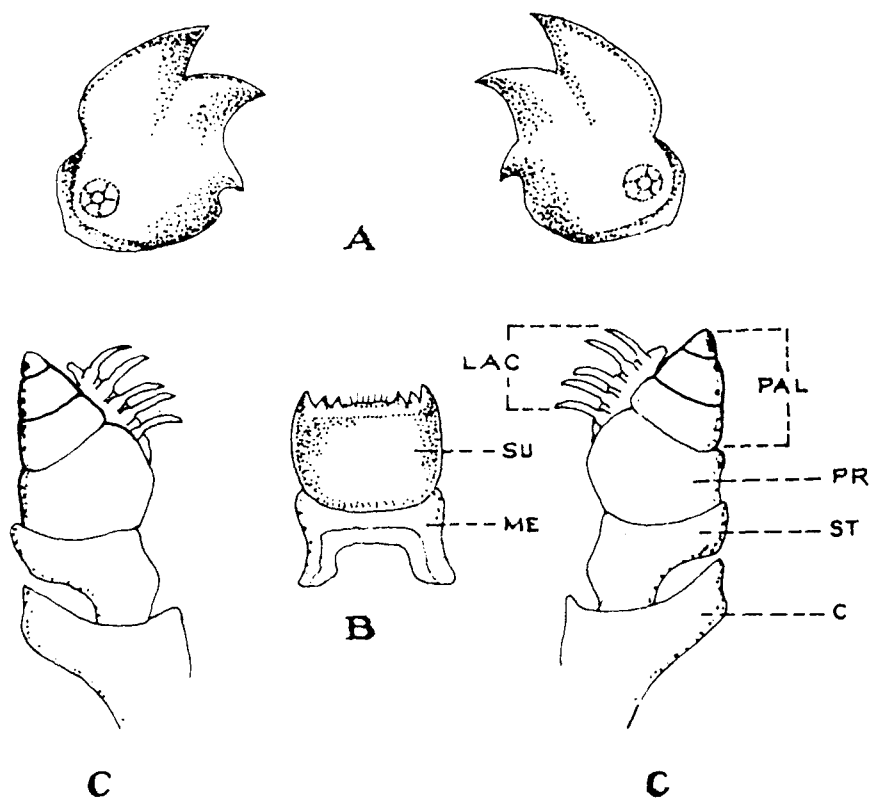


FIGURE . 5

Club: Club consists of four segments, basal segment being swollen and smooth. Of the other three segments, the apical one is shortest and cone shaped.

The first funicle and the last three apical segments of the club are covered with short hair like processes. The three apical segments of male (Fig.6.1.B) are slightly longer than those of female (Fig.6.1.A).

The total length of male antennae is 1.07 mm and that of female 1.03 mm, but the difference is not significant.

2.6.4.Pronotum

Broader than long with a slight lateral bulging at about its middle. Dorsum covered with shallow punctures.

The length (0.65 mm) and width (0.80 mm) of female pronotum is more than that of male (0.59 x 0.69 mm).

Legs

Coxa: Swollen and short. Fore coxa longer (0.46 mm) than mid (0.24 mm) and hind (0.28 mm) coxa.

Trochanter: Short and triangular, inner margin fringed with short hair like processes.

Fig. 6

1. Antennae of *C.salviniae*

A - Female

B - Male

CB - Club

FUN - Funiculus

SC - Scape

2. Ventrites of *C.salviniae*

C - Female

D - Male

MRL - Median raised lobe

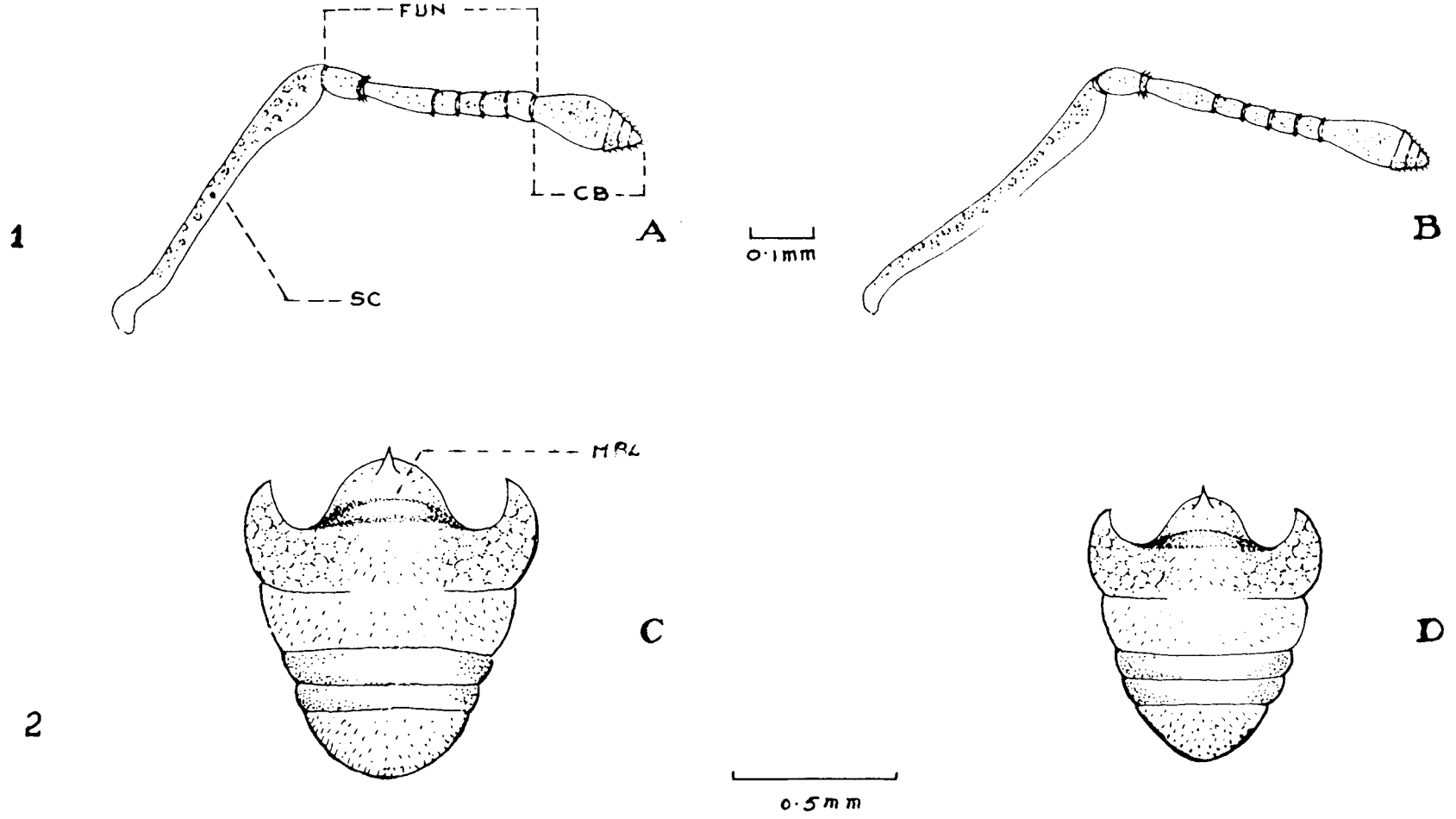


FIGURE. 6

Femur: Femur has a basal handle like portion, swollen at about its middle with a slight notch at sub-apical region. The outer margin of femur is covered with short hairs. Femur of fore leg is longer (0.72 mm) than in other two legs (mid 0.68 mm, hind 0.70 mm).

Tibia: Long and slender. A prominent short, stiff spur is present at the apical region. A circlet of short, spine like processes are present on fore and mid tibia. These spines are short in females than in males. A row of thirteen long spines are present at the distal end of hind tibiae. The spur on hind tibia has prominent hump in males, while in females this hump is not quite prominent. The hind tibial spur in female is relatively shorter than the fore and mid legs. The inner margin of the tibia is covered with long hair like processes which are shorter along the outer margin.

Tarsi: Four segmented. First being the longest, fourth one much compressed and visible only at higher magnification. Tarsal segments are sparsely covered with hairs at the inner angles, while the outer margins show short hair like processes.

Pretarsus: Length more or less equal to the tarsel segments and it is of uniform breadth. They are covered with long hairs ventrally and with short hairs dorsally. The claws at the apex of pretarsus are prominent, curved and bilobed.

In female, the differences between the length of fore (2.40 mm) and mid (2.49 mm), mid and hind (2.44 mm) and for (Fig.7.A) and hind legs (Fig.7.C) were insignificant.

For male, fore (2.31 mm) and mid (2.13 mm) legs differed significantly; but the differences between mid (Fig.8.B) and hind legs (2.08 mm) were insignificant. However, the fore (Fig.8.A) and hind legs (Fig.8.C) showed significant differences.

There was no significant differences between female and male fore legs but the mid (Fig.7.B) and hind legs of female and male differed significantly.

2.6.5. Scutellum

Oval with a convex surface.

2.6.6. Wings

Elytra: Strongly convex and chitinised, gently curved

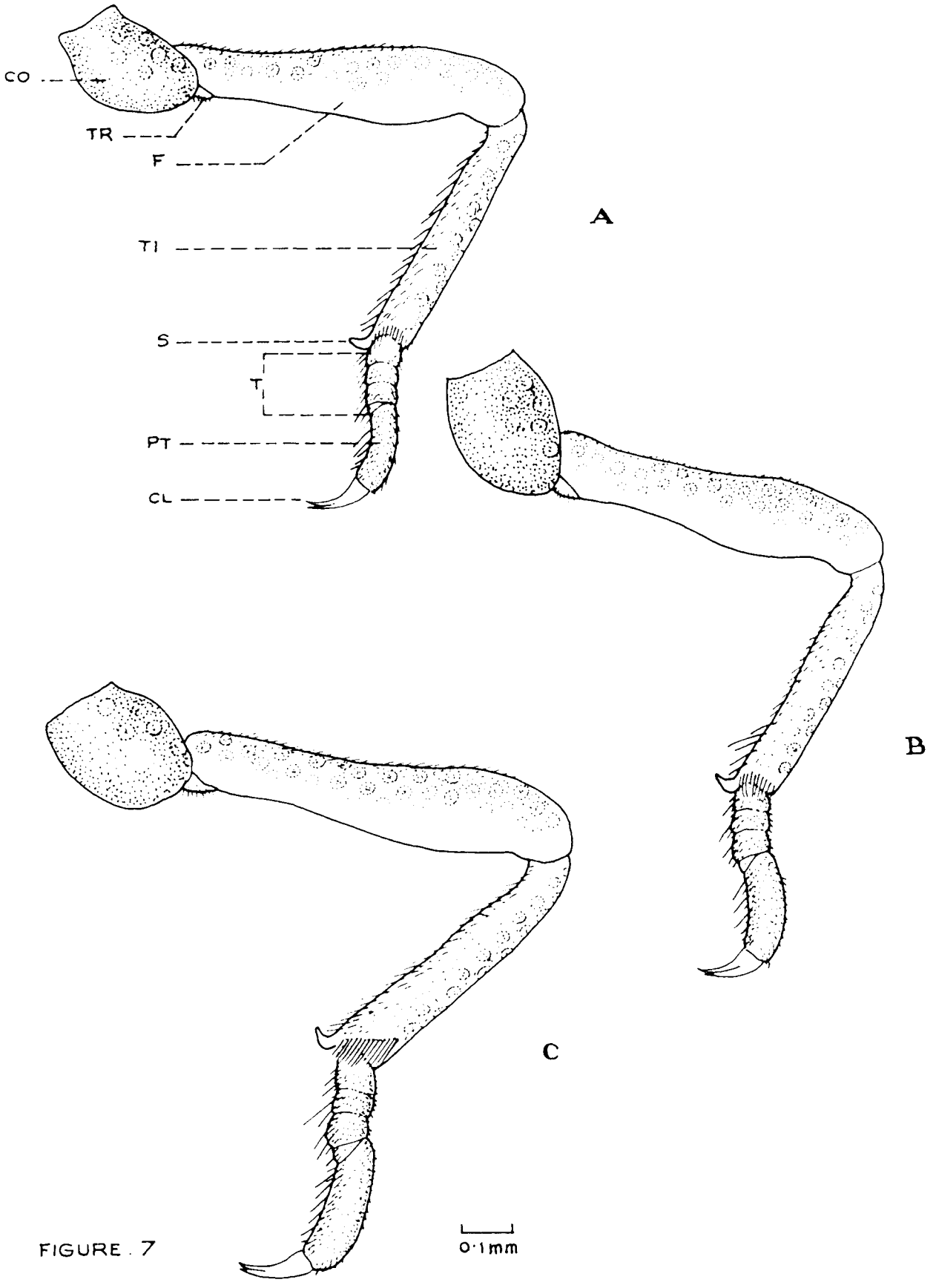


FIGURE. 7

Fig. 8

Legs of male C.salviniae

A - Foreleg

B - Midleg

C - Hindleg

CL - Claw

CO - Coxa

F - Femur

PT - Pretarsus

S - Spur

T - Tarsus

TI - Tibia

TR - Trochanter

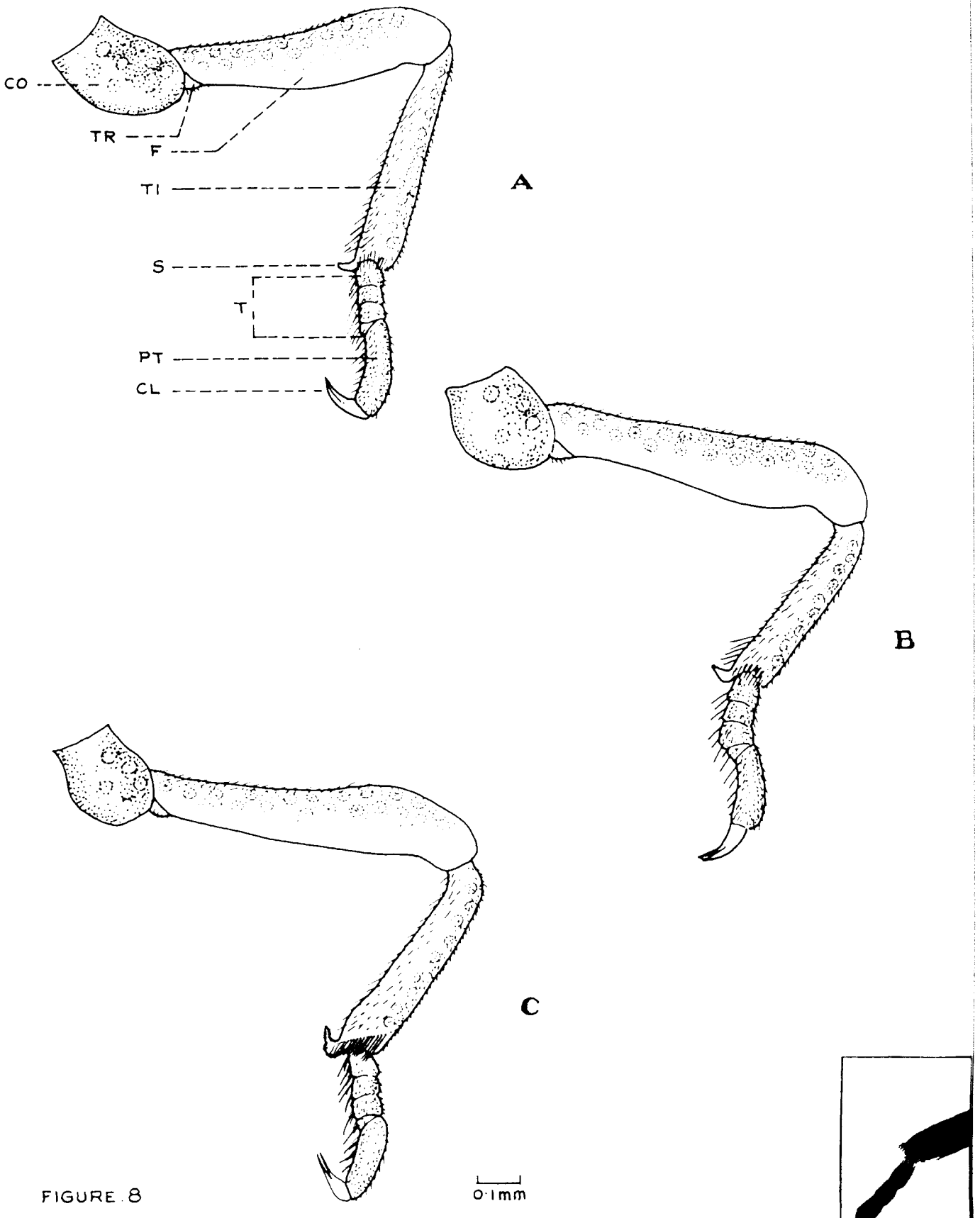


FIGURE 8

laterally and strongly curved posteriorly. Linear striae contain deep punctures (Fig.9.A).

The size of elytra of female (1.60 x 1.00 mm) varied significantly from the males (1.26 x 0.96 mm).

Hind wing: Elongate membraneous oval, being narrowed basally. Most of the veins are atrophid. Sub-costa is very short and confined to the basal portion and it distally fuses with the radius. Close to the radial vein a triangular, sclerotised patch could be seen at about one-third distance from the base. Median vein faint, cubital vein short with a distinct anal vein at the base extending about half the length of the cubital vein. Wing margins armed with short hairs which are slightly longer at the posterior margin and the wings are spiculate (Fig.9.B).

The females have larger hind wings (4.16 mm x 1.21 mm) than the males (3.43 mm x 1.12 mm).

2.6.7. Abdomen

Only the last segment is visible from the dorsal side. Ventrally five segments are visible. First ventrite wider than long with a median raised ridge, flanked on either side by two sub-circular depression forming the boundary of hind

coxal cavity. Median ridge with a prominent central blunt spine like process which is not distinct in females. The depression is bordered by a strongly sclerotised region which meets with the transverse sclerotised patch present on the median raised lobe. Median area spiculate with laterally scattered punctures.

Second segment is fused with the first and the suture connecting the two ventrites are not distinct at the middle region. The third and fourth visible segments are narrow and spiculate. The fifth visible segment is more or less hemisphearical in females (Fig.6.2.C) as compared in males (Fig.6.2.D) and covered with spicules.

2.6.8. External genetalia

Male

Aedeagus: Distal end prominently tongue shaped arising from distinct shoulders, continued as long, slender aedeagal apodemes one on either side. Apexes of aedeagal apodemes are pointed. Aedeagus with two elongate, narrow, triangular sclerotized patches towards its caudal end and with a more or less round tip (Fig.10 C).

Tegmen: Tegmen having a cylindrical and a broadened part. The apical region conical broadly 'U' shaped, sclerotized

and fringed with short hairs, with an inwardly directed narrow tongue like sclerotized area. Lateral arms of tegmen slender and sclerotized. The lateral arms of parameres unite into a long median broad like process (Fig.10.B).

Spiculum gastrale: Long and stout, both ends broadened, caudal end sub triangular and flattened with a deep internal furrow (Fig.10.A).

Female

Bursa copulatrix short, cylindrical preceeding a very long fine duct of spermatheca at its cephalic region. Spermatheca short and hard and hook-shaped and more or less bud shaped, sac like spermathecal gland attached to the spermatheca (Fig.11). Collum well developed. The bursa opens by a very short ductus to the outside. Apophysus of ovipositor short consisting of a broad basal segment bearing short, slender blunt processes called stylus.

3.Nature of attack

3.1.Mode of attack : Larva

First instar larva scraped the green matter on young leaf buds. As a result, linear scars were observed on

Fig. 10

Male genetalia of C.salviniae

A - Spiculum gastrale

IR- Internal furrow

B - Tegmen

SA- Sc lerotised area

C - Aedeagus

A, AP - Aedeagal apodemes

IS - Internal sac

MSP - Median Sclerotised patch

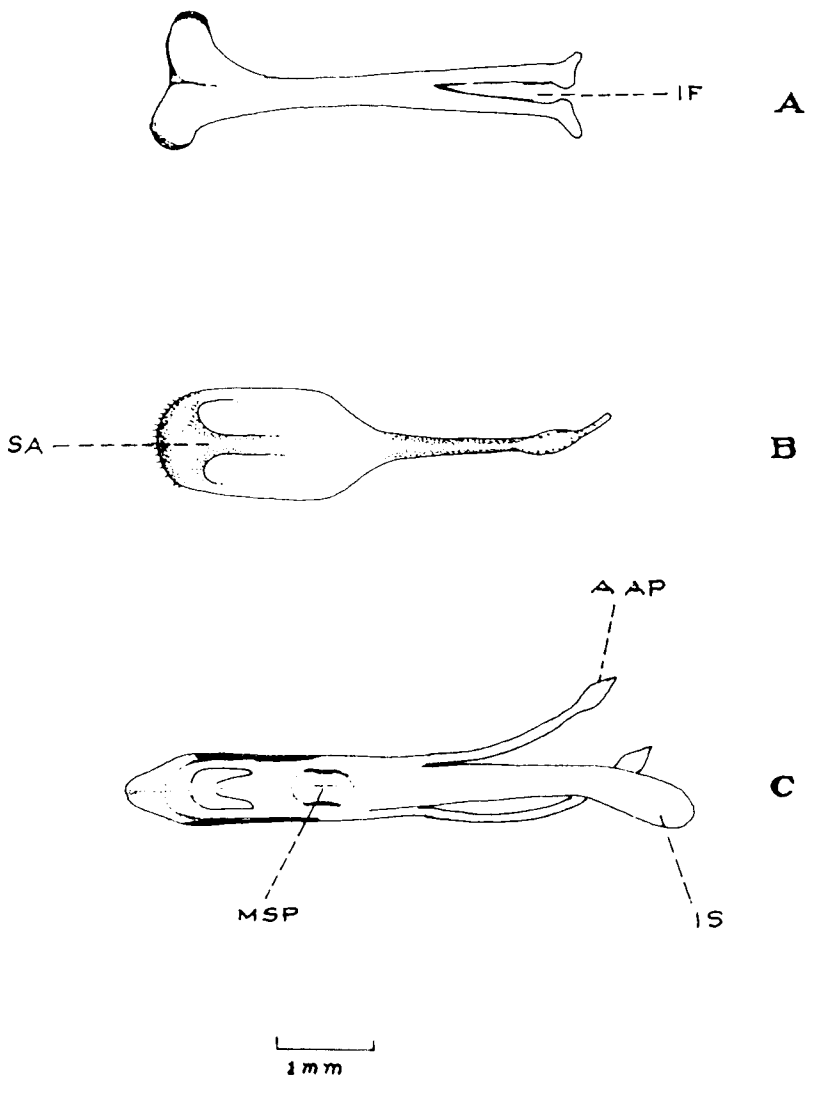


FIGURE . 10

Fig. 11

Female genetalia of C.salviniae

DB - Ductes bursa

SD - Spermathecal duct

SG - Spermathecal gland

SL - Styli

ST - Spermatheca

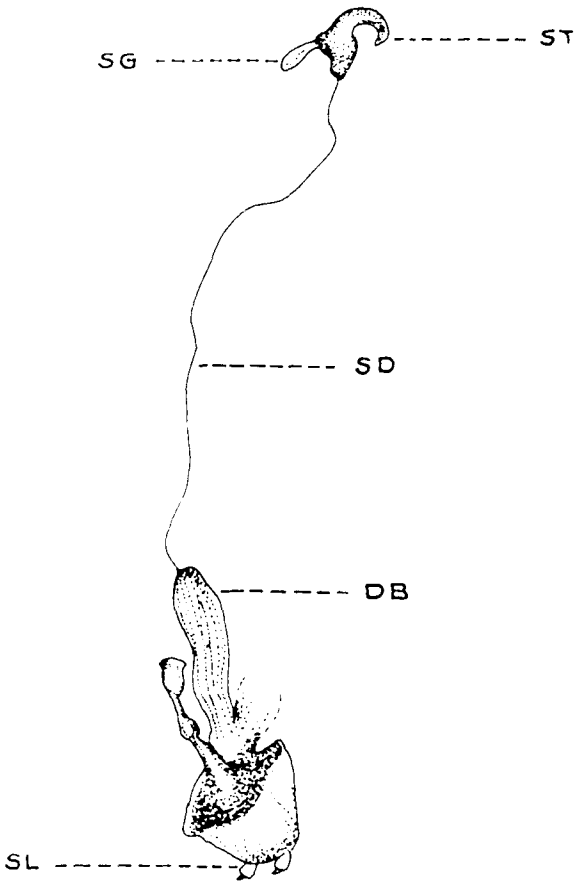


FIGURE .11

tender leaves. After 4 to 5 days, the larva entered the plant tissues through the basal portion of leaf and either remained there or tunnelled inside the rhizome. The larva tunnelled at the nodal region of the rhizomes and this area turned brownish after about a week. The leaves then became characteristically darkened, partly or completely, resulting in the death and disintegration of plant tissues.

3.2.Mode of attack : Adults

Adults were usually found feeding on unopened leaf buds and tender leaves. As a result of their feeding, the buds and leaves were completely destroyed, thereby arresting the growth of the weed. The weevils were also found feeding on rhizomes producing scars on them and occasionally on 'roots', causing disintegration at the point of their attack.

The visible symptoms due to the attack of C.salviniae included gradual change of colour from normal green to an yellowish green, which further turned to rusty brown followed by the arrest of growth of leaves. The leaf size and root length also gradually reduced and finally the weed changed into a brownish black mass.

3.3.Feeding damage to *S.molesta* due to *C.salviniae*

3.3.1.Weight loss

The pooled data indicated a significant difference between treatments from 30 days onwards (Table 3 a). The maximum weight recorded was in control tanks (1.554 kg) after 60 days. The least weight was recorded after 90 days in treatment with 16 insects (0.264 kg). Analysis of Variance table is presented in Appendix I.

Table-3 a. Mean weight of *Salvinia* (kg) in association with different population loads of *C.salviniae* (at biweekly intervals)

Interval (days)	15	30	45	60	75	90
Treatment (No. of weevils)						
0	0.571	0.987	1.350	1.554	1.461	1.094
4	0.603	0.940	1.108	1.019	0.961	0.630
8	0.546	0.882	0.952	0.856	0.762	0.418
12	0.530	0.806	0.805	0.746	0.587	0.396
16	0.562	0.726	0.702	0.645	0.503	0.264
C D	0.038	0.071	0.091	0.100	0.082	0.045

3.3.2.Reduction in leaf area

The analysis of data on leaf area reduction clearly indicated a significant difference between treatments. The mean leaf area was higher after 60 days of release in control (10.186 cm^2). The reduction in leaf area was found to be maximum after 90 days in treatment with 16 insects (1.406 cm^2) followed by 12 insects (2.394 cm^2) (Table 3 b). Analysis of Variance table is presented in Appendix II.

Table-3 b. Mean leaf area (cm^2) reduction due to feeding by different population loads of C.salviniae (at monthly intervals)

Interval (days)	Initial	30	60	90
Treatments (No.of weevils)				
0	7.962	8.568	10.186	7.420
4	7.942	7.658	6.698	3.408
8	7.574	6.408	4.842	2.724
12	8.348	6.166	4.552	2.394
16	8.364	5.274	3.920	1.406
C D	1.023	0.641	0.694	0.615

3.3.3.Reduction in root length

The data presented in Table 3 c indicated the effect of C.salviniae on root length of the weed. The mean root length was higher after 60 days in control (23.062 cm). It is evident that the reduction in root length was significant in treatment number 5 having 16 insects. Analysis of Variance table is presented in Appendix III.

Table-3 c. Mean reduction in root length (cm) of Salvinia due to the attack by different population levels of C.salviniae (at monthly intervals)

Interval (days)	Initial	30	60	90
Treatments (No. of weevils)				
0	21.388	26.350	23.062	20.230
4	21.530	22.462	20.930	14.400
8	19.250	16.416	16.120	13.340
12	21.370	15.760	14.026	12.630
16	20.566	14.336	13.150	6.516
C D	3.014	1.614	1.638	1.698

3.3.4.Visual symptoms due to C.salviniae on S.molesta

After 15 days of release of insect, a gradual colour change of the weed mass was observed in the treatment having 16 insects. Browning of the weed was observed after 30 days (Plate 2) in this treatment, while a slight colour change was also observed in control tank. After 60 days, a 65 to 75 per cent browning occurred (Plate 3) and the whole weed mass changed into brownish black mass after 90 days of release (Plate 4).

3.4.Feeding damage by adult

3.4.1.Effect of different population levels of males and females of C.salviniae on S.molesta leaf.

From the analysis of the data (Table 4 a), it was found that after 24 hrs, treatment with three female insects significantly differed from the rest of the treatments. Treatments with one, two, three and four males were found to be on par and these varied significantly with one (0.145 cm^2) and four females (0.210 cm^2). Analysis of Variance table is presented in Appendix IV.

After 48 hrs, the treatment with one male caused minimum damage (0.110 cm^2). The treatment with four and

Plate 2

a. Control

b. Symptoms of attack 30 days after the release (16 weevils)

PLATE. 2

a

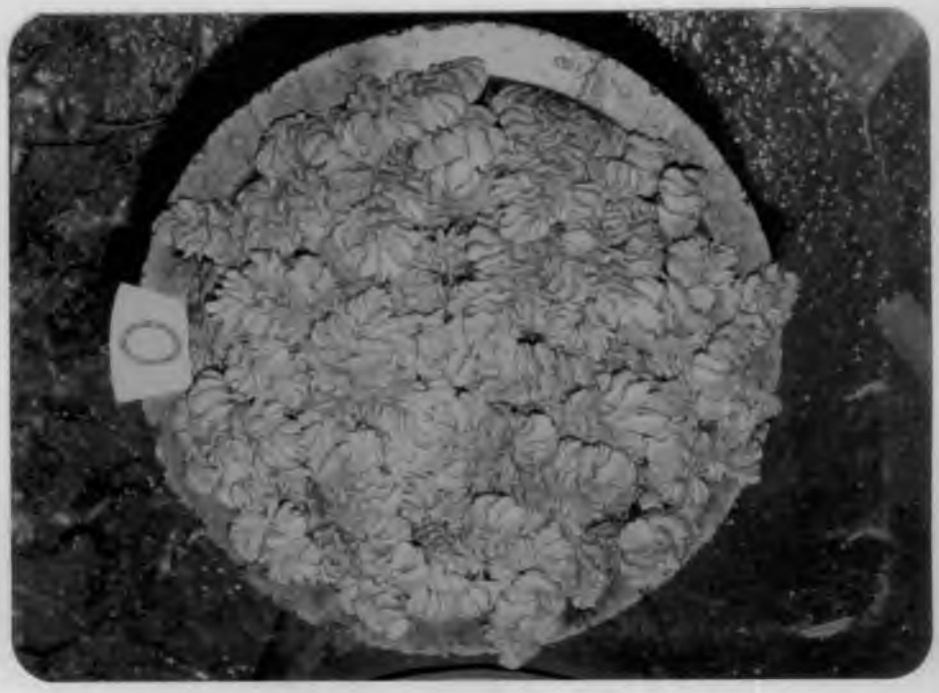
b

Plate 3

a. Control

b. Symptoms of attack 60 days after the release (16 weevils)

PLATE-3



a

b

Plate 4

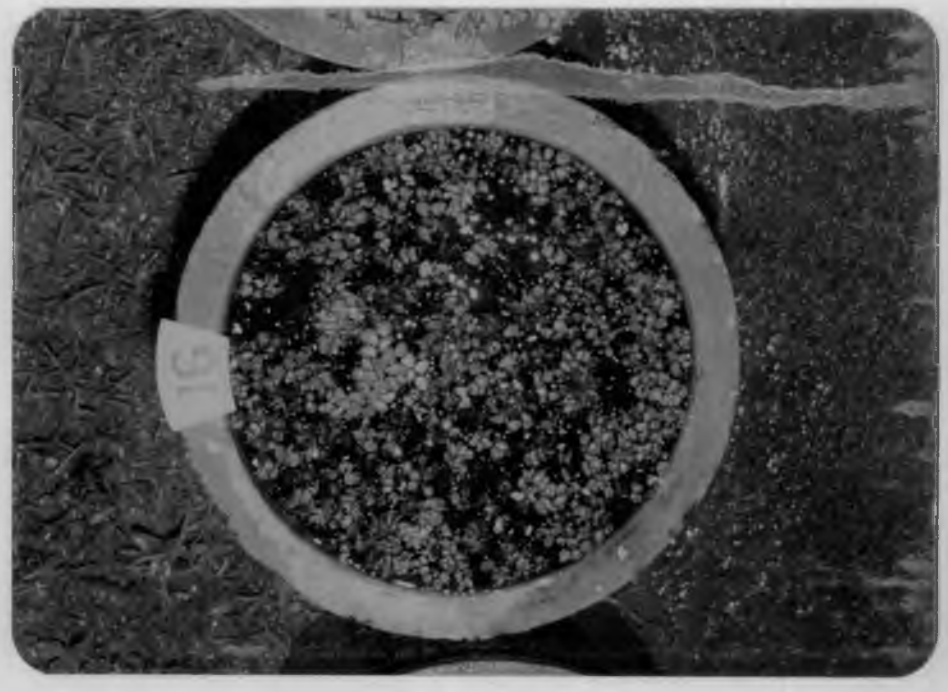
a. Control

b. Symptoms of attack 90 days after the release (16 weevils)

(The young green plants are the secondary growth germinated after the death and decay of the primary growth)

PLATE-4

a



b

two females were found to be on par. After 72 hours, the treatment with three female insects (0.568 cm^2) showed significant variation with all other treatments.

Table-4 a. Extent of feeding by different population loads of male and female C.salviniae on S.molesta leaf (cm^2)

Time (hours)	24	48	72	96	120	mean
Treatment (No. of insects						
1 male	0.055	0.110	0.138	0.168	0.188	0.131
2 male	0.095	0.215	0.250	0.290	0.313	0.232
3 male	0.072	0.125	0.188	0.248	0.268	0.180
4 male	0.120	0.180	0.313	0.385	0.413	0.282
1 female	0.145	0.225	0.360	0.380	0.393	0.300
2 female	0.273	0.398	0.553	0.680	0.698	0.520
3 female	0.353	0.500	0.568	0.675	0.713	0.571
4 female	0.210	0.348	0.490	0.550	0.573	0.434
C D	0.070	0.100	0.124	0.137	0.129	

Similar trends were found after 120 hrs where the mean consumption of area by three females was 0.713 cm^2. Females consumed more leaf area in all the treatments than males. As the number increased the consumption rate also increased. But the mean area damaged by four females was much lesser than that by three females (Fig.12). Analysis of variance table is presented in Appendix V.

3.4.2.Effect of C.salviniae on S.molesta leaf at different population levels.

Analysis of observations (Table 4 b) revealed that after 24 hrs, the feeding by one insect was negligible while the area consumed by two (0.368 cm^2), three (0.425 cm^2) and four (0.330 cm^2) insects were on par and higher. After every 24 hours as the number of weevils increased the area consumed also increased concomitantly. The feeding damage by one insect was found to be negligible in all the treatments.

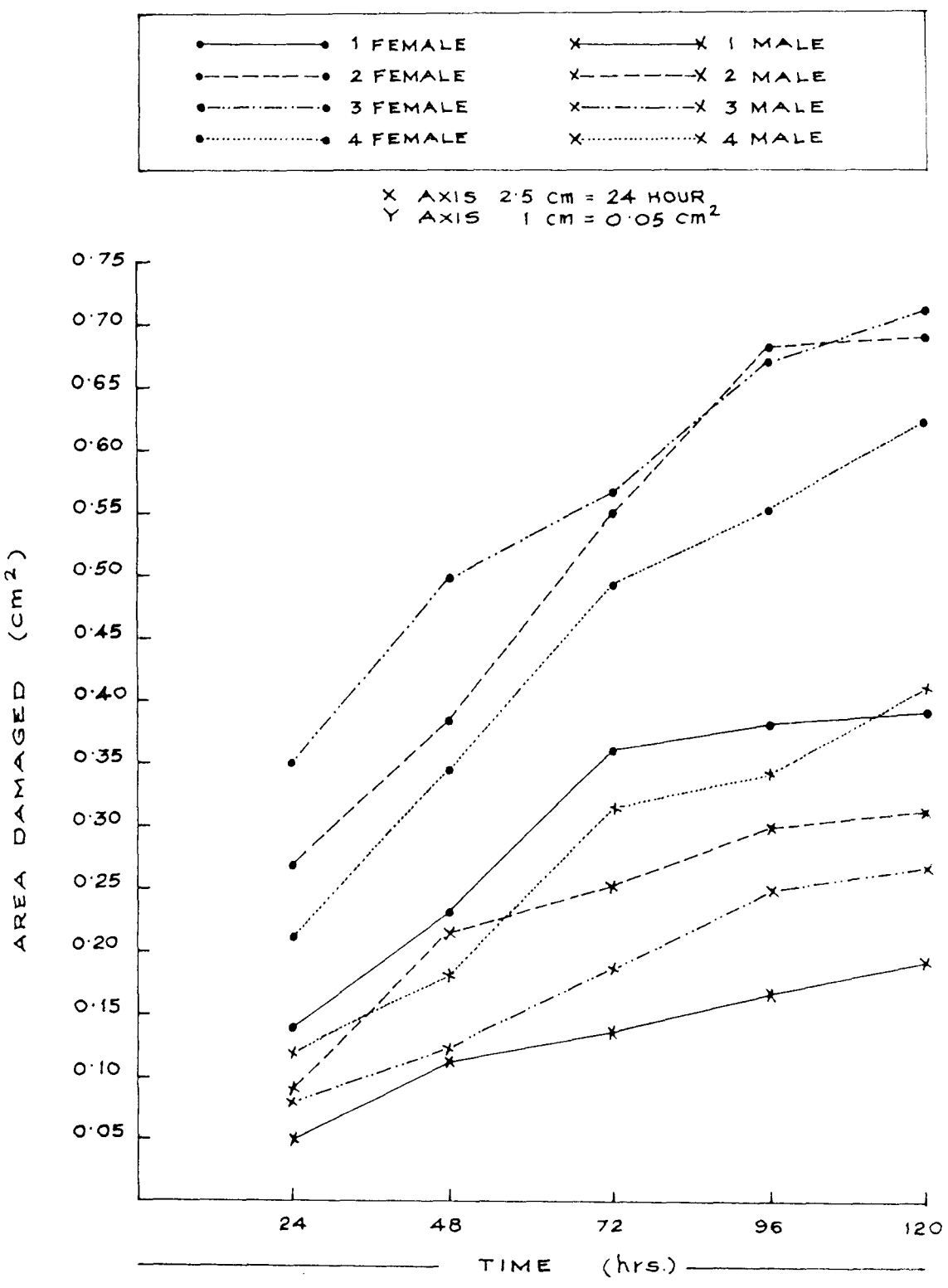

1 FEMALE
2 FEMALE
3 FEMALE
4 FEMALE
1 MALE
2 MALE
3 MALE
4 MALE
X AXIS 2·5 cm = 24 HOUR
Y AXIS 1 cm = 0·05 cm²
AREA DAMAGED (cm²)
0·75
0·70
0·65
0·60
0·55
0·50
0·45
0·40
0·35
0·30
0·25
0·20
0·15
0·10
0·05
24
48
72
96
120
TIME (hrs.)

FIGURE. 12

Table-4 b. Extent of feeding different numbers of C.salviniae leaf on S.molesta

Time (hours)	24	48	72	96	120	Mean
Treatment (No. of insects)						
1	0.220	0.370	0.495	0.548	0.580	0.438
2	0.365	0.613	0.803	0.973	1.010	0.753
3	0.425	0.625	0.755	0.923	0.980	0.741
4	0.330	0.528	0.803	0.935	0.985	0.715
C D	0.104	0.146	0.180	0.207	0.206	

3.4.3.Effect of male and female C.salviniae on S.molesta leaf.

The data presented in Table 4 c indicate that females consumed maximum leaf area in all the treatments. Analysis showed that the feeding by females (1.823 cm^2) was significantly higher than that of males (0.826 cm^2).

3.4.4.Effect of different population levels of male and female C.salviniae on S.molesta leaf buds

The results showed that (Table 5 a) the maximum damage was caused by two female insects (1.818 cm^2) after 48 hrs which significantly differed from all other treatments.

The least damage was by one male insect (0.863 cm^2). Analysis of Variance tables presented in Appendix VI.

Table-4 c. Effect of male and female C.salviniae on S.molesta leaf buds.

Time (hours)	24	48	72	96	120	Mean
Sex						
4 male	0.343	0.630	0.888	1.090	1.180	0.826
4 female	0.995	1.493	1.968	2.285	2.375	1.823
C D	0.135	0.224	0.216	0.237	0.240	

3.4.5. Effect of C.salviniae on S.molesta leaf buds at different population levels.

Data presented in Table 5 b indicate that one insect caused very little damage and it significantly differed from all other treatments. Four insects caused the maximum damage to the bud region after 48 hrs (1.471 cm^2).

3.4.6. Effect of males and females of C.salviniae on S.molesta leaf buds.

It can be observed from the Table 5 c that females caused more damage to leaf buds (1.098 cm^2) than males (0.422 cm^2) after 24 hours. By this time about 80 per cent

of the bud surface was consumed by females while the males consumed about 50 to 60 per cent of the total area. After 48 hours the difference in feeding area was less as compared to the damage after 24 hours. Analysis of Variance table is presented in Appendix VII.

Table-5 a. Extent of feeding by different population levels of male and female C.salvinia on S.molesta leaf buds (cm^2)

Time (hours)	24	48	Mean
Population			
1 male	0.203	0.863	0.533
2 male	0.333	1.088	0.710
3 male	0.483	1.115	0.799
4 male	0.678	1.328	1.000
1 female	0.295	1.245	0.770
2 female	1.613	1.818	1.715
3 female	1.325	1.645	1.485
4 female	1.305	1.615	2.000
C D	0.242	0.291	

Table-5 b. Extent of feeding damage by different numbers of C.salviniae on S.molesta leaf buds (cm^2)

Time (hours)	24	48	Mean
No.of insects population			
1	0.249	1.540	0.651
2	0.976	1.450	1.213
3	0.904	1.380	1.142
4	0.989	1.471	1.230
C D	0.377	0.452	

of the bud surface was consumed by females while the males consumed about 50 to 60 per cent of the total area. After 48 hrs the difference in feeding area was less as compared to the damage after 24 hrs. Analysis of Variance table is presented in Appendix VII.

3.4.7. Effect of adult C.salviniae on the growth of S.molesta.

Experiments on the effect of adult male and female weevils on the growth of the weed revealed that the growth of all the three buds

were completely arrested by the weevils in 30 days, while in control plot new side shoots were put forth by that time. The damage by one weevil was negligible. Male and female weevils caused the same effect on the growth of Salvinia though an initial rapid reduction in growth was observed by the attack of female weevils.

Table-5 c. Effect of males and females of C.salviniae on leaf buds of S.molesta (cm^2)

Time (hours)	24	48	Mean
Sex			
4 male	0.422	1.098	0.760
4 female	1.134	1.580	1.357
C.D	0.756	0.928	

4.Dispersal studies

The experiment conducted in plastic pools showed that the rate of dispersal of adults was very slow being about 5 to 10 cm per day. The dispersal was found to be random and non-directional (Fig.13). Out of 25 insects released, only 22 insects could be located after 24 hrs. Three insects remained at the release site. The maximum movement

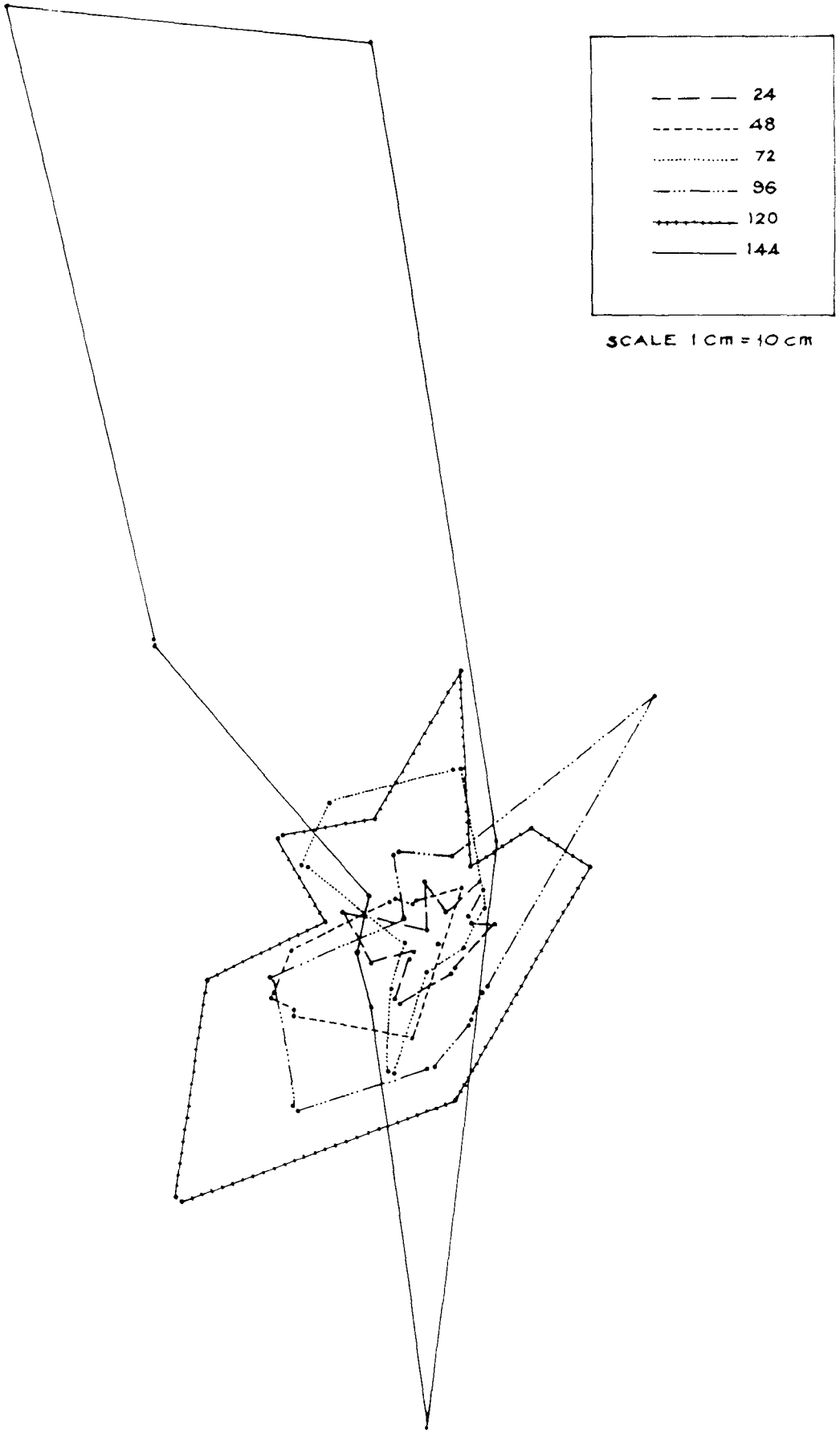


FIGURE . 13

of adults per day was 16.5 cm. It was found that after 120 hours, all the insects dispersed away from the release site. After 144 hrs, only one insect could be located on the periphery of the tank after travelling a distance of 170 cm. Studies on phototropism revealed that the adults were attracted to light traps and were capable of flying a distance of 40 m or more.

Table-6. Mean rate of dispersal (cm) of C.salviniae

Replication	I	II	III	IV	V
Time (hrs)					
24	5.12	4.86	3.43	3.53	0.08
48	8.84	4.96	4.06	4.00	3.73
72	9.64	5.80	6.00	3.40	4.50
96	11.66	5.63	11.36	12.00	-
120	16.32	9.30	10.80	-	-
144	25.00	12.36	-	-	-

Discussion

DISCUSSION

The present studies were undertaken to investigate the biology, morphology, nature of damage and dispersal habits of C.salviniae.

1.Biology of C.salviniae

Eggs were deposited singly either in leaf bases or in scars of rhizomes. C.salviniae has also been recorded to lay eggs within unopened leaf buds or suspended in the root mass (Forno et al., 1983). Studies indicated that weevils preferred young leaves than buds for egg laying. The incubation period was 7.9 days at 31°C. Forno et al. (1983) in their biological studies with this insect had reported similar results.

The larva after hatching remained outside for 2 to 3 days, scraping the unopened leaf buds and tender plant parts and occasionally browsing externally on the roots as reported by Sands et al. (1983). After a period of 3 to 4 days, the larva tunnelled within leaf base or the nodal region of rhizome. It completes its three instars feeding on rhizome or leaves within a period of 21 to 28 days. These observations are in conformity with those of Forno et al. (1983).

The larva pupated in cocoons usually below leaf base and rhizome. Pupal period in the laboratory averaged 11.3 days which is also in line with the results reported by Forno et al. (1983).

Emergence of adult from cocoon took place during day or night. Newly emerged adults had a metallic brown colour which turned to dark-brown in two days. Later, after four to five days, the weevils became wholly blackish. Adult life expectancy extended for a much longer period of 172 to 279 days as compared to the longevity (60 days) reported by Jayanth and Sudha (1986). Variations in climatic conditions between the places where the biological studies are undertaken could be implicated in moderate deviations in the life expectancy. But, in this case, such an explanation can not be held as valid in view of the lack of striking variations in the laboratory conditions in Bangalore and Kerala. A short life expetancy would be the result of hostile environmental conditions, lack of food or incidence of physiological diseases. In a laboratory culture raised at Bangalore, the lack of food or hostile environment can

not be expected to be present but there is a postibility for the test insect populations being under stress of some physiological diseases leading to shortening of the adult life expectancy.

Mating occurred four to five days after emergence. A pre-ovipositional period of five to ten days was recorded, which agrees with the results obtained by Forno et al. (1983).

2.Morphology

2.1.Immature stages

The eggs laid were ovocylindrical, pale-yellow with an average size of 0.56 x 0.25 mm.

Freshly emerged larvae were creamy-white in colour with a well developed head and pronotum. The larvae possess three thoracic and ten abdominal segments as also reported by May and Sands (1986). The three instars differed significantly in the width of head capsule and length of mandible. The present studies showed more or less similar head capsule measurements as reported by May and Sands (1986). These measurements were 0.19 mm, 0.24 mm and 0.28 mm for three instars, respectively. The mandible length increased from 0.05 to

0.07 and 0.09 mm for the first, second and third instars, respectively. The mean size of the instars were 1.80 x 0.38 mm, 2.79 x 0.69 mm and 3.5 x 0.98 mm for the first, second and third instars, respectively.

The spiracles on dorsal side were retractile and body segments armed with long and short setae. Four to seven hook-shaped setae were present on the anal segments. The setae on the ninth segment were elongate. The fine dorsal setae are shorter than the lateral setae.

As in the majority of curculionids, pupation took place in a cocoon made of plant parts. The size of the cocoon was 1.72 x 2.88 mm. However, Forno et al. (1983) recorded a slightly larger size of 2 x 2.6 mm.

2.2.Adults

Males and females were of the same shape, but for the larger size of the females (Females 2.92 x 1.05 mm and males 2.02 x 0.95 mm). These measurements are closer to the reports by Forno et al. (1983) but are slightly higher than those reported by Calder and Sands (1985). Rostrum punctate and weakly convex towards the apex. The females had a longer rostrum (1.22 x 0.40 mm) than that of males (1.03 x 0.35 mm).

Mandibles were the only mouth part visible from outside. They are reddish-brown in colour, strongly sclerotised and three lobed. Maxilla are three lobed, cardo short and stipes with a prominent notch. Palpus three segmented and the apical two segments tapering towards the apex. Marshall (1916) reported a three segmented palpus in some of the related genera under the sub family Errhininae. Lacinia consisted of a short tooth like process. Submentum broad and 'U' shaped. Mentum has a filament like processes at the middle region. Palpi with distinct lobes on either side.

Antenna is reddish-brown in colour and eleven segmented. The scape is elongate and slender towards the base and swollen apically. Funicle pubescent and six segmented. However, Marshall (1916) reported a five segmented funicle in another related genera (Mecinas) of Cyrtobagous. First funicular segment broader, second slender and elongate, segment three to six subequal in length and shape. Club swollen, fusiform and acuminate and four segmented. The three apical segments covered with yellow pubescence. But, Calder and Sands (1985) reported pubescence on the third apical

segment only. The male antenna (1.07 mm) and female antenna (1.03 mm) are of almost equal in size. Eyes are sub-oval and placed towards the base of the rostrum.

Pronotum sparsely punctate and wider than long, widest at its middle. The width of pronotum was distinctly different in males (0.69 mm) and females (0.80 mm) while the difference in length between male (0.59 mm) and female (0.65 mm) was insignificant.

All the three pairs of legs were similar. Femora and outer tibia are clothed with small hair like processes and the inner sides of tibia, tarsus and pre-tarsus are clothed with long non-adhesive hairs which is characteristic of aquatic weevils. Anterior femora and coxa are a little longer than others and the hind femora stouter than others. Male hind legs could be distinguished by the presence of a prominent hump shaped tibial spur. The arrangement of spines on the distal part of hind tibia is an important character to distinguish the hind legs from the anterior ones. In the present studies, it is found that the spines are arranged in a circle towards the distal end of first tarsus near the tibial spur in the fore and mid legs, while in hind legs

these spines are arranged in a linear form. Tarsal segments are four, the fourth segment being smaller and triangular in shape. Pre-tarsus had a bi-lobed claw at its apex, which are free as in most of the curculionids. Fore legs (2.31 mm) are longer than mid (2.13 mm) and hind (2.08 mm) legs in males, whereas in females, fore (2.40 mm) mid (2.49 mm) and hind (2.44 mm) legs are of equal length.

Scutellum oval and convex, elytra broader than pronotum, widest behind the basal region. Pleural region is gently curved anteriorly and strongly curved posteriosly to a blunt narrow apex. Striae have deep punctures concealed by scales. These observations agree with the findings of Calder and Sands (1985). Female elytra (1.60 x 1.00 mm) was slightly longer than that of male (1.26 x 0.96 mm). Hind wing is elongate and oval. Most of the veins are crowded at the basal region. Subcosta is very short and it fuses distally with radius. A sclerotised patch was present close to the radial vein at the basal region of the wing. Median vein faint, cubital vein curved at the distal end. Anal vein distinct and confined to the basal region. Wing spiculate

with short hairs on its outer margin and long hairs on its inner margin. Female wings (4.16 x 1.2 mm) were larger than that of male (3.4 x 1.1 mm).

On the ventral side, five sternal plates are visible. First plate had a raised lobe with a sub-circular depression on either side, which forms the boundary of the coxal cavity. The median area spiculate. As in the great majority of this subfamily, the suture separating the first and second segment is obscure. Sexual diamorphism is found with respect to the shape of the fifth ventral plate, which is more or less hemispherical in females, while in males the shape is more or less conical. Similar observations were made by Calder and Sands (1985) also.

Aedeagus is distinctly broader, with long slender aedeagal apodemes on either side. Lateral part of aedeagus has distinct sclerotised shoulders. Internal sac membranous, long and tubular with more or less round tip. A median plate like sclerotised structure at the caudal region and two elongated triangular patches were also present. The former was referred as median-plate like sclerite by Calder and Sands (1985). Tegmen broadened caudally and slender towards the apex.

The caudal region, sclerotised with short hairs and an inwardly directed tongue like sclerotised structure. The lateral arms of paramers fused together. Spiculum gastrale, long and slender, sub-triangular posteriorly with deep furrow anteriorly. Female genetalia with a short cylindrical membranous bursa copulatrix, preceeding a long, fine spermathecal duct. Spermatheca short, hook shaped and sclerotised. Apophysus of ovipositor short bearing a pair of two segmented styli. Spermathecal gland bud shaped and more or less cylindrical.

3.Nature of attack

3.1.Mode of attack

Adults usually fed on leaf buds and young leaves. At times they were found feeding on rhizome and roots. Feeding of the buds and leaves resulted in the formation of circular holes on them which arrested further growth of the weed. These results are in accordance with those of Forno et al. (1983) and Jayanth and Sudha (1986). Feeding produced scars on rhizomes and the root became brittle and break at the point of attack.

Contrary to the findings of May and Sands (1986), larval scraping on buds resulted in the formation of linear scars on opened leaves. A complete destruction of buds before tunnelling into rhizome was reported by May and Sands (1986). In about four to five days, the larva entered the leaf base, either remained there or tunnelled into the rhizome (Sands et al., 1983). No larvae were found tunnelling the root petiole as reported by May and Sands (1986). Tunnelling resulted in the browning of the rhizomes and yellowing, browning and brittling of the leaves. Finally the attacked plant parts disintegrated.

3.2.Extent of damage

Analysis of weight loss due to C.salviniae feeding showed no differences between treatments with 16 and 12 insects 30 days after release; the weight recorded was 0.726 kg and 0.806 kg respectively. From 45 days onwards, the treatments were found to be significantly different. The weight was highest after 60 days in the control tanks (1.554 kg). The lowest weight was after 90 days in the treatment with 16 insects (0.224 kg).

Experiments on leaf area reduction showed a significant difference between the treatment with 16 insects (5.274 cm^2) and all other treatments after 30 days of release. This treatment also showed a greater reduction in leaf area after 90 days of release.

The mean root length was found to be higher after 30 days of release in control tanks (26.350 cm). After 90 days, a maximum reduction in root length was observed in treatment with 16 insects (6.516 cm). However, there was no significant difference between the treatment with 12 insects and 16 insects.

3.3. Symptoms of damage

Colour changes were first noticed in about 15 days after the release. This was observed in a tank with 16 insects. Browning of the weed occurred after one month of release. After another 30 days browning spread to about 65 to 75 per cent of the tank surface. The whole weed changed into a brownish black mass after 90 days. But under field conditions the complete destruction of the weed occurred after five to ten months as reported by Room (1986) and ten to twelve months as reported by Joy et al. (1985).

3.4.Feeding damage by adult C.salviniae on leaves and buds of S.molesta.

Females fed a larger leaf area than males. They consumed an area of 1.823 cm^2, while the males only 0.826 cm^2. The consumption rate was not proportional to the weevil population. This may be due to the crowding of the insects on a limited leaf surface when the weevil number increased.

In the experiments on bud damage also, the females inflicted severe damage when compared to the males. Females consumed (4.538 cm^2) about three times more bud area than males (1.690 cm^2). Feeding tests conducted by Forno and Bourne (1985) showed that females fed 10 per cent more bud area than males.

4.Dispersal studies.

The weevils were having a slow moving pace as reported by Joy et al. (1984). They can hardly move a distance of 5 to 10 cm per day on legs. The movement was random and non-directional under experimental conditions. The present studies indicated that flight was also a means of dispersal for C.salviniae.

Kissinger (1966) and Room et al. (1981) have also recorded that adult weevils are attracted to light traps. Scarcity of food material seems to be the primary factor that causes dispersal of the weevil by flight.

Summary

SUMMARY

Biology

Studies on the biology of Cyrtobagous salviniae showed that the mean incubation period of egg is 7.9 days the range being 6 to 9 days ($\bar{x}$ = 7.9 days). The larval period ranges from 21 to 28 days with a mean of 23.5 days. There are three larval instars the stadia occupying 9 to 10, 8 to 10 and 7 to 10 days respectively. The pupal period ranged from 9 to 13 days the mean being 11.3 days. The adult life span varied widely from 172 to 279 days, the mean being 211.9 days. A pre-ovipositional period of 5 to 10 days was recorded.

Morphology

Egg is ovocylindrical in shape (0.56 x 0.25 mm), larva crescntic with indistingustable body segmentation. Body segments possess long and short setae which are much reduced in the last instar. Instars could be separated based on head capsule width and mandible length. Head and pronotum well developed and mandible reddish brown in colour, sclerotised and with pointed tips. Pupa rounded oval in shape with cocoons woven using plant parts. Adults are small in size and black in colour.

Head is small and placed towards the apex of the rostrum. The mouth parts are biting type. Mandibles are well developed and three lobed. Maxilla are three lobed. Labrum is 'U' shaped with filamental process at its median region. Rostrum is slightly curved towards the apex and with shallow punctures on the dorsal side. Antenna is geniculate and reddish brown. Scape is elongate, funiculus six segmented and club four jointed. Pronotum broader than rostrum base with shallow punctures. Forefemur is longer than the mid and hind ones. Tibia is long and slender and inner angle armed with long water repellent hairs. Hind tibia has linear spines towards the distal end. The hind tibial spur has a prominent hump in males. Tarsi are four segmented and the pre-tarsus has a bifid claw. Elytra arched and sclerotised with deep punctures and striae at intervals. Venation on hind wing is much reduced. There were five ventrites. The ventrite 3 and 4 are much reduced. The posterior margin of fifth ventrite is slightly rounded in females. Aedeagus with long aedeagul apodemes. Internal sac is membraneous and as long as aedeagus. Female genetalia are provided with a well developed

spermatheca and fine spermathecal duct. The ovipositior possesses a pair of styli at the caudal region.

Nature of attack

Adults usually feed on the leaf buds and tender leaves arresting the further growth of the plant. Larval tunnelling resulted in the desintegration of the plant parts. Under experimental conditions, the maximum weight loss of Salvinia was recorded after 90 days in treatment consisting of 16 adult weevils. The leaf area and root length were the lowest after 90 days in this treatment. Yellowing was noticed 15 to 30 days after the release of the insect. After 90 days, the weed mass was completely darkened. In an experiment on feeding damage to Salvinia, it was found that the females consumed more of the leaf and bud than the males.

Dispersal studies

The dispersal was found to be random and non-directional. They moved a distance of 5 to 10 cm in a day. They were also capable of flying, especially when the food resources were reduced.

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* Originals not seen.

Appendices

APPENDIX - I

Analysis of variance table showing the weight of *Salvinia* (kg) after 90 days of treatment.

Source	S S	df	M S S	F
Total	2.993	24		
Treatment	2.914	4	0.729	184.972**
Error	0.079	20	0.004	

** Significant at one per cent level.

APPENDIX - II

Analysis of variance table showing the leaf area of *Salvinia* (cm^2) after 90 days.

Source	S S	df	M S S	F
Total	112.250	24		
Treatment	107.904	4	26.976	124.124**
Error	4.347	20	0.217	

** Significant at one per cent level.

APPENDIX - III

Analysis of variance table showing the root length of *Salvinia* (cm) (after 90 days)

Source	S S	df	M S S	F
Total	551.296	24		
Treatment	478.162	4	119.540	72.154**
Error	33.135	20	1.657	

**Significant at one per cent level.

APPENDIX - IV

Analysis of variance table showing the extent of feeding damage by *C.salviniae* on *S.molesta* leaf after 24 hours (cm^2)

Source	S S	df	M S S	F
Total	0.369	31		
Treatment	0.306	7	0.043	18.798**
Error	0.955	24	0.002	

**Significant at one per cent level.

APPENDIX - V

Analysis of variance table showing the extent of feeding damage by C.salvinia on S.molesta leaf after 120 hours (cm^2)

Source	S S	df	M S S	F
Total	1.272	31		
Treatment	1.083	7	0.154	19.580**
Error	0.189	24	0.007	

**Significant at one per cent level.

APPENDIX - VI

Analysis of variance table showing the effect of C.salviniae on S.molesta leaf bud after 48 hrs (cm^2)

Source	S S	df	M S S	F
Total	3.953	31		
Treatment	2.992	7	0.427	10.690**
Error	0.960	24	0.040	

**Significant at one per cent level.

APPENDIX - VII

Analysis of variance table showing the effect of male and female C.salviniae on S.molesta leaf bud after 48 hrs (cm^2)

Source	S S	df	M S S	F
Total	123.990	7		
Treatment	122.261	1	122.261	424.220**
Error	1.729	6	0.288	

**Significant at one per cent level.

BIOLOGY, MORPHOLOGY, NATURE OF ATTACK AND DISPERSAL OF *Cyrtobagous salviniae* CALDER & SANDS (CURCULIONIDAE: COLEOPTERA)

By

LEENA K. T.

ABSTRACT OF A THESIS

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Kerala Agricultural University

Department of Agricultural Entomology

COLLEGE OF HORTICULTURE

Vellanikkara - Trichur

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ABSTRACT

In studies on the biology and morphology of Cyrtobagous salviniae Calder & Sands (Curculionidae : Coleoptera), a very successful agent for the bio-control of the menacing weed Salvinia molesta Mitchell, the females were found to insert their eggs on leaf base and rhizome scars. The egg period was 7.9 days. There are three instars, the average larval period was 23.5 days. The pupal period extended for 11.3 days. Adults showed a mean life span of 211.9 days. A pre-oviposition period of five to ten days was recorded. The three larval instars differed in respect of the relative size of head capsule and width of mandible. Adult females are slightly larger than the males. The spine like processes towards the distal end of the hind tibia are arranged in a linear manner, while in fore and midlegs these spines are arranged in a circular manner. The hind leg spur of the male shows a prominent hump, while in females the spur does not have a hump.

Observations on the nature of damage showed that the adults were capable of arresting the growth of the weed by feeding on the buds and leaves. Occasionally they feed

on rhizomes and roots. Larval scraping followed by tunnelling resulted in the decay of plant parts. Weed mass showed discolouration about 15 days after initiation of feeding by the weevil and the whole weed became a black mass in about 90 days. The rate of dispersal of adult weevils was found to be very slow.