BIOECOLOGY OF *Orthogalumna terebrantis* WALLWORK ON WATERHYACINTH

By

BABYKALA. P.

THESIS

Submitted in partial fulfilment of the
requirement for the degree

Master of Science in Agriculture

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Department of Agricultural Entomology
COLLEGE OF HORTICULTURE
Vellanikkara - 680654
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DECLARATION

I hereby declare that this thesis entitled **"Bioecology of *Orthogalumna terebrantis* Wallwork on waterhyacinth"** is a bonafide record of research work done by me during the course of research and this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship and other similar title, of any other University or Society.

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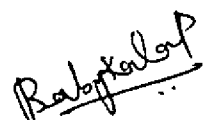

BABYKALA, P.

DR. P.J.JOY
Professor
AICRP on Biological Control
of Crop Pests and Weeds

College of Horticulture
Vellanikkara
Date: 17-8-1994

CERTIFICATE

Certified that this thesis entitled "Bioecology of *Orthogalumna terebrantis* Wallwork on waterhyacinth" is a record of research work done independently by **Ms.Babykala, P.** 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.

Dr. P.J.Joy
Chairman
Advisory Committee

CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Ms.Babykala,P.** a candidate for the degree of Master of Science in Agriculture with major in Agricultural Entomology agree that the thesis, entitled "**Bioecology of *Orthogalumna terebrantis* Wallwork on waterhyacinth**" may be submitted by **Ms.Babykala,P.** in partial fulfillment of the requirement for the degree.

Chairman

Dr. P.J.Joy

Members

Dr. D.Sitarama Rao

Sri. V.K.G.Unnithan

Dr. P.Sreedevi

External Examiner

17/8/94

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Dedicated to

matha

pitha

guru

daivam

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Introduction

INTRODUCTION

Waterhyacinth [*Eichhornia crassipes* (Mart.) Solms.] is a free floating, perennial, stoloniferous herb which is a native of the Neotropics. The species is a true indigene of South America (Sculthorpe, 1967). Waterhyacinth was originally imported as an ornamental plant. Attracted by the beautiful lilac coloured flowers, it was warmly received into many countries. At present the weed enjoys the world wide distribution, mostly in the tropics and subtropics, covering extensive areas of several water bodies. Waterhyacinth is recognized as the most damaging aquatic weed in India, having caused immeasurable damage to the environment.

The consequences of waterhyacinth infestation has become painfully, obvious and nearly every conceivable use of water resources stands impaired where infestation became severe. In Kerala it occurs widely, hindering navigation, paddy cultivation and irrigation. Herbicidal methods of control are quite effective, but only for short periods due to the quick regeneration of the weed from slender horizontal stolons and seeds. Moreover, the use of herbicides cannot be recommended in water bodies since it involves severe pollution problems. Mechanical method of control is too expensive for widespread adoption. Sankaran

(1982) reported that manual, mechanical and chemical methods have so far failed to bring the weed under control.

Biological control which is safer, more stable and far more economic since it is self-perpetuating would be the most desirable method to suppress the weed. In its native range, waterhyacinth is attacked by complex of arthropods (Bennett and Zowlfer, 1968). *Orthogalumna terebrantis* Wallwork (Acarina : Galumnidae) is one of the six natural enemies considered to be promising for introduction into other countries (Deloach, 1975).

Orthogalumna terebrantis is one among the few species of phytophagous oribatid mites and is native to South America. It also occurs in Florida and Lousiana in the United States (Cordo and Deloach, 1976).

After extensive host specificity tests the mites were introduced into India in 1985 under the All India Co-ordinated Research Project on Biological Control of Crop Pests and Weeds and field release were initiated in 1986. The weevil *Neochetina eichhorniae*, which was imported into India in 1982 found to be specific to waterhyacinth. It has already got established under field conditions throughout Kerala and Bangalore. Jayanth (1988) reported

successful biological control of waterhyacinth by *N. eichhorniae* in Bangalore.

Eventhough the insect was released in Kerala in 1983, no significant control has been achieved even after these ten years. It is hoped that the release of this mite will add to the stress already being caused to waterhyacinth by the weevils and bring about a quicker control of the weed. The present studies have been undertaken to generate detailed information on the following aspects.

1. Biology of *O. terebrantis* Wallwork.
2. To study the morphology of the mites with a limited objective of identifying the larval and nymphal stages among the field population.
3. Feeding habits and nature of damage caused by mites to the waterhyacinth.
4. Intensity of weed damage caused by mites and weevils in open and shaded conditions.
5. To study the interaction between *N. eichhorniae* weevil and *O. terebrantis* mites on waterhyacinth.

Review of Literature

REVIEW OF LITERATURE

2.1 Origin and distribution of Waterhyacinth *Eichhornia crassipes* (Mart.) Solms

Waterhyacinth belongs to the family Pontederiaceae placed under the order Liliales. It had been described much earlier by Von Martius (1824) under the name *Pontederia crassipes*.

The genus *Eichhornia* was named by Kunth (1842) who described the plant as *Eichhornia speciosa* and the nomenclature was later corrected in 1883 by Laubach and Zu as *Eichhornia crassipes*.

Waterhyacinth (*Eichhornia crassipes* (Mart.) Solms is a free floating, perennial, stoloniferous herb which is native of Neotropics. Today it is distributed throughout the world in the tropics and sub-tropics and extends from 40° N to 45° S latitude (Holm *et al.*, 1977). The spread of this weed to North America, Central and South America, Asia, Australia, Oceania, Africa and Europe was documented by various reporters (Gay and Berry, 1960; Little, 1967; Frye, 1972 and Gupta, 1973).

There is no authentic record of its entry into India but it definitely arrived in Bengal before 1900

(Gopal and Sharma, 1981). It has spread throughout India and is believed to occupy over 200,000 ha. at present (Anon, 1979).

2.2 Productivity

The plant propagates and multiplies vegetatively as well as through seeds. Parija (1934) observed seven fold increase in waterhyacinth spread in 50 days. Poling and Barr (1965) reported that two plants of waterhyacinth could multiply into 1200 in 120 days. While Holm *et al.* (1977) observed thirty offspring from two plants in 23 days. The same author reported that the seed can survive for even 15 years.

Attracted by its beautiful lilac violet flowers, waterhyacinth was originally imported as an ornamental plant and it soon escaped to lakes, rivers, ponds, canals, reservoirs and paddy fields. Waterhyacinth, which ranks among the top ten worldwide weeds (Holm *et al.*, 1977), is considered to be the most formidable aquatic weed in India.

2.3 Problems posed by waterhyacinth

Waterhyacinth creates numerous problems in relation to the use and management of water resources and water-ways.

Webber (1897) stated that waterhyacinth is noteworthy as a grave handicap to inland navigation as in Louisiana where several acres of water surface are covered with the weed.

Kar (1939) reported that waterhyacinth interfers with seed germination and seedling establishment in paddy.

Davies (1959) reported that waterhyacinth restricts the breeding of fish.

Guscio *et al.* (1965) reported that the flow of water is reduced by 40 to 95 per cent in irrigation channels and this may cause flooding as was frequent in Malaysia and Guyana.

Timmer and Weldon (1967) reported that waterhyacinth impairs the quality of water. The plant-cover imparts obnoxious smell, colour and suspended particulate matter to water, making it unfit for human consumption.

According to Rao (1969) the plants are also known to carry pests and pathogens of several crops such as *Attractomorpha crenulata* and *Rhizoctonia solani*.

Waterhyacinth in dense growth could obstruct water flow in irrigation channels, interfere with navigation and hydroelectric power generation (Krishnamoorthi, 1976).

It reduces the volume of available fresh water by favouring loss through evapotranspiration. Gopal and Sharma (1981) reported that various authors recorded 1.26 to 9.85 per cent increase in water loss, compared to open water surface.

2.4 Management of waterhyacinth

2.4.1. Mechanical control

The earliest method was simple m
is still being practised in most of the developing countries.

The pre-rainy period (April-May) is more suitable for manual removal as the weed is confined to a relatively smaller area (Ambasht and Ram, 1976).

Phillipose (1963) reported that depending upon the density of the weed mat, 100 to 300 man days per hectare are required for mannual removal.

The coastal areas, dragging of the weed mat int
the sea with nets attached to boats is practised commonly (Anon, 1952).

The Engineers of Army Corps in USA have developed several equipments from time to time (Tabita and Woods,

1962; Wunderlich, 1958) to combat this weed in water ways and lakes.

Grant (1962) and Hearne (1966) suggested the construction of floating barriers which prevent waterhyacinth from reaching other water bodies. Gupta (1976) pointed out that in coastal areas in India, tidal sea water has been used successfully to control this menace. According to Jamieson *et al.* (1977) in Queensland and New South Wales the waterhyacinth is flushed into the sea which kills them.

Hamdoun and Tighani (1977) pointed out that manual control was very expensive, time consuming and unsatisfactory. Several mechanical devices have been developed, of which the draglines and floating boom are the simplest (Gangstad, 1976). In India a few such machines were developed at the Central Institute of Fisheries Technology, Cochin (Velu, 1976). However none of the devices were found to be promising.

Phillipose (1963) reported that the mechanical sweeping out of waterhyacinth is a slow process. The large water content of the plant and huge quantities of water carried in the roots make transportation difficult.

2.4.2 Chemical control

A large number of inorganic weedicides including ammonia, formalin, sodium chloride, sulphuric acid, arsenic oxide and copper sulphate have been tried against waterhyacinth (Bose, 1945).

Recently a wide range of organic herbicides have become available, 2,4-D being the most commonly recommended herbicide. Hilebrand (1946) first reported the effect of 2,4-D on waterhyacinth and soon several papers followed. Rao and co-workers (1981) obtained good control of the weed by the application of 2,4-D amine at 7.2 kg/ha. Studies at Hissar (HAU, 1972) revealed that 2,4-D @ 1.51 kg/ha gave cent per cent control after 21 days. Bajpai and Chauhan (1973) reported that MCPA @ 1 kg a.i/ac gave 91 per cent control.

Gupta and Subbaiah (1982) reported that spraying with 2,4-D Na + paraquat or 2,4-D amine alone and in combination with sandovit killed waterhyacinth within 30 days. Killing was quick with 2,4-D amine treatment and slow with 2,4-D Na + paraquat. Resprouting was not noticed upto 90 days with 2,4-D amine at 3.6 kg a.i/ha.

The chemical control, though quick and effective, has several negative aspects. The rapid kill of a large thick mat of waterhyacinth adds a huge quantity of organic

matter to the water body. It sinks to the bottom and releases large amounts of nutrients. This results in the development of algal blooms and general eutrophication (Naidu and Singh, 1958).

The chemicals used in the water bodies often move out of the system in many ways and affect organisms far away from the water body particularly in down stream region. Many chemicals persisted in the sediments and in water and water quality is adversely affected (Faust and Aly, 1962).

These consideration have led to investigate alternate methods of checking of waterhyacinth like the biological control.

2.4.3 Biological control

Biological control by using host specific insects and organisms is relatively cheap and free from harmful environmental hazards and pollution. As early as 1959, Robyns had emphasised the need for studies on biological control of waterhyacinth. The biocontrol agents of waterhyacinth reported so far include phytopathogens, insects, mites, snails, fishes and manatees.

2.4.3.1 Snails

The snail, *Marisa cornuarietes* has been found to

feed on the roots and leaves of waterhyacinth (Ferguson and Butler, 1966). It prunes and inhibits flowering but does not help to control the weed. It prefers submerged plants and hence, in mixed stands waterhyacinth increases.

2.4.3.2 Manatee

This vertibrate animal, *Trichechus manatus* has also been suggested for controlling waterhyacinth (Allsopp, 1969). Though a voraceous feeder, manatee is not effective because of its preferential feeding habits.

2.4.3.3 Fish

The chinese grass carp (*Ctenopharyngodon idella* Val. is the most promising fish species (Sutton and Blackburn, 1976). In India Mehta and Sharma (1972) tried grass carp against waterhyacinth, but without success.

2.4.3.4 Phytopathogens

Several species of fungi have been reported from time to time on waterhyacinth.

Agharkar and Banerjee (1932) were the first to report *Fusarium* species on waterhyacinth which caused reddish brown spots on petioles followed by chlorosis and withering of leaves. Nag Raj and Ponnappa (1970) reported *Myrothecium roridum* Var. *eichhorniae*, *Corticum sasaki*,

Marasmiellus inoderma and a new species of *Alternaria eichhorniae* from waterhyacinth.

Rintz (1973) found that the zonal leaf spot of waterhyacinth is caused by *Cephalosporium zonatum*. Conway (1976) evaluated the fungus *Cercospora rodmanii* for its biocontrol potential. Results of glass house and field studies indicated that the fungus was responsible for the decline of *E. crassipes* in Rodman Reservoir, Florida.

The fungi *Cercospora rodmanii* and *Acremonium zonatum* were tested as biological control agents for *E. crassipes* in South-eastern U.S.A. (Charudattan *et al.* 1976). Addor (1977) reported that the virulence of *C. rodmanii* is enhanced by insect attack. Investigations by Freeman (1977) revealed several pathogens which displayed promising effects as biocontrol agents of waterhyacinth. The pathogens are *A. zonatum, Bipolaris stenospila, Cercospora rodmanii, Rhizoctonia* spp. and *Uredo eichhorniae*.

Rahim and Tawfig (1986) investigated the possible biological control of *E. crassipes* by *Drechslera spicifera*. The pathogen did not affect new leaf production. Rahim (1984) found *Phoma sorghia* causing leaf spot of waterhyacinth in Sudan. Martyn (1985) reported that waterhyacinth decline in Texas was caused by *Cercospora piaropi*.

Charudattan (1987) developed a mycoherbicide containing *C. rodmanii* for use against waterhyacinth. Liyanage and Gunasekera (1989) suggested an integration of *M. roridum* and 2,4-D in waterhyacinth management.

2.4.3.5 Insects

1. Grasshoppers

a) *Cornops aquaticum* Bruner (Orthoptera : Acrididae)

Guido and Perkins (1975) studied the biology and host specificity of *Cornops aquaticum* Bruner, a potential biological control agent for waterhyacinth. They reported that *C. aquaticum* is sufficiently specific to *Eichhornia* spp. and potentially useful to introduce for biological control of *E. crassipes* in the U.S.A.

b) *Gesonula punctifrons* (Stal.) (Acrididae : Orthoptera)

A field study was carried out in Karnataka, India in 1976-77 to determine the effectiveness of the acridid *G. punctifrons* in controlling waterhyacinth. However, in view of the rapid propagation of the weed and the long life-cycle of the grasshopper, it is suggested that it should be used in conjunction with another exotic natural enemies such as *Neochetina* sp. for the effective control of the weed (Manoharan *et al.*, 1981).

2. *Acigona infusella* Walker (Pyralidae : Lepidoptera)

Sands and Kassulke (1983) described the biology and host specificity of a South American moth, *A. infusella* on waterhyacinth in Australia under quarantine conditions.

3.*Arzama densa* Walker (Noctuidae : Lepidoptera)

Vogel and Oliver (1969) suggested that *A. densa* can be used for waterhyacinth control in South Louisiana. Baer and Quimby (1982) observed some natural enemies on *A. densa* on waterhyacinth in Louisiana. Mortality of the moth was caused mainly by the larval parasites *Lydella radicis* and *Campoletis oxylus* which lessened the efficiency of this biocontrol agent.

4. *Argyractis subornata* (Pyralidae : Lepidoptera)

Forno (1983) studied the life history and biology of a waterhyacinth moth *A. subornata* in Australia.

5. *Sameodes albiguttalis* (Pyralidae : Lepidoptera)

Deloach and Cordo (1978) studied the life history and ecology of the moth *S. albiguttalis*, a potential candidate for the biological control of waterhyacinth. Larvae of the pyralid *S. albiguttalis* caused heavy but sporadic damage to waterhyacinth in Argentina. Cordo and Deloach (1978) studied the host specificity of *S. albiguttalis* in

Argentina. Whereas Center (1984) studied the dispersal and variation in infestation intensities of waterhyacinth moth, *S. albiguttalis* populations in peninsular Florida.

Wright and Bourne (1986) investigated the effect of leaf hardness on penetration of waterhyacinth by *S. albiguttalis*. The possibility of altering epidermal hardness by applying plant growth regulators to favour attack by *S. albiguttalis* is being explored.

6. *Neochetina bruchi* (Curculionidae : Coleoptera)

Perkins and Maddox (1976) conducted the host specificity studies and reported the high preference of the weevil *N. bruchi* for waterhyacinth. Abjar and Bashir (1984) described the biology and life tables of *N. bruchi* introduced into white Nile, Sudan, for checking waterhyacinth. Deloach and Cordo (1983) obtained 67 per cent control of waterhyacinth in Argentina within 4 years by release of *N. bruchi* and 90 to 95 per cent control in 6 years.

Jayanth and Nagarkatti (1987) probed the host specificity of *N. bruchi* introduced into India for biological control of waterhyacinth, and concluded that *N. bruchi* is safe for field releases in the country.

Wright and Stegeman (1990) used the computer programme CLIMAX, in overseas locations of waterhyacinth infestations controlled by *N. bruchi* were climatically matched to Australian locations. The results suggested that *N. bruchi* could be valuable instrument of the biocontrol of waterhyacinth not only in Australian's tropics, but also in similar regions where existing biological control agents appear less effective.

7. *Neochetina eichhorniae* (Curculionidae : Coleoptera)

Spencer (1974) reported that *N. eichhorniae* has been released against waterhyacinth in the U.S.A., prompted by the studies in Argentina.

Fosse and Perkins (1977) reported a kairomone produced by the young growing tissues of waterhyacinth. This kairomone apparently attracts the weevils, part of the chemical complex is obviously used as a phagostimulant and oviposition stimulant for *Neochetina* spp.

Deloach and Cordo (1976) reported that the pupae of the insect were invariably attached to the live roots of waterhyacinth which indicated its high degree of host specificity.

Wright (1980) showed that the collapse of a water-hyacinth population begins within 2 years after the liberation of *N. eichhorniae*.

Forno (1981) found that 10 pairs of the weevils and their progeny per 0.58 m^2 considerably reduced the growth of floating, anchored and rooted plants within one generation.

Single and multiple host specificity tests showed that *N. eichhorniae* fed and regularly reproduced almost exclusively on *E. crassipes* (Nagarkatti and Jayanth, 1984).

Goyer and Stark (1984) chronicled that tank grown waterhyacinth was severely affected by one month exposure to *N. eichhorniae*. Under field conditions adults and larvae reduced the vigour and reproduction of *E. crassipes* and in some instances proved even fatal in the released sites in Louisiana.

Center (1985) determined the life table analysis for assessing sublethal effects of herbivory on waterhyacinth shoots. Leaf life tables show that damage caused by *S. albiguttalis* and two species of waterhyacinth weevils results in an overall 34 per cent reduction of leaf longevity. Thus even without direct shoot mortality a

certain degree of control was achieved. But he opined that the damage caused by *N. eichhorniae* is constant and effective.

Cofrancesco *et al.* (1985) reported that *N. eichhorniae* was first released in Louisiana during 1974 and insect populations were well established by 1978. The waterhyacinth over 1.1 million acres in 1974 in Louisiana was reduced to 301100 acres by 1980. This 4 year study (1980-83) indicated that *N. eichhorniae* effected reductions in waterhyacinth height, density and biomass at the test sites and was a major factor contributing to the reduction in waterhyacinth acreage in Louisiana.

Comparative damage potential of *N. eichhorniae* and *N. bruchi* against waterhyacinth was carried out under quarantine conditions in a glass house at Bangalore. It has been concluded that *N. bruchi* and *N. eichhorniae* show excellent promise for biological control of waterhyacinth under south Indian conditions (Jayanth and Nagarkatti, 1984 and Jayanth, 1988).

Jayanth and Visalakshy (1990) conducted studies on drought tolerance in *N. eichhorniae* and *N. bruchi* on *E. crassipes* and demonstrated that the adults of these insects could survive for up to 48 and 28 days respectively, under 95 per cent RH in the absence of food and water.

When water alone was provided they were able to survive for 56 and 82 days respectively. Muscle development was retarded in starved adults and they could not migrate from dried up water tank beds. It is concluded that these curculionids could be released as biological control agents even into tanks which dry up for some time of the year, without subsequent reintroduction being necessary as the insects would survive below plants debris or in crevices in the soil.

Akbay (1991) used optimization and simulation techniques to estimate initial weevil populations. A mathematical programming and simulation model was used to estimate the numbers of weevils necessary to initialize the INSECT model that stimulates othe biological control of *E. crassipes* by weevils.

2.4.3.6 Mites

Orthogalumna terebrantis Wallwork (Acarina : Galumnidae)

The high degree of host specificity and damage displayed by *O. terebrantis* places it as one of the six potential biocontrol agents of waterhyacinth (Coulson, 1971; Perkins, 1973; Fosse, 1978).

Cordo and Deloach (1975) reported that female *O. terebrantis* oviposited only on their natural host plant,

waterhyacinth, in group tests with 22 species of plants. The nymphs fed on waterhyacinth and only slightly on three other test plants of Pontederiaceae.

The host specificity test revealed that *O. terebrantis* is capable of attacking only waterhyacinth, as evidenced by gallery formation (Jayanth and Nagarkatti, 1988).

2.4.3.6.1 Lifecycle, behaviour and ecology of *O. terebrantis* Wallwork

The waterhyacinth mite *O. terebrantis* belongs to a small genus of Oribatid mites mainly inhabiting Madagascar, South Eastern North America, Central and South America (Balough, 1960; Bennett, 1968a,b)

Wallwork (1965) reported it as a leaf boring galumnid mite from Uruguay. He placed this mite under the genus *Orthogalumna*. But Bennett (1968a) placed it under the genus *Leptogalumna*.

Cordo and Deloach (1976) studied the biology of the waterhyacinth mite in Argentina. They observed that at 25°C the egg period lasted 7 to 8 days and that of the larval and 3 nymphal stages (Proto-, deuto- and tritonymps) together were completed in another 15 days.

Fosse (1977a) studied the temperature optima for the

development of *O. terebrantis*. The mite laid more eggs at 20 to 40°C than at 10 to 30 or 15 to 35°C, although there was no statistical difference in mite oviposition at these temperature regimes. A temperature regime of 15 to 30°C was found to be the most favourable for mite oviposition.

Fosse (1977a) reported that the optimum development of *Orthogalumna* mites occurred at 10 to 30°c and at 15 to 35°C.

Fosse (1977a) reported that a female mite after a pre-oviposition period 1 to 2 days produced an average of 21.2 and 23.91 eggs/female whereas Visalakshy and Jayanth (1991) reported 58.5 eggs during its life time which is 50 per cent more than the earlier report.

Cordo and Deloach (1975) recorded adult longevity as 46.0 days on *Eichhornia* leaves with feeding spots of *Neochetina* weevils. Visalakshy and Jayanth (1991) reported that when adults were provided leaves with feeding spots of *Neochetina* spp. and at 65 to 75 per cent RH, the survived for 73.75 ± 37.98 days and with humidity alone 38.20 ± 14.32 days. When mites were kept without humidity and food, they survived only for 1 to 2 days.

Cordo and Deloach (1976) observed that two or three generations a year occurred in the field.

Bennett (1972) reported that the leaf mining galumnid mite *O. terebrantis* were introduced in the Kafue River System in Zambia in 1971.

Perkins (1973) determined the feeding specificity of the Argentine strain of *Orthogalumna* to *E. crassipes*. The Argentine strain was found to feed only *E. crassipes*. He also observed that the Argentine strain and Florida strain showed differences in the feeding behaviour.

Perkins (1973) conducted preliminary studies on the different strains of the waterhyacinth mite from Argentina. He observed the mite *O. terebrantis* to be a promising biocontrol agent of *E. crassipes*, because the immature forms caused major damage to the weed by mining leaves parallel to the laminae.

2.4.3.6.2 Field establishment and evaluation of the effects of *O. terebrantis*

Bennett (1968a) reported that insects and mites are potential controlling agents of waterhyacinth. Andres and Bennett (1975) reported that the oribatid mite *O. terebrantis* indigeneous to South America and already naturalized in the Southern United States, is highly specific to *E. crassipes*.

Cordo and Deloach (1976) observed that populations

of about 200,000 galleries/m^2 or 75,000 immature mites per m^2 (or 10,000 galleries/plant), are necessary to inflict damage to waterhyacinth so as to result in the drying up of most of the leaves.

Fosse and Perkins (1977) attributed the kairomone from young growing tissues of waterhyacinth to apparent concentration of the mites, around fresh feeding sites of *Neochetina* sp.

O. terebrantis is a much more important biological control agent than has been suspected to be in the past, because it opens waterhyacinth to increased attack by phytopathogens and saprophytes as reported by Fosse (1978).

Center (1985) reported that waterhyacinth mites are never sufficiently common to discern a recurring pattern. They seem restricted to older leaves. These organisms are leaf miners and remain on one leaf through out their entire immature period. For this reason they are vulnerable to displacement. Their life cycle requires about 3 weeks during which a waterhyacinth shoot can produce three or four leaves. Galleries are not conspicuous until after the adult emerged. Thus even if eggs are deposited on young leaves, the injury may not be apparent until leaves get older.

O. terebrantis was introduced into India in 1982 under the All India Coordinated Research Project on Biological Control of Crop Pests and Weeds at Bangalore. Field release of *O. terebrantis* initiated in September 1986, after host specificity tests under quarantine conditions conclusively proved that it is no threat to the safety of cultivated crops (Jayanth and Nagarkatti, 1989).

Establishment of the exotic mite *O. terebrantis* on waterhyacinth in Bangalore was reported by Jayanth and Visalakshy in 1989.

2.4.3.7 Interaction between weevil and mite

Fosse (1976) reported that thick populations of *O. terebrantis* and *N. eichhorniae* reduce size and density of waterhyacinth more significantly than the reduction by either arthropod alone, though no evidence of negative interaction between *N. eichhorniae* and *O. terebrantis* has been discovered.

Cordo and Deloach (1976) reported that either adult or larval weevils would probably consume or damage mite eggs which is accidental and unavoidable. When large populations of mites are present along with large weevil populations, there is apparently insignificant stress upon waterhyacinth mite populations.

Fosse (1977b) indicated that *O. terebrantis* would not consume *Neochetina* eggs. He also observed that *N. eichhorniae* lays more eggs per female in the presence of *O. terebrantis* than alone.

Fosse (1977b) also observed that the weevils and mites in combination tended to act synergistically in their attack on waterhyacinth.

Fosse (1978) studied in combined effect of *N. eichhornia* and *O. terebrantis* on waterhyacinth. He observed an inevitable decrease in the size and the density of waterhyacinth following a buildup of weevil and mite population. Plant density reduced by 45 per cent over a 50 week period.

Jayanth and Visalakshy (1989) investigated the possible synergistic effect of *O. terebrantis* and *N. bruchi* together to control *E. crassipes*. A combination of the two arthropods reduced more significantly the size and density of *E. crassipes* than either of them applied alone. They suggested the release of *O. terebrantis* along with *N. eichhorniae* and *N. bruchi* as it is likely to increase the stress load on the weed and improve the overall control of waterhyacinth.

2.4.3.8 Arthopod fungus relationships

Charudattan *et al.* (1976) mentioned that *Acremonium zonatum* is some times more severe in the presence of *N. eichhornia* and *O. terebrantis* and suggested integrated control using pathogens along with these arthopods. However, Fosse (1978) did not find a single instance where *A. zonatum* developed in feeding spots of *N. eichhorniae*. Perkins (1973) found lesions of *A. zonatum* apparently developing around feeding spots of *N. eichhorniae*. This occured under unusual conditions in the field and is not typical of the attack of this pathogen.

Fosse (1977b) reported that all fungal lesions of this pathogen developed in tunnels of *O. terebrantis* after the adult mite had created its emergence hole. The adult mite which often crawls back into adult tunnels, apparently picks up fungal spores and carries them back into the tunnel. High humidity and temperature inside the tunnels are conducive to the development of *A. zonatum*.

Fosse (1976) reported that *O. terebrantis* may be a better control-agent than has been indicated in the past. This is due to facultative interaction with the fungus *A. zonatum* and synergistic relationship with *N. eichhorniae*. Both organisms increase the indirect effect of the mite on waterhyacinth.

Addor (1977) experimented on biocontrol of waterhyacinth with multiple agents and tentatively concluded that *Arzama, Neochetina, Cercospora* and *Orthogalumna* in combination are capable of establishing and sustaining an acceptable level of biological control of *E. crassipes* in the test environment.

2.5 Integrated control of waterhyacinth

Deloach and Cordo (1978) predicted a synergistic effect between the moth *S. albiguttalis* and the weevil *Neochetina* sp.

Kasno and Soerjani (1980) preferred the combination of *Myrothecium roridum* fungus and *N. eichhorniae* weevil in controlling *E. crasspies* to the use of any one of them alone.

Center *et al.* (1982) studied the combined effect of *N. eichhorniae* and a growth retardant EL-509 on waterhyacinth. They found that the growth retardant was ineffective without weevils and the weevils appeared to be more effective when used in combination with the retardant. The combined effect was additive.

Manoharan *et al.* (1981) suggested that the acridid *Gesonula punctifrons* in conjuction with *N. eichhorniae*

might bring about waterhyacinth control.

Charudattan (1984) reported enhanced control with *C. romanii* by using the fungus in conjuction with arthropods or with low dose of 2,4-D.

The toxicites of commonly used waterhyacinth herbicides and additives to its biological control agents were tested in the laboratory. Effect of herbicide exposure on flight muscle development of *Neochetina* weevil seemed to be related to the time of year at which exposure occurred. Effects of herbicide application on dispersive behaviour were determined by placing marked weevils on artificial weed mats in Florida. Mats were subsequently sprayed with a standard solution of 2,4-D. Weevils consistely migrated from sprayed plants to adjacent healthy unsprayed plants (Haag, 1986).

Charudattan (1986) reported that integration of the fungal pathogen *C. rodmanii* with natural population of arthropods (mainly *N. eichhorniae* and *N. bruchi*) appeared to provide complete control of *E. crassipes*.

Center and Durden (1986) reported that *E. crassipes* plants recovering from 2,4-D were small due to intense weevil damage, and were sinking. Standing crop and shoot size was inversely proportionate to the number of weevil

since larval galleries and proportion of the laminae were eaten by adults. Long duration of the weevil attack reduced plant size. By Autumn, the middle and downstream sections were completely controlled by insects. By Summer of 1984 the weevils had killed most of the plants in the upstream too.

Patnaik *et al.* (1987) studied effects of some weedicides on the waterhyacinth weevil (*N. bruchi*) and its host. The study concluded that diquat gave effective control of *E. crassipes* without harming *N. bruchi*.

Galbraith (1987) studied the pathogenicity of an Australian isolate of *A. zonatum* to waterhyacinth and its relationship with other biological control agents. He investigated the possibility of developing *A. zonatum* as a mycoherbicide to supplement the arthropod biological control programme in Australia. He suggested that the role of *A. zonatum* was probably due to its ability in exerting a chronic stress on plants already under attack by arthropod biological control agents.

Haag *et al.* (1988) reported selective patterns of herbicide application for improved biological control of waterhyacinth. They studied the effects of two different patterns of applying 6.7 kg Rodeo (Glyphosate)/ha on *E.*

crassipes regrowth and on waterhyacinth weevil (*N. eichhorniae* and *N. bruchi*). Population dynamics were studied in seven ponds in Alachua country. In the first treatment, after half the weed mat had been sprayed, the infestation was left with a short boundary area along which daughter plants could form and colonize open water. In these ponds a reduced plant expansion rate fostered the success of the weevils and the resulting heavy insect feeding damage led to the total decline of the weed population.

In the second treatment, after half the weed mat was sprayed, the infestation was left with a long boundary area along which daughter plants could form. In these ponds the plant population rapidly expanded to fill available open water; plant growth rate surpassed the weevil population rate of increase, and insect feeding damage was not sufficient to bring the weed mats under control.

Liyanage and Gunasekera (1989) suggested integration of *M. roridum* and 2,4-D in waterhyacinth management. Gupta *et al.* (1989) evaluated the effect of a mixture of 2,4-D and paraquat on the curculionid *N.. eichhorniae*. The study concluded that the use of 2,4-D and paraquat and *N. eichhorniae* are compatible in the control of *E. crassipes*.

Application of 2,4-D at 0.5 to 2.0 kg/ha to waterhyacinth resulted in changes in plant quality including decreased leaf hardness and increased nitrogen content. The possible effects of these changes on the weeds biological control agents, the pyralid *S. albiguttalis* and the curculionids *N. eichhorniae* and *N. bruchi* have been discussed by Wright and Bourne (1990).

Materials and Methods

MATERIALS AND METHODS

3.1 Biology

Studies on the biology of *O. terebrantis* were carried out under laboratory conditions at the insectary of the All India Co-ordinated Research Project on Biological Control of Crop pests and Weeds, College of Horticulrue, Vellanikkara during 1991-93. The mites were reared on waterhyacinth plants maintained in cement concrete tanks.

A leaf with inactive tritonymphs was taken and kept in a petridish, with moistened filter paper disc at the base. The freshly emerged adult mites were used for the study. Fifty adults of *O. terebrantis* were released on the young central leaf of waterhyacinth. After 48 hours the mites were collected to prevent fresh oviposition. The collected mites were again released on another set of plants to record the pre-oviposition period. This process was continued upto 5 days. The leaves were checked for the presence of eggs and the eggs were counted.

3.1.1 Number of eggs deposition holes per square cm of leaf area

A microslide of 0.5 mm thickness was taken and on it, a 1 cm square was marked. The slide was kept on the

lower leaf surface under a low power binocular microscope in different positions of the leaf. The oviposition holes contained within the square were counted.

3.1.2 Size of ovipositional holes

A calibrated ocular micrometer was used to measure the size of egg oviposition holes in two dimensions, namely length and width under a low power binocular microscope.

3.1.3 Study of duration of different instars

Duration of different instars after hatching was determined by observing the leaf under stereo binocular microscope with powerful transmitted lighting. The larvae and other nymphal stages were observed in detail by this method and the duration recorded. Several observations were made and the mean instar duration arrived at.

3.1.4 Length of galleries made by different instars

The length of the galleries made by different instars was measured using a calibrated ocular micrometer in a low power microscope, identifying the different instars under powerful transmitted lighting. Emerging adults were collected and used for fecundity studies.

3.1.5 The number of emergence holes

The number of emergence holes that appeared on the lower and upper surface of leaf lamina were counted and recorded.

3.1.6 Longevity tests

Ten freshly emerged adults were collected and placed on a leaf fixed in a small glass vial. The mouth of the vial was plugged with cotton to prevent water loss such vials were later kept inside a glass container (7x5 cm) with moistened cotton, covered with filter paper at the base to provide adequate humidity. The mouths of the glass containers were closed tightly with a closely knitted long cloth, held by rubber bands. The leaf was replaced once in 3 days. The dates of death of the adult mites were noted and the longevity of mites calculated.

3.1.7 Fecundity

The number of eggs laid by the females during its life time was arrived at by releasing freshly emerged mites on leafs and confining them. The number of ovipositional holes were periodically counted and recorded till the death of the females.

3.2 Morphology

Measurements of adult mites, larval and nymphal stages and eggs were taken using on ocular micrometer from mounted specimens.

3.2.1 Preparation of slides

The mites in different stages were first collected in alcohol and later cleared in lactophenol medium consisting of lactic acid (50 parts), phenol crystals (25 parts) and distilled water (25 parts). After clearing for about 24 hours the mites were washed in water and then mounted in Hoyer's medium which consists of:

Distilled water	50 ml
Gum arabic	30 grams
Chloral hydrate	200 grams
Glycerine	20 grams

After mounting the slides were warmed under a lamp at about 50 to 60°C for 24 hours, for drying of the medium and clearing of the specimens. Then the slides were ringed with nail polish to seal the edges to make it permanent and then labelled and stored in slide trays.

The specimens were studied under a phase contrast

microscope. Drawings were made using a camera lucida; measurements of various parts were made using a calibrated ocular micrometer.

3.2.2 Measurements

The measurements of various life stages and organs of adult mites were recorded. The length of the adult mite was measured from the anterior margin of the gnathosoma to the posterior margin of hysterosoma and the body width across the widest of the notogaster.

Maximum length of prodorsum was measured from the base of prodorsum to apex of the rostrum. Length of notogaster was measured from the base of the Prodorsum to the posterior margin of the notogaster.

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

3.3 Study of nature of damage

3.3.1 Nature of damage of *Orthogalumna* mite and *Neochetina* weevil of waterhyacinth

Experiments on the nature of damage of *Orthogalumna* mite and *Neochetina* weevils on waterhyacinth were conducted in R.C.C. tanks (35 cm diameter) using completely randomised design, *Eichhornia* plants under both open and

Plate 1. The treatment tank in partially shaded condition

partial shade (11 to 34 per cent light infiltration) conditions were used for this trial (Plate 1). Five replications were maintained for each condition. For partial shade condition the site was initially located by measuring uniform light intensity using LUX meter.

For both type of conditions 1/3 rd of the tanks were filled with soil and the remaining with water. Fresh cowdung was added to all tanks @ 250 g/tanks. Five plants each of 4 to 5 weeks old clumps were used for the study. After 15 days field collected adult mites and weevils were used for release on the plants. The treatments were

1. Ten weevils alone per tank
2. 100 mites alone per tank
3. 10 weevils plus 100 mites per tank

Uninoculated check was also maintained for each treatment for comparison. Water level in the tanks was maintained by addition of water regularly.

Length of petiole, length and width of pseudolamina and length of root of five randomly selected plants from each tank were observed at fornightly intervals. Total number of plants and leaves also was noted. For measuring the length and width of the leaves, the longest available leaf was used and unopened and decaying ones were not

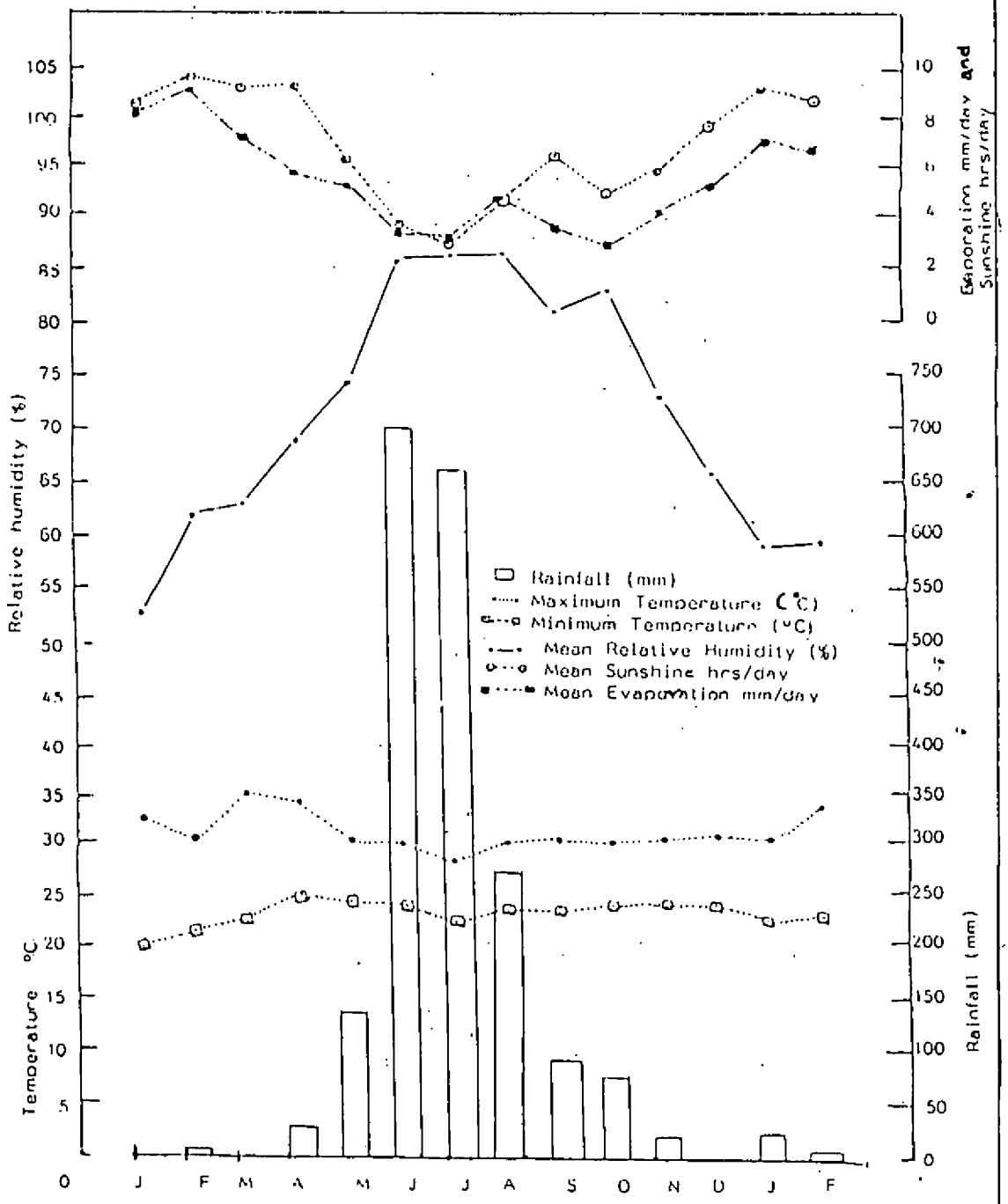


Fig. 1. Monthly meteorological data for the experimental period Jan '93 to Feb '94

included. While counting the number of plants, daughter plants that had not fully separated from the mother plants were not included.

The temperature, relative humidity and light intensity (in partial shade) during the period of study fluctuated between 19.4°C to 36.4°C, 27 to 98 per cent and 11 to 34 per cent respectively (Fig. 1)

3.3.2 Nature of damage by different density of mites on waterhyacinth

Experiments on nature of damage was conducted in earthern pots (25 cm diameter) using completely randomised design and three replications were maintained for the trial. The 2/3rd portion of the pots were filled with soil and fresh cowdung was added in all tanks about 50 g/pot.

Eichhornia plant of 3 to 4 weeks old clumps were used for the study. Field collected adult mites @ 10, 20, 40 and 80 per clump were released in the pots (one plant per pot). Water level in the tank was kept constant. Total number of plants and leaves, total number of galleries per leaf and the mite population were observed.

3.4 Adult behaviour

3.4.1 Feeding preference

For finding out the feeding preference by adults on

the leaves with and without fresh feeding scars of *Neochetina* weevils, samples of leaves were collected from the field and the number of galleries per leaf as well as the number of adult mites on the dorsal and ventral sides of the lamina and the petioles of injured and uninjured leaves was noted.

3.5 Arthropod and fungus relationship

Waterhyacinth plants showing typical symptoms of disease were developed from galleries and weevil feeding scars was separately collected from the field to isolate the pathogens. The infected plants were washed in running tap water to remove soil particles and dried with blotting paper. The diseased portions of infected plants showing characteristic disease symptoms were cut into small bits and then surface sterilized with 0.1 per cent mercuric chloride solution for 45 seconds. The bits were then washed in three changes of sterile water to remove the traces of mercuric chloride adhering to it. Each bit was carefully picked up and placed aseptically in a sterilized petridish containing potato dextros agar (PDA). The plates were incubated under laboratary conditions. The isolates were purified by isolation and organisms were maintained on PDA by subculturing periodically. This subcultured fungus is taken for identification of fungus.

3.6 Statistical analysis

Statistical analysis of the data recorded was carried out in completely randomised design, wherever necessary, following Panse and Sukhatme (1985). The $\sqrt{x}$ transformations were carried out, wherever necessary.

RESULTS

Results of the studies on *O. terebrantis* biology and morphology; the nature and extent of attack and interaction with *N. eichhorniae* weevils.

4.1. Biology

The duration of different life stages of the mite reared under controlled conditions is presented in Table 1. *O. terebrantis* had only one larval stage, but three nymphal stages-Proto-, deuto- and tritonymphs.

4.1.1. Eggs

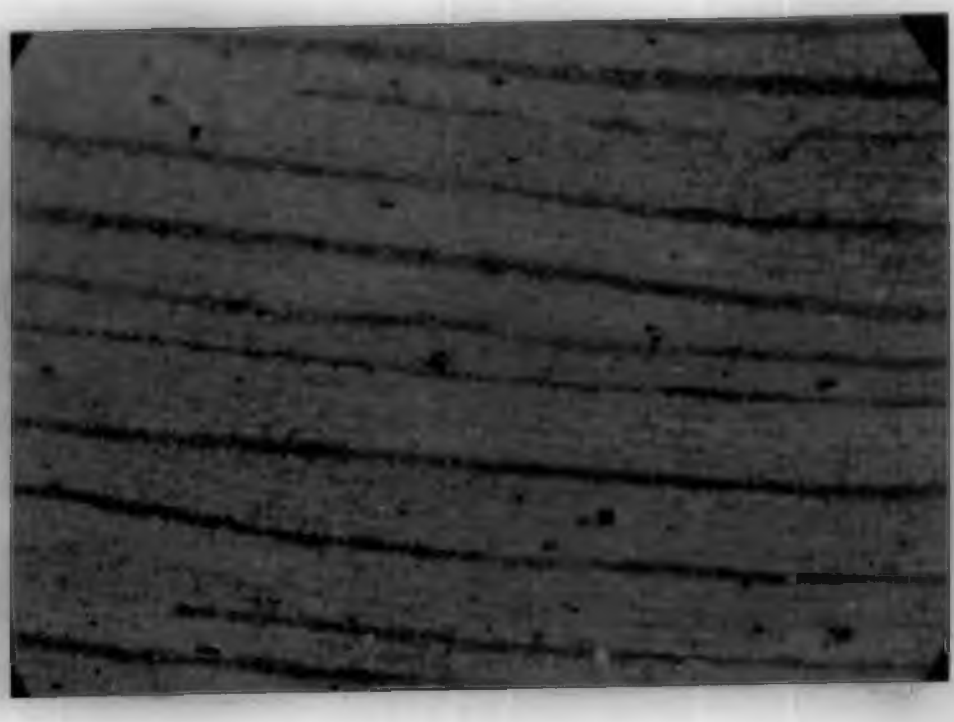
The eggs appeared light yellowish, shiny and translucent (Plate 2). The adult female cut a round hole of about 0.1 mm diameter with its mouth parts and laid the egg in the hole, into the aerenchyma cells of the leaf. Eggs were laid only on the lower surface of the younger central leaves (Plate 3). The eggs measured 0.12 mm in length and 0.070 mm in width. The incubation period varied from 5 to 8 days average being 5.8 days (Table 1).

4.1.2. Larva

After eclosion, the hexapod larva produced small yellowish spots, about 0.2 mm diameter, on the upper

Plate 2. The egg of *O. terebrantis* exposed from ovipositional holes
Original size (0.120 x 0.070 mm)

Plate 3. The ovipositional holes of *O. terebrantis* in lower surface of leaf
Original size (0.08 to 0.1 mm diameter)



surface of the leaf through feeding. The larval period lasted 3 days, followed by an inactive period of 1.6 days. The gallery length at this time was 0.157 mm. The larvae measured, on an average, 0.182 mm long and 0.081 mm wide (Table 1).

4.1.3 Protonymph

The protonymphs could be differentiated from the larvae by the presence of the fourth pair of legs. This stage too lasted for 3 days, followed by an inactive period of 1.6 days. The protonymph measured in length 0.301 mm and in width, 0.132 mm with a gallery length of 1.094 mm (Table 1).

4.1.4 Deutonymph

The deutonymphal period was lasting for 3 days followed by an inactive period of 1.6 days. The nymph reached a maximum of 0.399 mm in length and 0.175 mm in width with a gallery length of 2.473 mm (Table 1).

4.1.5 Tritonymph

The longest among the developmental stages. The tritonymphal stage had a duration about 4 days of active period followed by an inactive stage for 3 days (Plate 4). They attained a length of 0.411 mm and a width of 0.264 mm, the gallery length being 4.024 mm (Table 1).

Plate 4. Active movement of tritonymph when the galleries were exposed (0.411 mm long and 0.264 mm wide)

Table 1. Duration of the different stages of O.terebrantis with their measurements and length of galleries attained during each instar under controlled conditions

Stage	*Duration (days)	*Measurements of stages (mm)						*Total length of galleries (mm)
		Length			Width			
		Mean	Minimum	Maximum	Mean	Minimum	Maximum	
Egg	5.8	0.120			0.070			
Larva	3.0	0.182	0.109	0.202	0.081	0.054	0.093	0.157
First inactive stage	1.6							
Protonymph	3.0	0.301	0.247	0.325	0.132	0.109	0.148	1.094
Second inactive stage	1.6							
Deutonymph	3.0	0.399	0.470	0.511	0.175	0.148	0.214	2.473
Third inactive stage	1.6							
Tritonymph	4.0	0.411	0.420	0.460	0.264	0.240	0.280	4.024
Fourth inactive stage	3.0							

*Mean of ten replications

Fig. 1A. Egg

Fig. 1B. Pteromorphae (Wing)

Fig. 1C. Sensillus

4.1.9 Ovipositional period

The ovipositional period lasted till the death of mite.

4.1.10 Fecundity

The total number of eggs produced during the whole life period ranged from 21 to 67 (Mean 41.5 eggs).

4.1.11 Adult longevity

Adults lived for a period of 57.3 days in the laboratory (range 30 to 60 days) at 29.1 ± 4.6°C temperature and 75 per cent RH.

4.2 Morphology

Measurements of *O. terebrantis* are presented in Table 1 and 2.

4.2.1 Egg

Eggs were elliptical with a mean length of 0.120 mm and width 0.070 mm. Its chorion was thin and transparent (Fig. 1 A).

4.2.2 Larvae

The larvae had three pairs of legs but no genital opening (Plate 5). The mean length and width of body were

Fig. 2A. Larvae of *O. terebrantis*

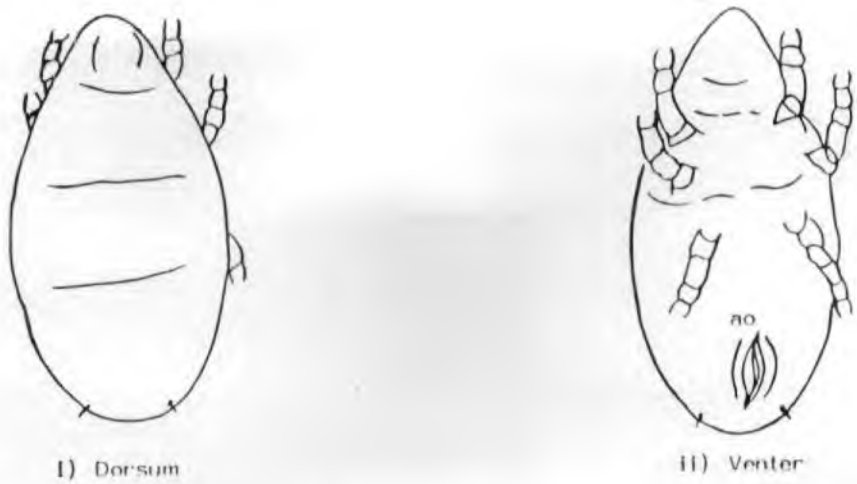
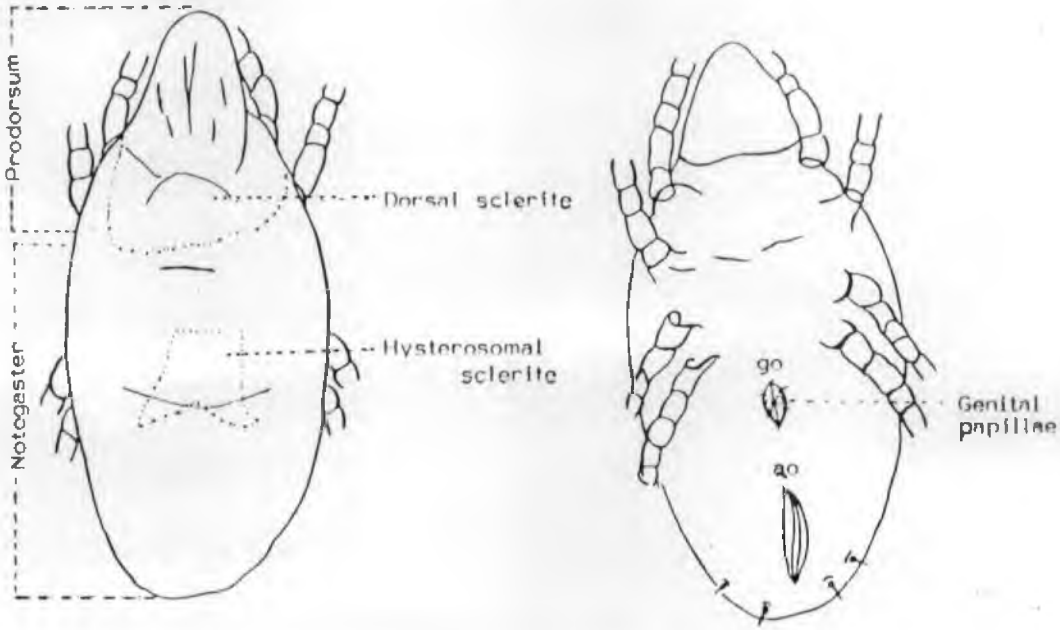


Fig. 2B. Protonymph of *O. terebrantis*



ao - anal opening
go - genital opening

Plate 5. The hexapod larvae of *O. terebrantis*
(0.182 mm long and 0.081 mm wide)

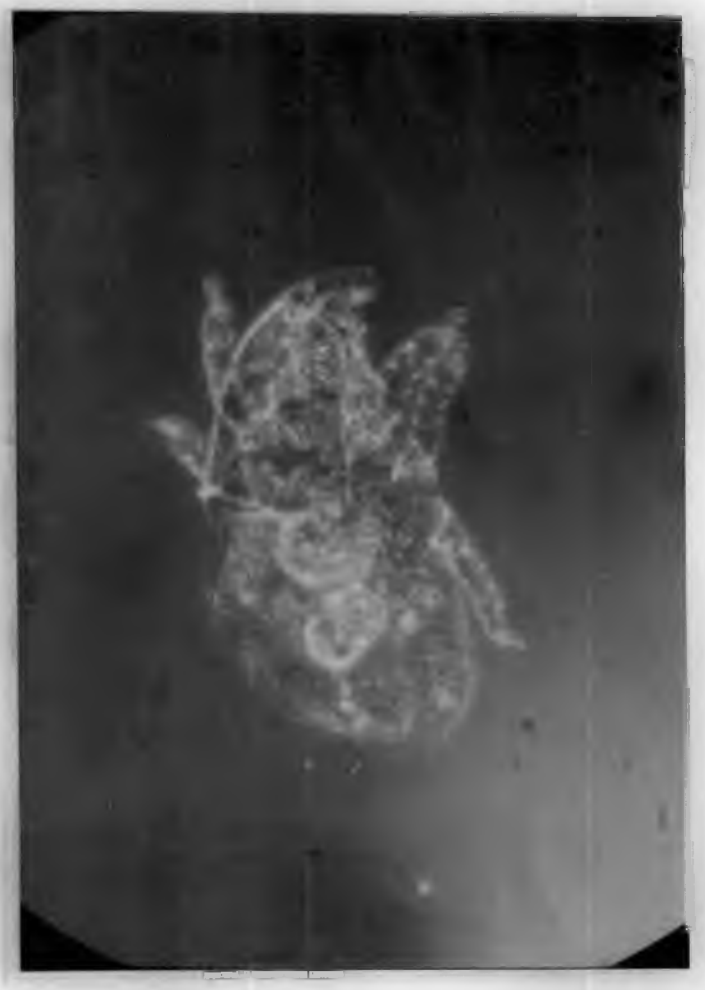
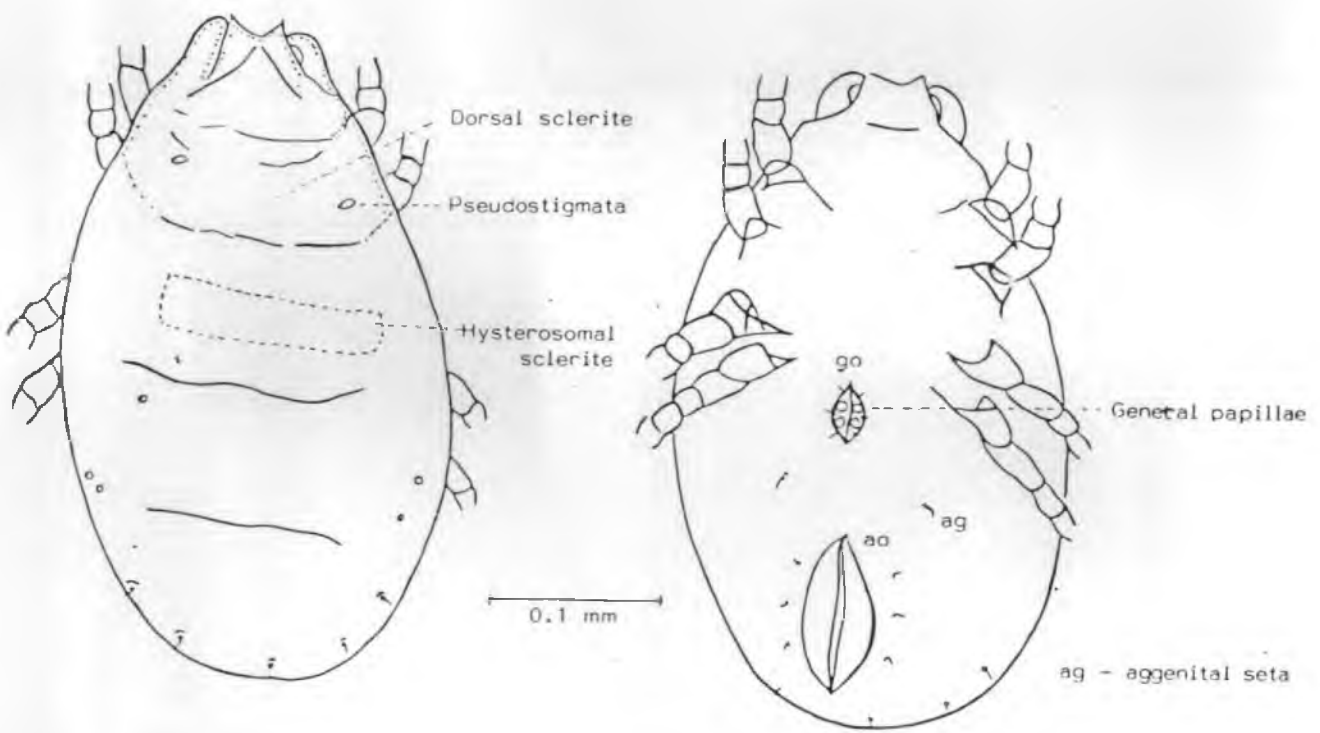


Fig. 3. Deutonymph of *O. cerebrantus*



0.182 mm and 0.081 mm respectively. The prodorsum, 0.072 mm in length measured on an average. The length of notogaster on an average 0.102 mm. Dorsal side with two fine ridges but without dorsal sclerites. A pair of notogaster setae was present. Ventral side with well developed anal opening. A pair of chelicera was present (Fig. 2 A).

4.2.3. Protonymph

The protonymph with four pairs of legs, and the primordium of the genital opening with only one pair of genital papillae. The dorsal sclerites covering the prodorsum poorly developed and not pronounced in hysterostomal region (Fig. 2 B). The prodorsal sclerite with a discountinuous line separating propodosoma and metapodosoma. A well developed fine ridge was present on notogastral region. The average length of prodorsum and notogaster was 0.102 mm and 0.200 mm respectively. Their mean body length and width were 0.301 mm and 0.132 mm respectively. Legs were ending with a single claw. Anal and adanal setae were lacking.

4.2.4 Deutonymph

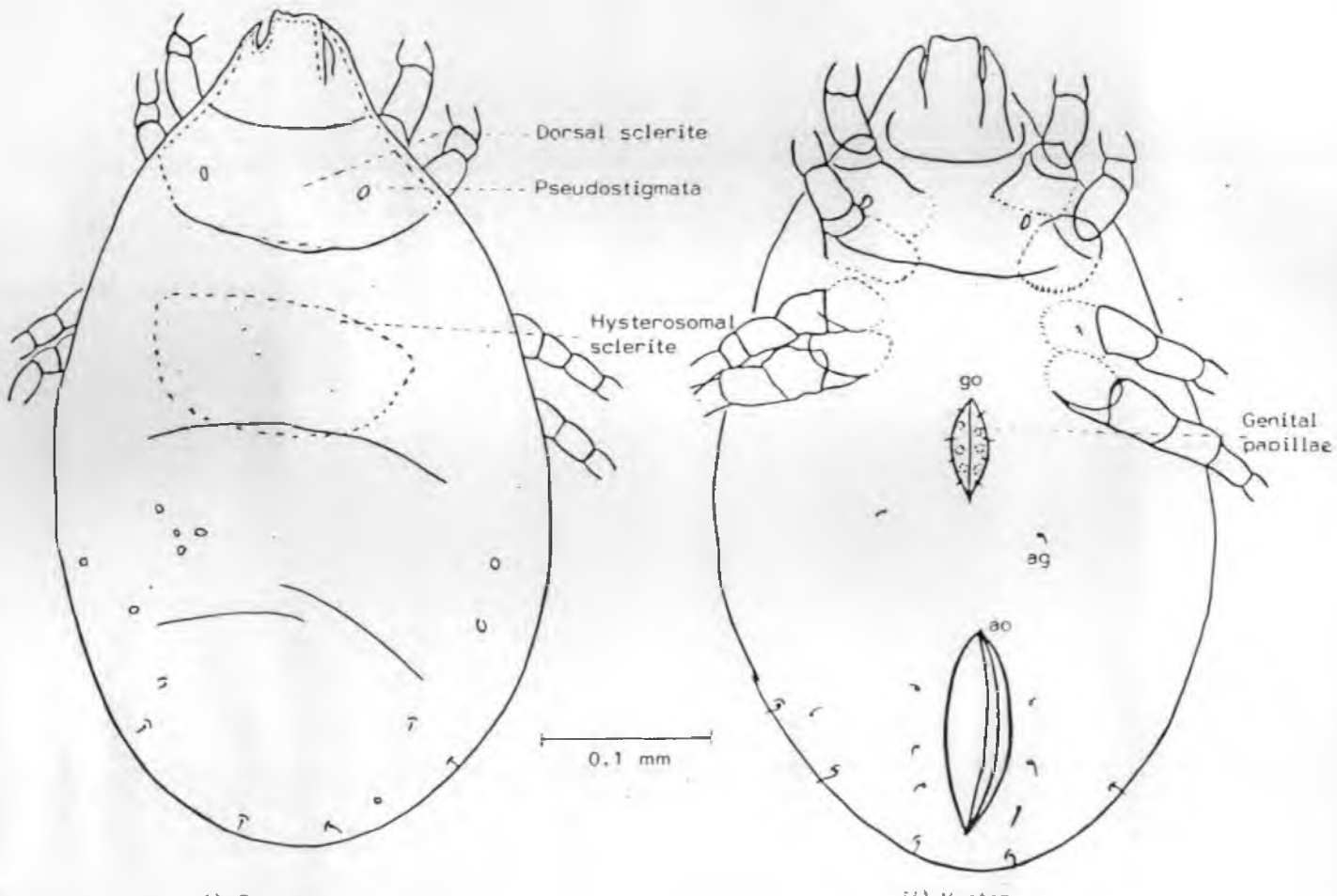
Two pairs of genital papillae were present. The prodorsal sclerite were more developed than the hysterosomal sclerite. The prodorsal ridge with three discoun-

Table 2. Length of prodorsum, notogaster and width of notogaster of O.terebrantis

Stage	Prodorsum			Notogaster					
	Length (mm)			Width (mm)			Length (mm)		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Larva	0.072	0.054	0.093	0.081	0.054	0.093	0.102	0.093	0.140
Protonympth	0.102	0.190	0.140	0.132	0.109	0.148	0.200	0.189	0.214
Deutonympth	0.142	0.115	0.156	0.175	0.148	0.214	0.240	0.218	0.257
Tritonympth	0.181	0.148	0.214	0.254	0.231	0.346	0.326	0.305	0.346
Adult	0.130	0.114	0.147	0.260	0.240	0.280	0.270	0.231	0.297

Plate 6. Dorsal and ventral view of tritonymph
(0.411 mm length x 0.264 mm width)

Fig. 4. Tritonymph of *O. terebrantis*

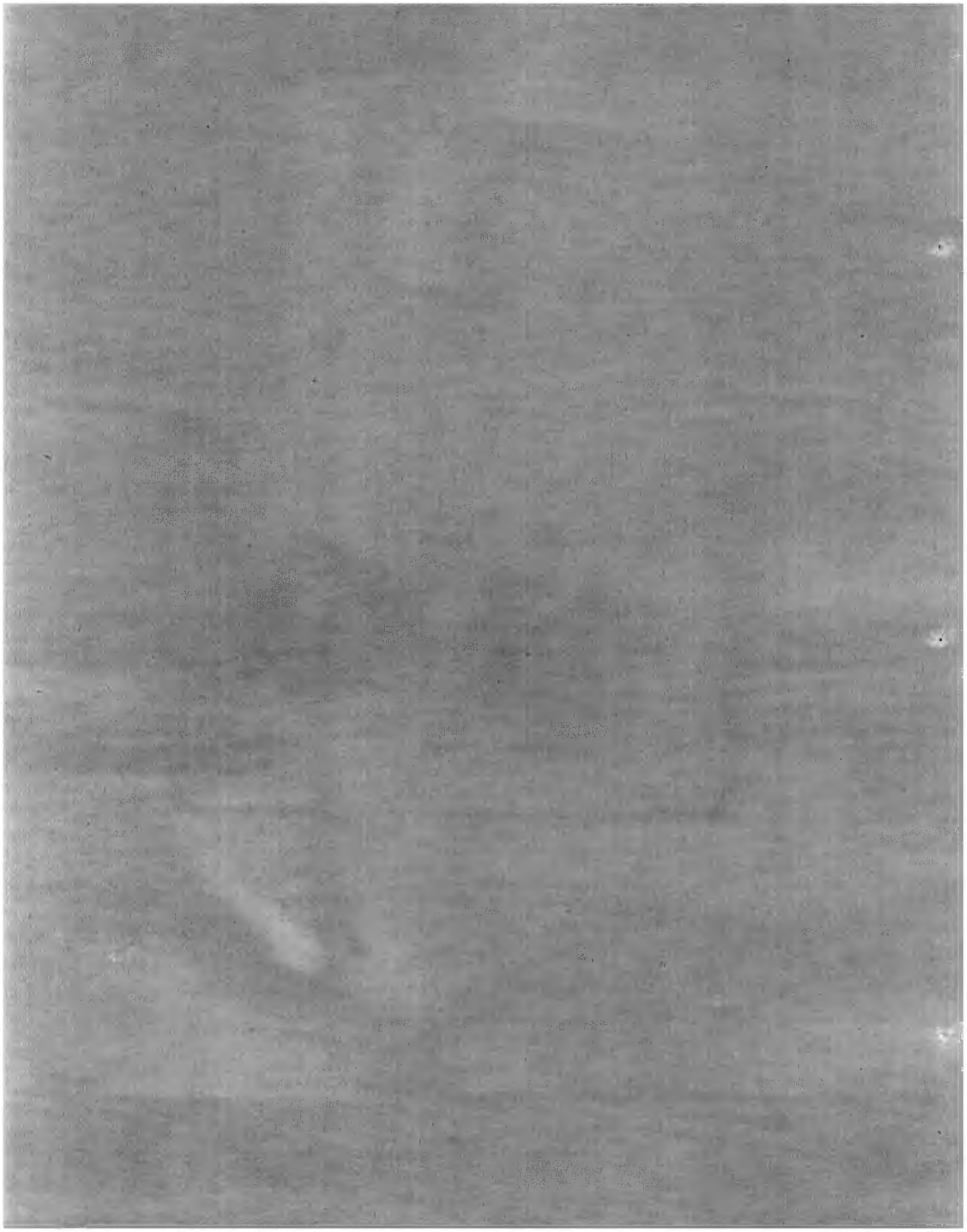


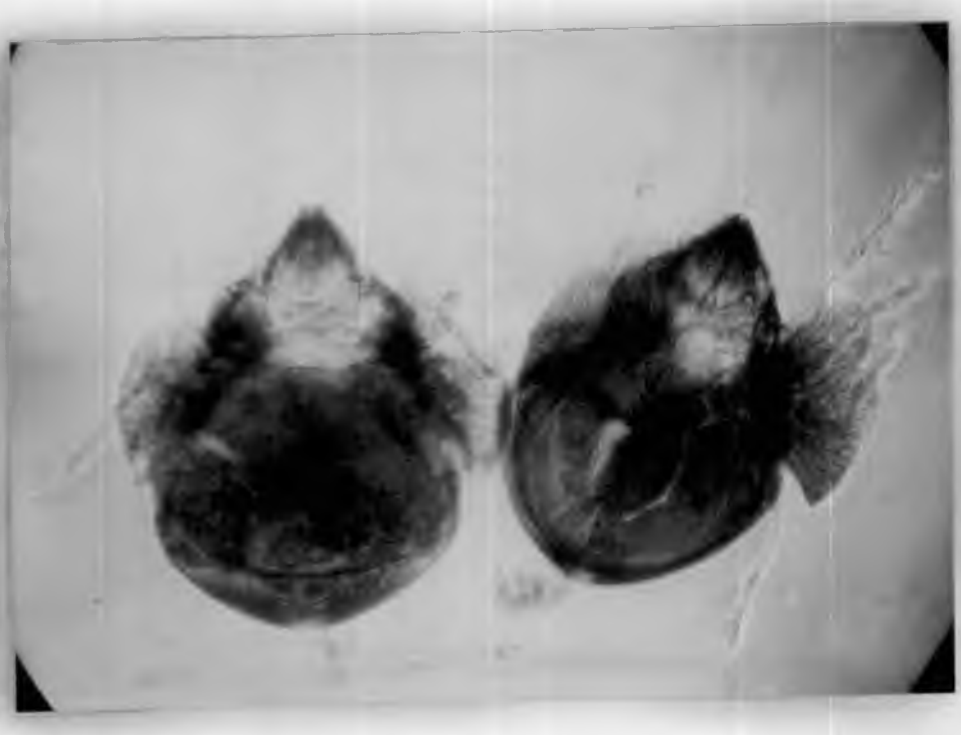
tinuous sclerites jointed by an unscleritized fine ridge. The pseudostigma was weakly developed, being represented by a small chitinised pouch (Fig. 3). The coxisternal sclerites of 3rd and 4th pairs of legs were weakly developed. The three pairs of anal setae were well developed. Their mean body length and width 0.399 mm and 0.175 mm respectively. Mean length of prodorsum and the notogaster length were measured as 0.142 mm and 0.240 mm respectively.

4.2.5 Tritonymph

Tritonymphs with three pairs of genital papillae. Pseudostigma was weakly developed, being represented by a small chitinised pouch (Fig. 4). Sensillus was absent in all the nymphal stages. The prodorsal sclerite and hysterosomal sclerites were well developed in the tritonymph than in the other nymphal stages (Plate 6). Coxisternal sclerites, a pair of aggenital setae and 3 pairs of adanal setae were well developed and 4 to 5 notogaster setae were visible. A fine ridge was present on the posterior part of notogaster and another well developed ridge was present just below the hysterosomal sclerite. Their mean body length and width were 0.411 mm and 0.264 mm respecetively. Mean length of prodorsum and notogaster length were measured as 0.181 mm and 0.326 mm respectively.

Plate 7. Adults of *O. terebrantis*
(0.431 mm long x 0.26 mm wide)





4.2.6 Adult

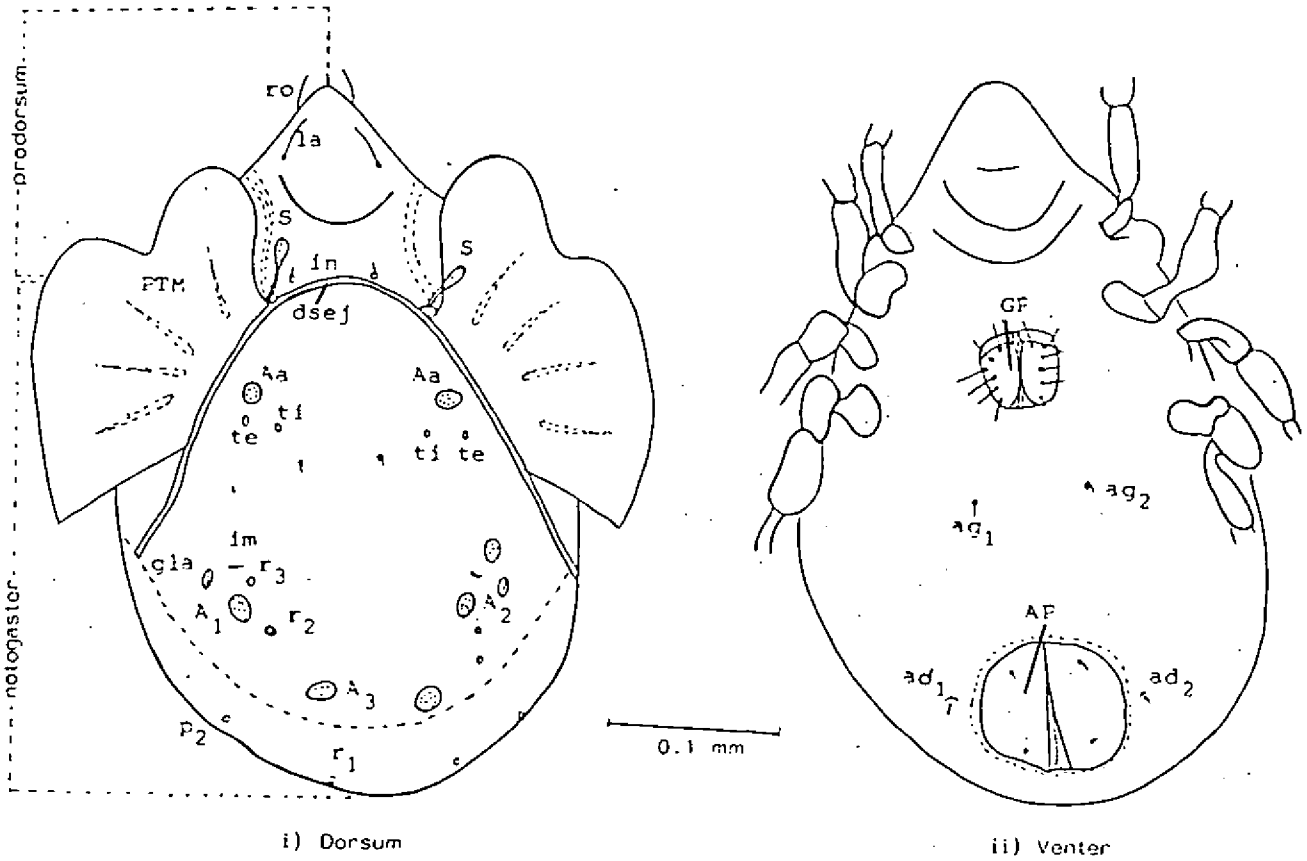
4.2.6.1 Dorsal region

Prodorsum anteriorly tapering and roughly triangular with a frontally pointed rostrum extending over the mouth parts. A pair of teeth or chelicerae with 1 to 3 incisions were present (Fig. 7A). Gnathosoma constricted with simple four segmented palps. The chelate-dentate sclerotized chelicera with one seta. The dorso-sejugal suture was strongly developed, arched and complete. Area porosae, sacculi and pori were present in the integument (Fig. 5). The sub segments of area porosae Aa, A_1, A_3 are well defined, but those of A_2 were well defined only in some cases. The lateral abdominal gland is in the form of sacculus with a slit like aperture. Pairs of distinctive lysifissures were present on the dorsal side of the integument. The lysifissures being represented only by as insertions. Notogaster setae were invisible. In addition to lysifissures the dorsum of the hysterosoma had a pair of laterally fixed pteromorphs. The pteromorph (wing) had deep indentation on the ventral margin, partly dividing the wing into two lobes. The anterior lobe was broadly rounded and the posterior one larger than the anterior, tapering at the end (Fig. 1B). The anterior margin of each pteromorph was ornamented with a series of cuticular

Key to Symbols

Aa	-	Area porosa adalaris
A_{1-3}	-	Notogastral areae porosae
ad_{1-2}	-	Adanal setae
ag_{1-2}	-	aggenital setae
an_{1-2}	-	anal setae
Ap	-	Anal plate
dsej	-	dorsosejugal suture
Gp	-	genital plate
gla	-	oil gland
g_{1-6}	-	genital setae
t_e, t_i, P_2	-	notogastral setae
in	-	interlamellar setae
im	-	Pori
ro	-	rostral setae
PTM	-	pteromorphae
s	-	sensillus

Fig. 5. Adult of *O. terebrantis*



ridges and conspicuous radiating veins. The pseudostigma was completely covered by the base of the pteromorph. Sensillus was relatively short, with slender, curved stem and globular roughend head (Fig. 1C). Notogaster dark brown in colour with various designs marked on it. Mean length of prodorsum was 0.130 mm and the length and width of notogaster were 0.270 mm, 0.260 mm respectively. (Plate 7).

4.2.6.2 Ventral region

The ventral side of hysterosoma was divided by a parabolic transverse suture. The anterior half had a genital plate and the posterior half, an anal plate, both being widely separated (Fig. 5). Genital aperture trapezoidal in shape, slightly broader anteriorly. Six slender setae were present on the genital plate (Fig. 7B). Anal and adanal setae were short and fine. A pair of short aggenital setae was present. Anal plate with two smooth setae of which an_2 located anteriorly and an_1 posteriorly. (Fig. 7C). Sexual dimorphism was lacking, but an ovipositer in the females and a short aedeagus in the males detected. Both the sexes possessed three pairs of genital acetabula.

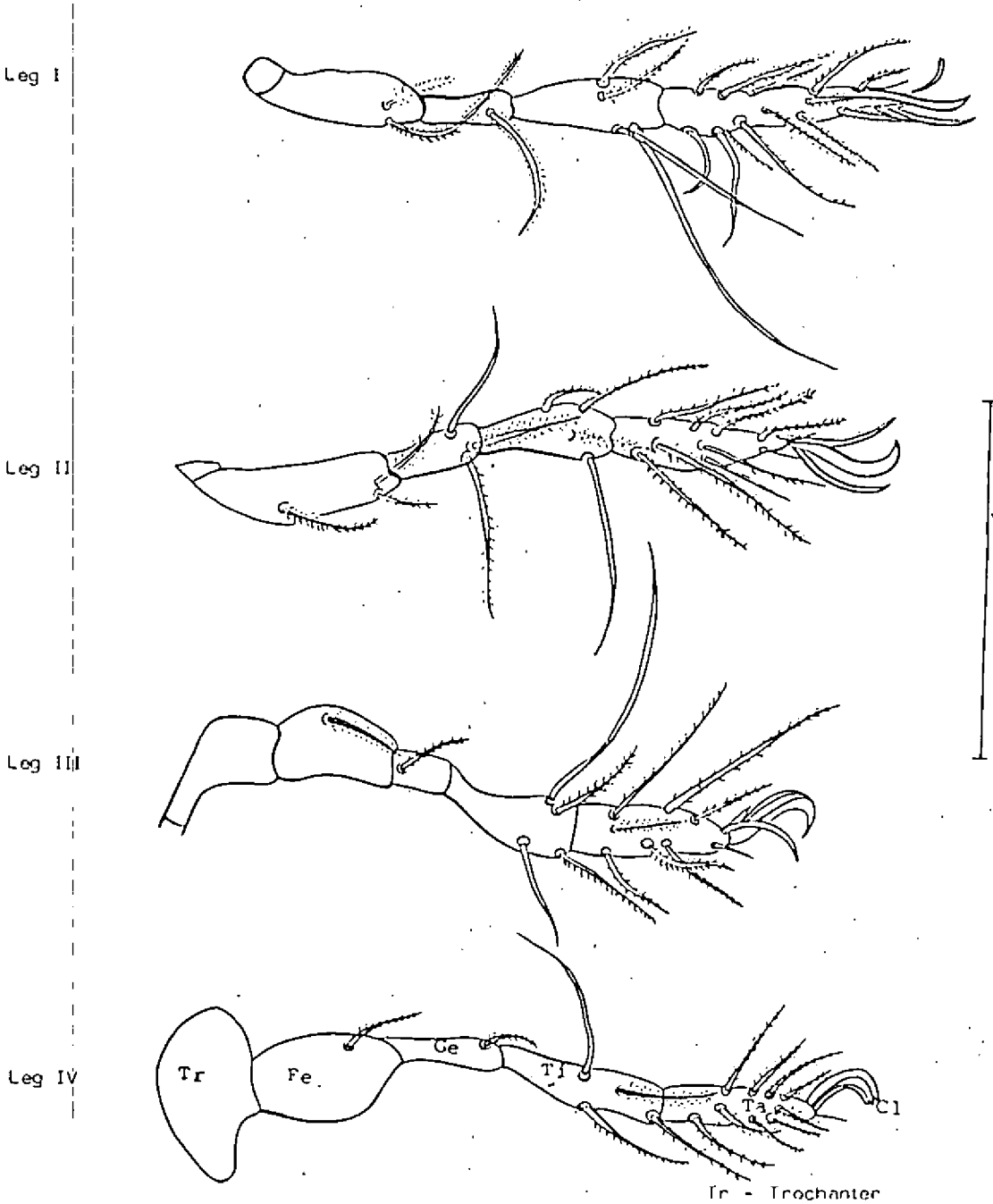
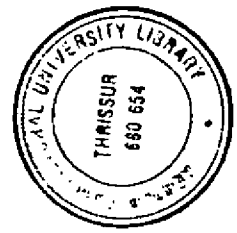


Fig. 6. Legs of *O. terebrantis*

Tr - Trochanter
Fe - Femur
Ge - Genu
Ti - Tibia
Ta - Tarsus
Cl - Claw



4.2.7 Legs

4.2.7.1 Immature stages

Three pairs of five segmented legs in the larvae and four pairs in the nymphal stages. The tarsus of immature stages with a single claw and few simple setae.

4.2.7.2 Adult

Adults with four pairs of legs consisting of five segments and four joints each. They were articulared into the acetabuli and usually consisted of a trochanter, femur, genu, tibia and tarsus. Terminally the tarsus with three claws on a short peduncle, the lateral claws were more slender than the median and sharply angled. Two types of setae were present on the legs; several simple setae and pilose setae. Third and fourth pairs of legs were slender than the first and the second (Fig. 6). The lengths of legs from first to fourth pair were 0.212, 0.192, 0.166 and 0.214 mm respectively (Table 3).

Fore femur was longer (0.072 mm) than the second (0.069 mm), third (0.037 mm) and fourth (0.050 mm).

The fourth leg genu was longer (0.036 mm) than the first (0.028 mm), second (0.023 mm) and third (0.016 mm).

Fig.7A.Chelicera

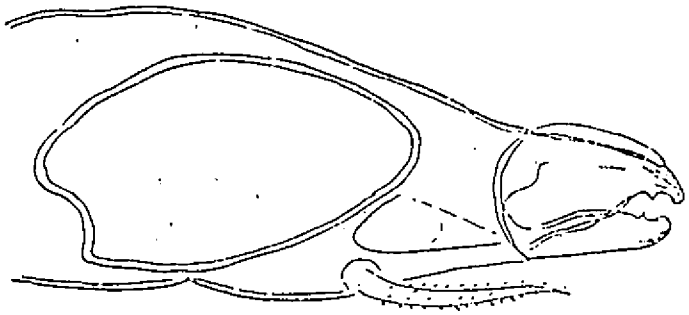
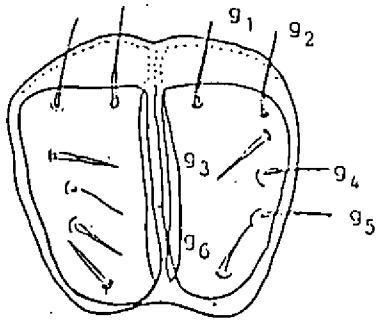
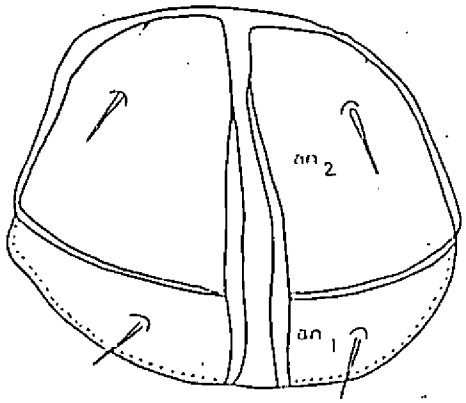


Fig. 7B. Genital plate



g - genital setae

Fig. 7_C. Anal plate



an - anal setae

0.1 mm

Table 3. Leg measurements of *O. terebrantis* (mm)

	Mean length	Range
Legs		
a) Total length		
1. I leg	0.212	0.206 - 0.264
2. II leg	0.192	0.173 - 0.214
3. III leg	0.166	0.156 - 0.181
4. IV leg	0.214	0.173 - 0.247
b) Femur		
1. I femur	0.072	0.066 - 0.082
2. II femur	0.069	0.066 - 0.082
3. III femur	0.037	0.033 - 0.041
4. IV femur	0.050	0.049 - 0.057
c) Genu		
1. I genu	0.028	0.024 - 0.033
2. II genu	0.023	0.016 - 0.033
3. III genu	0.016	0.016 - 0.016
4. IV genu	0.036	0.033 - 0.049
d) Tibia		
1. I tibia	0.028	0.024 - 0.033
2. II tibia	0.033	0.033 - 0.033
3. III tibia	0.041	0.033 - 0.049
4. IV tibia	0.048	0.041 - 0.066
e) Tarsus		
1. I tarsus	0.086	0.082 - 0.099
2. II tarsus	0.065	0.057 - 0.074
3. III tarsus	0.070	0.066 - 0.082
4. IV tarsus	0.082	0.074 - 0.099

Plate 8. The characteristic infestation symptom of the mite

Plate 9. Active role (feeding) of immature of *O. terebrantis* in waterhyacinth leaf destruction

The fourth tibia was longer (0.048 mm) than the third (0.041 mm), second (0.033 mm) and first (0.028 mm).

The first leg tarsus was longer (0.086 mm) than the fourth (0.082 mm), third (0.070 mm) and second (0.065 mm).

The differences in length of fore (0.212 mm) and second (0.192 mm), second and third (0.166 mm), third and fourth (0.214 mm) legs were significant. But the differences in length of fourth and fore legs were not conspicuous.

4.3 Nature of attack

The characteristic infestation symptom of the mite (Plate 8) developed within 5 to 7 days after egg deposition. Small greyish brown spots first appeared on the lower surface. These brown spots extended to feeding galleries, which contained the small larvae. The larval stage was succeeded by three nymphal stages viz., proto, deuto and tritonymphs. Continued feeding produced galleries that extended from base towards the apex of the leaf between the veins and vice-versa.The tunnels were found often filled with frass and moulting skin of the immature stages (Plate 9). The frass of the nymphs made the basal part of the gallery appear darker. Many times, a nymph

Plate 10. The sequences of drying of waterhyacinth leaf due to *O. terebrantis* attack

crossed a vein and continued its gallery in the neighbouring interveinal area. The length of tunnels increased with the development of the mites, which was indicated by the elongation of the brown spots into longitudinal streaks on the outer leaf lamina. Such brown streaks later coalesced to form large brown areas, leading to the drying up of the entire leaf (Plate 10).

4.3.1 Oviposition

Females of *O. terebrantis* made ovipositional holes, 0.08 to 0.1 mm in diameter with their mouth parts, by eating off the leaf tissue, on the lower surface of the leaf, leaving the upper epidermis intact. They laid solitary eggs, mostly sideways to the oviposition hole, deeply embedded in the aerenchyma cells.

The length of the oviposition holes ranged from 0.075 to 0.125 mm, the average being 0.107 mm. The width ranged from 0.050 mm to 0.100 mm, the average being 0.080 mm (Table 4).

4.3.1.1 Ovipositional holes per unit area

The number of ovipositional holes varied with the mite population per plant. Ovipositional holes were present uniformly except for the thickened basal part of the

Table 4. Mean number and dimensions of oviposition holes, eggs and emergence holes of *O. torobrantis* (mean of 10 replications)

Ovipositional holes (mm)		No.of eggs/ (cm^2)	Emergence holes		
			No. of emergence holes/leaf		Diameter (mm)
Length	Width		Upper lamina	Lower lamina	
0.1	0.8	7.1	168.1	171.5	0.31

petiole. Ovipositional holes per unit area ranged from 3 to 13/cm^2, the average being 7.1/cm^2 (Table 4).

4.3.2 Length of galleries

The length of galleries made by the larval and the nymphal stages increased with the development of the mites. The average length of the galleries at the larval stage was 0.157 mm and the average length of the galleries during proto-, deuto- and tritonymphal stages were 1.094, 2.473 and 4.024 mm respectively (Table 1).

4.3.3 Number of emergence holes on the leaf lamina

Field collected leaf samples showed almost equal number of emergence holes on the lower (168.1) and the upper leaf lamina (171.5) (Table 4).

4.3.4. Extent of damage by the developing stages of *O. terebrantis*

The analysis showed that the tritonymphs feeding gallery was longer (1.579 mm) and it was on par with the deutonymphs feeding gallery; but the tritonymphal feeding gallery length showed significant variation with the larval and the protonymphal feeding gallery length. The larva fed just a minimum 0.157 mm (Table 5).

Table 5. Length of galleries by different developmental stages of *O. terebrantis*

Mean length of galleries in mm by *O. terebrantis* nymphs				
Larva	Proto-	Deuto-	Trito-	CD (0.05)
0.157	0.927	1.365	1.579	0.236

4.4. Damage potential of the mites

The amount of damage caused by the mites at different population levels are presented in Table 6.

The data presented in Table 6 indicate that 10 mites caused minimum number of galleries per leaf and it is significantly different from T_2, T_3 and T_4. Eighty mites caused maximum damage to the leaf after 90 days due to the higher number of galleries per leaf.

Table 6. Damage potential of *O. terebrantis* on *E. crassipes* leaf at different population levels

Treatment No.	No. of mites released per plant	Total number of galleries per leaf at 30, 60 and 90 days after mite release		
		30 days	60 days	90 days
T_1	10	42.10	45.60	55.56
T_2	20	62.40	72.00	89.80
T_3	40	72.80	79.20	91.00
T_4	80	79.00	109.66	131.22
CD (0.05)		18.13	30.04	39.18
SEm±		5.560	9.213	12.015

4.4.1 Reduction in foliage

The data presented in Table 7 indicate the effect of *O. terebrantis* on the number of leaves of *Eichhornia*. The mean number of leaves was higher after 90 days in T_1 (10 mites) and there was no significant reduction in the number of leaves between the treatments except in T_4 (80 mites) even 90 days after the release of the mites.

4.4.2 Reduction in plant population

The analysis data on reduction in plant population clearly indicated significant differences between the treatments. The reduction in the number of plants was found to be maximum after 90 days in treatment with 80

Table 7. Number of leaves of *E. crassipes* at different mite population levels

Treatment No.	No. of mites released per plant	Number of leaves at different mite population levels after 30, 60 and 90 days of release		
		30 days	60 days	90 days
T_1	10	28.30	26.30	23.00
T_2	20	30.00	26.30	20.00
T_3	40	29.50	21.66	18.30
T_4	80	29.30	21.66	12.30
CD (0.05)		NS	NS	4.67
SEm±				0.822

Table 8. Effect of *O. terebrantis* on waterhyacinth population

Treatment No.	No. of mites released per plant	Number of *E. crassipes* at different mite population levels during 30, 60 and 90 days after release of mites		
		30 days	60 days	90 days
T_1	10	4.73	6.30	6.50
T_2	20	4.53	5.66	5.53
T_3	40	4.73	5.83	4.01
T_4	80	4.20	5.13	3.27
CD (0.05)		NS	NS	1.69
SEm±				0.493

mites per plant (3.27) followed by 40 mites (4.01). Mean number of plants was higher in treatment (T_1) with 10 mites (6.50) (Table 8).

4.4.3 Rate of population increase

The rate of population increase of *O. terebrantis* is presented in Table 9.

The data presented in Table 9 indicated that the rate of increase of the mite population per leaf was highest after 90 days in T_4 (80 mites) and that the minimum increase in the mite population per leaf was in T_1 (10 mites) 90 days after release.

Table 9. Rate of increase of *O. terebrantis* population on *E. crassipes*

Treatment No.	No. of mites released per plant	Mite population per leaf on *E. crassipes* after 30, 60 and 90 days of release		
		30 days	60 days	90 days
T_1	10	1.53	3.60	7.26
T_2	20	2.00	4.10	8.56
T_3	40	2.53	5.16	14.00
T_4	80	3.10	6.43	23.50
CD (0.05)		0.624	1.44	3.77
SEm±		0.191	0.443	1.157

4.4.3.1 Damage potential of *O. terebrantis* in the presence of *Neochetina* weevils under field conditions

4.4.3.1.a Number of galleries per leaf

Field samples showed that the maximum number of mite galleries per leaf was present on leaves with *Neochetina* feeding marks. Average number of galleries made by *O. terebrantis* along with *Neochetina* was 92.42 per leaf whereas, it was 65.70 galleries per leaf on *Neochetina* - free plants. However the difference was not statistically significant (Table 10).

Table 10. Number of galleries and mite population on leaves with and without *Neochetina* - feeding

Particulars	Leaves with weevil feeding	Leaves without weevil feeding	CD
Number of galleries per leaf	92.42	65.70	NS
Number of mites per leaf	66.00	28.70	25.48

4.4.3.1.b Population of *O. terebrantis* with and without the weevil feeding

The differences in the mite population on the leaves with and without *Neochetina*- feeding was significant. There was 129.9 per cent more mites in the presence of *Neochetina* weevils than in its absence (Table 10).

4.5 Extent of damage by *O. terebrantis* under experimental conditions

The extent of damage by *O. terebrantis* with and without weevils under open and partially shaded conditions was ascertained by measuring the reduction in size of roots, length of petiole, number of plants and the number of leaves on the attacked plants.

4.5.1 Effect of mites and the weevils on root length

The mean root length under partially shaded and open conditions of waterhyacinth recorded is presented in Table 11. The analysis indicated a significant disparity between treatments from 15th day onwards. The maximum root length was noted in T_5 (open condition in control tanks, 36.1 cm) on 90th day and minimum in T_4 (100 mites plus 10 weevils per tank in partially shaded condition) on 45th day, followed by T_8 (100 mites and 10 weevils per tank in open condition) on 60th day. Plants with ten weevils alone per tank (T_2) and 100 mites plus 10 weevils per tank (T_4) showed a steady reduction in root length and all the plants collapsed within a period of 60 days. Whereas in open condition, the treatments with 100 mites plus 10 weevils per tank (T_8) collapsed on 75th day, but in the treatment with ten weevils per tank in open condition (T_6), the plant collapse was noticed only on 105th day. In

Table 11. Effect of O. terebrantis and N. eichhorniae infestation on root length of E. crassipes under partially shaded and open condition as observed at biweekly intervals after release

Treatments	Mean root length of E. crassipes (cm) at different intervals (days) after release of mites and weevils							
	Initial	15	30	45	60	75	90	105
Partial shade condition								
T_1 Control (uninfested)	22.16	24.32	25.64	25.88	27.53	31.54	30.68	32.34
T_2 Weevil infested	20.32	22.54	19.96	19.32	ab	ab	ab	ab
T_3 Mite infested	20.68	23.38	21.62	24.28	24.00	24.52	24.30	24.04
T_4 Mite + Weevil	22.14	22.46	20.68	16.44	ab	ab	ab	ab
CD (0.05)	NS	3.52	4.094	6.016†	5.355	5.349	5.58	4.66
Open condition								
T_5 Control (uninfested)	22.42	31.66	34.22	35.42	35.84	35.96	36.10	36.02
T_6 Weevil infested	22.64	30.94	26.96	28.26	22.44	24.20	21.10	ab
T_7 Mite infested	22.00	30.22	30.80	29.92	25.38	26.00	26.82	26.44
T_8 Mite + Weevil	22.76	28.48	22.56	21.92	18.80	ab	ab	ab
CD (0.05)	NS	3.52	4.094	5.628	5.355	5.67@	7.39a†	4.66
SEm±		1.22	1.427	1.977	1.834	1.813	1.872	1.554

NS - Not significant
ab - Completely collapsed
† - C.D. for comparison between 19.32 and others
@ - C.D. for comparison between 24.20 and others
a† - C.D. for comparison between 21.10 and others

Table 12. Effect of O. terebrantis and N. eichhorniae infestation on petiole length of E. crassipes under partially shaded and open condition as observed at biweekly intervals after release

Treatment	Mean petiole length of E. crassipes (cm) at different intervals (days) after release of mites and weevils							
	Initial	15	30	45	60	75	90	105
Partial shade								
T_1 Control (uninfested)	5.70	6.58	6.01	6.52	6.71	7.98	9.65	12.20
T_2 Weevil infested	5.50	5.30	5.07	3.33	ab	ab	ab	ab
T_3 Mite infested	5.14	5.64	4.68	4.30	4.42	5.23	6.10	7.55
T_4 Mite + Weevil infested	5.12	5.58	4.93	3.46	ab	ab	ab	ab
CD (0.05)	NS	1.273	0.69	0.60[+]	0.67	0.77	1.16	2.36
Open condition								
T_5 Control (uninfested)	5.02	4.56	4.22	4.84	5.22	5.12	5.22	7.07
T_6 Weevil infested	5.24	3.93	3.62	3.54	3.43	3.05	3.00	ab
T_7 Mite infested	5.04	4.07	3.86	3.50	3.54	3.55	3.67	3.70
T_8 Mite + Weevil infested	5.12	3.80	3.79	3.52	3.20	ab	ab	ab
CD (0.05)	NS	1.273	0.69	0.56	0.67	0.82[@]	1.54a[+]	2.36
SEm±		0.197	0.241	0.198	0.229	0.262	0.391	0.789

NS - Not significant
ab - Completely collapsed
+ - C.D. for comparison between 3.33 and others
@ - C.D. for comparison between 3.05 and others

a[+] - C.D. for comparison between 3.00 and others

increasing trend, but under open conditions, there was an initial decrease followed by an increasing trend on all days excepting the 75th, after the release. In all the other treatments the petiole length recorded a decreasing trend except in the treatment with 100 mites per tank under partially shaded conditions (T_3) where an increasing trend was noticed. There was a significant difference in the petiole length of plants in the control tanks (T_1) and treatments with 100 mites per tank (T_3) under partially shaded conditions. In open conditions in the treatments with 100 mites per tank (T_7), the petiole length showed a decreasing trend which was obvious in the observation from 15th day onwards after the release of the mites. On 105th day under both the conditions, the results showed significant differences between the treatments and control tanks.

4.5.3 Effect of mites and weevils on laminar width

The mean laminar width under partially shaded and open conditions of waterhyacinth recorded in the experiment is presented in Table 13.

The analysis indicated significant differences between treatments from the 30th day onwards. The maximum laminar width was in partially shaded condition in the control tanks (T_1) on 105th day and the minimum in the

Table 13. Effect of O. terebrantis and N. eichhorniae infestation on leaf width of E. crassipes under partially shaded and open condition as observed at biweekly intervals after release

Treatment	Mean laminar width of E. crassipes (cm) at different intervals (days) after release of mites and weevils							
	Initial	15	30	45	60	75	90	105
Partial shade								
T_1 Control (uninfested)	6.07	6.20	6.21	6.09	6.33	6.90	6.90	7.59
T_2 Weevil infested	6.03	5.70	4.62	4.12	ab	ab	ab	ab
T_3 Mite infested	5.90	5.90	5.58	4.86	4.64	4.51	4.51	4.60
T_4 Mite + Weevil infested	6.13	5.76	4.30	3.93	ab	ab	ab	ab
CD (0.05)	NS	NS	0.386	0.408[+]	0.571	0.460	0.692	0.651
Open condition								
T_5 Control (uninfested)	5.97	6.19	5.86	5.91	5.07	5.28	5.31	5.32
T_6 Weevil infested	6.12	5.96	5.64	4.59	4.10	3.75	3.56	ab
T_7 Mite infested	6.53	6.06	5.66	5.24	4.35	4.25	3.88	3.85
T_8 Mite + Weevil infested	6.16	5.82	5.18	4.24	3.88	ab	ab	ab
CD (0.05)	NS	NS	0.386	0.384	0.571	0.488[@]	0.915a[+]	0.651
SEm±			0.134	0.134	0.152	0.156	0.231	0.217

NS - Not significant
ab - Completely collapsed
+ - C.D. for comparison between 4.12 and others
@ - C.D. for comparison between 3.75 and others

a[+] - C.D. for comparison between 3.56 and others

treatment having ten weevils alone per tank in open conditions (T_6) on 90th day. The laminar width of plants in control tanks under partially shaded conditions showed an increasing trend initially followed by a reduction and then again an increasing trend. Whereas the laminar width of plants in the control tanks under open conditions (T_5) showed a decreasing trend. The laminar width of all the plants in all the treatments showed a decreasing trend, under both the types of conditions except in 100 mites alone per tank (T_3) under partially shaded condition.

4.5.4 Effect of mites and weevils on laminar length

The mean laminar length, under both the types of conditions, of water hyacinth recorded is presented in Table 14.

The analysis indicated significant differences between treatments from 15th day onwards. The maximum laminar length recorded was in control tanks (T_1) under partially shaded conditions on 105th day and minimum in treatment having ten weevils per tank (T_6) in open conditions on 90th day. The laminar length of plants in control tanks (T_1) under partially shaded conditions showed an increasing trend with one exception on 30th day. Whereas the laminar length in the open conditions of plants in control tanks (T_5), initially decreased; but soon showed

Table 14. Effect of O. terebrantis and N. eichhorniae infestation on leaf length of E. crassipes under partially shaded and open condition as observed at biweedly intervals after release

Treatments	Mean laminar length of E. crassipes (cm) at different intervals (days) after release of mites and weevils							
	Initial	15	30	45	60	75	90	105
Partial shade								
T_1 Control (uninfested)	4.49	4.63	4.36	5.04	5.23	5.31	5.56	6.94
T_2 Weevil infested	4.25	4.24	3.87	3.26	ab	ab	ab	ab
T_3 Mite infested	4.61	4.42	3.92	3.48	3.28	3.48	3.45	3.42
T_4 Mite + Weevil infested	4.28	4.17	3.73	3.01	ab	ab	ab	ab
CD (0.05)	NS	0.522	0.401	0.55†	0.453	0.600	0.556	0.559
Open condition								
T_5 Control (uninfested)	4.24	4.08	3.94	4.27	4.28	4.24	4.35	4.38
T_6 Weevil infested	4.14	3.73	3.21	3.46	3.08	2.44	2.42	ab
T_7 Mite infested	4.23	3.67	3.24	3.14	3.89	3.58	3.40	3.20
T_8 Mite + Weevil infested	4.37	3.45	3.29	2.89	2.49	ab	ab	ab
CD(0.05)	NS	0.522	0.401	0.52	0.455ϱ	0.636	0.736a†	0.559
SEm±		0.182	0.14	0.182	0.156	0.203	0.186	0.186

NS - Not significant
ab - Completely collapsed
† - C.D. for comparison between 3.26 and others
ϱ - C.D. for comparison between 3.08 and others

a† - C.D. for comparison between 2.42 and others

an increasing trend. The laminar length in all the other treatments showed a decreasing trend.

4.4.5 Effect of mites and weevils on the number of leaves

The mean number of leaves in the partially shaded and open conditions of waterhyacinth plants recorded in the experiment is presented in Table 15.

Here, the $\sqrt{x}$ transformation of data was made before the analysis. The analysis indicated significant differences between the treatments from 15th day onwards. The maximum number of leaves recorded was in open condition in control tanks (T_5) 137.20 nos. followed by 134.20 nos. in partially shaded conditions (T_1) on 105th day and minimum in partially shaded conditions with ten weevils plus 100 mites (T_4) and 10 weevils per tank (T_3) on 45th day followed by treatments having ten weevils per tank (T_6) in open condition on 90th day. In the treatment with 100 mites per tank under partially shaded condition, the number of leaves initially increased upto 45th day and then a decreasing trend prevailed. Whereas in open conditions, the number of leaves showed increasing trend upto 90 days and then onwards a decreasing trend prevailed.

4.5.6 Effect of mites and weevils on the growth of waterhyacinth

The mean number of plants, recorded under both the

Table 15. Effect of O. terebrantis and N. eichhorniae infestation of leaf production of E. crassipes under partially shaded and open condition as observed at biweekly intervals after release

Treatment	Mean number of leaf of E. crassipes of different intervals (days) after release of mites and weevils							
	Initial	15	30	45	60	75	90	105
Partial shade								
T_1 Control (uninfested)	46.6 (6.81)	79.2 (8.89)	90.4 (9.48)	108.4 (10.40)	114.0 (10.62)	131.6 (11.40)	129.2 (11.30)	134.2 (11.57)
T_2 Weevil infested	45.2 (6.71)	77.6 (8.79)	67.2 (8.18)	33.0 (5.70)	ab	ab	ab	ab
T_3 Mite infested	42.8 (6.53)	77.8 (8.81)	83.0 (9.10)	81.0 (8.95)	72.4 (8.42)	71.0 (8.39)	64.0 (7.94)	40.8 (6.28)
T_4 Weevil + Mite infested	46.8 (6.63)	77.2 (8.75)	65.0 (8.04)	22.6 (4.74)	ab	ab	ab	ab
CD (0.05)	NS	0.31	1.22	0.819[+]	1.19	1.28	0.808	0.95
Open condition								
T_5 Control (uninfested)	47.8 (6.88)	85.5 (9.20)	116.4 (10.71)	116.8 (10.79)	119.4 (10.86)	132.0 (11.44)	140.2 (11.76)	137.2 (11.60)
T_6 Weevil infested	49.2 (7.00)	83.4 (9.12)	101.0 (9.99)	89.8 (9.46)	95.0 (9.58)	73.0 (8.22)	46.0 (6.65)	ab
T_7 Mite infested	41.2 (6.42)	81.4 (9.01)	99.0 (9.26)	86.4 (9.34)	88.0 (9.32)	79.6 (8.66)	72.6 (8.48)	64.0 (12.80)
T_8 Weevil + Mite infested	45.0 (6.70)	81.8 (9.04)	49.8 (6.98)	47.2 (6.81)	44.6 (6.54)	ab	ab	ab
CD (0.05)	NS	0.31	1.22	0.77	1.19	1.36[@]	1.069a[†]	0.95
SEm±		0.109	0.427	0.269	0.410	0.436	0.270	0.318

/X - Transformation of data was made before analysis. The values given in parenthesis indicate transformed data
NS - Not significant
ab - Completely collapsed
+ - C.D. for comparison between 5.70 and others
@ - C.D. for comparison between 8.22 and others
$a^{\dagger}$ - C.D. for comparison between 6.65 and others

types of conditions, of waterhyacinth is presented in Table 16.

Here also $\sqrt{x}$ transformation was carried out for analysis. In the experiment, a set of five plants each were used in all the treatments. In the treatment with ten weevils alone (T_2) and T_4 (10 weevils plus 100 mites combinations per tank) under partially shaded conditions, all the plants collapsed and sank into the tank by the 60th day. Whereas in open conditions in the treatment having (T_8) ten weevils plus 100 mites per tank, all the plants collapsed by 75th day, but in the treatment with ten weevils alone per tank (T_6), collapse occurred only by 105th day. The number of plants showed a steady increase in the control tanks (T_1) under partially shaded conditions upto 75th day and then a decrease set in. Whereas in the T_5 (control tanks in open conditions) the number of plants showed an increasing trend upto 90th day and then followed a decreasing trend, though exceptions were noticed. But the rate of multiplication slowed down gradually with the passing of time. The treatments with 100 mites alone per tank (T_3 and T_4) perpetrated no collapse of plants upto 105th day in both conditions. The number of plants in that treatment showed an increasing trend at first, but soon decreasing set in due to occasional rotting in a few replications. The number of plants showed a

Table 16. Effect of O. terebrantis and N. eichhorniae infestation on plant growth of E. crassipes under partially shaded and open condition as observed at biweekly intervals after release

Treatment	Mean number of plants of E. crassipes at different intervals (days) after release of mites and weevils							
	Initial	15	30	45	60	75	90	105
Partial shade								
T_1 Control (uninfested)	11.2 (3.27)	20.0 (4.59)	26.0 (5.09)	32.0 (5.64)	33.0 (5.75)	36.4 (6.02)	35.6 (5.95)	34.6 (5.87)
T_2 Weevil infested	12.0 (3.44)	19.2 (4.37)	17.2 (4.12)	9.25 (2.91)	ab	ab	ab	ab
T_3 Mite infested	11.6 (3.38)	21.6 (4.64)	23.0 (4.78)	24.0 (4.85)	23.0 (4.76)	18.4 (4.49)	18.8 (4.30)	21.4 (4.60)
T_4 Mite + Weevil infested	12.6 (3.54)	22.2 (4.71)	17.4 (4.13)	7.4 (2.68)	ab	ab	ab	ab
CD (0.05)	NS	0.27	0.55	1.72[†]	0.515	0.66	1.26	0.60
Open condition								
T_5 Control (uninfested)	11.4 (3.33)	23.8 (4.87)	34.0 (5.82)	39.6 (6.28)	40.0 (6.32)	36.4 (6.01)	41.0 (6.39)	40.0 (6.31)
T_6 Weevil infested	12.4 (3.49)	21.6 (4.63)	33.4 (5.76)	24.2 (4.90)	18.8 (4.31)	12.75 (3.45)	10.5 (3.19)	ab
T_7 Mite infested	13.4 (3.65)	23.0 (4.78)	30.4 (5.68)	28.2 (5.30)	24.4 (4.92)	24.8 (4.96)	23.4 (4.80)	21.2 (4.55)
T_8 Mite + Weevil infested	13.4 (3.65)	20.2 (4.49)	29.6 (5.42)	16.0 (3.93)	15.6 (3.92)	ab	ab	ab
CD (0.05)	NS	0.27	0.55	0.672	0.515	0.70[@]	1.67a[+]	0.60
SEm±		0.094	0.172	0.234	0.176	0.225	0.424	0.20

/X - Transformation of data was made before analysis. The values given in parenthesis indicate transformed data
NS - Not significant
ab - Completely collapsed
† - C.D. for comparison between 2.91 and others
@ - C.D. for comparison between 3.45 and others
a[+] - C.D. for comparison between 3.19 and others

steady increase in control tanks of partially shaded condition (5 to 34.6) and open condition (5 to 40) as well.

4.6 Arthropod and fungus relationship

The fungi could be isolated from all the disease affected leaf and petiole in PDA medium. The fungi species like *Fusarium, Aspergillus* and *Rhizopus* were isolated from mite and weevil feeding spots at the time of experiments.

Arthropods other than *O. terebrantis* and *N. eichhorniae*

The grasshopper *Gesonula punctifrons*, aphid (?*Rhopalosiphum* sp.) and spider mites were noticed during the course of study.

Discussion

DISCUSSION

5.1 Biology

Females of *O. terebrantis* made circular holes with their mouth parts, eating off the leaf tissue. They laid solitary eggs, mostly sideways to the oviposition holes, deeply embedded in aerenchyma cells. This type of concealed ovipositon behaviour was observed in phytophagous oribatid mites *Punctoribates longiprosus* and *Scheloribates decarinatus* occurring on waterhyacinth and *Chromolaena odorata* respectively, and this could protect the egg from predators, washing away by running water, rain and other such adverse climatic conditions (Haq and Ramani, 1985).

The incubation period ranged from 5 to 8 days, the average bring 5.8 days at 27 ± 3.2°C. The incubation period recorded by other researchers were 6 to 7 days (Sumangala and Haq, 1990) and 7.6 days (Visalakshy and Jayanth, 1991). The reason for the shorter incubation period in this study could be attributed to the climatic differences.

The larval and nymphal stages were completed in about 20.8 days at 27 ± 3.2°C. Cordo and Deloach (1976) and Visalakshy and Jayanth (1991) recorded the nymphal

period as 15 days and 17.9 days respectively under green house condition. The difference in the range of larval and nymphal duration may be due to the differences in climatic conditions, the locations of study being quite different.

The development and completion of life stages in *O. terebrantis* took 26.6 days at 27 ± 3.2°C. Visalakshy and Jayanth (1991) observed development and completion of life stages of *O. terebrantis* within 25.5 days. Haq and Adolph (1981 a) recorded more or less similar developmental periods for other oribatid mites like *Galumna flabellifera orientalis* (24.8 days) and *Galumna longipluma* (24.5 days).

The active life stages were preceded by an inactive period. During the inactive period the body appeared swollen and turbid. The inactive periods from larval to protonymph, proto-to deutonymph and deuto to tritonymph were 1.6 days each whereas the inactive period from tritonymphs to adult was 3 days. Visalakshy and Jayanth (1991) observed inactive periods of similar range. During the inactive period from tritonymphs to adult, the hardening and pigmentation of body cuticle and wings were completed. These observations agree with those on other oribatids like *G. flabellifera orientalis* and *G. longipluma* (Haq and Adolph, 1981 a).

The mating pairs were never noticed during the period of study and it agrees with the report of Sengbusch (1961). His observations confirmed sperm transfer through spermatophores as the usual method in many oribatid mites. In these oribatid mite species, sperm transfer was accomplished by the deposition of spermatophores into the external environment which were later transfered to the female genital pouch (Sengbusch, 1961 and Haq and Adolph, 1981 b).

5.2 Morphology

5.2.1 Immature stages

The eggs were elliptical, the average size being 0.120 x 0.070 mm. The larvae were characterized by three pairs of legs and the absence of the genital opening. The protonymph had four pairs of legs, and the primordium of genital opening also appeared but there was only one pair of genital papillae. The deuto - and tritonymph had two and three pairs of genital papillae respectively, and the sensillus was lacking in all the nymphal stages. In the present studies too, the measurements of the length and width of notogaster agreed with those reported by Visalakshy and Jayanth (1991).

5.2.2 Adult

Detailed morphology of the adult is given under

results. The sensillus and lobed pteromorph are found to be the key characters by which the *O. terebrantis* could be distinguished from other species. The morphological and biometrical observations agree with the observations of Wallwork (1965) excepting in certain minor points.

5.3. Nature of attack

O. terebrantis deposited the eggs deep into the aerenchyma tissue of the leaves by cutting and eating off the leaf tissue. The ovipositional holes (0.08 to 0.11 mm in diameter) were found only on the ventral surface of the leaf lamina. This may be due to the tendency of oribatids to inhabit the ventral surface of leaves and can be regarded as an adaptation to escape from natural hazards, over-exposure to light and wind etc. Such ovipositional habits may prevent the chances of desiccation and predation of the eggs as suggested by Haq and Ramani (1985) in the case of *P. longiprosus*. The emerging larvae exhibited active feeding which was externally visible 5 to 7 days after egg deposition. Larval and nymphal feeding produced galleries that extended towards the apex of the leaf between the veins. The galleries finally reached an average length of 4.024 mm. They later coalesced to form extensive cavities. The cavities and tunnels were found often filled with frass and moulting skin of the immature

stages. Such tunnels and galleries appeared externally as brown streaks. These streaks later coaleasced to form large brown areas, leading to the drying up of the entire leaf. These observations agree with the findings of Cordo and Deloach (1976) and Sumangala and Haq (1990). As a result of the mite feeding the green surface of the plant becomes reduced and it makes the plant vulnerable to the attack of pathogens. Adult mites were found on exposed parts of leaf surfaces, but usually they remain clustered in fresh feeding scars of *Neochetina* or in broken areas of the leaf. There were 129.9 per cent higher mite population in the presence of *Neochetina* weevils than in its absence. Cordo and Deloach (1976) had also observed the same phenomenon. However, there was no significant differences in the number of galleries per leaf in the presence of *Neochetina* as in its absence.

As only the oldest leaves were affected by the mites, their effect on the plant was not pronounced enough to hinder the development of the plant. This is in conformity with the results obtained by Center (1985). He reported that this mite affected only the older leaves close to the end of their life expectancy and the plant seems to withstand the leaf injury by rapid production replacing those injured.

5.4 Damage potential of the mites

Analysis of the number of galleries per leaf due to *O. terebrantis* feeding showed no significant differences between treatments T_4 (80 mites per plant) and T_3 (40 mites per plant) on 30th day after release and the number of galleries recorded was 79.0 and 72.8 per leaf respectively. From 60th day onwards, the treatments were found to be significantly different. The total number of galleries per leaf was highest after 90 days in T_4 (131.22). The lowest number of galleries per leaf was 42.1 after 30 days in the treatment with 10 mites per plant (T_1).

Analysis of the leaf number reduction due to *O. terebrantis* feeding showed that there was no difference between treatments T_4 and T_3, 60 days after release, the number of leaves recorded was 21.66 each under both the treatments. From 90th day onwards the treatments were found to be significantly different. The number of leaves was highest (30.0) after 30 days in the treatment with 20 mites per plant (T_2). The lowest number of leaves was recorded after 90 days in T_4 (12.3). The mean number of plants was found to be higher after 90 days of release in the treatment T_1 (6.50). The maximum plant reduction was observed in T_4 (3.27 Nos.). However, there was no significant difference between T_3 and T_4. Experiments on the rate

of increase in the mite population showed a significant difference between the treatment T_4 (23.5) and all the other treatments after 90 days of release.

5.5 Extent of damage

The extent of damage by *Orthogalumna* and *Neochetina* was ascertained on the basis of different parameters. Analysis of data indicated a significant difference between treatments from 15th day onwards, except in leaf width, which showed significant difference from 30th day onwards. The growth rate of waterhyacinth was more in open condition with 100 per cent light intensity than in partially shaded condition with only 11 to 34 per cent light infiltration. This observation was in close agreement with the result of Soekisman (1977) who found a direct correlation between stolon number and light intensity. He also observed that the plant is heliophilous and grows best under high light intensity and high temperature.

The results indicated that there was significant difference in root length between treatments recorded from 15th day onwards. Eventhough the plant having ten weevils alone per tank (T_6) in open condition survived upto 100 days, there was a significant reduction is root length as compared to those in the uninfested control (T_5). The root length of the plants initially decreased then increased

under partially shaded condition in T_3 (100 mites alone per tank), whereas in T_7 (100 mites alone per tank in open condition) root length increased at first, then it reduced, and again increased. In T_3 and T_7 the root length was less compared to T_1 and T_5 (control tanks).

In the treatments T_2, T_4 and T_8 the petiole length progressively decreased. In T_7 petiole length decreased whereas in T_3, the petiole length increased but it was significantly lesser than uninfested control tanks (T_1 and T_5). The low light intensity might be the reason that promoted elongation of petiole in partially shaded conditions. The laminar length and width in all the treatments decreased except in uninfested control tanks under both light intensites.

The results indicated that in all the treatments the number of leaves under both light intensities decreased except in control tanks. The treatments T_3 and T_7 showed that there were no collapse of the plants upto 105th day. However, there was considerable reduction in the number of leaves in T_3 than in T_7. The typical mite damage and the loss of leaves by the plant was mainly restricted to the older leaves and so their effect on the plant was not pronounced to hinder its development. This

is in conformity with the results obtained by Center (1985).

In the treatments T_2 (10 weevils alone per tank) and T_4 (100 mites plus 10 weevils per tank) under partially shaded conditions, the plants completely collapsed by about the 60th day and there were no significant differences between the treatments. Fosse (1978) observed that predominantly the shaded areas had consistently higher number of weevils per plant than the areas in full sun for most of the day. This may be due to the preference of these weevils for shaded areas for feeding and oviposition.

The plants in treatment with 100 mites plus 10 weevils (T_8) in open condition collapsed by around the 75th day. The effect of weevil and mite combination on size and density of waterhyacinth was significantly superior to the independent action of the biocontrol agents. This is in line with the observation of Fosse (1976) who reported that the weevils laid more eggs per female in the presence of the mites. He also reported the release of a kairomone from the waterhyacinth tissue on which the arthropods (mite and weevil) fed. The kairomone apparently contained an oviposition stimulant and a phagostimulant that acted both on the weevils and on the mites. It may be

the reason for the mites preferably feeding on fresh feeding scars of *Neochetina*. Fosse (1977b.) recorded a higher rate of oviposition and feeding by the weevil and the mites on plants with a higher level of kairomone.

The higher level of kairomone must be possible only in the presence of mites along with the weevils. In this study also the treatment with 100 mites plus 10 weevils per tank (T_8) may have induced greater oviposition and consequent feeding accomplishing an early collapse of the plants when compared to T_6 (10 weevil alone per tank) under open conditions. Even though the plant growth-rate was greater in open condition due to high light intensity when compared to the partially shaded condition, the treatment T_8 took only another 15 days for complete collapse of plants when compared to T_2 and T_4. The reason for the quick collapse of the plants in T_8 was due to the increasing population of immature stages of mites and weevils, as suggested by Fosse (1977 b).

However, in the treatment T_6 the plants collapsed only by 105th day. This is in conformity with the findings of Jayanth and Nagarkatti (1984) who reported that the weevil took 13 to 16 weeks for complete collapse of the *Eichhornia* plants. The reason for the greater time required for the collapse of *Eichhornia* in T_6 was due to

the absence of *Orthogalumna* mites and consequent lower level of the kairomone. It led to the lesser oviposition stimulant and phagostimulant in the *Neochetina* weevil population when compared to the treatment T_8.

This study proved the potential effectiveness of the weevil and the mite combination in the control of waterhyacinth and it was evident that the synergistic effect of *O. terebrantis* and *Neochetina* were more stressing on waterhyacinth than the effect of either agent alone.

In the mite-alone-released treatments (T_3 and T_7) there was no collapse of the plants upto the 105th day. In the treatments T_3 and T_7, the damage symptom and the loss of leaves were not sufficient to hinder the growth of the plants. This study indicated that the mites alone were not effective in limiting the plant growth. But an over all leaf reduction was observed when compared to the uninfested control tanks (T_1 and T_5). The reduction in number of plants in these treatments was due to occasional rotting and natural infestation by aphids.

This study proved that the mites were more effective in controlling the plant growth in the presence of *Neochetina* weevils under both the conditions than when being alone and concluded that *O. terebrantis* alone did

not create sufficient stress to supress waterhyacinth under normal condition. With this mite, growth rate of the plant was also a critical factor, since the plant-growth-rate was too slow to show any visible reduction in the plant population.

The results emphazise the need to undertake experiments on an integrated approach, involving the use of native and introduced phytopathogens such as *Alternaria eichhorniae* and *Cercospora rodmanii* with the various herbicides, growth retardants and physical barriers along with the weevil and mite release.

The herbicide application may be timed in such a way as to minimally interfere with the bioagents. Slowly acting compounds may be used which would allow the majority of the bioagents to complete development before the plants die. Haag (1991) suggested that a pattern of herbicide application may be implemented which would leave some of insect and mite populations available to attack subsequent regrowth. Growth retardants may also be used which would slow plant growth sufficiently for the weevil and the mites to overtake them as reported by Center *et al.* (1982).

5.6 Arthropod and fungus relationship

The natural occurrence of pathogens like *Fusarium*, *Rhizopus* and *Aspergillus* were noticed on the weevil and the mite infested plants. The weevil and the fungus increase the detrimental effect of the mite on waterhyacinth. The earlier workers like Fosse (1976), Charudattan *et al*. (1978), Charudattan (1986) and Galbraith (1987) reported the effectiveness of the insect and the fungus combination for the control of waterhyacinth. The present findings also agree well with the earlier findings.

5.7 Arthropods other than *O. terebrantis* and *N. eichhorniae*

Spidermites and insects such as aphids and grasshoppers were also noticed along with *O. terebrantis* and *N. eichhorniae*. Presence of these native organisms on waterhyacinth along with *O. terebrantis* and *N. eichhorniae* may give more stress to waterhyacinth and thereby achieve a better control of the weed. These observations also support the earlier findings of Pieterse (1972), Sankaran and Rao (1972) and Manoharan *et al*. (1981).

Summary

SUMMARY

Biology

Studies on the biology of *O. terebrantis* showed that the mean incubation period was 5.8 days; the range being 5 to 8 days. The larval and nymphal stages were completed in about 20.8 days. It had one larval and three nymphal stages namely, proto, deuto and tritonymph, with an inactive period of 1.6 days each between larval and protonymph, proto and deutonymph, and deuto and tritonymph, whereas the inactive period between tritonymph and adult was 3 days. The adult mites congregated on fresh weevil feeding scars or the youngest leaf of waterhyacinth for feeding and oviposition. The adult mites lived for a period of 57.3 days. The average pre-oviposition period was 4 days and ovipositional period prolonged till the death of the mite. The mean number of eggs produced by females during whole life time was 41.5 eggs.

Morphology

The eggs were elliptical in shape (0.120 x 0.070 mm). The larvae had three pairs of legs but no genital opening and dorsal sclerites. Nymphs had four pairs of legs ending in single claws. Sensillus and pteromorphae

were absent in all the nymphal stages. The proto, deuto and tritonymphs could be distinguished based on the number of genital papillae and the development of dorsal sclerites in subsequent nymphal stages.

Adults were shiny, dark brown to nearly black and heavily sclerotized. Prodorsum anteriorly tapering and roughly triangular with a frontally pointed rostrum extending over mouthparts. A pair of chelicerae present with 1 to 3 incisions and one seta. Gnathosoma constricted with simple four segmented palps. The dorsosejugal suture was strongly developed, arched and complete. Area porosae, sacculi and pori were present in the integument with a pair of laterally fixed pteromorphs. The sensillus was relatively shorter and slender with curved stem and globular roughened head. The ventral side of hysterosoma divided by a parabolic transverse suture. The anterior half being the genital plate and posterior half the anal plate, they were widely separated. Genital aperture trapezoidal in shape with six slender setae . Anal and adanal setae short and fine. A pair of short aggenital setae present. Sexual dimorphism lacking. Adults had four pairs of legs consisting of five segments and four joints each. They were articulated into the acetabuli and usually consist of the trochanter, femur, genu, tibia and tarsus. Terminally

the tarsus had three claws on a short peduncle, the lateral claws sharply angled and more slender than the median.

Nature of attack

The adult mites deposited the eggs deep into the aerenchyma cells of the leaves by cutting and eating off the leaf tissue. The larval and nymphal feeding produced galleries that extended from the base towards the apex of the leaf between the veins and vice-versa. The immature stages played an important role in the destruction of the inner leaf tissue. The galleries which appeared as brown streaks; were covered externally by the upper epidermis. Such streaks later coalesced to form large brown areas leading to the drying up of the entire leaf.

Damage potential of the mites

As the mite load increased from ten to eighty per plant, the number of leaves and plants showed significant reduction from the 90th day onwards.

Extent of damage

The plants in tanks having 10 weevils alone and 100 mites plus 10 weevils combination collapsed in 60 days in partially shaded condition, whereas in open condition, the plants collapsed by the 75th day in the treatment having

100 mites plus 10 weevils per tank. The plants in tanks having 10 weevils alone under open condition, collapsed by the 105th day. In tanks having 100 mites alone, the plants did not collapse upto the 105th day under both the conditions.

Arthropod and fungus relationship

Parasitic fungi like *Fusarium* and saprophytic fungi *Aspergillus* and *Rhizopus* were isolated from mite and weevil feeding spots.

Arthropods other than *N. eichhorniae* and *O. terebrantis*

Spidermites and insects like grasshoppers (*Gesonula punctifrons*) and aphids (?*Rhopalosiphom* sp.) were noticed.

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APPENDIX-I

Monthly meteorological data for the experiments period January '93 - February '94

Month	Temperature °C		Average relative humidity (%)	Mean rainfall (mm)	Mean sunshine hours (No. of hours of bright sunshine	Mean evaporation (mm/day)
	Maximum	Minimum				
January '93	32.6	20.7	53	0	8.2	8.1
February	34.1	22.0	62	6.6	9.0	9.4
March	35.4	23.7	63	0	7.11	9.0
April	34.5	25.0	69	32.1	5.82	9.1
May	34.4	24.8	74	131.1	5.27	6.5
June	30.1	23.9	86	700.3	3.37	3.3
July	28.1	22.9	87	661.3	3.02	2.4
August	29.6	23.4	87	276.7	4.75	4.8
September	30.6	23.1	81	85.3	3.67	6.4
October	30.7	23.4	83	74.6	2.87	4.8
November	31.5	23.6	73	18.0	4.07	5.8
December	31.6	23.1	66	0	5.29	7.5
January '94	32.9	22.6	58	19.4	7.17	9.1
February	34.8	23.1	59	1.7	6.6	8.7

APPENDIX-II

Summary of analysis of variance of tables of the different growth parameters of waterhyacinth plants observed at biweekly intervals after release of *O. terebrantis* and *N. eichhorniae* under partial shade and open condition

Source	df	No. of plants	No. of leaves	Petiole length	Laminar length	Laminar width	Root length
			Mean squares at the time of release				
Treatment	7	0.999	0.178	0.267	0.119	0.207	4.11
Error	32	0.198	1.499	0.347	0.063	0.238	6.54
Total	39						
			Mean squares at 15 days interval				
Treatment	7	0.187	0.139*	4.920**	0.810**	0.181**	79.94**
Error	32	0.045	0.060	0.986	0.166	0.211	7.55
Total	39						
			Mean squares at 30 days interval				
Treatment	7	2.426**	7.070**	3.280**	1.121**	2.062**	13.15**
Error	32	0.149	0.915	0.291	0.098	0.091	10.19
Total	39						
			Mean squares at 45 days interval				
Treatment	7	7.830**	24.140**	8.330**	2.597**	3.220**	269.64**
Error	31	0.275	0.363	0.197	0.166	0.090	19.56
Total	38						
			Mean squares at 60 days interval				
Treatment	5	3.980**	12.610**	9.120**	4.770**	3.900**	166.70**
Error	24	0.156	0.844	0.264	0.122	0.117	16.83
Total	29						
			Mean squares at 90 days interval				
Treatment	4	5.700**	18.800**	28.660**	5.270**	7.490**	130.22**
Error	17	0.237	0.367	0.766	0.207	0.269	17.54
Total	21						
			Mean squares at 105 days interval				
Treatment	3	3.980**	36.130**	61.000**	14.70**	13.080**	149.28**
Error	16	0.202	0.508	3.120	0.174	0.236	12.084
Total	19						

* Significant at 5% level, ** Significant at 1% level

APPENDIX-III

Analysis of variance table of the feeding behaviour of *O. terebrantis* in presence or absence of *N. eichhorniae*

a) Number of mites per leaf

Source	df	S.S	M.S.S	F
Treatment	1	6956.45	6956.45**	
Error	18	11778.10	654.33	10.63
Total	19	18734.55		

b) Number of galleries

Source	df	S.S	M.S.S	F	Table F
Treatment	1	3569.79	3569.79		
Error	18	24758.80	1375.49	2.59	4.41 (5% level)
Total	19	28328.62			

** Significant at 1% level

APPINDIX-IV

Analysis of variance of tables of length of galleries produced by different developmental stages of *O. terebrantis*

Source	df	S.S	M.S.S	F
Treatment	3	9.201	3.067**	
Error	36	2.449	0.068	45.10
Total	39	11.650		

** Significant at 1% level

APPENDIX-V

Summary of analysis of variance tables of damage potential of O. terebrantis at different population levels on waterhyacinth plants observed at monthly intervals after release of O. terebrantis

Source	df	No. of plants	No. of leaves	Galleries/ leaf	No. of mites per leaf
			Mean squares 30 DAR		
Treatment	3	0.19	0.973	779.67**	1.45
Error	8	0.675	8.25	92.77	0.11
Total	11				
			Mean squares 60 DAR		
Treatment	3	0.6966	16.89	22940.52**	4.73
Error	8	0.585	10.00	254.68	0.59
Total	11				
			Mean squares 90 DAR		
Treatment	3	6.37**	60.5**	2869.68*	164.01**
Error	8	0.812	6.177	433.14	4.021
Total	11				

* Significant at 5% level
** Significant at 1% level
DAR - Days after release

BIOECOLOGY OF *Orthogalumna terebrantis* WALLWORK ON WATERHYACINTH

By

BABYKALA. P.

ABSTRACT OF A THESIS

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requirement for the degree

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Faculty of Agriculture
Kerala Agricultural University

Department of Agricultural Entomology
COLLEGE OF HORTICULTURE
Vellanikkara - 680654
THRISSUR

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ABSTRACT

The mite biology, morphology, nature and extent of damage and interaction with *N. eichhorniae* were studied.

The mite laid solitary eggs sideways to the oviposition holes, deeply embedded in the aerenchyma cells. The incubation period was 5.8 days. The larvae and nymphs fed by making galleries. The larvae, proto and deuto nymphal stages were completed in 3 days each, while that of tritonymph took 4 days. The duration of inactive stages from larva to proto, proto to deuto and deuto to tritonymphal stage were 1.6 days each, whereas from tritonymph to adult, it was 3 days. Adult longevity was 57.3 days. Preovipositional period was 4 days and the total number of eggs produced during the whole life period was 41.5 eggs.

The larvae have three pairs of legs but no genital opening. The nymphal stages have four pairs of legs, ending in single claws. The proto, deuto and tritonymphal stages have one, two and three pairs of genital papillae respectively. This character helps in identification of larval and nymphal stages. The adults are pteromorphs and sexual dimorphism is absent. Sensillus is relatively short with curved stem and globular roughened head. Terminally the tarsus of the leg has three claws on a short peduncle

the lateral claws more slender than the median and sharply angled.

The larval and nymphal feeding produces galleries on leaves of waterhyacinth resulting in brown streaks on the leaf lamina. Such brown streaks later coalesce to form large brown areas, leading to drying up of the entire leaf.

As the mite load increased from ten to eighty the number of plants and number of leaves showed significant reduction 90 days after release.

The extent of damage caused by *O. terebrantis* with or without weevil under open and partially shaded conditions of waterhyacinth plants was experimented upon, and it showed that, the root length, petiole length (in open condition), laminar width and length, number of leaves and number of plants under both light intensities (partially shaded and open condition), in general showed a decreasing trend. The plants in tanks having ten weevils alone per tank and 10 weevils plus 100 mites per tank under partially shaded conditions collapsed within 60 days, whereas in open condition of that having 10 weevils plus 100 mites per tank, all the plants collapsed by the 75th day. In the treatment with ten weevils alone per tank in open condition the collapse occurred only at 105 days. In the treat-

ment with 100 mites alone per tank, there was no collapse of plants upto 105 days (in both conditions).

The number of mite galleries and mite population per leaf with *Neochetina* feeding marks was comparatively more in the presence of weevils than in their absence.

Fungi like *Fusarium, Aspergillus* and *Rhizopus* were isolated and also the spider mite and insects like aphids and grasshoppers were noticed.