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UAS Tech. Series **No. 22**

SOIL BIOLOGY AND ECOLOGY IN INDIA

(Proceedings of the First All India Symposium held at UAS, Bangalore
September 22-26, 1976)

Edited by

C. A. EDWARDS AND G. K. VEERESH

1978

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PREFACE

This publication contains the papers submitted to the First All India Symposium on Soil Biology and Ecology held at Bangalore from 22nd to 26th November, 1976. It was made possible by a grant from the Indian Council of Agricultural Research towards travel and subsistence expenses and for printing costs. It took place during a consultancy to U.A.S. by C.A. Edwards funded by FAO/UNESCO/UNDP. This aimed at initiating Soil Ecology and Soil Pesticide work at U.A.S. Because this was the first Symposium of its kind, most contributions that were offered were accepted, so the treatment of the various diverse areas may be somewhat unbalanced due to more research work being done on some topics than others.

One of the main achievements of the Symposium was to initiate an Indian Society of Soil Biology and Ecology with about 60 founder members. A Constitution for the Society was drawn up and Officers elected with Professor G. K.Veeresh as its first President. The second Symposium of the Society is planned for March 1979.

It is hoped that this volume will lay a firm foundation for future work on soil organisms in India and that the new Society will continue and flourish.

C. A. EDWARDS AND G. K. VEERESH

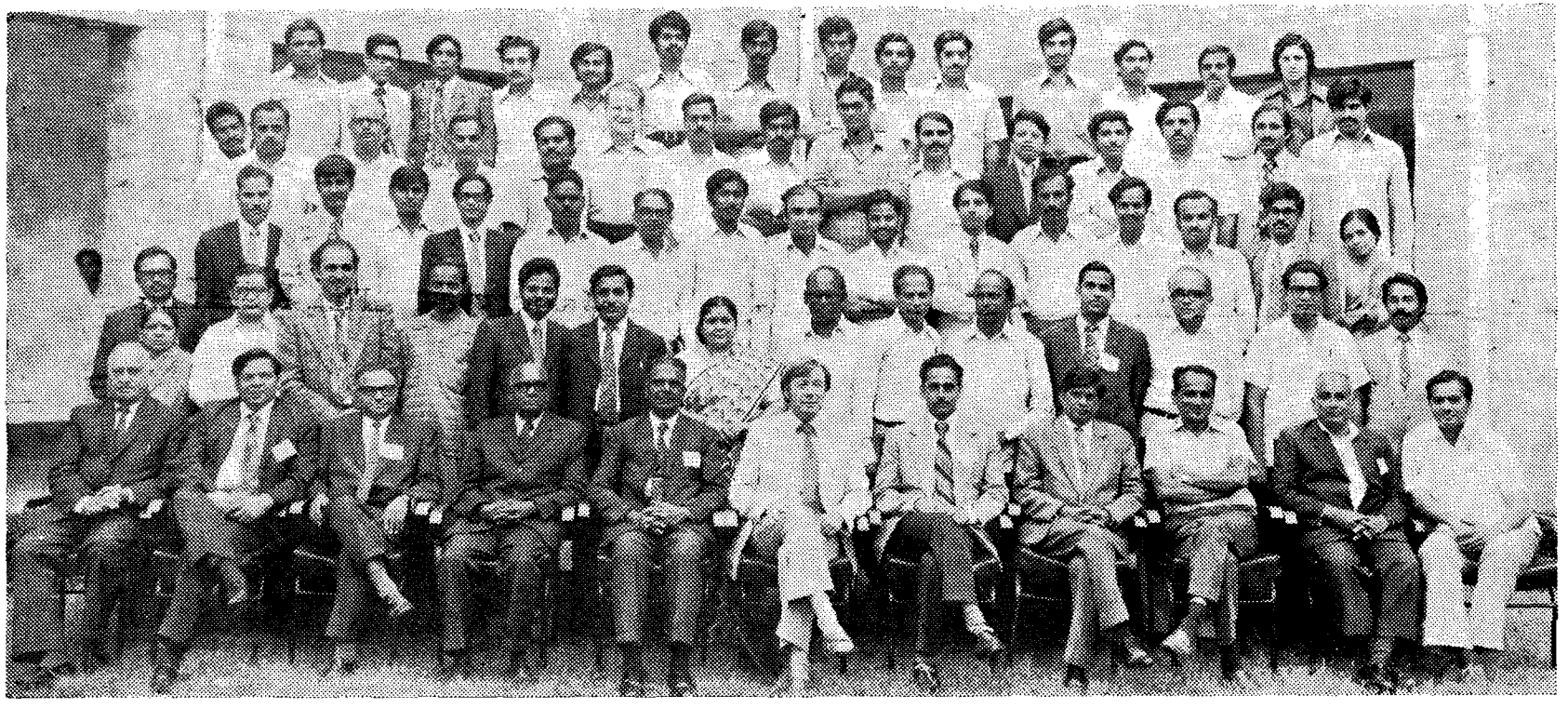
ACKNOWLEDGEMENTS

A Symposium on Soil Biology and Ecology was held at UAS, Bangalore under the sponrsorship of UNDP/ICAR/UAS on September 22-26, 1976. About 100 Scientists from all over India participated. Over 70 papers were presented and deliberated upon. Out of them, 57 papers were selected for publication. The papers included deal with all aspects of soil fauna, including microfauna and macrofauna source. They constitute a basis for planning further work as also such symposia in future since the work on soil biology in this country has been of recent origin. Further occasions for exchange of ideas on this new discipline in the country in the area of soil zoology, is proposed to be provided under the auspices of Indian Society of Soil Biology and Ecology which was launched at the time of the First Symposium and it is likely that the Second Symposium on Soil Biology and Ecology will be held during March, 1979.

The interest evinced by Late Dean K. Ramakrishnan who was the sub-project Co-ordinator, Dr. H. C. Govindu, Sr. Professor, UNDP and Dr. C. A. Edwards, Rothamsted Experimental Station, U. K., who served as UNDP consultant at UAS, in this publication is acknowledged. The painstaking effort put in by Dr. G. K. Veeresh, Professor of Entomology in editing and proof checking of the material deserves special mention. The support by the ICAR as a part of their matching grant for UNDP project including this publication is a acknowledged.

B. V. VENKATA RAO
Editor and Secretary
UAS, Communication Council

Participants of the First All India Symposium on Soil Biology and Ecology held at UAS, Bangalore, November, 22–26, 1976



Sitting – (L to R) Sriyuths S. V. Govinda Rajan, S. N. Das, K. J. Joseph, M. Puttarudraiah, G. P. ChannaBasavanna, C. A. Edwards, G. K. Veeresh, B. N. Chowdaiah, R. B. Patil, T. S. Thontadarya, B. H. Krishnamurthy Rao

Standing I Row – (L to R) A. Balasubramanian, (Mrs) M. B. Shyamala, G. M. Talati, Janardhan Singh, A. H. Shah, M. Vikram Reddy, A. K. Sanyal, (Miss) Usha K. Mehta, H. David, B. V. David, Gubbaiah, V. S. Kavadia, V. Lakshminarayana, Dr. A. B. Vyas, M. A. Haq.

II Row – L to R Basalingappa, A. K. Hazara, D. S. Tayade, M. M. Pramanik, G. Thimmaiah, G. N. Rao, D. N. Raghunatha Reddy, H. P. Prabhuswamy, T. P. Rajendran, V. B. Agarwal, A. Regupathi, K. A. Kulkarni, R. Balasubramanian, A. Sankara Reddy, Mrs. Kubra Banu

III Row (L to R) John, Muthalic Desai, P. R. Mohalkar, G. H. Venkataramaiah, B. L. V. Gowda, R. Mitchell, Panchabhavi, Abraham Vergees, Ramesh Chandra Rao, S. V. Mahajan, Arunkumar, H. P. Mohan, M. Jayaramaiah, B. N. Viswanath, D. Rajagopal.

Last Row – (L to R) Sundar, S. K. Mitra, A. K. Bhaduri, P. V. Sharma, N. Vijaya Mohan Reddy, M. R. V. Reddy, P. Veeraraju, B. V. Ramakrishna, Lingaraju G. A. Nair, E. Ramaiah, S. P. Patel, C. A. Viraktamath, K. D. Gorpade

INAUGURAL ADDRESS

By

Dr. H. R. ARAKERI

Vice-Chancellor, University of Agricultural Sciences

Soil is the product of the continuous action through the action of climatic and biological agents upon the parent rocks. Both climate and living organisms are active factors in soil formation. The effects of burrowing invertebrates and the growth of microorganisms is considerable in breaking up the rocks and minerals. Most forms of life contribute to the formation of soil in one form or another. Soil is the medium on which plants grow so that human beings and animals also depend on soil for their subsistence. No real substitute for soil as medium for plant growth has been found. Soil scientists and agronomists have studied the soil in detail from the soil fertility and soil productivity points of view. The microfauna of soil has been studied in detail by zoologists and microbiologists from many different aspects. In recent years, studies have been intensified with a view to examining the possibilities of making readily available the most essential nutrients for plant growth *e.g.*, nitrogen through microbial activity. The subject of soil biology and ecology has not been studied very much in tropical countries and little information is available on the role played by different groups of animals and microorganisms in soil in the tropics. I am glad that you have assembled here to draw up a programme of studies in this discipline, which has received so little attention in India so far.

Many groups of animals find soil as a suitable habitat. Some animals such as earthworms, symphyla, protura, some mites and springtails spend their whole life cycles in the soil and constitute the permanent soil fauna. Others such as millipedes, centipedes and insects such as white grubs spend a major part of their life cycles in the soil. Many of our most injurious insect pests of crops spend at least some stage of their life in soil, for instance the cutworms, hairy caterpillars, fruit flies, which are all major pests of crops, spend the pupal stage of their life in soil. Several beneficial arthropods such as centipedes, predatory beetles, parasitic wasps and predatory mites also live in soil and exercise a check on the harmful fauna.

Several soil pest problems have been studied in Karnataka. The studies started as early as 1930s on the biology of ground beetles and their role as pests on certain crops. Problems of compaction of garden soil worried vegetable growers around Bangalore and were studied during 1950s. These studies led to the establishment of the involvement of certain species of

earthworms which were responsible for making the soil hard, rendering it unprofitable to raise on any vegetable crop, especially root crops like carrot, raddish, turnip etc. Such soils could be reclaimed to normal tilth and productivity by controlling the earthworms. Similarly, the seriousness of the problem of white grubs was realised in the State as early as 1930s and some studies on their control have been intensified recently so that as a result of these investigations, it has been possible to attack the pest in several satisfactory ways. Such studies are being made on various species of white grubs in different regions.

I am very happy to note that scientists not only from Agricultural Universities but also from general universities are paritcipating in this Symposium. I feel that this is a very happy augury and it is good that these general universities are also participating in this Symposium. The only care that is required is to ensure that there is not just repetition of similar work under the guise of collaboration and that there should be no domination by any one group under the guise of coordination. The work should be planned in such a way that one complements and supplements the work of others thus helping to provide answers to problems that are posed. It would be best to identify the work that is required to be done in the different disciplines and decide which part will be done by whom. The Coordinators should initiate and assist in carrying out the programmes as required.

I would also like you to keep in mind not only the pest aspect of soil biology but also other aspects especially the beneficial aspects of the soil organisims and the effects of pesticides and agriculture on the soil as a whole. Soil application of chemicals for controlling soil pests has many implications such as how these chemicals affect microorganisms in soil and other beneficial insects. The question as to whether the plants take up pesticides applied to soil and to what extent the quality of the crop produced is affected, should also be studied.

You will be glad to learn that it is proposed to build up a well-equipped Soil Biology Laboratory with the assistance of U.N.D.P. in this University in its role as a Centre of Excellence on Plant Protection. This Symposinm is most appropriate at the present juncture. Dr. C.A. Edwards, who is one of the outstanding authorities in soil biology, is here to render assistance in setting up this Laboratory. I am sure that his expertise will be fully made use of by all of you who are present as participants in this Symposium in addition to contributing your best in achieving the goal set by you and for yourselves.

I wish you all success in your deliberations and I will be looking forward to your recommendations with regard to coordination and collaborative research work in this new avenue on an all-India basis, which will help to pave way towards solving some of our soil and soil pest problems.

PRESIDENTIAL ADDRESS

By

C. A. EDWARDS

It is a privilege to be one of the organizers of this symposium, the first of its kind in India. When the idea of organizing such a symposium was first discussed as part the FAO/UNESCO/UNDP/ICAR programme we anticipated that it would be a relatively modest meeting involving no more than about 30 workers. However, the enthusiastic response to our circulars which were sent to all the major scientific institutions in India made it very clear that, far from being neglected, the study of soil ecology in India is already alive and needs only a catalyst of the kind that we hope this Symposium will provide to bring it to full vigour and activity. The large number of participants and contributions are a clear indication of the need for a forum for the many workers to get together and exchange ideas and results of their research. We hope that our discussions here will provide a firm framework for future collaboration and development of soil biology and ecology in India.

First, I should like to discuss briefly the history of soil biological work. The chemistry of the soil has been studied for considerably more than 100 years. In the early days, soil fertility was considered to be dependent only on how much nitrogen, potassium, or phosphate was present in the soil. At a later stage, the question of soil structure began to be considered and physicists began to consider problems of soil climatic conditions. Until fairly recently many pedologists looked upon soil as a relatively inert structure rather than as a living substrate.

However, discoveries such as the association of legume nodules with the fixation of nitrogen in the soil, the realization that soil teemed with microbial life (Ehrenberg, 1837) and the publication of Charles Darwin's classic book "The Formation of Vegetable Mould through the Action of Worms (1881)" began to show that soil was not just an inert mineral mass. Another worker of the same period (Muller, 1879) also clearly recognized the importance of invertebrate animal life in the establishment of different humus forms.

Nevertheless, it was several decades before the importance of the soil fauna in soil began to be appreciated, although the suggestion that termites might be of importance in soil fertility was made as early as 1887 (Drummond, 1887). The development of an appreciation of the importance of soil organisms, particularly the fauna, in soil fertitty was a very gradual process.

A few workers began to establish the great diversity and numbers of soil animals during the first four decades of the twentieth century (Diem, 1903, Berlese, 1897–1900; Morris, 1922, Bornebusch, 1930; Jacot, 1940), and in the 1940's and 1950's there was a great increase in the number of reports that were published. In 1950, two books with the same title 'Bodenbiologie' written by W. Kuhnelt and H. Franz (both of Vienna), summarized knowledge of the soil fauna until that time. These were followed almost immediately by another book, 'Microfaune du so' (Delamare - Debouteville, 1951) which also considered the fauna of tropical soils. Work was also developing in U.S.S.R. under the leadership of Professor Ghilaroa.

In 1955, an International Symposium was arranged in England which was major development in the study of the soil fauna. The proceedings of this conference were published as a book 'Soil Zoology' (Kevan, 1955). This was the precursor of a series of regular international conferences which have been attended by both soil zoologists and microbiologists and have led to considerable advances in research in soil biology. The proceedings of each of these conferences have been published. They include 'progress in Soil Zoology' (Ed. Murphy, 1962) from a Symposium at Rothamsted, England in 1958; 'Soil Organisms' (Ed. van der Drift and Doeksen, 1963) from a Symposium at Oosterbeek, Holand in 1962; 'Progress in Soil Biology' (Ed. Graff and Satchell, 1967) from a Symposium at Braunchweig in West Germany, 1966. 'Colloquium Pedobiologiae' (Ed. Athias 1971) from a Conference at Dijon in France in 1970 and 'Progress in Soil Biology' (Ed. Vanek, 1974) from a Conference in Prague, Czechoslovokia in 1973. The last conference was at Uppsala in Sweden in 1976 and the next is proposed to be in New York State, USA, in 1979.

Another development since 1962, has been the publication of a regular 'News Bulletin' with two or three copies a year, containing full information on work in progress in Soil Zoology and Soil Microbiology, that has been circulated to all collaborating soil zoologists, and soil microbiologists. This was edited and circulated until 1970, by Dr. Jacques d' Aguilar and since then by Dr. Marcel Bouche of France. This has been a major factor in promoting awareness of research and international collaboration in work in soil biology ecology.

Another important contribution to the development of work in soil biology and ecology was the implementation of the International Biological Programme, 1969–1974. This encouraged much new work on a whole ecosystem basis and led to the first attempts to develop compartmental models to explain the processes occurring in representative soil ecosystems, including energy and nutrient flow.

This, then is the present state of our knowledge of soil ecology and biology. Although much progress has been made, we still have much to learn. Most of our present knowledge has been based on work in temperate regions. Both the soils and climate differ so greately in the tropics, and such data we have has indicated that both the pathways and rate of organic matter turnover and nutrient flow may differ greatly from those in temperate regions.

There is an urgent need for work of this kind in the tropics, and it is our hope that this Symposium will stimulate such work in India. The aims of the Symposium are multifold.

1. We wish to compare data and attempt to establish the present state of our knowledge of the ecology and biology of Indian soils.

2. We hope to provide a basis for greatly improved cooperation, collaboration and communication.

3. We aim to encourage the establishment of a thorough census of the Indian Soil fauna.

4. One of our main aims is to encourage the preparation of complete faunal lists and relatively simple faunal keys.

5. Another objective is to initiate a series of un-informal meetings, workshops and regular symposia.

6. We plan to initiate a regular Newsletter of Bulletin in India, of the kind cirulated in Europe, and exchange information with our European and North American colleagues.

7. Finally we wish to establish a new "Society of Indian Soil Biology and Ecology" with its own officers and journal. We shall discuss this in the final session on Friday.

Before I conclude, I must discuss the title chosen for this Symposium. Soil Biology and Ecology is an all-embrasing topic, implying thorough coverage of all the myriads of living organisms in soil. To achieve such a comprehensive review is obviously impossible and our discussions will be subject to severe limitations; firstly we shall consider, primarily, the fauna of the soil, with only brief mentions of the extremely important soil becteria, fungi, actinomycetes, protozoa nematodes. Secondly, most of the contributions will involve work that refers only to India. Finally, because of the economic implications, a part of our programme will consider the interactions of soil organisms with soil pesticides. Pesticides are among the most drastic treatments that may affect so-called natural ecosystems. Some of them are extremely persistent, and others very toxic to a wide range of organisms, so that a single treatment with these chemicals can result in comparatively long-lasting effects on soil ecosystems.

The main reason for limiting most of our deliberations to the soil fauna is that there already exist opportunities for soil microbiologists and nematologists to meet together and compare their data, whereas most soil zoologists work in comparative isolation.

In furure discussions, we hope that no such limitations will be made, because it is essential that all aspects of the soil ecosystem should be considered together. For this reason we have chosen the title 'Soil Biology and Ecology' in the hope that future activities will involve all relevant disciplines. I hope, that in the future, this will come to be termed 'The First Indian Symposium of Soil Biology and Ecology'.

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Soils of India and their Role as Habitat for Biological Activity

S. V. Govinda Rajan
Emeritus Scientist, Bangalore

Abstract

309 Soil is the product of weathering of rocks, resulting in their breakdown through physical, chemical and biological action on the weatherable minerals present in them.
314 Soils in India have formed from a variety of parent rocks including igneous, metamorphic and sedimentary rocks and also from parent materials derived from a range of alluvial and colian formations. About 25 soil groups distinguished on the basis of important characters have been distinguished on the Soil Map of India.

320 The soil groups of extensive occurrence are the red loam and sandy loams as occur largely in the peninsular and eastern regions; the red and yellow soils of the eastern region; the Laterite soils occurring in narrow belts along the east and west
326 coasts of the peninsula; the Black soils as occur in the Daccan plateau; the Desertic soils of the western region; and the alluvial soils of the Indo Gangetic plains and the deltaic areas of the major rivers. Wide variations in the texture and structure of these soils are met with.

334 Soil consists of a heterogeneous mixture of mineral and organic particles and aggregates ranging in size from colloidal particles to sand particles up to 2 mm
336 diametre and separated by air and water filled spaces. Soil offers many advantages
341 as an environment for animals. Chief among these are the high degree of protection from predators, protection from light, buffering and ambient temperature and moisture variations, and access to large quantities of living and dead plant materials as food supply.

On the contrary, soils may have properties that impose limits on soils-inhabiting animals Chief among these are the factors associated with texture and structure of the soil. Soil texture refers to the relative proportions of the various size groups of primary particles like clay, silt and sand, while structure is the arrangement of the soil particles and their aggregates along with the pore space between them. Structure is a factor dependant upon many physical factors like temperature, topography, tillage practices, water regime and of activity of soil organisms both micro and macro. Structure influences plant growth in many ways; through aiding retention, availability and movement of water, aeration and root development.

A large variety of micro fauna and larger organisms collectively referred to as soil animals inhabit the soil and participate in decomposition of soil matter and influencing their physical and physico chemical characters.

The soil animals include not only those which live permanently in the earth, but also many, which though temporary inhabitants, make an essential contribution to soil formation, besides influencing their chemical composition and structural formation. While extensive studies have been made of the role of soil micro-organisms including bacteria, actinomycetes, and fungi on influencing the decomposition of organic matter in soils, improving soil fertility and related aspects, work on the action of soil micro-organisms under Indian conditions have been of a limited nature. Studies have been made on the action of burrowing animals like earthworms and termites on the structure and fertility conditions of some soils in the country, while the influence of non-burrowing animals like protozoa on soils have been more widely studied and reported. There exists large scope for widening the studies on a larger range of animals under varied conditions as obtain in this country.

Soil is the most valuable resource we have, since this is essential to the entire plant life on which animal and human life depends. Soils supply the nutrients required by growing plants and plants food for animals, fibre and other products which, besides supporting human life, furnish raw materials which maintain industrial activities and help to build the economy and wealth of nation. The study of soils, their formation, their characteristics, their fertility and their relationship to the environment has naturally attracted wide attention and these studies have helped in understanding their potentialities for exploitation, the limitations that exist in their use, and the optimum management methods and procedures which can ensure maintenance of their productivity under sustained use.

Soil is the product of weathering of rocks, resulting in their breakdown through physical, chemical and biological action on the weatherable minerals present in them. Soils in India have been formed from a variety of parent rocks including igneous, metamorphic and sedimentary rocks and also from parent materials derived from a range of alluvial and eolian formations. Soils in different regions differ not only because of differences in the mode of origination, but also from inherent physico-chemical properties characteristically associated with their colour, organic matter content, their reaction, texture, structure, depth, internal drainage, characters of their base exchange complex, the quantity of major and minor plant nutrients present in them and those present in an available form. In the Soil Map of India as at present recognised (Govinda Rajan and Datta Biswas, 1968) 23 soil groups have been distinguished based on important characters, of which some occur over extensive areas of the sub-continent, while the others are of restricted occurrence.

The soil groups of extensive occurrence and those which are agriculturally important are the red loam and sandy loams such as occur largely in the Peninsular and Eastern regions ; the red and yellow soils of the Eastern region ; the laterite soils occurring in narrow belts along the east and west coasts of the

Peninsula ; the black soils of the Deccan and Malwa Plateaus ; the Desertic soils of the western region, and the alluvial soils of the Indo-Gangetic plains and the Deltaic areas of the major rivers. These soils differ widely in their characteristics such as soil depth, texture, pH, water holding capacity, clay mineral content organic matter content, plant nutrient content and also productivity.

Soil consists of a heterogenous mixture of mineral and organic particles and aggregates, ranging in size from collodial particles to sand particles up to 2 mm in diameter, and separated by soil and water filled spaces. When one examines a sample of soil taken from the field one may find that it is composed of (1) large pebbles and stones ; (2) coarse sand, (3) fine sand, (4) silt, (5) lumps or clods of varying sizes which consist of clusters of soil particles cemented by organic matter and clay, (6) plant roots, (7) a dark coloured substance spread throughout the soil mass referred to as *humus,* (8) dead leaves, and (9) ants, termites, earthworms and other forms of animal life. For purposes of quantifying the content of different sizes of particles and for grading soil texture only the mineral matter which is less than 2 mm in diameter is considered.

Soil Texture and Structure

Soil texture refers to the relative proportions of the various size groups of primary particles like clay, silt and sand. Thus, a soil with more than 40 per cent of clay is referred to as a clay soil ; a soil with over 50 per cent of sand is referred to as a sandy soil, while "loam" refers to a texture where the different soil particles are distributed in more or less equal proportions. The size of sand grains further modify the textural name ; thus we have names like coarse sandy clay, fine sandy loam etc., to refer to the type of sand fractions preponderant in the soils of the concerned textures.

Another physical property of soil frequently referred to is the soil structure, which refers to the arrangement of the soil particles and their aggregates along with the pore spaces between them. Natural aggregates are called *peds* and are fairly waters table. Thus, we have different types of structure based on the shape and arrangement of peds. We have platy structure, where the peds exhibit a matted, flattened or compressed appearance ; prismatic where the peds exhibit a long vertical axis and are bounded by flattened sides ; black-like where peds resemble imperfect cubes like baby blocks but are smaller, and spheroidal where the peds look like imperfect spheres like marbles and are usually smaller. Structure is a factor dependant upon many physical factors like temperature, topography, tillage practices, water regime and of activity of soii organisms both micro and macro. Structure has an important influence on burrowing animals, since upon it depend their ability to burrow successfully. Soil that is too compacted may preclude penetration ; soil that is too fine may not

retain the form of the burrow and the animals may perish through inadequate aeration. Soil texture can affect the rate of burrowing. Hence, clay soil would delay the activity of burrowing animals compared to soils lighter in texture.

Soil and Living Organisms

A large variety of micro-organisms and larger organisms that are collectively referred to as soil animals, inhabit the soil and participate in decomposition of soil matter and influence the physical and physico-chemical characters. Soil offers many advantages as an environment for animals. Chief among these are the high degree of protection from predators and protection from light ; buffering of ambient temperature and moisture variations and access to large quantities of living and dead plant material as a food supply. On the other hand, soils may have properties that impose limitations on soil-inhabiting animals. Chief among these are the small dimensions and irregular shape of the majority of natural interstices, intermittent flooding or desication of surface layers where most of the organic matter is located, abrasions of coarse textured mineral soils and adverse ionic conditions such as high salinity and low pH.

In this paper, the soil animals excluding micro-organions represented by the vast group of bacteria, actinomycetes and fungi will be considered briefly. Such animals include not only those which live permanently in the earth, but also those which although only temporary inhabitants make an essential contribution to soil formation. These animals are very diverse in structure and size and show few morphological features in common. They may be divided into burrowing forms which make their own tunnels, and non-burrowing species which use existing crevices. We will consider here only rodents, earthworms and termites under the class of burrowing animals and protozoa under the class of non-burrowing animals, in so far as the limited studies or observations that have been made on the role of these animals in different soils of India.

Burrowing Animals

1. Rats and Rodents : These large animals inhabit practically all soils in the country and their distribution varies considerably on the soil, climatic and crop conditions. Rat burrows provide for subsoil aeration, but in cases of irrigated lands such burrows prove to be disadvantageous because of induced rapid percolation of irrigation waters and also the collapse of field bunds. Crops are damaged by cutting the roots, and stems of paddy ; moreover, destruction of harvested crops is also extensive and particularly noticeable in the light textural soils of the red and yellow soil regions. In the heavy clay soils of the Deccan trap area it is likely that such damage is less extensive where the crops such as cotton do not offer good food material for the rodents.

Desert rodents the desert gerbil is a major pest in the arid sandy region of Western Rajasthan and these gerbils burrow extensively and multiply very rapidly. They are a menace to crops, grasses and seedlings of trees. The burrows cause a depletion in the moisture regime of the soil, thereby doubly increasing the hazard in land use in those areas already affected by other adverse features.

2. *Earthworms*: The physical effects of earthworms on soils result from their burrowing, ingestion of soil and organic matter and deposition of casts on the soil surface or beneath the surface. The role played by earthworms in increasing soil fertility has been studied by many workers. Between 1925 and 1930 extensive studies were made in Madras (Memories of Madras Agricultural Department, 1954) on the role of eathworms in influencing soil conditions in betelvine cultivation. These studies revealed (1) that earthworm casts are rich in mineral constituents in a more available form than those present in ordinary soils and (2) application of lime or mineral fertilizers decreases the population of earthworms, while organic manures increase them. Under a scheme between 1954-1957 at the Indian Institute of Science, Bangalore (Report ICAR Scheme, Indian Institute of Science, Bangalore) studies on the influence of earthworm on soils showed that the percentage of soil aggregates in the size range of 2.0 to 4.0 mm diameter increased in earthworm bearing soil compared to control soil, while a corresponding decrease in aggregates in the range of 2.0 to 0.125 mm diameter was recorded. The fact that earthworm castings are rich in humus and plant nutrients is mainly due to (1) aeration resulting from their burrowing activity and consequent imprint on soil structure, (2) the rich chemical composition of casts and (3) the decomposition products arising from the dead bodies of the worms themselves. Gupta and Ram Sakal (1967) made a comparative study of cultivated and garden soil casts to ascertain the role of earthworm on the availability of nutrients. Earthworms swallow large amounts of soil together with decaying animal and vegetable matter, grind them to rubble in their gizzards and intestines and cast out a product which is practically colloidal humus rich in plant nutrients. They made a study of alluvial soil from Varanasi and sample of casts and of parent soil from nearby locations for total N, Carbon, available P, total P, K and Ca. They found that the C/N ratio was lower in the casts compared to parent soil in both cultivated and garden soil; cultivated soil casting were richer in NO_3-N compared to garden soil castings. Excerpts from their paper are given in Table I.

3. *Termites*: Termites are mostly earth-dwellers. Humus-feeding termites habitually ingest mixed soil and in this respect resemble earthworms. They build termite hills, mounds or nests technically called termitaria both above and below ground level. These termitaria are of different shapes and sizes depending upon the species of termites which build them. They may be conical from 4 to 6

TABLE I

Composition of parent soil and earthworm casts derived from it
(Gupta M. K. and Ram Sakal, 1967)

	CaO%	K_2O%	Total P_2O_2%	Avail P(ppm)	Org. C %	Total N%	NO_3-N ppm	Ratio C/N
Garden soil								
I. Earthworm casts	1.02	0.896	0.29	87	0.579	0.070	9.7	8.3
Parent soil 0–15 cm	0.85	0.712	0.20	74	0.380	0.035	7.0	10.8
II. Earth casts	1.10	0.791	0.25	84	0.572	0.067	8.5	8.5
Parent soil 0-15 cm	0.80	0.662	0.21	66	0.303	0.030	4.6	10.1
Cultivated soil								
I. Earth casts	1.35	0.525	0.15	77	0.485	0.055	11.6	8.8
Parent soil 0–15 cm	1.09	0.480	0.10	62	0.242	0.024	7.7	10.8
II. Earth casts	1.30	0.385	0.16	82	0.478	0.051	9.9	9.2
Parent soil 0–15 cm	1.00	0.290	0.12	59	0.235	2.022	6.9	10.3

ft. in height or smaller dome-shaped or even flat mounds. The termitaria built in the red soils region whether they be in the cultivated fields or in forest areas are conical and reaching up to 6 ft. in height. In the alluvial soils region and the black soils it is unusual to find such mounds, the more common ones being smaller dome shaped or flat mounds. Shrikande and Pathak (1948–51) studied the physical-chemical characters of termite galleries formed by *Odonototermes spp.* and other species in Kanpur soils and observed that the termite galleries showed higher nutrient levels nitrogen, carbon and aggregation and exhibited higher biological activity compared to the adjacent soil.

Pathak and Lahiri (1959) studied the chemical and allied properties of termitaria built by *Odonototermes obscuripes* as compared to those in adjacents oil. The results of analysis showed that termite nests have a higher percentage of lime, magnesia and phosphoric acid as compared with the control soil. The high loss on ignition is attributed to its high organic matter content. Table II summarises the results of their analysis.

They found a great increase in clay and silt relative to sand in mounds built on very sandy soils. Also the aggreation of soil from these mounds had 67.7 per cent of clay aggregates of particle size larger than 2μ compared to 48.1 per cent in undisturbed soil. 19.2 per cent of silt sized particles were incorporated in aggregates in the mound soil, while only 5 per cent were aggregated in the undisturbed soil. Aggregates from undisturbed soils were more easily dispersed in water than those from monnd samples. They also found that the mounds had a water-holding capacity about 5 times that of adjacent soil. They also found that nitrogen fixation in the soil of termite nests was higher than in the control. The data on CO_2 evolution suggest an overall higher micro-biological activity of the termite nest soil.

TABLE II

Chemical and mechanical analysis of soils from termite nests and nearby areas
(Pathak, A. N. and Lahiri, L. K., 1959)

Soil particulars		*Termite nest*	*Control*
Oven dry moisture	Per cent	5.33	1.59
Loss on ignition	,,	62.75	1.81
CaO	,,	3.64	0.67
MgO	,,	0.0121	0.0093
K_2O	,,	0.306	0.743
P_2O_5	,,	0.472	0.176
Organic C	,,	36.49	0.47
Total N	,,	1.17	0.05
Ratio C/N	,,	31.18	9.40
Physical properties			
Original soil	,,	0.10	0.37
Coarse sand	,,	6.10	56.69
Fine sand	,,	15.06	18.17
Clay	,,	15.57	20.95
Organic matter (organic × 1.72)		62.76	0.81
Percentage of clay aggregates larger than 0.002 mm		62.70	48.10
Silt sized particles in aggregated form		19.15	5.01
Moisture equivalent		64.20	17.90
Water holding capacity		239.5	46.0
pH		4.5	8.1
Base exchangeable bases (m. e)		86.48	18.96
Total exchangeable bases (m. e.)		49.60	18.40
Biological activity of soils			
Nitrogen fixation (g)		0.350	0.011
Nitrification (ppm)		10.64	1.40
Co_2 evolution (in mg % after 24 hrs)		31.68	10.12

Non-burrowing animals 1. Protozoa

In the course of extensive studies on the occurrence of protozoa in soils and their role in sewage clarification, Pillai and co-workers (1941, 1942) found two species *viz.*, *Colpidium* and *Colpoda* most common and dominantly occurring in Indian soils. They find that these soil animals are active in producting mucin and other mucilaginous materials which help to bind soil particles, facilitate better aggregate formation and thereby improve soil structure.

Kasi Viswanath working with Pillai during 1968–72 made detailed studies on the occurrence of protozoa in different soils from Karnataka and their role in forming water-stable aggregates. They found that the conditions favourable for the development of Protozoa and of the species *Colpidium* in particular, and

for the formation of water-stable aggregates, include aeration conditions and adequate supply of water besides carbonaceous matter such as straw. It was found that the soils under continuous fertilizer treatments over a four year period, with different levels of P_2O_5 in the fields of the University of Agricultural Sciences, Bangalore showed that the soils which received the highest levels of super-phosphate (320 lb/acre) contained the largest number of protozoa particularly species of *Colpidium* and *Colpoda* and the same soils had the highest percentage of water stable aggregates and gave the highest yields (straw and grain) of both the varieties of ragi (*Eleusine coracana*) grown in the trials.

TABLE III

Total protozoa, total percentage of water stable aggregates and yields of ragi (Purna *variety*) *under fertilizer trials* (*i*) *UAS, Bangalore*

Treatments	Total protozoa (ii) ($\times 10^2$/g soil)		Total percentage of water stable aggregates		(iii) Yield of ragi g/sq yd	
					grain	straw
	Autoclaved sewage	Agrl. medium	A	B		
P_0 (0 lbs superphosphate)	143	23	37.5	59.8	460	713
P_1 (40 lbs superphosphate)	104	83	38.8	68.3	577	846
P_2 (80 lbs superphosphate)	107	517	38.8	73.1	666	1082
P_3 (160 lbs superphosphate)	94	476	39.7	75.8	726	1190
P_4 (320 lbs superphosphate)	800	1863	40.7	80.7	926	1878

(i) Total protozoa, total percentage of water stable aggregates and yields of ragi are the average of three replicates.

(ii) Autoclaved sewage and agricultural medium methods of determination of protozoa counts are described in the Thesis.

(iii) A : Wet-sieved by the method developed and described in the investigation (chapter II of Thesis)

B : Wet-sieved by the method of Kemper and Chepil (1965) Methods of analysis, Agronomy series No. 9 ; American Soc. Agron, Madison, Wis. U.S.A.

From a large number of experiments conducted to ascertain the relative efficiencies of protozoa, bacteria and other organisms in assisting soil aggregation, they obtained confirmative evidence that protozoa are pre-eminently influential in effecting soil aggregation. Their work shows that protozoa work directly and indirectly in improving the fertility of the different soils studied by them.

References

Govinda Rajan, S. V. and Datta Biswas, N. R., 1968, Classification of Indian soils and their mapping. *Proc. Intern. Geographical Congr.*, Vol. I, 374–376.

Gupta, M. L. and Ram Sakal, 1967, Role of earthworms on the availability of nutrients in garden and cultivated soils, *J. Indian Soc. Soil Sci.*, **15** : 149–152.

Kasi Viswanath, G., 1972, *Role of protozoa in soil.* Ph.D. Thesis Indian Institute of Science, Bangalore.

Kasi Viswanath, G. and Pillai, S. C., 1968, Occurrence and activity of protozoa in soil. *J. Scient. Industr. Res.*, **27** : 187-195.

Memoirs of Madras Agricultural Department, 1954, Superintendent, Government Press, pp. 874.

Pathak, A. N. and Lahiri, L. K., 1959, Studies on termite nests I. Chemical, physical and biological characteristics of a Termitarium in relation to its surroundings. *J. Indian Soc. Soil Sci.*, **7** : 87-90.

Pillai, S. C., 1941, The function of protozoa in the activated process. *Curr. Sci.*, **10** : 84-85.

Pillai, S. C. and Subramanyam, V., 1942, Role of protozoa in the aerobic purification of sewage. *Nature, Lond.*, **154** : 179-180.

Shrikande, J. C. and Pathak, A. N., 1948, Earthworms and insects ni relation to soil fertility, *Curr. Sci.*, **17** : 327-328.

Shrikande, J. G. and Pathak, A. N., 1951, A comparative study of the physico-chemical characters of the castings of different insects. *Indian J. agric. Sci.*, **21** : 401-408.

Survey of microflora in soils in relation to their structure and the role of earthworms in soils, 1957, Scheme Report, Indian Council of Agricultural Research, Indian Institute of Science, Bangalore, pp 1-24.

Soil Microbes and their Interaction with Soil Invertebrates

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Abstract

A great variety of organisms live in soil including microorganisms, many large and small animals and insects. The microflora and microfauna grow in soil in close association with each other with or without discernable mutual benefit. They may oppose each other, or they may coexist without exhibiting such associative or antagonistic interactions. Amongst the better studied interactions are the pathogenic relationships of microorganisms with soil insects. Infections of soil insects caused by fungi, ricketts iae, viruses, bacteria and protozoa and their practical utility of these pathogens as biocontrol agents of insects are discussed. The predatory action of protozoa on soil-borne plant pathogenic bacteria is also discussed.

The need for research on the role of microorganisms in carbon and nitrogen nutrition of of insects is emphasized. Likewise, the need for research on population equilibria between soil microflora and microfauna in mixed environment is emphasized.

SOIL contains a wide assortment of organic and inorganic substances, water and gases and thus, provides a unique medium for growth and development of microorganisms and soil invertebrates. These microflora and microfauna grow in soil in close association with each other, with or without mutual benfits such as commensalism, mutualiasm and symbiosis or they oppose each other through such phenomena as, antibiosis, competition for the same substrate, parasitism, predation etc. Further, in some environments, the range of substances for growth and development of these organisms can be quite varied in which case two or more groups of organisms may coexist without exhibiting such associative or antagonistic interactions.

A great variety of organisms lives in soil including microorganisms, many large and small animals and insects. Although the contribution of various microflora, microfauna and insects to the soil biomass varies from soil to soil, by and large, the contribution of the total microflora is much larger compared to that of soil microfauna and insects. A typical example of dry matter production in soil is presented in Table I.

TABLE I

Populations of soil microorganisms and soil invertebrates

I) *Soil microorganism* Cells/g of soil (Alexander, 1961)	
1) Bacteria	$10^6 - 19^9$
2) Fungi	$10^3 - 10^6$
3) Actinomycetes	$10^4 - 10^8$
4) Algae	$10^2 - 10^4$
5) Protozoa	$10^3 - 10^5$
II) *Soil invertebrates* No/ per sq m of soil (Kevan, 1965)	
1) Earthworms	30 — 2000
2) Potworms	200 — 20,000
3) Slugs and snails	100 — 8500
4) Millipedes and centipedes	900 — 1700
5) Woodlice	100 — 400
6) Spiders	180 — 840
7) Fly maggots	1000 approx.
8) Ants	200 — 500
9) Spring tails	10,000 — 40,000
10) Mites	20,000 — 1,20,000
11) Nematodes	$1.8 - 120 \times 10^6$
III) Dry matter production in a deciduous wood land (Richards, 1974)	
Bacteria	7.30 kg/ha
Fungi	454.00 ,,
Actinomycetes	0.20 ,,
Protozoa	1.00 ,,
Nematodes and earthworms	14.00 ,,
Total microflora	461.00 ,,
Total biomass	497.00 ,,

Amongst the soil animals, wireworms, chrysomelid beetles, white grubs, weevils, termites, earthworms, millipedes, centipedes, ants, springtails, woodlice, moths, spiders, nematodes and protozoa occur more commonly in soil. The majority of these participate in improving soil aeration, drainage, structure and organic matter decomposition. However, their most important contributions are mixing of the crop debris with the underlying soil and comminution of crop residues. These activities of soil invertebrates permit more and more rapid decomposition of organic debris. Large quantities of excrement are produced by soil invertebrates and these provide a more favourable environment for development of bacteria and fungi. Such microbially-enriched faeces are in turn, reingested by earthworms together with the plant material and mineral soil, and cast in the form of crumbs made up of comminuted particles and such crumbs rich in avialable nutrients are preferentially colonized by the micro-organisms. More refractile tissues of plant and animal origin are broken down to finer particles through such animal ingestion and excretion and rendered more amenable to microbial attack. Although much information is available on the role of soil animals such as, earthworms, millipedes and centipedes in improving soil physical properties, very little is known about the role of soil animals in general, in providing a more suitable environment for the growth and development of soil microflora.

Among the better known interactions between the soil fauna and soil microflora, pathogenic and predatory relationships between them may be mentioned. This aspect has received more attention in view of the pest resistance to the commonly-used pesticides and the environmental effects these pesticides produce and hence the attempts to find out safer and more selective alternative pest control methods such as, biological control of insect pests. In nature, many such interactions between microorganisms and insects occur but because these organisms are inconspicuous they have gone unnoticed.

The discovery and practical use of milky disease bacteria against Japanese beetle by Dutky in 1940 gave impetus to the use of variety of bacteria for control of insects (Falcon, 1971). Likewise, viruses and fungi pathogenic to insect pests as biocontrol agents has received greater attention (Heimpel, 1965; Medelin, 1968; Roberts and Yendol 1971). Protozoa are known to feed on bacteria and to lesser extent on other microorganisms (Sherman, 1916; Cutler, 1923). Most of the earlier studies on the role of protozoa in controlling the bacterial population in soil were confined to the more commonly occurring non-pathogenic bacteria. It is only recently, that these studies on the role of protozoa in regulating the populations of soil bacteria have been extended to soil-borne plant pathogenic bacteria (Halte and Alexander, 1975).

The available information on the pathogenic interaction between the soil fauna and soil microflora is briefly reviewed below:

TABLE II

Viral infections of some soil insects (David, 1975)

Types of virus	*Coleoptera*	*Isoptera*
Baculovirus	4	—
Iridovirus	4	—
Poxvirus	9	—
Parvovirus	1	—
Other RNA viruses	5	—
Unclassified viruses	3	3

TABLE III

Fungi infecting insects (Robert, 1973)

Genera	*Important hosts*
1) *Coelomomyces*	Aquatic insects primarily mosquitoes
2) *Lagenidinm*	-do-
3) *Entomophthora*	mites, grasshoppers, aphids, lepidopterous larvae and flies.
4) *Beauveria*	Soil insects and lepidopterous larvae
5) *Metarrhizium*	-do-
6) *Hirsutella*	mites

Viral diseases of insects: Viruses as biocontrol agents of insects offer many advantages over others. Some of the viral infections on soil insects recorded so far are presented in Table II (David, 1975). The maximum number of viruses infecting soil insects has been recorded for coleopterous insects. Among other insects which are not considered as typical soil insects, lepidopterans are found to be more susceptible to viral infections. Although, a number of viruses are known to cause fatal diseases in insects, only baculoviruses have been favoured as pesticidal agents because of their selective infectivity and absence of cross infection. Baculoviruses have potentials for use as biocontrol agents especially for the root grubs of the family Scarabaeidae and Rhinoceros beetles. Persistence of viruses infecting *Prodonia litura* in soil has been studied by our laboratory. The virus persists for well over a year in soil. Likewise, many polyhedral viruses obtained from various insect hosts are being examined for their use as biocontrol agents of insects.

Fungal diseases of insects: Approximately 35 genera of fungi infecting insects have been recorded. Of these only six have received much attention. These are presented in Table III (Roberts, 1973). Amongst these six, fungi of the genera *Beauveria* and *Metarrhizium* have been examined more critically, because of the rapid induction of the disease in soil insects by these fungi under more favourable moisture regime in the soil, as compared to that in the above-

ground insect habitats. In case of *Metarrhizium,* 200 insect species, most of them soil-inhabiting, are known to be susceptible. A species of *Cladosporium* has been isolated by our laboratory. This has proved highly infective to *Tetranychus ludeni.*

Rickettsial diseases of insects: Infection of soil-dwelling Coleoptera larvae by the members of the genus *Rickettsiella* is common (Krieg, 1963). So called blue disease in Japanese beetles is caused by *R. popilliae.* In view of their obligate parasitism *Rickettsiella* cannot be cultured easily and used as biocontrol agents. Moreover, *Rickettsiella* cause many diseases in human beings and animals, and hence, it is not safe to use these bacteria for controlling insect pests.

Bacterial diseases of insects: Over 90 species of bacteria are known to be pathogenic to soil insects. (Anonymous, 1969; Bulla, 1975). Amongst them, many crystalliferous and non-crystalliferous species of *Bacillus* have received much attention. These are listed in Table IV. These bacterial species infect a wide range of lepidopterous and coleopterous insects. Many commercial preparations of these bacteria as insecticides are now available.

TABLE IV

Bacterial pathogens of soil insects (Bulla *et al.*, 1975)

Bacteria	*Hosts*
I - Non-crystalliferous	
i) *Bacillus lentimorbus*	Japanese beetle
ii) *B. cereus*	Some Coleoptera
iii) *Pseudomonas septica*	*Melolontha melolontha* (Scarabaeid)
iv) Micrococci	-do-
v) Staphylococci	-do-
vi) *Serratia mareescens*	(Lepidoptera, Isoptera)
II - Crystalliferous	
i) *Bacillus popilliae*	Japanese beetle
ii) *Bacillus thuringiensis*	Lepidoptera and some Coleoptera

Protozoan diseases of insects: In contrast to the rapid action of viruses, bacteria, and fungi, protozoans act rather slowly on their host insects. The class sporozoa contains by far the largest number of entomophilic species of protozoa. These protozoa are found to infect Scarabaeidae (Weiser, 1963). Some protozoa are known to attack the boll weevil under natural conditions (Cross, 1973) *Glugea gurti* and *Mettesia grandis* hold more promise in controlling cotton boll weevil.

Protozoa as predators of soil microorganisms: Although the predatory action of protozoa on soil bacteria and to some extent soil algae has been known for a long time, very litttle seems to have been done to examine the role of protozoa and their holozoic mode of nutrition in regulating the microbial populations in soil particularly, that of plant pathogenic bacteria. Amongst the preferred bacteria may be mentioned the species of the genera *Aerobacter*, *Agrobacterium*, *Azotobacter*, *Bacillus*, *Escherichia*, *Micrococcus*, *Rhizobium* and soil *Pseudomonas* Amongst the plant pathogenic bacteria fed by protozoa, species of the genera *Erwinia*, *Xanthomonas* and *Pseudomonas* may be mentioned. On these latter, some studies have been initiated in our laboratory. Presently the role of protozoa in controlling the population of *Pseudomonas*, *Colanacearum* causing vascular wilt in solanceous crops is being critically examined in our laboratory. The literature on predatory action of protozoa and the work initiated in our laboratory on this will be reviewed by my colleague Mr. J. H. Kulkarni later in this symposium.

This brief review has attempted to highlight some of the pathogenic relationships between soil microorganisms and microfauna and their practial utility However, it is much more important to initiate some studies on the role of soil microfauna in modifying the soil environment.

More recently some studies on wood-digesting bacteria and nitrogen-fixing bacteria present in insect guts have been initiated. On the ecological side, studies on the interactions amongst protozoa and bacteria in the presence of limiting concentrations of food substrates in the environment are being carried out. French *et al.* (1976) have isolated anaerobically-growing bacteria from the hindgut contents of termites. These bacteria were found to fix atmospheric nitrogen. The hindgut tissue of three diffrent species of termites when assayed for nitrogen fixation gave fairly high acetylene reduction activity. The responsible organism has been identified *Citrobacter freundii.* This study has opened up the interesting possibility of further research on the role of nitrogen-fixing bacteria in nitrogen nutrition of termites which are adapted to nitrogen-poor environment such as wood. Likewise strains of *Bacillus*, *Arthrobacter Alcaligenes* and *Serratia* have been isolated from the hingdut of termites (Thayer, 1976). These bacteria were capable of digesting wood with a very high efficiency. This again, emphasizes the role of gut microflora in carbon-nutrition of termites. Jost *et al.* (1973) studied the food web between protozoa and bacteria. In the presence of limiting concentrations of glucose, but in the absence of a protozoan, *Azotobacter* and *Escherchia coli* introduced into the system competed for the limited carbon substrate. In the competition, *Azotobacter* was suppressed, but *E. coli* was stimulated. With the introduction of protozoa in to the system the population of both bacteria were regulated in such a manner that the two bacteria and the protozoan could thrive equally well.

In a system consisting of either *E. coli* or *Azotobacter* and protoza, the protozoan could feed on either of the bacteria. More such studies are needed to understand the population equilibria esiablished amongst the microflora and microfauna in nature. More studies are also needed on the nutritional dependence of the soil microflora and microfauna on each other. Darbyshire (1972) noted increased nitrogen fixation under sub-optimal temperature conditions by *Azotobacter* in the presence of *Colpoda steinii* as compared to the fixation in the absence of the protozoan. Such studies emphasize the interdependence of soil microflora and microfauna and explain to some extent the observed population differences in mixed environments.

References

Alexander, M., 1961, *Introduction to Soil Microbiology*. John Wiley and Sons, Inc., New York, pp. 472.

Anonymous, 1969, *Principles of plant and animal pest control*. vol. 3 pp. 165–195. National Academy of Sciences, Washington, D.C.

Bulla, L. A. Jr., Robert, A. R. and St. Julian, G., 1975, Bacteria as insect pathogens. *Ann. Rev. Microbiol.*, **29**: 163–190.

Cross, W. H., 1973, Biology, control and eradication of the boll weevil. *Ann. Rev. Entomol.* **18**: 17–46.

Cutler, D. W., 1923, The action of protozoa on bacteria when inoculated into sterile soil. *Ann. Appl. Biol.*, **10**: 137–141.

David, W. A. L., 1975, The status of viruses pathogenic for insect and mites. *Ann. Rev. Entomol.*, **20**: 97–117.

Darbyshire, J. F., 1972, Nitrogen fixation by *Azotobacter chroococcum* in the presence of *Colpoda steinii-I* Influence of temperature. *Soil Biol. Biochem.*, **4**: 359–369.

Dutky, S. R., 1963, The milky diseases. *In Insect pathology*: An advanced treaties vol. 2, E. A. Steinhaus Ed. Academic Press, New York, pp. 75–114.

Falcon, L. A., 1971, Use of bacteria for microbial control of insects. *In microbial control of insects and pests*. H. D. Burges and N. W. Hussey Ed. Academic Press, New York, pp. 67–95.

French, J. R. J., Turner, G. L. and Bradbury, J. F., 1976, Nitrogen fixation by bacteria from the hindgut of termites. *J. Gen. Microbiol.*, **95**: 202–206.

Habte, M. and Alexander, M., 1975, Protozoa as agents responsible for the decline of *Xanthomonas campestris* in soil. *Appl. Microbiol.*, **29**: 159–164.

Heimpel, A. M., 1965, Microbial control of insects. *World Review of pest control*, **4**: 150–161

Jost, J. L., Drake, J. F., Fedrickson, A. G. and Tsuchiya, H. M., 1973, Interaction of *Tetrahyomena pyriformis, Escherichia coli, Azotobacter vinelandii* and glucose in mineral medium. *J. Bacteriol.*, **113**: 834–840.

Kevan, D. K. McE, 1956, The soil fauna – *In Ecology of soil-borne plant pathogens. Prelude to Biological control*. K. F. Baker and W. C. Snyder Ed. University of California Press, Berkley, pp. 33–57.

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KRIEG, A. F., 1963, Rickettisae and Ricketsioses in Insect pathology. An advanced treatise. vol. I, E. A. Steinhaus, Ed. Academic Press, New York, pp. 577-617.

MEDELIN, M. F., 1968, Fungal parasites of invertebrates. I-Entomogenous Fungi. *In The fungi*. G. C. Ainsworth and A. S. Sussman, Ed. Vol. 3, Academic Press, pp. 227-238.

RICHARDS, B. N. 1974, *Introduction to the soil ecosystem*. Longman Group Ltd., Burnl Mill., pp. 265.

ROBERTS, D. W., 1973, Means for insect regulation. Fungi. *Ann. N.Y. Acad. Sci.*, **217** : 76-84.

ROBERTS, D. W. AND YENDOL, W. G., 1971, Use of fungi for microbiol control of insects. In Microbial control of insects and mites, H. D. Burges and N. W. Mussey, Ed. Academic Press, New York, pp. 125-149.

SHERMAN, J. M., 1916, Studies on soil, protozoa and their relation to the bacterial flora. *J. Bacteriol.*, **7** : 165-185

THAYER, D. W., 1976. Facultative Wood digesting bacteria from the hingut of the termites *J. Gen. Microbiol*, **95** : 287-296

WEISER, J., 1963, Sporozoan infections. In Insect pathology. An advanced treatise. Vol 2, E. A. Steinhaus, Ed. Academic Press, New York, pp. 291-334.

The Protozoa in Soil and Sewage

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ABSTRACT

The colonial Vorticellid protozoa which rapidly oxidize and purify sewage are derived from the soil. They do not generally develop in large numbers in soil because of insufficient quantity of nutrients and water for them in soil as compared with sewage. But there are other forms of protozoa, such as the species of *Oikomonas*, *Balantiophorus*, *Colpidium*, *Colpoda* and *Vorticella*, which are more commonly found in all fertile soils, and they have been found to flocculate the soil colloids and to form water stable aggregates, which contribute to the structure of the soil and its aeration.

The role of soil protozoa in the purification of sewage, which is evident more strikingly in the activated sludge process, and the role of protozoa in soil is discussed.

In this way a new approach has been made from the researches on sewage purification at the Indian Institute of Science, Bangalore, to study the protozoa in soil and their role in the soil economy.

Discovery of Protozoa and Early Studies

The discovery of microorganisms in the middle of the seventeenth century represents one of the most significants achievement of science by the endless curiosity of man. Leeuwenhoek, a Dutch lens-maker, discovered protozoa in

1675 when he examined a drop of standing rain water through his microscope. The first protozoan he saw was a species of *Vorticella* (Leeuwenhoek, 1677; Bhatia, 1936). That was just a glimpse of a new world of life and it marked the beginning of the study of microorganisms.

During the last three centuries, notably in the last few decades, great advances have indeed been made in the different areas of microbiology, though not about the protozoa in water and soil, with the aid of continuously improved techniques which, of course, always form an essential part of research and development.

Although protozoa were among the microorganisms first discovered, very little work was carried out on this group of organisms until about 1830; Interest was, however, evinced then in the study of protozoa and this interest in recording new and newer species and describing their morphology and structure has continued. Now more than thirty thousand species of protozoa are known (Curtis, 1969).

Modern experimental microbiology began in the middle of the last century with the classical work of Pasteur, who showed the relation of microorganisms to certain diseases, to fermentation and to changes in biological media. He demonstrated, among other things, that the pebrine disease in silkworm is due to a protozoan, *Nosema bombycis* (Leechevalier and Solotorovsky, 1965). Another important piece of work in protozoology was the discovery by Lavern in 1880 of *Plasmodium* sp. which causes malaria (Lavern, 1880). Metchnikoff in 1882 traced the continuity of phagocytic and digestive activity from amoeba through the primitive sponges with an inner core of amoeboid cells with phagocytic activity (Humphrey and White, 1964).

The Growth of Ideas on Protozoan Activity in soil

The studies on the pathogenic protozoa and on the phagocytic activity of protozoa apparently influenced the thinking of those interested in the soil protozoa, and it was ganerally held that protozoa caused diseases and that they also consumed bacteria.

Russell and Hutchinson in 1909 reported that sterilisation of soil, either by application of heat (98°C for 1 hr) or by antiseptics (such as toluene), led to increased crop yields and they explained that this increase as due to the destruction of these protozoa in the soil which adversely affected the useful bacteria. That report on the theory of partial sterilisation of soil for crop production immediately evoked an extensive inquiry in different parts of the world into the occurrence and activity of protozoa in soil and also into the effects of sterilisation of soil by heat and antiseptics. On these aspects a large

volume of literature has accumulated and most of the available information has, in fact, been reviewed from time to time since 1909 (Kopeloff and Coleman, 1917; Sandon, 1927; Cutler, 1929; Pillai and Subrahmanyan, 1945–46; Singh, 1960, 1964; Heal and Stout, 1967; Kasi Viswanath and Pillai, 1968; Darbyshire, 1975).

The idea of protozoan activity in the Nitrogen changes and the factors influencing the development of protozoa in soil

Since the early years of scientific study of agriculture it has been held that the nitrogen transformation in soil are extremely important for crop yields which, as Norman (1946) stated, "are probably more directly related to the supply of nitrogen in the soil than to any other single factor". It was indeed in the course of search for the cause of nitrification that microbial activity in soil was discovered. Among the microorganisms, the bacteria which ammonify, nitrify, and fix atmospheric nitrogen have apparently received the most attention.

Russell and Hutchinson (1909) stated that as a result of partial sterilisation of the soil the amount of ammonia of produced was so closely connected with the increase in the bacterial numbers that no reasonable doubt could be entertained as to its bacterial origin. They believed that the protozoa in the soil adversely affected ammonification, but several others (Lipmann *et al.*, 1912; Hutchinson, 1914; Waksman, 1916; Hills, 1916) showed that both ammonification and nitrification proceeded normally in the presence of protozoa.

The object of the prolonged studies of Sandon (1927) on the climatic and soil conditions, such as pH, total nitrogen, organic matter (loss on ignition) and moisture on protozoa was to explain their relative abundance of protozoa in different soils. He found that of all the soils examined, none, even the most barren, was entirely free from protozoa; that the highest numbers were found in arable and garden soils; that temperature, moisture, "reaction" (pH), and soil texture were of little importance, but abundance of organic matter was beneficial except in peaty soils. Sandon's studies were mostly ecological in nature and they yielded, as he himself put it, "disappointingly little really convincing information" on the functional activity of the protozoa in soil. This has generally been the experience of the later investigators, although a few of them stated that protozoa seemed to have a role in soil (Umbreit, 1962; Dogiel, 1965).

At the same time, reference may be made to an observation made many years ago at Bangalore (Pillai and Subrahmanyan, 1945–46) that when cultures of actively growing protozoa, such as *Colpoda* sp., were introduced into the soil treated with sterilized sewage and maintained at about 50 per cent moisture, the protozoa were found to collect on their bodies the soil bactereia and other materials in the soil, including fine silt and clay. As a result of such aggregating

or flocculating activity of the protozoa, it was observed that the pore space in the soil increased considerably. Thus, in one series of experiments in which a culture of *Colpoda* sp. was used, there was an increase of about 8 per cent in the pore space of the soil system (increase over the control soil samples in which the protozoan culture was not introduced).

Possible influence of protozoa in the process of soil aggregation and aeration

In considering the question of occurrence and development of protozoa in soils, especially under the conditions most favourable for the growth of crops it should be remembered that protozoa are generally much bigger than the bacteria and also that they, unlike the other groups of microorganisms in soil, require more oxygen for respiration: *e.g.*, one million cells of *Colpidium campylum* consumed 112.5 c. mm of oxygen per hour at 19.8°C (Hall, 1938); and 100,000 cells of *Vorticella* sp. consumed 9.31 cc. of oxygen per hour (at N.T.P.), and their respiratory coefficient for a period of 40 minutes was 0.81 (Pillai *et al.*, 1947). For this reason it may be expected that, immediately after intensive bacterial decomposition of organic matter (bacteria seem to be the first to develop on any organic matter), the protozoa may be associated with an activity which ensures a necessary supply of oxygen and that such an activity, in all probability, may be in harmony with other conditions favourable to the whole population of the soil in the top six inches, to the different processes in that environment and to plant growth.

A possible condition in which the protozoa may be involved for their benefit and for the benefit of the soil community in general, including roots of plants, is aggregation of the finest particles which otherwise impede or interfere with the exchange of gases. This is perceptible in waters polluted with organic matter, and is more evident during aerobic treatment of sewage particularly by the activated sludge process.

The conditions in water and sewage in which protozoa cause flocculation or aggregation

In natural waters a variety of microorganisms and higher forms of life are always present, although these waters are constantly polluted with the waste products of the organisms. At the same time it is remarkable that, in these waters, the concentration of dissolved oxygen is rarely, if ever, reduced to an extent detrimental to the organisms. On the other hand, the conditions are different in water as it becomes sewage with little or no dissolved oxygen: in sewage all aerobic organisms are rendered inactive or they die, if conditions for aeration are not promoted by adequate treatment. Treatment with activated sludge brings about rapid clarification or flocculation of sewage and oxygenation. In the process of flocculation and oxygenation of sewage it has been shown in

this laboratory that ciliate protozoa, such as the species of *Vorticella, Carchesium, Zoothamnium, Epistylis,* and *Opercularia,* play an outstanding role (Pillai, 1941 ; 1942 ; 1949 ; 1951 ; 1952 : Pillai and Subramanyan, 1942 ; 1944 ; Pilla, and Rajgopalan, 1948 Pillai *et al.* 1948 ; 1948a). These protozoa are present only in small numbers in natural waters, they exist as cysts in raw sewage and they develop in large numbers in aerated sewage and activated sludge. They are derived originally from the soil.

Stokvis and Swellengrebel (1911) found that only living cells of *Colpoda cucullus* were able to clear the emulsions containing *Bacillus typhosus, B. megatherium, Vibrio cholera, V. dunlar, "V. El Tor", Spirillum voluntas.*

Protozoan activity in the clarification and oxidation of sewage during its flow on soil

For over half a century, all the sewage from the City of Bangalore currently about 50 million gallons a day, has been allowed to flow down on the outskirts of the city (since 1974 part of this sewage undergoes primary treatment). The sewage as it flows over stones and sand has been found to be clarified and oxidized in a few hours. The conditions and the extent of purification of the flowing sewage have been studied in this laboratory (Pillai *et al.,* 1953, 1960, 1975) and one of the points of considerable interest is the influence of protozoa, particularly of the species of *Epistylis* and *Carchesium,* on the flocculation of the suspended and colloidal matter in the sewage and soil.

Influence of protozoa on the purification of sewage during filtration through sand

It was one of the earliest experiments by Schloesing and Muntz in 1877 in the field of sewage treatment that formed the basis of soil microbiology. Their experiment was on the filtration of sewage through sand and limestone, and showed that the formation of nitrate in the effluent was due to "organized ferments" or microorganisms. This filtration experiment not only confirmed Pasteur's suggestion of the possibility of nitrification being due to bacterial action (Russell and Russell, 1961) but was indeed the beginning of the investigation of soil microorganisms.

In 1909, Fowler made an observation at Manchester, England, on the growth of *Carchesium* at the base of a secondary percolating filter treating the effluent from the primary contact beds and reported : "The effluent from the percolating filter is, except for a small amount of suspended humus, clear and bright, nonputrefactive, and practically saturated with dissolved oxygen. Nitrification is well advanced, and the 4–hour oxygen test and albuminoid ammonia are below the limits of impurity of the Mersey and Irwell Joint Committee. Yet considerable development of *Carchesium* takes place in the outlet

channel, with, as has been found, simultaneous diminution in the dissolved oxygen content" (Fowler 1909). Continued observations on the quality of the effluent from a well managed sewage farm at Madurai, South India, have shown that the clear land-filtered effluent supported a variety of microorganisms particularly protozoa of the species of *Carchesium* and *Epistylis*, and higher forms of life such as fish (Pillai *et al.*, 1947).

Kasi Viswanath and Pillai (1974) used one-foot deep columns of sand as well as mixtures of sand and bentonite clay as filtering media which were treated with different forms of organic matter such as straw, cowdung, farmyard manure, groundnut cake, sewage and inorganic fertilizers (ammonium sulphate and superphosphate). The development of bacteria, actinomycetes, yeasts, fungi, algae and protozoa in these different filters and the quality of the effluents from them were studied. These filters maintained in the laboratory may to some extent, represent the field conditions in which the soil receives organic and inorganic fertilisers and, at the same time, permit the examination of filtrates or effluents which may indicate the results of soil metabolism. This may be regarded as a system in which the principles of sewage purification by intermittent downward filtration, "contact bed", or trickling filter are applied to some extent in the study of soil processess. According to Barritt (1933), "the process of nitrification in soils and (sewage) filter beds is essentially the same".

Russell (1912) observed that the nitrogen changes in sewage were similar to those in soil, although they occurred more quickly in sewage than in soil. Fowler (1934) observed that both activated sludge and arable soils were similar living systems and that the chemicals which eliminated the protozoa in the soil also eliminated the protozoa in the activated sludge. In view of these observations on the similarity of soil and sewage especially in the microbiological oxidation of organic matter, experiments were carried out with sand filters as in the study of the behaviour of sewage in a sand filter, following the quality of the effluents which may give a measure of the oxidative changes in the soil.

Water stability of "flocs" or "aggregates" of activated sludge

Filtration of sewage through soil or sand or stones is only one of the methods of sewage treatment. The activated sludge process, which is based on intensive aeration of sewage, is a more efficient method of sewage treatment. In this process the rapid flocculation of the suspended and colloidal matter in sewage in a few hours is a point of great interest. This has resemblance to the aggregation of clay in soil, although it is relatively a much slower process. Activated sludge itself, as it is formed from colloidal sewage during vigorous agitation, demonstrates the formation of water stable "flocs" or "aggregates" which promote dissolution of oxygen in the sewage. The clarifiction of sewage, sludge formation and oxygenation seem to be an integrated process which, as

has been shown in this laboratory (Pillai, 1941) and recently further confirmed in the Water Pollution Research Laboratory, Britain (1968; Curds and Fey, 1969; Curds, 1973) and elsewhere (Sudo and Aiba, 1971; Kuiper 1973; Varma *et al.*, 1975) is largely due to the activity of Vorticellid protozoa.

Comparative study of the water stability of the sludges formed during treatment of sewage by different methods

It is now established that, during the so-called activated sludge method of sewage treatment, the turbid, colloidal putrescible sewage is converted into a sparkingly clear effluent and a granular, readily settleable sludge. Evidence has earlier been given that, in this "rapid and dramatic" (Ministry of Technology, Britain, 1968) transformation of sewage, the dominant protozoa (*e.g. Epistylis* sp.) have a vital role (Pillai and Subramanyan, 1942; 1944). The very nature of the formation of activated sludge by intensive aeration and agitation of sewage suggests that the sludge particles constitute a species of extremely water stable "aggregates", which requires analysis and study from an angle which has not so far been attempted. In this connection the sludges formed by other methods of treatment of sewage were also examined.

In seeking information on the water stability of sewage solids and different sludges, the following materials were prepared: (1) raw sewage solids; (2), (3), and (4) "chemical sludges" prepared by coagulating sewage with required amounts of lime, alum, or ferric chloride; (5) the sludge formed from sewage under controlled anaerobic conditions in the laboratory; (6) Septic tank sludge; (7) activated sludge formed during aeration of successive portions of sewage by "fill-and-draw" method in the laboratory; and (8) activated sludge from the plant at this Institute. The details of the preparation of these materials and the experiments carried out are briefly given below.

(1) *Raw sewage solids* were prepared over a period of 55 days by evaporating samples of sewage collected every day on a water bath and drying the solids later in an oven (104°–106°C) for one hour. The dried solids were preserved in glass stoppered bottle in a moisturefree condition.

(2), (3) and (4) "chemical sludges" were obtained by coagulating sewage with lime (2), alum (3), or ferric chloride (4). Samples of sewage (2 litres) were coagulated separately with 2 g lime, 1.2 g alum, or 0.8 g ferric chloride. The sludges formed were removed and dried on a water bath. This was continued for 45 days in order to obtain representative samples.

(5) "Anaerobic" sludge was prepared by adding sewage daily to a bottle, to which air had no access, and the sludge was removed after 86 days and dried on a water bath.

(6) *Septic tank sludge*: Samples of sludge from one of the septic tanks at this Institute were collected and dried.

(7) *Activated sludge prepared in the laboratory*: This sludge was obtained by continuous aeration of successive portions of raw sewage as in the activated sludge process, but by the "fill-and-draw" method, over a period of 84 days. The accumulated sludge in excess of about 15 per cent was periodically removed and dried.

(8) *Activated sludge from the plant at this Institute*: Samples of sludge from the activated sludge plant were collected and dried.

The volume of sewage used and the weight of the material obtained by each treatment are given in Table I.

All these materials were wet sieved by the method standardised in this laboratory (Kasi Viswanath and Pillai, 1968a; 1973). The results of "aggregate" analysis are given in Table II.

TABLE I

Volume of sewage and the weights of the materials obtained by different treatments of sewage in the laboratory

Treatment	Volume of sewage (litres)	Dry weight (g) of the material
None: raw sewage solids	124	57.30
"Lime sludge"	90	81.53
"Alum sludge"	150	35.45
"Ferric chloride sludge"	150	46.00
Anaerobic sludge*	173	9.98
Aerobic sludge*	168	25.02

* 7 and 8: Wet sludges from the septic tank and activated sludge plant at this institute were collected and dried. About 50 g each of these sludges was set apart for the experiment

TABLE II

Percentage of water stable "aggregates" formed by different treatments of sewage

Treatment	Aggregate size (mm) 0.25	0.50	1.00	2.00	Total percentage
None (sewage solids)	11.7	Nil	Nil	Nil	11.7
"Lime" sludge	Nil	1.6	4.2	89.8	95.6
"Alum" sludge	15.6	6.3	15.0	54.6	91.5
"Ferric chloride" sludge	Nil	18.2	23.0	49.6	90.8
Anaerobic sludge (lab)	23.5	8.5	11.5	4.5	48.0
Septic tank sludge*	1.4	14.2	31.9	42.3	89.8
Activated sludge (lab)	10.5	23.5	6.0	54.9	94.9
Activated sludge (tank)	2.5	Nil	9.5	87.5	99.5

* Septic tank sludge contained considerable amount of soil which, on heating, gave relatively high percentages of water stable aggregates (Table III).

TABLE III

Silica (SiO_2) contents of dried and powdered samples of sewage solids, activated sludge (from the plant) and septic tank*

Material (dry)	mg SiO_2/g	Percentage
Sewage solids	15.2	1.52
Activated sludge	58.2	5.82
Septic tank sludge	410.2	41.02

* The materials (500 mg each) were treated with hydrogen peroxide till all the organic matter was destroyed and concentrated hydrochloric acid was then added. The acid was evaporated and this process of addition of the acid and evaporation was repeated. The materials were washed into Whatman No. 44 filter paper and the residue (acid-insoluble) matter, mostly SiO_2) was dried and weighed.

The results given in Table II bring out three main points of considerable interest. First, the behaviour of raw sewage solids when put back in water : sewage contains millions of bacterial cells, but the solids prepared from sewage, when added to water, rendered the water nearly as turbid as the sewage and showed poor water stability because the total percentage of aggregates was only 11.7 with no aggregates of 2 mm, 1 mm or 0.50 mm diameter. Secondly, chemical or biological treatment of sewage caused the formation of water stable aggregates, the percentage of which varied from 48 ("anaerobic" sludge prepared in the laboratory) to 99.5 (the activated sludge from the plant at this Institute). It is of interest to note that the percentage of water stable aggregates of 2 mm diameter, formed in the activated sludge plant and that formed by treatment of sewage with lime are comparable, which seems to confirm an empirical observation that activated sludge behaves like "a very heavy chemical precipitant" (Martin, 1927). Thirdly, the total percentage as well as the percentage of 2 mm diameter water stable aggregates in the "biological sludges" prepared in the laboratory under aerobic and anaerobic conditions, differ, widely, the total percentage and the percentage of 2 mm in the "aerobic" or "aerated" sludge being nearly twice and were 11 times, respectively, than in the "anaerobic" sludge. The aerobic organisms, notably the dominat protozoa, in the activated sludge apparently have a role in the formation of water stable aggregates during sewage purification.

These and earlier observations led on to another series of experiments in which mixtures of sewage, soil and clay were shaken and aerated, and the consequent changes and formation of water stable aggregates were studied.

Experiments with mixtures of sewage, soil and clay (bentonite)

In conical flasks of 500 ml capacity, 300 ml capacity, 300 ml tap water or settled sewage was taken and known amounts of soil (Bangalore red soil, passed

through 2 mm sieve) and bentonite clay (whitish gray variety, powdered and passed through 300–mesh sieve) were added and the mixtures were aerated on a rotary shaker (200 r p m). The contents of the different flasks were; (1) Sewage only (control): (2) Sewage with 1 g soil; (3) Sewage with 1 g clay; the other flasks contained with water with; (4) the soil; and (5) the clay, respectively.

After aeration for 24 hours the liquids in the flasks were allowed to stand for half an hour and the supernatant liquids were decanted, and the decanted liquids were examined for turbidity, total solids, organic matter (oxygen absorbed from acidified potassium permanganate in 3 min), ammoniacal, nitrite and nitrate nitrogen, and water soluble phosphorus. The results of those examinations are not included here.

Fresh mixtures of sewage with the soil or the clay were added to the respective containers. For 8 days the mixtures of sewage with the soil, and the clay showed gradual decrease in the turbidity of the supernatant liquids, but at the end of the 9th day, there was an increase in the turbidity and the experiment was stopped. The contents of the flasks were shaken well and allowed to settle for half an hour. The deposits formed were measured, transferred to Petri dishes and air dried at room temperature (26°C) on a laboratory bench. The volumes of the deposits and their dry weights are given in Table IV. The air dried materials were wet sieved (Table V.) The sludge obtained by aerating sewage only was too little for wet sieving, and so it was not used.

TABLE IV

Volumes and weights of deposits formed at the end of aeration of sewage for 9 days with soil, and bentonite clay

Treatment	Volume (ml)	Weight (g, air-dry)
Sewage	30	0.50
Sewage+soil	50	8.08
Soil+water	25	4.94
Sewage+bentonite clay	50	9.72
Bentonite clay+water	60	8.86

TABLE V

Percentages of water stable "aggregates" formed in sewage aerated for 9 days with soil, and bentonite clay

Treatment	Aggregate size (mm) 0.25	0.50	1.00	2.00	4.00	Total percentage
Sewage+soil	14.62	12.96	4.61	15.08	36.67	83.94
Soil+water	22.25	16.71	Nil	Nil	Nil	38 96
Sewage+bentonite clay	3.49	1.99	7.05	11.21	67.95	91.69
Bentonite clay+water	4.26	3.76	0.63	Nil	Nil	8.62

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The results (not given here) confirm the observations on the purification of flowing sewage and the process of purification by activated sludge and also indicate their application to the conditions in soil. The rapid flocculation or aggregation of the soil and clay added to the sewage under aerobic conditions and the rapid oxidation of the organic matter, including nitrification, seem to have a considerable bearing on soil processes, although, of course, there are at least three conditions in these experiments which do not normally occur in an arable soil, namely, the relatively large amount of organic matter, water and the artificial aeration.

The results given in Table V on the formation of aggregation of 4 mm diameter in sewage aerated with bentonite clay (67 per cent), and with soil (37 per cent) are of unusual interest in the investigation of the whole mechanism of formation of water stable aggregates in ordinary soil. These experimental results emphasize not only the importance of organic matter but also the significance of the protozoan activity in the formation of really water stable aggregates. It should be noted that such large protozoa may not always be actively present in an arable soil for the aggregate formation but that they indicate the role of smaller forms of protozoa in the important process of flocculation or aggregation of clay in soil (Kasi Viswanath and Pillai, 1976).

Many years ago, in continuation of the work from this laboratory on the protozoa in activated sludge (Pillai and Subramanyan, 1942), Watson (1943) experimented with a small ciliate, *Balantiophorus minutes* Schew., which is "peculiarly well fitted for life in the surface soil, where the amount of free water is subject to frequent and drastic alteration, and is at all times limited save in water-logged soils". In agar plates cultures of this ciliate, it was observed that it could remain active in very restricted films of water, wriggling between bacterial masses on the surface of the agar in an almost amoeboid fashion and that it caused flocculation of the bacteria.

Discussion

The foregoing and other related observations in the literature indicate that some of the soil microorganisms, under favourable conditions, develop in sewage and oxidise the organic matter. Domestic sewage is one form of organic matter in water, in which the microorganisms can grow more freely and multiply than in soil treated with sewage or any other form of organic matter. But sewage, although it is a liquid and different from soil in all respects except in that it holds a small amount of organic matter and moisture, has not been compared with soil on the basis of oxidation of organic matter and its total effect on the ecology and economy of the two systems. Such a comparative study has now been made in this laboratory and the results showed that sewage and its purification provide a suitable substrate and a new method for studying some of the

soil processes (Kasi Viswanath and Pillai, 1974). "In fact", as Waksman (1931) also pointed out, "in view of the close similarity between many of the biochemical problems of water and sewage purification and those of the soil, the extensive investigations that have been made in the former fields are well worth careful consideration by the soil microbiologist".

By following the changes of sewage as it flows over soil and by the application of "fluidization" technique in the laboratory (Pillai *et al.*, 1975) it has been shown that the flocculation of colloids in the mixture of sewage and soil and the oxidation of organic matter in it during vigorous or turbulent flow of the sewage are brought about mainly by protozoa such as *Epistylis* sp. This has provided some fresh evidence on the basic biological principle of all artificial methods of sewage purification, more especially the activated sludge process, and has indicated a possible line of development for improving the efficiency of, e.g., activated sludge.

Activated sludge has been viewed, for the first time, as "aggregates" which are remarkably water stable. The sludge particles or "flocs" are violently tossed about during vigorous aeration of the sewage and when the aeration is stopped for few minutes or when the mixed liquor from the last chamber of the activated sludge plant is taken out and allowed to stand for a few minutes, the granular sludge particles settle out leaving a bright and clear supernatant liquid. Settled raw sewage or dry solids prepared from raw sewage, when put back into clear water, make the water as turbid and colloidal as the original sewage. The transformation of sewage into activated sludge or "aggregates" has been shown to be largely, if not entirely, due to the protozoan activity.

These observations on the different methods of sewage treatment, on the behaviour of flowing sewage and on the aggregate analysis of sewage and sludges were confirmed by laboratory experiments with mixtures of sewage, soil and clay, which further showed that, in the presence of organic matter, as it is in sewage, the protozoa flocculated or aggregated the added soil or clay and quickly brought about oxidative changes, including nitrification. These observations explain the nature af influence of organic matter in agricultural soils on the formation and stabilization of the water stable aggregates, essential for soil aeration and fertility.

The similarity of sewage and soil is confined, as stated earlier, to their organic matter and moisture contents and even here the one contains more organic matter and an incomparably more water than the other. For this reason, the conditions in the first system (sewage) for the formation of aggregates are highly exaggerated. In soil there is a slow but definite changes or process in the formation of water stable aggregates, as has been shown by the observational and experimental evidence just discussed.

References

BARITT, N. W., 1933, The nitrification in soils and biological filters. *Ann. appl. Biol.*, **20**: 165–184.

BHATIA, B. L., 1936, *The fauna of British India*. Vol. 1, p. 1, Taylor and Francis, Ltd., London.

CURDS, C. R. AND FEY, G. J., 1969, The effect of ciliate protozoa on the fate of *Escherichia coli* in the activated sludge process. *Water Res.*, **3**: 853.

CURDS, C. R., 1973, The role of protozoa in the activated sludge process. *Ann. Zool.* **13**: 161–169.

CURTIS, H., 1969, *The Maryellous Animals: An introduction to the protozoa*. p. 1, Heinemann Educational Books Ltd., London.

CUTLER, D. W., 1927, Soil protozoa and bacteria in relation to their environment. *J. Quekett Microscop. Club., London*, Ser 2, 15 (93): 309–330.

DARBYSHIRE, J. F., 1975, Soil protozoa–Animalcules of the subterranean microenvironment, in *Soil Microbiology, A Critical Review*. pp. 147–163, Edited by N. Walker, Butterworths, London.

DOGIEL, V. A., 1965, *General Protozoology*. Second edition, pp. 612–616, Revised by J. I.: Poljansky and E. M. Chejsin, Clarendon Press, Oxford.

FOWLER, G. J., 1909, The quality of effluents in relation to standards. *J. R. Sanit. Inst.*, **30**: 513–532.

FOWLER, G. J., 1934, *An introduction to the Biochemistry of Nitrogen Conservation*. p. 196, Edward Arnold and Co., London.

HALL, R. H., 1938, The oxygen-consumption of *Colpidium campylum*. *Biol. Bull.*, **75**: 395–408.

HILLS, T. L., 1916, The relation of protozoa to certain groups of soil bacteria. *J. Bact.*, **1**: 99–100.

HUMPHREY, J. H. AND WHITE, R. G., 1964, *Immunology for Students of Medicine*. Second edition, p. 9, Blackwell Scientific Publications, Oxford.

HUTCHINSON, C. M., 1914, Soil Bacteriology. pp. 81–88, Report of the Agricultural Institute and College, Pusa, India.

KASI VISWANATH, G. AND PILLAI, S. C., 1968, Occurrence and activity of protozoa in soil. *J. scient. industr. Res.*, **27**: 187–195.

KASI VISWANATH, G. AND PILLAI, S. C., 1968a, Influence of heat on soil structure. *Curr. Sci.*, **37**: 483–487.

KASI VISWANATH, G. AND PILLAI, S. C., 1973, Pretreatment of the soil in the determination of water stable aggregates. *Mysore J. agric. Sci.*, **7**: 550–556.

KASI VISWANATH, G. AND PILLAI, S. C. 1974, Influence of clay on soil processes. *Proc. Indian natl. sci. Acad.*, **40 B**: 167–181.

KASI VISWANATH, G. AND PILLAI, S. C., 1976, Influence of protozoa on soil aggregation. *Proc. All India Symposium on Soil Biology and Ecology*, held at the University of Agricultural Sciences, Hebbal, Bangalore, November 22–26, 1976.

KOPELOFF, N. AND COLEMAN, D. A., 1917, A Review of investigation in soil protozoa and soil sterilization. *Soil Sci.*, **3**: 197–269.

KUIPER, J., 1973, The role of protozoa in sewage purification, H_2O. **6**: 491–496.

LAVERN, A., 1880, A new parasite found in the blood of malarial patients: parasitic origin of malarial attack. *Bull. Mem. soc. med. hop.*, Paris, **17**: 158–164.

LEECHEVALIER, H. A. AND SOLOTOROVSKY, M., 1965, *Three Centuries of Microbiology*. p. 40 McGraw-Hill Book Company, New York.

LEEUWENHOEK, A. V., 1677, *Phil. Trans. R. Soc. London*, **12**: 821.

LIPMANN, J. G., BLAIR, A. G., OWEN, I. L. AND MCLEEN, H. C., 1912, Experiments relating to the possible influence of protozoa on ammonification in the soil., *New Jersey Agricultural Experimental Station Bull.*, No. 248.

MARTIN. A. J., 1927, The Activated Sludge Process. p. 317, Mcdonald and Evans, London.

MINISTRY OF TECHNOLOGY, Britain 1968, *Notes on Water Pollution*: protozoa in sewage treatment processes, No. 43.

NORMAN, A. G., 1946, Recent advances in soil microbiology. *Proc. Soil Sci. Soc. Ann.*, **11**: 9-15.

PILLAI, S. C., 1941, The function of protozoa in the activated sludge process. *Curr. Sci.*, **10**: 84-85.

PILLAI, S. C., 1942, Further studies on the role of protozoa in the activated sludge process, *Curr. Sci.*, **11**: 437-438.

PILLAI, S. C., 1949, Nature of activated sludge and its bearing on de-watering the material. *Curr. Sci.*, **18**: 382-383.

PILLAI, S. C., 1951, On the biological oxidation of sewage. *Curr. Sci.*, **20**: 75.

PILLAI, S. C., 1952, The special significance of certain peritrichous ciliate protozoa in the aerobic purification of sewage. *Indian Med. Gaz.*, **87**: 411-414.

PILLAI, S. C. AND SUBRAHMANYAN, V., 1942, Role of protozoa in the activated sludge process. *Nature, London*, **150**: 525.

PILLAI, S. C. AND SUBRAHMANYAN, V., 1944, Role of protozoa in the aerobic purification of sewage. *Nature, London*, **154**: 179-180.

PILLAI, S. C. AND SUBRAHMANYAN, V., 1945-46, Life cycles in the transformations of organic matter in sewage, soil and other biological media. *Sci. & Cult.*, **11**: 592-596.

PILLAI, S. C., RAJAGOPALAN, R. AND SESHACHAR, B. R., 1947, On the occurrence of protozoa in land-filtered sewage effluent *Curr. Sci.*, **16**: 254-256.

PILLAI, S. C., WADHWANI, T. K. AND SUBRAHMANYAN, V., 1947, Respiration of *Vorticella*. *Curr. Sci.*, **16**: 341-342.

PILLAI, S. C. AND RAJAGOPALAN, R., 1948, Influence of sea water on protozoal activity and purification of sewage by the activated sludge process. *Curr. Sci.*, **17**: 329.

PILLAI, S. C., WADHWANI, T. K., GURBAXANI, M. I. AND SUBRAHMANYAN, V., 1948, Role of protozoa in the concentration of nitrogen in the sludge during aerobic purification of sewage. *Curr. Sci.*, **17**: 93-95.

PILLAI, S. C., WADHWANI, T. K., GURBAXANI, M. I. AND SUBRAHMANYAN, V., 1948a, Observations on nitrite-producing bacteria from different sources and the role of protozoa in nitrification. *Curr. Sci.*, **17**: 122-123.

PILLAI, S. C. MOHANRAO, G. J., PRABHAKARA RAO, A. V. S., NATARAJAN, C. V. AND MADAPPA, I. B., 1953, Protozoal development and natural purification of flowing sewage. *Indian med. Gaz.*, **88**: 507-508.

PILLAI, S. C., MOHANRAO, G. J., PRABHAKARA RAO, A. V. S., SASTRY, C. A., SUBRAHMANYAM, P. V. R. AND NATARAJAN, C. V., 1960, Natural purification of flowing sewage. *Curr. Sci*, **29**: 461-465.

PILLAI, S. C., SRINATH, E. G., VISWANATHAN, C. V., MEERA BAI, B., KASI VISWANATH, G. AND SRIDHAR, M. K. C., 1975, Factors in the purification of flowing sewage and activated sludge process. *Water & Waste Treatment*, **18**: Part I, 36–42, Part II, 42–44.

RUSSELL, E. J. AND HUTCHINSON, H. B., 1909, The effect of partial sterilisation of soil on the production of plant food, *J. Agric. Sci., Camb.*, **3**: 111–144.

RUSSELL, E. J., 1912, *Soil Conditions and Plant Growth*. First edition, p. 100, Longmans, Green and Co., London.

RUSSELL, E. W. AND RUSSELL, E. J., 1961, *Soil Conditions and Plant Growth*. Ninth edition, p. 19, Longmans, Green and Co., London.

SANDON, H., 1927, *The Composition and Distribution of the protozoan Fauna of the Soil*. p. 68, Oliver and Boyd, London.

SCHLOESING, TH. AND MUNTZ, A., 1877, Surla nitrification par les fermentes organises, *Comptes Rendus de academic des Sciences*, **84**: 301–303.

SINGH, B. N., 1960, Interrelationship between micropredators and bacteria in soil. Presidential address, Section of Agricultural Sciences, *Forty-seventh Indian Science Congress*, Bombay, pp, 1–14.

SINGH, B. N., 1964, Soil protozoa and their probable role in soil fertility. *Symposium on Fertility of Indian Soils*, August 3–4, 1962, *Bull natl. Inst. Sci., India*, **26**: 238–244.

STOKVIS, C. S. AND SWELLENGREBEL, N. H. 1911, Purification of water by infusoria. *J. Hyg., Camb.*, **11**: 481–486.

STOUT, J. D. AND HEAL, O. W., 1967, Protozoa in *Soil Biology*. pp. 149–195, Editors A. Burgess and F. Raw, Academic Press, New York.

SUDO, R. AND AIBA, 1971, Growth of Vorticellidae isolated from activated sludge. *Japan J. Ecol.*, **21**: 70–76.

UMBREIT, W. W., 1962, *Modern Microbiology*. p. 301, W. H. Freeman and Company, San Francisco, and London.

VARMA, M. M., FINLEY, H. E. AND BENNETT, G. H., 1975, Population dynamics of protozoa in wastewater. *J. Wat. Pollut. Contr. Fed.*, **47**: 85–92.

WAKSMAN, S. A., 1916, Studies on soil protozoa. *Soil Sci.*, **1**: 135–152.

WAKSMAN, S. A., 1931, *Principles of Soil Microbiology*. Second edition, p. 298, Baillie, Tindall and Cox, London.

WATSON, J. M., 1943, Anabiosis in a soil ciliate. *Nature. London*, **152**: 693–694,

Energetics and the Analysis of Soil Biota

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ABSTRACT

The activities and exchanges within and between ecosystem components can be measured as calories. Energetics are a convenient and adequate measure for much that goes on at the producer and consumer levels. It can also define the input and output fo soil systems, but the primary consequence of soil metabolism is the burning-off of carbon to release micronutrients. Most of this is facilitated by symbiotic relations between arthropods and the microbial flora of the soil. The rates of decay are a function of a complex interacting set of biological processes that include: (i) mechanical breakdown of particles. (ii) Mutualistic associations of insects and microbes. (iii) The seeding effect of fecal matter. (iv) The aim of sugars from sucking herbivorous insects.

An analysis of such systems calls for a very different approach than used in any of the models for above-ground components. The soil biota is most significant for the chemical reactions whose rates and pathways are determined by complex symbiotic associations.

Terrestrial plants synthesize an average of about 0.8 kg of organic carbon per year over each square meter of land and the production may be as high as 4 kg (Whittaker, 1975). About 20 per cent of this energy is put into root tissues (Mitchell and Williams in press), thus, the mass of organic carbon in roots is often almost as large as the crop harvested. Below-ground growth is a very significant fraction of the total annual growth. In addition to that, all the dead above ground tissues also cycle back into the soil. It is possible to define the materials going into the soil and the materials coming out and with such a balance sheet in hand, the energy flows for an ecosystem can be defined. Until recently the functioning of the soil biota was defined in the same terms as are used for the above ground producer and consumer components. There is now reason to think that the soil biota must be treated differently if the biological processes that are of general importance in the soil are to be measured and defined. My object here will be to review some general concepts about ecosystems and the role of the soil biota in ecosystems.

The soil biota is the only common feature of all ecosystems. The simplest self sustaining ecosystems are the communities of algae and bacteria in the high temperature zones of hot springs (Mitchell, 1974). At the other extreme are caves and abyssal zones that are defined as ecosystems based on imported energy

sources. The one thing these three extreme examples have in common is a decomposer biota in a mineral substrate that serves to recycle the chemical elements that would otherwise remain locked up in dead organic carbon. The soil biota can be defined as a universal and essential component of all ecosystems.

Ecologists attempt to define ecosystems and explain their dynamics through energy flow models. Energy is used because all the activity of an ecosystem is due to the release of energy from organic carbon molecules and the mass of organisms is principally the mass of organic carbon. The potential kinetic energy derivable from organic carbon is readily measured, hence, both the mass and the activity of each ecosystem component can be measured in calories. Not only are calories a kind of common currency but also the carbon chemistry is reasonably consistent for all forms of life, hence, the conversion of mass to energy and the synthesis of organic carbon are governed by principles of great generality. That is why energy flow is the basic approach to ecosystem ecology and why it is likely to remain so.

But there is a growing awareness of processes in the soil that are not adequately characterized by simple energy flow models. While analytical models of soil processes are still being developed, it is possible to identify some of the peculiarities of the soil system that will be important in developing a basic analytical system characterizing soil functions. In opening this subject, I am able to do little more than explain a view presented by Robert Chew (1974).

The best way to gauge the significance of soil systems is to speculate on the consequence of soil systems not acting. If the soil biota suddenly ceased to function the 1.2×10^{11} tons of carbon fixed by terrestrial plants would be degraded by about 5 to 15 per cent through herbivory. The remaining 10 tons would be refractory molecules that break down very slowly through chemical processes. This virtually stable mass of carbon would represent almost 5 per cent of the total free CO_2 pool of the world. The withdrawal of that fraction of CO_2 by photosynthesis would decrease the glasshouse effect of CO_2 and result in about a 0.3°C decline in mean temperature per year (Thompson, 1975). The entire effect would not be felt because some of the CO_2 loss would be buffered by carbonate rocks.

The stability of our climate depends on the prompt decomposition of organic carbon, yet the study of the system that recycles carbon aud micronutrients has lagged far behind. The neglect of the soil biota by American ecologists has been documented. In recent years only 4 per cent of the research papers published in the journal Ecology dealt with decomposition and about 8 per cent of the research projects supported by the U. S. National Science Foundation dealt with decomposition. When Americans entered into the

they massive Biome Programmes as a part of the International Biological Programmes intended to fit all ecosystem components together. The deficiency of information on soil biology was so great that their subprojects were double the portion previously allocated to soil studies and the publications on soil biology were 5 to 7 times greater than usual in Ecology (Mitchell *et al.*, 1976). But even with this new support, soil biology studies remained at the level of developing techniques and determining base-line data. The basic biological functions and interactions of a soil system are yet to be worked out in a comprehensive fashion.

Still some basic features of the soil system are known and the areas of fruitful research can be suggested. The provocative essay of Hairston, Smith and Slobodkin (1960) pointed out that decomposers appear to be nutrient limited. That is, the decomposers are able to break down organic carbon as rapidly or more rapidly than it is produced. This was an obvious inference from the fact that the coal age is long past. But the bulk of the organic carbon is cellulose and much of the cellulose is in very large pieces. Only a few microorganisms can attack cellulose and most of these require some other organic substrate to be present. How is it that all dead organic carbon is decayed at the rate at least equal to that of carbon production ?

The decay is a surface phenomenon and a major role of insects is to increase surface area. If plant parts were to decompose due to a flora on the surface only, the process would be very slow and logs and sticks would accumulate rather rapidly. Insects act to riddle wood with holes and also to pulverize it. Simple mechanical breakdown of plant particles immensely increases the rate of decay by increasing the surface area on which the microbial flora can act.

When soil respiration is measured it is necessary to abandon the simplistic hope of finding a relation between the mass of carbon and the decomposers. Decomposition rates are in all likelihood related to surface area not mass of the resource.

But as Chew (1974) points out, and is well known, insects do more than chew large pieces into small pieces. Their guts are chemical retorts in which the pH and micronutrients are regulated with the result that decomposition is very rapid. All wood-feeding insects have a symbiotic microbial association. In many cases the microbial flora has co-evolved with the insect and the two form a symbiotic relationship. The best known co-evolved relationships are those of the ant Atta and the Macrotermitidas (Wilson, 1971).

In these symbiotic systems decay is stimulated and procedes much more rapidly than on simple exposed surfaces. This primary facilitation of decay is

only a part of the contribution. When insect faces are mixed with dead plant material the resultant decomposition will be much greater than the two materials alone. Insects, thus, contribute to decay in three ways : 1) mechanical breakdown, (2) facilitating decay of ingested materials and 3) the seeding and stimulation of decay of non-ingested materials.

Another source of enhancement for microbial decomposers may be from sucking insects. Insects like aphids, scales and spittle bugs pass a large amount of sugar through their bodies. In a study by Hinton (1971) it was shown that over half the intake was egested as honey dew. About 1.1 kcal of sugars rained down on each m^2 per year and these sugars certainly must affect microbial growth, yet I know of no speculation along these lines.

In most ecosystems the rates of change are defined as the flow of material from a resource base to a consumer. The rate of flow is looked on as a consumer property that is defined by resource utilization models. Those models ranging from growth models such as the logistic to more complex resource utilization models such as the Holding "disc" equation (Holding 1961), While these seem to be appropriate for the feeding strategies of herbivores, carnivores and parasites, they fail to define the properties of resource utilization of decomposers.

Models for primary production (Miller, 1972) are basically concerned with the analysis of how photosynthetic devices that trap light can be maintained and these are of no help in dealing with decomposers.

As one looks to the future with some hope of understanding soil systems on ecosystem flow model will usefully define how much enters the system and how long it takes to break down. The rate of breakdown will be likely to be related to a set of factors which, at present, appear to include :

1. The change in surface area due to invertebrate feeding.
2. The accelerated decay in the gardens and guts of insects with mutualistic microbial associates.
3. The seeding effects of faecal material.
4. The release of sugars from sucking herbivorous insects.

Decomposers cannot be treated as a simple set of species that eat and digest dead materials. They are, instead, a complex symbiotic association in which biotic interactions must be considered. Energetics alone will not adequately characterize the system.

Even the role of decomponents in the system is different than other components. Their primary effect is one of removing carbon so that micronutrients

are released in a form usable by plants. For all of these reasons the ecosystems of the soil must be treated more in terms of the chemistry of the biota than the energy flow through the soil.

References

Chew, R. M., 1974, Consumers as regulators of ecosystems: an alternative to energetics. *Ohio Journ. Sci.*, 74 : 359–370.

Hairston, D. G., Smith, F. E. and Slobodkin, L. B., 1960, Community structure, population control and competition. *Amer. Net*, **94** : 421–425.

Hinton, J. M., 1971, Energy flow in natural population of *Neophilaenus lineatus* (Homoptera). Oikos, **22** : 155–171.

Holling, C. S., 1961, Principles of insect predation. *Annv. Rev. Ent.* 6: 162–182.

Miller, P. C., 1972, Bioclimate, leaf temprature and primary production in red mangrove canopies in South Florida. Ecology, **53** : 22–45.

Mitchell, R., 1974, The evoluation of thermophily in hot springs. *P. Rev. Biol.* **49**: 229–242.

Mitchell, R., Mayer, R. and Downhower, J., 1976, An evaluation of thrree biome programs. *Science*, **192** : 859–865.

Mitchell, R. and Williams (in press). Dorwinian analyses: the new natural history. *In* the Dynamics and Analysis of Ecosystems. Ohio State Univ. Press, Columbus.

Odom, E. P., 1971, Fundamentals of Ecology. 3rd Ed. Saunders, New York.

Thompson, L. M., 1975, Weather, variability, climatic change and grain production. *Science*, **188** : 535–541.

Wilson, E. O., 1971, The insect Societies. Belknap Press. Harvard, Cambridge Mass.

Influence of Protozoa on Soil Aggregation

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Abstract

Leewenhoek was probably the first to record the occurrence of protozoa in soil when he saw in 1675 under the microscope, which he devised, a spacies of *Vorticella* in a drop of standing rain water. Since then, several workers have reported the presence of many species of protozoa in the soils of the world. Sandon in 1927 examined 148 samples of soil from different parts of the world and indentified 250 spacies of protozoa in those soils.

In 1909 Russel and Hutchinson stated that the protozoa in the soil had a harmful effect on the bacteria which were considered to be the makers of plant food. Later studies of many investigators indicated the effect of protozoa on the soil productivity

was not harmful, and a few others suggested that the protozo were some way useful in the soil but that in what way they were useful was not clear.

At the same time evidence has been accumulating that there are some protozoa, *e.g.* the species of *Colpidium*, *Colpodo* and *Vorticella*, which are always found in fertile soils. The studies carried out at the Department of Biochemistry, Indian Institute of Science, Bangalore, have shown that these protozoa considerably influence the formation and stabilization of water stable aggregates in the soil. Soil aggregation is a very vital process, a major contributory factor in soil aeration for the benefit of plant roots.

The experimental results of the studies at Bangalore will be presented and discussed.

Introduction

Russell and Hutchinson (1909) and Russell and Golding (1911) stated that some of the soil protozoa, such as *Amoeba nitrophila*, *Colpoda cucullus*, *Vorticella purtina* and *Euglena* sp. kept down the numbers of beneficial bacteria involved in the production of plant food and that, therefore, they be eliminated by the application of heat or antiseptics to the soil. The work of these investigators on the partial sterilisation of soil, however, evoked further work on the protozoa in soils. Later workers gave evidence that not only the protozoa were normally present in all fertile soils (Alexander, 1961; Manwell, 1961) and were not harmful to the productivity of the soils (Singh, 1961) but that the organisms were in some way useful in agricultural soils (Stout and Heal, 1971, Kasi Viswanath and Pillai, 1961), although the nature of their usefulness was not clear (Sandon, 1927; Umbreit 1962; Dogiel, 1965: Darbyshire, 1975).

Work on the biochemistry of sewage and soil has been going on for many years in Indian Institute of Science, Bangalore (Pillai *et al.*, 1971) and it was observed, among other things, that some of the protozoa derived from the soil were exteremely useful in the process of sewage purification by their ability to flocculate the sewage colloids most efficiently (Pillai, 1941; 1952; Pillai *et al.*, 1960; 1975). The researches on the mechanism of sewage purification led to a study of the influence of some of the soil protozoa, *e.g.*, the species of *Colpoda*, *Colpidium* and *Vorticella*, on soil aggregation, a process somewhat similar to the flocculating or clarifying action of activated sludge.

The present paper gives a brief account of some of the experiments on the influence of protozoa on soil aggregation.

Material and Methods

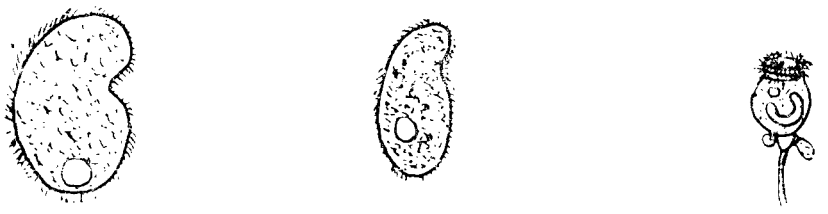
The materials used were sand, clay, soil and sewage. The sand was obtained from a river bed. The fraction of the sand that passed through 40-mesh sieve and retained on 70-mesh sieve was washed in acid (1 : 1 H_2SO_4), dried & used.

The clay used was bentonite clay: two varieties of clay, one whitish grey and the other reddish brown, which were obtained from the Karnataka State Department of Mines and Geology. Both the varieties of clay were powered and the materials that passed through 300-mesh sieve were used. In addition to these varieties of clay, the finally suspended clay and other erodible portion of the surface soil (collected soon after a heavy rain) was also used in some experiments.

The soil used was Bangalore soil, a red loam, with about 23 per cent clay, 25 per cent silt and 49 per cent sand.

The sewage used was from the sewage works at this Institute.

A new medium (agricultural medium) was developed for the cultivation of the protozoa, the composition of which has been described (Kasi Viswantah and Pillai, 1974). This medium consists of aqueous extracts of organic matter (straw, leaf, cowdung and groundnut cake) and inorganic materials (ammonium sulphate and superphosphate) in certain proportions. The cultures of ciliate protozoa *Colpoda cucullus*, *Coipidium colpoda* and *Vorticella microstoma* (Fig. 1) which are among the commonest forms of protozoa in all soils of the world, were isolated from the garden soil at the Institute. The details of the media for the bacteria, actinomycetes, fungi and algae have also been described (Kasi Viswanath and Pillai, 1974).



COLPODA CUCULLUS (87μx 300) | COLPIDIUM COLPODA (100μx 225) | VORTICELLA MICROSTOMA (x 250)

FIG. 1. THREE OF THE COMMONEST FORMS OF CILIATE PROTOZOA IN THE SOIL

The culture of mixed becteria was prepared by inoculating 100 mg of the Bangalore soil into 300 ml nutrient broth taken in 500 ml conical flask. The flask was shaken on a rotary shaker (200 rpm) for 18 hours. At the end of aeration for 18 hours, the contents to the flask were centrifuged at 200 rpm for 10 minutes. The sediment formed was washed with distilled water.

Water stable aggregates formed in the systems containing sand, mixtures of the sand and clay, the soil and the mixtures of the soil and clay were determined by the method standardised in this laboratory (Kasi Viswanath and Pillai, 1968a, 1973).

The turbidity of the suspensions of clay was measured in Klett-Summerson photoelectric calorimeter with the aid of a violet filter (420 m).

Experiments and Results

Extent of aggregation of sand and mixtures of sand and clay by bacteria and protozoa

In two series of 6 petri dishes each, 50 g sand, 40 g sand and 10 g bentonite (whitish gray variety) were taken. 10 g clay, *i.e.*, as 20 per cent of the mixtures, was used because Bangalore red soil, which was employed in most of the experiments, contained about 20 per cent clay.

The contents of all these Petri dishes were mixed with the agricultural medium (25 ml for each dish) and the Petri dishes were autoclaved, allowed to cool at room temperature and were inoculated with a loopful of the culture of mixed bacteria and the ciliate protozoan, *Colopoda cucullus.* The petri dishes were kept on a laboratory bench (at room temperature 26°C) for five days. The period of five days was fixed in this and other experiments for three main reasons.

First, it was earlier observed that the protozoa multiplied to largest numbers generally after 3 days and thereafter their numbers decreased after five days. Second, it was reported that in the soils treated with organic substances, generally the maximum bacterial numbers were recorded after 4 days (Myers and McCalla, 1941). Third, it was thought that the principle of 5-day BOD (Biochemical Oxygen Demand) determination could be applied here.

At the end of five days, the contents of the petri dishes were transfered to 250 ml beakers with 250 ml distilled water and were allowed to stand overnight and wet sieved (Table I and II). Since there was no aggregation of sand only, the results are not given here.

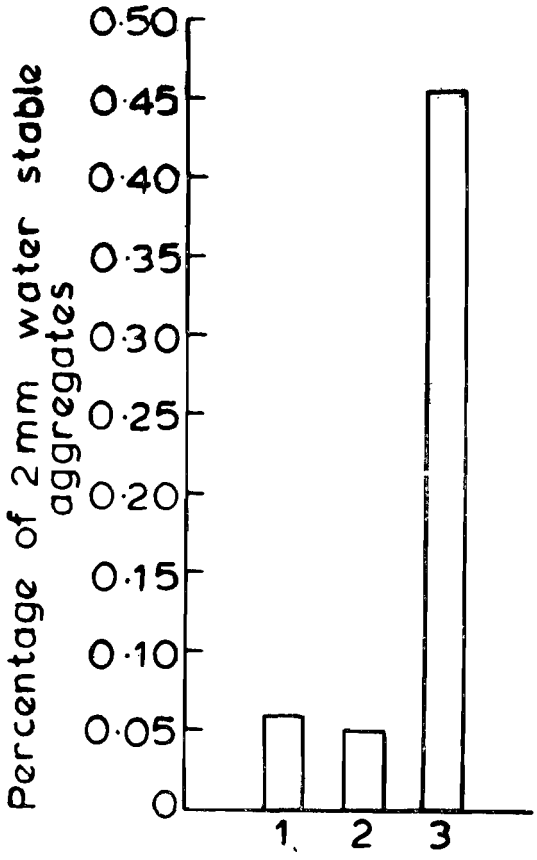
Table I

Influence of mixed soil bacteria and the protozoan Colpoda cucullus *on aggreation of mixtures of sand and clay*

Treatment	Size of aggregate (mm) 0.25	0.50	1.00	2.00	Total percentage
Mixture of sand and clay in "agricultural medium" :					
Without any inculation (control)	41.80	28.80	0.42	0.07	71.09
Inoculated with mixed soil bacteria	64.40	6.00	0.48	0.05	70.93
Inoculated with *Colpoda cucullus*	48.60	18.60	0.54	0.47	68.21

In explaining the results given in Table I, it has to be remembered that although the size of the sand used in the experiment was between 0.25 mm and 0.50 mm (40–70 mesh), the proportion of the different particle sizes within these limits in the samples may vary considerably and, for this reason, the variations recorded in this table refer to the sand particles or fractions of 0.25 mm and

0.50 mm are not to be considered as aggregates. Moreover, when these particles were powdered and put in distilled water, the water did not become turbid, suggesting that they were merely primary particles and not aggregates of sand and clay. True aggregates formed as a result of bacterial or protozoae activity are those of 1 mm and 2 mm diameter. When these aggregates wern powdered and put into water, the water turned turbid indicating that the clay, and only the clay, in the mixtures of sand and clay was aggregated by the organisms. Between the mixed bacteria and the protozoan, *Colpoda cucullus*, the latter was by far more efficient (over 9 times) in the formation of aggregates larger than 2 mm (Fig. 2).



1. SAND AND CLAY ONLY. (CONTROL)

2: SAND AND CLAY INOCULATED WITH MIXED SOIL BACTERIA.

3: SAND AND CLAY INOCULATED WITH THE PROTOZOAN COLPODA CUCULLUS.

Fig. 2 Relative influence of mixed soil bacteria and the protozoan *Colpoda cucullus* on the formation of 2 mm aggregates from the mixtures of sand and clay

In the next series of experiments, the sand and different percentages of clay were used.

Extent of aggregation by the mixed soil bacteria and the protozoan Colpoda cucullus ***in the mixtures of sand and different percentages of clay***

In this series, sand and clay were mixed in the following proportions (sand : clay per cent) : 95 and 5 ; 90 and 10 ; 85 and 15 ; 80 and 20 ; and 60 and 40. The amount of clay was varied to study the efficiencies of the organisms in the aggregation, as it was becoming increasingly clear that the main material to be aggregated in the soil is clay.

All these mixtures were taken in Petri dishes and were autoclaved with 25 ml "agricultural medium". After the Petri dishes were cooled, the mixtures were inoculated with the mixed soil bacteria and ciliate protozoan *Colpoda cucullus* in the manner described above. At the end of five days, as in the earlier series, the mixtures were wet sieved. Since the sand fractioned used was not uniform, as pointed out earlier, only the aggregates of 1 mm and 2 mm were considered (Table II and Fig. 3).

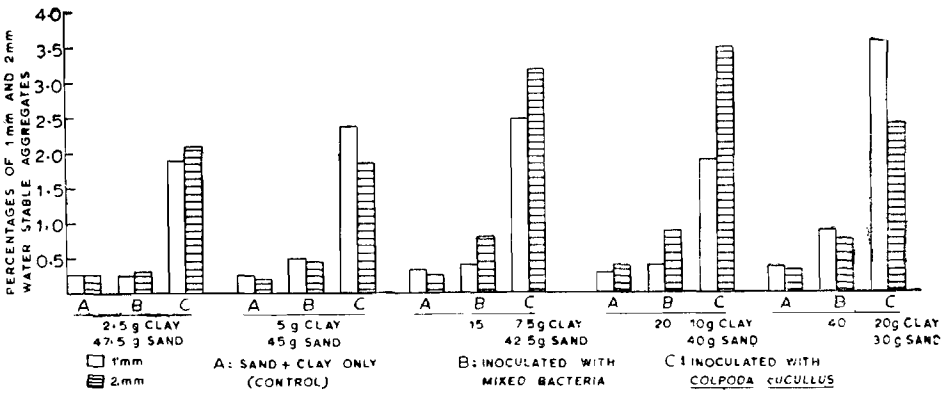


FIG.3. INFLUENCE OF MIXED SOIL BACTERIA AND THE PROTOZOAN COLPODA SP ON THE FORMATION OF 1mm AND 2mm AGGREGATES FROM SAND AND CLAY

The results (Table II and Fig. 3) confirm the observation that the protozoan *Colpoda cucullus* is strikingly more efficient in bringing about the formation of 1 mm and 2 mm aggregates in the different mixtures containing various amounts of clay and sand. The efficiency of the protozoan was 7 to 9 times higher than that of the mixed bacteria in the formation of 2 mm and 1 mm aggregates in the mixture containing 5 per cent clay and 95 per cent sand. The much higher efficiency of the protozoan than the mixed bacteria in this respect may also be seen in the other mixtures containing greater amounts of clay.

Further experiments of the above lines were carried out, using Bangalore red soil.

TABLE II

Influence of mixed soil bacteria and Colpoda cucullus *on aggregation of mixtures of sand and clay in "agricultural medium"*

Treatment		size of aggregates (mm) 1.00 mm			2.00 mm		
		A	B	C	A	B	C
Sand and clay mixed in the proportions of: Sand	Clay						
95	5	0.2	0.2	1.9	0 2	0.3	2.1
90	10	0.2	0.4	2.4	0.1	0.5	1.8
85	15	0.3	0.4	2.5	0.2	0.8	3.2
80	20	0.2	0.4	1.9	0.4	0.8	3.5
60	40	0.4	0.9	4.1	0.3	0.4	2.9

A : Control; B : Mixed soil bacteria; C : *Colpoda cucullus*

Influence of mixed soil bacteria and Colpoda cucullus *on the formation of water stable aggregates in soils treated with different forms of organic matter and inorganic fertilisers.*

In this experiment Bangalore red soil passed through 4 mm sieve was used. 50 g soil taken in a series of Petridishes was mixed with 25 ml of the following: (1) distilled water; (2) straw extract; (3) cowdung extract; (4) leaf extract; (5) groundnut cake extract; (6) ammonium sulphate (100 mg/l) and superphospate (50 mg/l); and (7) "agricultural medium". The following amounts of the organic materials were separately taken in a litre of distilled water and boiled for ½ hour: 3.5 g straw; 3.5 g cowdung; 3.5 g leaf powder; and 1 g groundnut cake. The Petridishes containing the soil and the media were autoclaved three times on alternate days to ensure sterility.

Mixed bacteria (0.5 ml of the washed suspension) and cells of *Colpoda cucullus* (0.5 ml) were inoculated into the series of Petridishes. At the end of five days of incubation at room temperature (24° to 25°C), the contents of the Petridishes were wet sieved.

The results (Table III) show that although there were not striking differences in the total percentages of water stable aggregates in the soil, the protozoan invariably caused an increase in the aggregates. Since all the soil samples were repeatedly autoclaved soil aggregation should have occurred to an appreciable extent even before the start of the experiment (Kasi Viswanath and Pillai, 1968 a; 1972). This also raises the point about the use of soil as such in the study of soil aggregation, particularly where soil samples have to be autoclaved in experiments on the efficiency of specific organisms in the formation of water stable aggregates.

TABLE III

Treatment	Size of aggregates (mm) 0.25	0.50	1.00	2.00	Total percentage
I Soil + water	20.4	7.4	1.0	1.6	30.4
with mixed bacteria	20.9	8.1	1.0	1.4	31.4
with *Colpoda cucullus*	21.2	8.4	1.9	0.9	32.4
II Soil + straw extract	20.2	8.9	1.2	1.2	31.5
with mixed bacteria	20.9	11.4	2.1	1.9	36.3
with *Colpoda cucullus*	25.4	8.4	5.1	0.9	39.8
III Soil + cowduney extract	21.4	8.7	1.1	0.9	32.1
with mixed bacteria	20.7	9.2	1.9	3.4	35.2
with *Colpoda cucullus*	27.2	4.9	4.4	5.1	41.6
IV Soil + leaf extract	21.4	7.9	0.4	1.1	30.8
with mixed bacteria	21.7	9.2	2.1	0.7	33.7
with *Colpoda cucullus*	24.1	8.7	3.7	1.9	38.4
V Soil + groundnut cake extract	22.8	4.2	0.9	1.1	29.0
with mixed bacteria	24.1	5.2	1.1	1.2	31.6
with *Colpoda cucullus*	29.1	5.3	0.7	1.8	36.9
VI Soil+ammonium sulphate+superphosphate	18.1	7.1	Nil	Nil	25.2
with mixed bacteria	18.4	7.0	Nil	Nil	25.4
with *Colpoda cucullus*	18.0	7.9	Nil	Nil	25.9
VII Soil + "agricultural medium"	20.7	4.7	1.7	2.1	29.2
with mixed bacteria	24.1	9.4	1.9	2.9	38.3
with *Colpoda cucullus*	30.2	9.5	2.7	4.1	46.5

In view of the above results, it was thought useful to add different amounts of clay to the soil samples and then carry out the autoclaving. Experiments with the different amounts of clay mixed with the soil are next considered.

Influence of mixed bacteria and Colpoda cucullus *on aggregation of different amounts of clay added to the soil*

For this experiment a relatively finer fraction of the Bangalore red soil was used so that it could mix more intimately with the added clay (red variety bentonite, powdered and passed through 120–mesh sieve). The soil that had been passed through 40–mesh sieve and the fraction retained on 70–mesh sieve was used. The soil was mixed with the clay in Petridishes in the following proportions and each of these mixtures was treated with 30 ml "agricultural medium" and autoclaved (repeatedly as in the previous experiments).

Soil (g)	Clay (g)
47.5	2.5
45.0	5.0
42.5	7.5
35.0	15.0
30.0	20.0
25.0	25.0

Only the "agricultural medium" was used as the source of energy for the microoganisms because, among the different materials used in the previous experiment, this medium gave the highest percentage of water stable aggregates. Petri dishes were inoculated with the mixed soil bacteria and *Colpoda cucullus* and were allowed to remain for 5 days at room temperature (26°C). At the end of 5 days, the contents were wet sieved (Table IV).

TABLE IV

Influence of mixed bacteria and Colpoda cucullus *on aggregation of clay added to the soil*

	Treatment	Size of aggregates (mm) 0.25	0.50	Total percentage
I	Soil + "agricultural medium"	13.7	14.2	27.9
	with mixed becteria	14.4	12.1	26.5
	with *Colpoda cucullus*	18.5	15.2	33.7
II	Soil + "agricultural medium" + 5 per cent clay	14.1	13.9	28.0
	with mixed bacteria	14.7	13.9	28.6
	with *Colpoda cucullus*	18.2	18.1	36.3
III	Soil + "agricultural medium" + 10 per cent clay	14.9	14.1	29.0
	with mixed bacteria	14.9	14.6	29.5
	with *Colpoda cucullus*	18.9	16.7	35.6
IV	Soil + "agricultural medium" + 15 per cent clay	14.2	13.2	27.4
	with mixed bacteria	14.2	13.9	28.1
	with *Colpoda cucullus*	18.4	16.7	35.1
V	Soil + "agricultural medium" + 30 per cent clay	14.9	13.9	28.8
	with mixed bacteria	14.1	14.9	29.0
	with *Colpoda cucullus*	14.8	19.4	34.2
VI	Soil + "agricultural medium" + 40 per cent clay	15.3	13.4	28.7
	with mixed bacteria	14.4	14.2	28.6
	with *Colpoda cucullus*	19.4	19.7	39.1
VII	Soil + "agricultural medium" + 50 per cent clay	14.9	16.4	31.3
	mixed bacteria	17.1	12.9	30.0
	Colpoda cucullus	18.9	19.4	38.3

The results (Table IV) show (1) that *Colpoda cucullus* brought about a higher percentage of water stable aggregates than the mixed bacteria, and (2) that, with increasing amount of clay in the mixture, there was an increase in total percentage of water stable aggregates, although this increase was not in conformity with amount of added clay.

Since the aggregating effect of the mixed bacteria was not appreciable, one of the commonest bacteria in soil, *Pseudomonas fluorescens* was used in a further series of experiments to compare its efficiency with that of *Colpoda cucullus*. Martin and Waksman (1940) and Swaby (1949) studied the aggregating effect of this bacterium. Swaby also pointed out that most workers have tried to interpret "field phenomena" by experiments with pure cultre of microorganisms, often especially selected because they possessed good aggregating properties; that little account was taken of the fact that the soil contains numerous organisms all competing with one another; and that no attempt was made to estimate the relative proportion of microorganisms beneficial, useless or harmful to aggregation, that are present in soil after the addition of organic materials. Salonius *et al.* (1967) confirmed that species of *Pseudomonas* are among the commonest bacteria in soil.

Influence of the bacterium Pseudomonas fluorescens ***and*** Colpoda cucullus ***on the formation of water stable aggregates in the soil***

In this series of experiments the soil was not autoclaved. The particle size of the soil was finer (passed through 120–mesh sieve) than the soil used in the earlier experiments. 20 g soil was taken in each of a series of four Petridishes, which were treated with the following: (1) 15 ml bactotryptone medium, (2) 15 ml bactotryptone medium and a loopful of *Pseudomonas fluorescens* (3) 15 ml "agricultural medium", and (4) 15 ml "agricultural medium" and a loopful of *Colpoda cucullus*. The petri dishes were kept at room temperature for 3 days and the contents of Petridishes were wet sieved.

The results (Table V) show that both the bacterium and the protozoan

TABLE V

Influence of Pseudomonas fluorescens *and* Colpoda cucullus *on the formation of water stable aggregates*

Treatment	Size of aggregates (mm) 0.25	0.50	1.00	Total percentage
Soil + bactotryptone medium	4.38	Nil	Nil	4.38
Soil + bactotryptone medium + *Pseudomonas fluorescens*	20.88	1.48	Nil	22.36
Soil + "agricultural medium"	12.84	1.32	Nil	14.14
Soil + "agricultural medium" + *Colpoda cucullus*	34.75	4.44	0.31	39.50

caused considerable increases in the total percentage of water stable aggregates with reference to control media. Here again the protozoan proved much more efficient than the bacterium in briting about soil aggregation.

In the next series of experiments, instead of unsterilised soil samples, autoclaved soils were used to study the soil aggregation by the cultures of these and other organisms.

Influence of Pseudomonas fluorescens, Arthrobacter ***sp.,*** Bacillus ***sp.,*** Colpoda cucullus ***on the formation of water stable aggregates in the soil***

In this experiment the soil that passed through 2.00 mm (10–mesh sieve) and the following cultures of bacteria and protozoan were employed : *Pseudomonas fluorescens*, *Arthrobacter* sp., *Bacillus* sp., and *Colpoda cucullus*. Samples of 50 g soil were taken in 6 Petri dishes, four of which were treated with nutrient broth (30 ml each), and two of which were treated with an aqueous extract of 0.1 per cent groundnut (30 ml of the extract). All the Petri dishes were autoclaved as indicated earlier and 4 of them were inoculated with a loopful each of the above mentioned bacteria and the protozoan. The other two Petri dishes served as controls. The six petri dishes were kept at room temperature, 26°C, for 5 days, After this period, the contents of the Petri dishes were wet sieved.

The results (Table VI) indicate (1) that none of the bacteria added to the autoclaved soil, containing nutrient broth, brought about any aggregation of the soil; and (2) that the protozoan *Colpoda cucullus* added to the autoclaved soil, containing groundnut cake extract, caused an increase of 18.6 per cent (over the corresponding control) in the water stable aggregates.

TABLE VI

Influence of Pseudomonas fluorescens, Arthrobacter *sp.*, Bacillus *sp. and* Colpoda cucullus *on the formation of water stable aggregates in the soil*

Treatment	Size of aggregates (mm) 0.25	0.50	1.00	2.00	Total percentage
Soil + nutrient broth	66.6	6.4	2.4	2.2	77.6
Soil + nutrient broth + *Pseudomonas fluorescens*	54.6	10.2	9.4	2.4	76.6
Soil + nutrient broth + *Arthrobacter* sp.	63.6	7.4	5.0	3.2	79.2
Soil + nutrient broth + *Bacillus* sp.	64.6	8.0	3.2	0.8	76.6
Soil + groundnut cake extract	49.8	4.8	2.4	7.6	64.6
Soil + groundnut cake extract + *Colpoda cucullus*	64.4	3.4	5.8	3.0	76.6

This observation on the formation of water stable aggregates in the soil by the ciliate protozoan *Colpoda cucullus* led to a further series of experiments, one of which is described below.

A further experiment with Colpoda cucullus

A loopful of this organism was introduced into 20 g unsterilised soil that passed through 120–mesh sieve along 15 ml "agricultural medium" taken in a Petri dish. A similar Petri dish with the same amount of the soil and the medium but without the introduction of the protozoan was maintained as the control. After five days of incubation of the Petri dishes at room temperature, 26°C, the contents of the Petri dishes were wet sieved.

The results (Table VII) further confirm the remarkable efficiency of the protozoan *Colpoda cucullus* in the formation of water stable aggregates in the soil. Introduction of this organism into the unsterilised soil increased the water stable aggregates by 96 per cent over the soil which the protozoan was not introduced.

TABLE VII

Influence of the protozoan Colpoda cucullus *on the formation of water stable aggregates in the soil*

Treatment	Size of aggregates (mm) 0.25	0.50	1.00	Total pereentage
So.l + "agricultural medium"	0.23	0.63	Nil	0.86
Soil + "agricultural medium" + *Colpoda cucullus*	0.95	0.63	0.10	1.68

Although *Colpoda cucullus* appeared to be a most efficient organism in the formation of water stable aggregates, it was considered necessary to search for other organism involved in the vital process of soil aggregation. In this connection, half a dozen microorganisms, which are representative of actinomycetes, yeasts, and protozoa were tried, along with bacteria and the protozoan already used. The details of this study are given below.

Extent of soil aggregation by representative forms of bacteria, actinomycetes, yests, fungi, algae and protozoa

Samples (20 g) of the soil that passed through 120–mesh sieve were taken in a series of Petri dishes and 10 ml "agricultural medium" was added to each of them. All the Petri dishes were autoclaved. A loopful each of the cultures of bacteria (*Pseudomonas fluorescens, Arthobacter* sp. and *Bacillus* sp.) actinomycetes (*Streptomyces* sp., and *Nocardia* sp.), yeast (*Saccharomyces* sp.), fungus (*Aspergillus* sp.), alga (*Euglena* sp.) and protozoa (*Colpoda cucullus*) and *Colpidium colpoda* was inoculated into the Petridishes which remained at 26°C for 5 days. At the end of incubation period of 5 days, the contents of the Petri dishes were sieved.

The results (Table VIII and Fig. 4) show that, among the different microorganisms tested, the soils inoculated with the protozoa (*Colpoda cucullus*) and

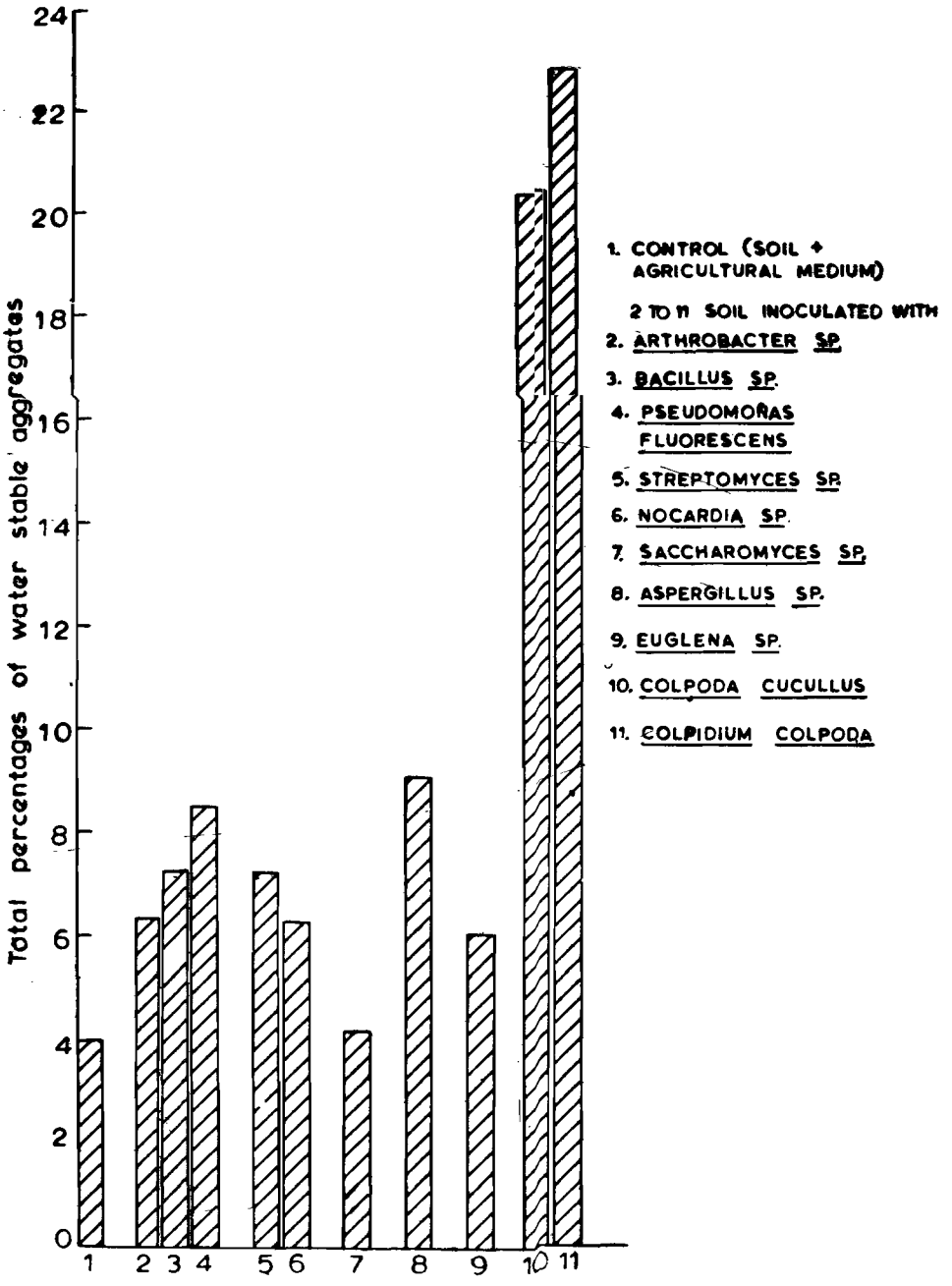


FIG. 4. INFLUENCE OF DIFFERENT MICROORGANISMS ON THE FORMATION OF WATER STABLE AGGREGATES

Colpodium colpoda) contained the maximum percentage of the total water stable aggregates, which was 2.5 times more than the bacteria, 3 times more than the actinomycetes, 5 times more than the yeast, 2.3 times more than the fungus and 3.3 times more than the alga.

In all the above experiments with the soil and microorganisms it was observed that no two experiments with the same soil samples and the same cultures of microorganisms gave consistent or reproducible results and that in fact, they gave results which varied very widely. For example, the experiments with *Colpoda cucullus*, the most efficient organism so far tested in soil aggregation showed the increases in the water stable aggregates with this protozoan varied from 18 to 180 per cent. This variation in the microbial activity and indeed in the behaviour of soil itself is traceable to the clay, the finest fraction in the soil to be aggregated (Kasi Viswanath and Pillai, 1972). In the light of these and othor observations it appeared desirable to use a suspension of clay in water for experimental purposes to obtain reproducible results.

TABLE VIII

Influence of different groups of microorganisms on the formation of water stable aggregates in soil

Microorganism	Size of aggregates (mm) 14.1 0.25	4.2 0.50	2.1 1.00	Total percentage
Colpodium colpoda	12.4	7.2	3.2	22.8
None :				
Soil + "agricultural medium"	1.4	2.4	0.2	4.0
Bacteria :				
Arthrobacter sp.	2.4	3.9	0.1	6.4
Bacillus sp.	4.1	2.9	0.3	7.3
Pseudomonas fluorescens	5.7	2.4	0.4	8.5
Actinomycetes :				
Streptomyces sp.	4.9	2.1	0.2	7.2
Nocardia sp.	3.7	2.2	0.4	6.3
Yeast :				
Saccharomyces sp.	1.9	2.2	0.1	4.2
Fungus :				
Aspergillus sp.	5.4	2.9	0.8	9.1
Alga :				
Euglena sp.	3.7	2.1	0.3	6.1
Protozoa :				
Colpodo cucullus	14.1	4.2	2.1	20.4
Colpodium colpoda	12.4	7.2	3.2	22.8

Experiments with different microorganisms using aqueous suspensions of clay and organic matter

For two of the following three experiments, an aqueous suspension of the

clay (whitish grey bentonite) that passed through 300–mesh sieve at a concentration of 1 mg clay per ml and for the other experiment, the runoff water (soon after a heavy rain) from a gradient land near the laboratory, consisting mostly of the soil clay, were employed.

In the first experiment, the clay suspension contained 10 per cent boiled sewage (boiled for half hour) as the source of nutrition to the different microorganisms inoculated. The organisms inoculated were a loopful of the cultures of *Pseudomonas fluorescens*, *Arthrobacter* sp., *Bacillus* sp.(all bacteria), *Streptomyces* sp. and *Nocardia* sp. (actinomycetes), *Saccharomyces* sp. (yeast), *Aspergillus* sp. (fungus), Euglena sp. (alga), *Colpoda cucullus*, *Colpidium colpoda* and *Vorticella microstoma* (all ciliate protozoa).

In the second experiment, to the bentonite clay suspension, defatted groundnut cake (0.1 per cent) and superphosphate (0.01 per cent) were added and the suspension was steam sterilised. The organisms used in the previous experiment were inoculated in the suspensions taken in a series of conical flasks of 250 ml capacity.

In the third experiment, the rain water (90 ml) with the clay and other erodible finer fractions of the soil was mixed with 10 ml sewage and steam sterilised. To the sterilised rain water and sewage mixture, the different microorganisms were inoculated.

After inoculation, the suspensions taken in conical flasks were shaken on a rotary shaker (200 rpm) for 5 days. At intervals of 24 hours, the turbidity of the supernatant liquids was measured. The values for turbidity of the supernatant liquids would give an idea of the extent of flocculation or aggregation of the suspended and colloidal matter that had been brought about as a result of the activities of the inoculated organisms. The amounts of the sediments from these suspensions were too little for wet sieve analysis.

The entire series of experiments were repeated and the values for turbidity (percentage reduction) of the supernatant liquids from the different flasks are given in Tables IX to XI. The results given in Tables IX to XI, unlike those of all the earlier experiments using sand, sand and clay, soil, and soil and clay and with different microorganisms, show that the experiments with the suspensions gave consistent or reproducible results. Moreover the results also further confirm that the ciliate protozoa are by far the most efficient in flocculating or aggregating the clay in the soil.

Discussion

In considering the influence of protozoa on soil aggregation it is necessary to indicate the growth of ideas on the microbiolgiocal nature of soil aggregation.

TABLE IX

Influence of different microorganisms on the flocculation of bentonite clay suspensions aerated with boiled sewage (10% v/v)

Microorganism	percentage of reduction in turbidity values at the end of aeration for 24 hr		48 hr		72 hr		96 hr		120 hr	
	I	II	I	II	I	II	I	II	I	II
Bacteria:										
Pseudomonas fluorescens	20	18	57	49	58	56	58	56	58	56
Arthrobacter sp.	22	21	53	52	55	52	55	52	55	52
Bacillus sp.	24	22	57	55	59	57	59	57	59	57
Actinomycetes:										
Streptomyces sp.	35	38	57	59	57	59	57	59	57	59
Nocardia sp.	39	41	53	53	58	59	58	59	58	59
Yeast:										
Saccharomyces sp.	18	21	32	30	35	33	35	33	35	33
Fungus:										
Aspergillus sp.	40	42	56	54	57	56	57	56	57	56
Alga:										
Euglena sp.	23	21	33	30	36	33	36	33	36	33
Protozoa:										
Colpoda cucullus	41	45	81	79	84	86	82	84	84	86
Colpodium colpoda	44	40	85	82	87	85	87	85	87	85
Vorticella microstoma	45	43	88	90	93	91	93	91	93	91

II is repetition of experiment I

Kanivetz *et al.* (1937) were the first to report the improvement of soil structure by the inoculation of microorganisms such as *Trichoderma lignorum, Aspergillus niger* to the soil and they found that both the microorganisms, after composting, increased the quantity of soil aggregates resistant to the disintegrating action of water. Waksman and Martin (1939) and Martin and Waksman (1940) demonstrated the binding effect of microorganisms (bacteria and fungi) on the fine particles in sand-bentonite mixtures and the soil.

Myers and McCalla (1941) followed the changes in soil aggregation in relation to bacterial numbers, hydrogen-ion concentration and length of time soil was kept moist and reported, (1) that the miximum aggregation occurred on the 8th day followed by a continuous decline in the percentage of the soil aggregated, reaching after 47 days a level approximating that of untested soils on the first analysis date; (2) that in no instance the maximum bacterial population corresponded with the maximum aggregation; (3) that there was a distinct tendency for the degree of aggregation to lag behind the change in the

TABLE X

Influence of different microorganisms on the flocculation of bentonite clay suspension aerated with 0.1 per cent groundnut cake extract and 0.01 per cent superphospate

Microorganism	Percentage reduction in the values for turbidity after acration for 24 hr		48 hr		72 hr		96 hr		120 hr	
	I	II	I	II	I	II	I	II	I	II
Bacteria :										
Pseudomonas fluorescens	22	19	48	50	55	53	55	53	55	53
Arthrobacter sp.	18	20	49	52	55	52	55	52	55	52
Bacillus sp.	21	23	51	50	51	52	52	51		
Actinomycetes :										
Streptomyces sp.	31	34	55	58	55	58	55	58	55	58
Nocardia sp.	32	35	51	56	52	56	52	56	51	56
Yeast :										
Saccharomyces sp.	17	15	28	27	30	32	30	32	30	32
Fungus :										
Aspergillus sp.	37	39	41	42	52	55	52	55	52	55
Alga :										
Euglena sp.	27	23	35	33	35	33	35	33	33	35
Protozoa :										
Colpoda cucullus	38	42	44	48	82	82	84	82	84	82
Colpidium colpoda	41	39	49	47	84	82	88	82	84	84
Vorticella microstoma	45	45	55	60	93	91	92	91	93	94

II is repetition of the experiment I

bacterial numbers ; and (4) that in the light of their investigation, it appeared that the several studies in the past relating to the effect of soil bacteria on aggregation merely served to report an acceptance of the long established fact that the bacteria of the soil are capable of transforming added organic matter either by partial decomposition or by synthesis, with the consequent effects of these on soil structure.

Martin (1946) isolated polysaccharides from several bacteria, including fructosans from *Bacillus subtilis* and *Azotobacter indicum* and dextrans from *Leuconostoc dextraricus* and two unidentified strains, and found them to be better crumb cement than casein or lignin. These polysaccharides were slowly decomposed by several microorganisms. Mehta *et al.* (1960) showed that aggregates prepared from soil amended with various polysaccharides including microbial polysaccharides from soil were destroyed by periodate treatment but not the stability of the natural of aggregates from a forest soil. Griffiths (1964) stated that based on the evidence presented by Mehta *et al.* (1960) the conclusion that aggregation in that particular soil was not attributable to polysaccharides seemed inescapable and that factors responsible for the high stability from old grassland and the forest soils, however, remain unexplained.

TABLE XI

Influence of different microorganisms on the flocculation of rain water containing suspensions of erodible fractions (clay and other finer particles) from the soil aerated with boiled sewage (10 pet cent v/v)

microorganism	Percentage reduction in turbidity values at the end of				
	24 hr	48 hr	72 hr	96 hr	120 hr
Bacteria :					
Pseudomonas fluorescens	1	32	42	47	51
Arthrobacter sp.	14	30	47	49	51
Bacillus sp.	12	35	46	47	52
Actinomycetes:					
Streptomyces sp.	20	24	47	47	51
Nocardia sp.	18	22	42	44	51
Yeast :					
Saccharomyces sp.	12	18	31	31	32
Fungus :					
Aspergillus sp.	30	35	48	48	51
Alga :					
Euglena sp.	25	35	40	40	41
Protozoa :					
Colpodo cucullus	32	60	75	81	83
Colpidium colpoda	30	60	76	80	83
Vorticella microstoma	35	55	79	85	92

Hubbell (1947) investigated the effect of microorganisms on percolation and found that inoculation of sterilised soil, which lacked aggregates above 0.17 mm, with fungi, actinomycetes, or bacteria showed the rate of percolation and that addition of media (each of these media intended to stimulate the growth of bacteria, actinomycetes and fungi) to unsterilised soil, that had passed through a 2.00 mm sieve, depressed the rate of percolation as compared to that of the check soil.

Swaby (1949) studied the aggregation of soil by pure cultures using seventy fine strains of bacteria, twenty one actinomycetes, fine of "proactinomycetes", fine of yeasts and fifty of fungi and made the following observations (1) that actinomycetes were found to be better aggregators than bacteria, but "proactinomycetes" and yeasts did not cement the soil at all; (2) that in general pure culture of fungi produced for better aggregation than all other microorganisms; (3) that while it was true that microbial threads and gums could largely account for the increased temporary aggregation of soils supplied with readily decomposable organic matter, it was evident that existing fungal and actinomycete hyphae *plus* capsulated bacteria could not account for the aggregation of natural Rothamsted soil to which fermentable material had not recently been added; and (4) that one must therefore conclude that the formation of

more permanent crumbs found in certain soils must be due to other cementing substances, *e.g.*, colloidal clay, humus or resistant gums produced by microorganisms no longer visible.

Harris *et al.* (1966) in their exhaustive review on dynamics of soil aggregation described the aggregation by indigenous populations and stated that aggregates formed by bacteria were small, compact, commonly regular, and possessed smooth edges and surfaces. The aggregates were water stable but fragile and easily crushed ; they rarely exceeded 0.56 mm in diameter. Streptomyces formed fairly compact aggregates which were approximately 2 mm in size and resistant to crushing. Aggregates formed by fungi were spongy, resisted crushing and were rarely smaller than 2 mm. However, characteristics of natural soil aggregates could not be associated with any specific group of microorganisms.

Thus the observations of the earlier investigations also indicate that bacteria, actinomycetes, yeasts, fungi and algae is soils are not effective or sufficiently efficient in the formation of water stable aggregates. However, it has happened that none of the investigators examined the efficiency of any of the soil protozoa, along with the other microorganisms, in soil aggregation, even as it has been increasingly recognised that protozoa are a normal component for soil population.

The immediate reason for investigating the protozoa in soil in this connection was the observation made in this laboratory that some of the protozoa in the soil, which go into sewage, develop vigorously in it under aerobic conditions, particularly in the activated sludge process of sewage treatment, flocculate the suspended and colloidal matter in the sewage and form extremely water stable aggregates of the sludge. This improvement in the knowledge of sewage purification and the application of this knowledge to soil processess have led to a totally new point of view of the protozoa in soil that they have at least a vital role in the formation of water stable aggregates.

References

Alexnader, M., 1961, *Introduction to Soil Microbiology*. p. 112, John Wiley and Sons, Inc., New York. pp 612–616.

Darbyshire, J. F., 1975, Soil protozoa – Animalcules of the substerranean microenvironment in *Soil Microbiology*. pp 147–163, Edited by N. Walker, Butterworths, London.

Dogiel, V. A., 1965, *General Microbiology*. pp 612–616 Revised by Poljansky, J. I. and Chejsin, E. M. Second edition, Clarendon Press, Oxford.

Griffiths, E., 1964, Microbial activity and soil aggregation, *J. agric. Soc.*, **45**: 1–5.

Harris, R. F., Chesters, G. and Allen, O. N., 1966, Dynomics of soil aggregation. *Adv. Agron.*, **18**: 107–169.

HUBBELL, D. S., 1947, Effect of soil aggregates on water movement in two calcareous soils. *Agron. J.*, **39**: 762–770.

KANIVETZ, I. I., KORNEEVA, N. P. AND MOROCHKOVSKII, S. F., 1937, Biochemical methods of structural formation of soils, *Chem at Indus.*, **42**: 565.

KASI VISWANATH, G. AND PILLAI, S. C., 1968, Occurrence and activity of protozoa in soil. *J. Scient. industr. Res.*, **27**: 187–193.

KASI VISWANATH, G. AND PILLAI, S. C., 1968a, Influence of heat on soil structure. *Curr. Sci.*, **37**: 483–487.

KASI VISWANATH, G. AND PILLAI, S. C., 1972, Significance of heating agricultural soils. *Indian J. argic. Sci.*, **42** : 75–80.

KASI VISWANATH, G. AND PILLAI, S. C., 1973, Pretreatment of the soil in the determination of water stable aggregates. *Mys. J. agric. Sci.*, 7: 550–556.

KASI VISWANATH, C. AND PILLAI, S. C., 1974, Influence of clay on soil processes. *Proc. Indian natl. Sci. Acad.*, **40** B : 167–181.

MANWELL, R. D., 1961, *Introduction to Protozoology*. p. 56, Edward Arnold (Publishers) Ltd.

MARTIN, J. P. AND WAKSMAN, S. A., 1940, Influence of microorganisms on soil aggregation and erosion. *Soil Sci.*, **50** : 29–47.

MARTIN, J. P., 1946, Microorganisms and soil aggregation : II. Influence of bacterial polysaccharides on soil structure. *Soil Sci.*, **61**: 157–166.

MEHTA, N. C., STREULI, H., MULLER, M. AND DEUEL, H., 1960, Role of polysaccharides in soil aggregation. *J. Sci. Fd. Agric.*, **11**: 40-47.

MPERS, H. E. AND MCCALLA, T. M., 1941, Changes in soil aggregation in relation to bacteria numbers, hydrogen–ion concentration, and length of time soil was kept moist. *Soil Sci.*, **51** : 189–200.

PILLAI, S. C., 1941, The function of protozoa in the activated sludge process. *Curr. Sci.*, **10**: 84–85.

PILLAI, S. C., 1952, The special significance of certain peritrichous ciliate protozoa in the aerobic purification of sewage. *Indian med. Gaz.*, **87**: 411–414.

PILLAI, S. C., *et al.* 1960, Natural purification of flowing sewage, *Curr. Sci.*, **29**, 461–465.

PILLAI, S. C. AND GANGULY, J. Association with Cama, H. R., *et al.*. 1971, Fifty years of biochemistry at the Indian Institute of Science, Bangalore, *J. scient. industr. Res.*, **30** : 618–639.

PILLAI, S. C., *et al.* 1975, Factors in the purification of flowing sewage and activated sludge process. *Water and Waste Treatment*, **18**, Part I, 36–42 : Part II, 42–44.

RUSSELL, E. J. AND HUTCHINSON, H. B., 1909, The effect of particial sterilisation of soil on the production of plant food. *J agric. Sci.* (Camb), **3**: 111–144.

RUSSELL, E. J. AND GOLDING, J., 1911, Sewage "sickness" in soil and its amelioration by partial sterilisation. *J. soc. chem. Ind.*, **33**: 471–474.

SALONIUS, P. O., ROBINSON, J. B. AND CHASE, F. E., 1967, A comparison of autoclaved and Gamma–irridiated soils as media for microbial colonization expriments. *Plant and soil.*, **27**: 239–248.

SANDON, H., 1927, *The Composition and Distribution of the Protozoan Fauna of the Soil.* p. 59 : *Oliver and Boyd*, London.

SINGH, B. N., 1961, Recent advances in soil protozoology, in *Recent Advances in Zoology in India*. pp 79–103, Proceedings of the Summer School held in Simla, 1961, Government of India Press, Faridabad, 1963.

STOUT, J. D. AND HEAL, O. W., 1967, Protozoa, in *Soil Biology*. pp 149–195, Editors Burges A and Raw, F., *Academic Press*, New York.

SOABY, R. J., 1949, The relationship between microorganisms and soil aggregation. *J. gen Microbiol.*, 3 : 236–254.

UMBREIT, W. W., 1962, *Modern Microbiology*. p. 301, *W. H. Freeman and Company*, San Francisco and London.

WAKSMAN, S. A. AND MARTIN, J. P., 1939, The role of microorganisms in the concervation of the soil. *Science*, **90** : 304–305.

Relationship between Holozoic Soil Protozoa and Plant Pathogenic Bacteria in Soil

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Predation of microorganisms by protozoa is one of the more dramatic interrelationships among microorganisms in nature. Of the many microscopic inhabitants of soil, bacteria stand out as particularly prone to the attack of predatory protozoa. Protozoa feed upon millions of bacteria and bring about stability in the microbial populations in soil (Alexander, 1961 ; Stout and Heal, 1967).

There is a considerable literature dealing with bacteria as food for ciliates. Some ciliates maintain a high rate and others low rate of feeding, and some die prematurely. Generally, gramnegative bacteria (particularly belonging to the family Entero-bacteriaceae) provide for higher division rates of protozoa than the *Bacillus* spp., (Stout and Heal, 1967). A ciliate *Colpoda steinii* is more commonly occurring species of predatory protozoa in soil.

The species of bacteria which are prone to attack by protozoa are *Aerobacter*, *Agrobacterium*, *Azotobacter*, *Bacillus*, *Escherichis*, *Micrococcus*, *Rhizobium*, *Xanthomonas* and soil *Pseudomonads* Rhizobial strains which were believed to be resistant to the attack of predators (Singh, 1942) have now been reported to be attaked by many ciliates and amoebae (Danso *et al.*, 1975 : Sardeshpande *et at.*, 1977). *R. melilotii* and *R. trifolii* were susceptible to predation by *Colpoda*, *Amoebae*, *Tetrahymena* and other protozoa (Danso *et al.*, 1975). Similarly, *Colpoda* spp., and *Uroleptus* spp., were reported to devour *Rhizobium*

spp., and *Azotobacter chroococcum* (Sardeshpande *et al.*, 1977). Though rhizobia were devoured by many protozoa , their number never went below 10^6 cells/g of soil even when large number of protozoa were present. They attributed this to the inability of the predator to obtain sufficient energy for growth from the sparse supply of prey cells. As the edible cells decline in number, not only is the avaliable nutrient supply diminished, but also, the distance between the survivors is increased, hence the protozoa must move far greater distance to obtain their prey. Alexander (1961) reported that amoebae required about 40,000 bacteria for one cell division. Similary, *Paramecium* required 18,000 cells of *Bacillus* per cell division (Clark, 1969).

Although, there is a considerable literature available on predation of soil bacteria, there is not much information on predation of borne plant pathogenic bacteria. A recent report by Habte and Alexander (1975) on the decline of *Xanthomonas campestris* in the presence of protrzoa has opened pu a new field of research. They reported the decline of *X. campestris* in non-sterile soil in which ciliates and flagellates formed the abundant forms of protozoa.

The role of protozoa. in controlling populations of *Pseudomonas solanacearum*, is being examined in our laboratory. *Pseudomonas solanacearum* is a soil-borne plant pathogen causing vascular wilt of solanaceous crops. This organism is known to survive saprophytically in soil.

Studies on the survival of *Pseudomonas solanacearum*, the causal agent of wilt in solanaceous crops, in two soils namely, red sandy loam soil of Bangalore and black clayey soil of Dharwar indicated that the pathogen survived under non-sterile conditions for 210 days in red sandy loam soil and 180 days in black clayey soil. Such differential survival of the pathogen suggested the probable occurrence of predatory protozoa. The two soils were inoculated with *P. solanacearum* at the rate of 2 ml of the bacterial suspension containing 10^7 cells/ml per ten grams of soil and incubated for a period of one week. It was found that the dominant species of protozoa, that developed in the two soils was *Colpoda steinii*. The protozoa was isolated and tested for its predatory activity, in broth culture, as well as in the two soils. When the pathogen and the predator were suspended in mineral salts medium containing hay extract, it was found that the predator population reached the maximum value of 10^5/ml of broth in three days and gradually declined thereafter. Correspondingly the prey population was reduced from 10^9 to 10^6 cells/ml. With further incubation the predator stopped multiplying and the prey population was reduced to 10^4 to 10^5 cells/ml. This indicated that the predator required a minimum threshold level of the prey above which it could multiply.

Similar studies were also carried out by inoculating the two soils with a known number of *Colpoda steinii* and *P. solanacearum* and incubating them The

data indicated that the predator population increased from 10^4 to 10^6 cells/g of soil in black clayey soil and from 10^4 to 10^5 cells/g of soil in red sandy loam soil during the first 15 days. The corresponding prey populations in the two soils was reduced from 10^9 to 10^6 cells/g in black clayey soil and from 10^9 to 10^8 cell/g of soil. This preliminary data demonstrated the role of holozoic protozoa in regulating the populations of plant pathogenic bacteria in soils. It also showed that the prey population has to be well above 10^4 to 10^5 cells/g of soil for the holozoic protozoa to mutliply. Detailed studies are in progress.

References

Alexander, M., 1961, *Introduction to Soil Microbiology*. John Wiley and Sons, Inc., USA and Toppan company Ltd., Japan, pp. 472.

Clark, F. E., 1969, *Ecological associations among soil microorganisms in, Soil-Biology*. Review of Research (Ed. UNESCO), pp 125–161.

Danso, S. K. A., Keya, S. O. and Alexander, M., 1975, Protozoa and the decline of *Rhizobium* populations added to soil. *Can. J. Microbiol.*, **21** : 884–895.

Habte, M. and Alexander, M., 1975, Protozoa as agent responsible for the decline of *Xanthomonas campestris* in soil. *Appl. Microbiol.*, **29** : 159–164.

Okabe, N., 1969, Population changes of *Pseudomonas solanacearum* and soil microorganisms in artificially infested natural field soils. *Bull. Fac. Agric. Shizuoka Univ.*, **19** : 1–29. (Japanees, English Summary).

Sardeshpande, J. S., Balasubramanya, R. H., Kulkarni, J. H. and Bagyaraj, D. J., 1977, Protozoa in relation to *Rhizobium*, S–12 and *Azatobacter chroococcum*. *Plant and Soil*, **47** : 75–81

Singh, B. N., 1942, Toxic effect of certain bacterial metabolic products on soil protozoa. *Nature*, London, **149** : 168.

Singh, B. N., 1946, A method of estimating the number of soil protozoa, especially amoebae, based on their differential feeding on bacteria, *Ann. Appl. Biol.*, **33** : 112–119.

Singh, B. N., 1949, The effect of artifical fertilisers and dung on the number of amoebae in Rothemsted soil. *J. Gen Microbiol.*, **3** : 204–210.

Stout, J. D. and Heal, O. W., 1967, Protozoa *in Soil-Biology*. (Ed ; Bergess, A. and Raw, F). Academic Press, London and New York, pp. 149–195.

Effect of Multiple Cropping on the Population Dynamics of the Lance Nematode (*Hoplolaimus indicus* Sher, 1963)

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Abstract

The effect of multiple cropping on population dynamics of the lance nematode, *Hoplolaimus indicus* Sher, 1963 was investigated in the irrigated upland area of Central Farm, Orissa University of Agriculture and Technology, Bhubaneswar under normal agroclimatic conditions of the region. Soil samples were collected twice monthly from ten replicated crop rotations and were analysed by Cobb's sieving technique. The year round observations made from January to December, 1975 showed the following: The maximum population build up of the nematode was observed around the month of May (on average, 260.1/250 g of soil), whereas, in February, the nematode number was minimum (averaging 38.1/250 g of soil). The cropping pattern of arhar – ragi – paddy produced the highest numbers on average (152.6/250g of soil), but lowest counts (on average, 57.1/250g of soil) were from the rotation of cauliflower – pumpkin – lady's finger – radish. Caulifiower, pumpkin, radish, groundnut and potato seem to be unfavourable hosts while ragi, paddy, cotton, arhar and maize appear to be more favourable hosts for the lance nematode. Apparently, host type, soil temperature and other ecological conditions influence the activity of this nematode species.

With the introduction of short-duration high-yielding varieties and adoption of new agronomic practices, intensification of agriculture has been possible through multiple-cropping. The shift in emphasis has been on production per unit time rather than production per unit area, as a result of which this system of cropping is rapidly gaining popularity and is suitable for countries like India, where there is longer sunshine hours but limited land area to bear the strain of an ever-increasing population. Such crop management practices, however, have some disadvantages in bringing up unusual pest and disease problems. For nematodes, not much information is available, although such data would be of value in crop planning, studying nematode behaviour and formulating new strategies for their control. Therefore, an attempt has been made here to study the effect of different cropping patterns on the population of a polyphagous and widely distributed nematods specice, *Hoplolaimus indicus*, commonly known as the lance nematode.

Material and Methods

Experimental data for this study were collected from the plots of a replicated (X3) long-term field trial on multiple-cropping conducted by the Agronomy

Department in the irrigated high-land areas of the Central Farm of the University, with sandy-loam type of soil, having a pH range of 5.5 to 6.5 (av. 5.7). Out of twenty crop sequences under test, observations on the following ten crop patterns are presented here.

Crop combinations

1. Ragi (T-20) - Mung (Pusa baisakhi) - Cotton (MCU-5) + Rice (OR45-61-23)
2. Cotton - Arhar (R60-37)
3. Wheat (Kalyan Sona) - Mung - Rice (OR141-192).
4. Ragi - Rice - Wheat
5. Arhar (S-5) - Ragi - Rice (CR141-192)
6. Rice (Annapurna) - Cauliflower (Banaras) - Groundnut (AK12-24)
7. Cauliflower (Snow ball) - Pumpkin (local) - Lady's finger (local) - Radish (local)
8. Cotton - Groundnut
9. Rice (OR45-61-23) - Ragi - Potato (K. chandramukhi) - Maize (Jowahar) - Mung
10. Rice (OR45-61-23) - Mung - Potato - Maize

Fertilizer applications and other cultural operations were different for each crop and had been given according to normal recommendations and farm schedules. The details are available but not given as their interactions were outside the scope of this study. The fields had been separately and differently irrigated but due to lack of uniformity, this factor was not taken into consideration.

For nematode extraction, soil samples were collected twice every month, throughout the year of 1975, which represented the third year running for the experiment. On each occasion, three probes were taken at random from each plot and soil samples were taken mostly from the 7.5 - 30 cm horizon. They were mixed in the laboratory, and by cone and quarter method, an aliquot of 250 ml of soil was obtaining and processed through Cobb's screening technique. and extracted by a improved Baermann funnel method (Schindler, 1961). After 48 hours, the nematode suspensions were recovered, and concentrated to about 10 ml. The nematodes were then killed and fixed by adding an equal volume of 5 per cent hot formalin into nematode suspension contained in 30 ml specimen tubes. One drop of glycerine was added to each specimen tube containing 20 ml of nematode suspension (finally in 2. 5 per cent formalin) before corking and storing the samples for future use.

Population densities of lance nematodes were estimated by counting their number in each nematode suspension with a stereoscopic microscope.

The experimental data were subjected to two-way statistical analysis to find the effect of months and crop sequences and their possible interaction on the population of lance nematodes.

Monthly meteorological data for the year 1975 have been presented in Table I.

TABLE I

Monthly meteorological data of 1975 for Bhubaneswar

Month	Temperature in °C Max.	Min	Mean	Sun shine hours/day	Humidity % Morn.	Even.	Mean	Total rainfall (in mm)	Soil Temperature °C (corrected) Morning 5cm	15cm	30cm	Evening 5cm	15cm	30cm
January	27.6	14.3	20.9	9.5	91	40	65	–	17.0	18.7	21.1	29.8	25.6	22.6
February	30.2	18.9	24.5	8.8	92	45	68	40.4 (4 days)	20.9	22.0	23.8	31.6	28.1	25.3
March	34.6	22.5	28.5	9.4	90	42	66	15.5 (4 days)	24.7	25.8	27.6	36.0	32.9	29.4
April	36.0	25.8	30.9	8.8	86	49	67	8.6 (3 days)	28.7	29.4	30.8	41.8	37.5	33.1
May	38.1	27.1	32.6	9.2	80	45	63	26.0 (3 days)	31.8	32.7	34.3	46.3	41.6	37.0
June	35.7	26.8	31.2	6.0	82	60	71	251.6 (16 days)	30.5	31.3	32.6	39.4	37.1	34.5
July	32.0	25.6	28.7	4.5	92	78	84	181.1 (19 days)	28.1	28.6	29.6	33.6	32.5	30.8
August	30.9	25.5	28.2	4.2	93	82	87	382.0 (21 days)	27.8	28.5	29.2	32.3	31.2	30.2
September	31.5	25.2	28.3	6.0	92	78	85	246.0 (20 days)	27.8	28.5	29.3	33.9	32.4	30.6
October	32.2	24.3	28.2	7.3	93	74	83	173.7 (20 days)	27.3	28.0	29.0	34.0	32.4	30.4
November	27.9	17.3	22.6	7.4	85	50	67	44.6 (17 days)	20.0	21.7	23.5	27.6	26.3	24.8
December	27.3	13.0	20.2	9.7	88	35	61	–	15.6	17.8	19.9	27.3	24.9	21.7

RESULTS AND DISCUSSION

Monthly population counts of *H. indicus* against each of the ten cropping patterns studied have been summarized in Table II. Results indicate that various crop sequences influenced the population of the nematode differently. On the average, maximum numbers occurred with the crop combination, Arhar-Ragi-Rice, closely followed by the rotation, Ragi-Mung-Cotton + Rice and cotton-Arhar, the average figures of which were highly significantly different to the

TABLE II

Average monthly recovery of Hoplolaimus indicus *from field plots under different croping patterns (1975) per 250 g of soil*

Crop patterns No.	Months												
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
H.L	21	28	17.5	214.5	354	66	376	114.5	181.5	149.5	152	69	145.2
2.	121	132.5	76	145	375	15	134.5	53.5	119.5	68.5	187	285.5	142.7
3.	84	35.5	48.5	8	37.5	30	146	63	141.5	88	42.5	59.5	65.3
4.	39	31.5	11	27	251.5	25	54.5	20	33	76.5	110.5	15	57.7
5.	75	27	103.5	65	823	21	260.5	106.5	107	208	16.7	18	152.6
6.	10	30	39.5	14	152	30	45.5	50	67	300.5	19.5	9	63.9
7.	20	10.5	25	12	193	67	85	88	75.5	57.7	39.5	18	57.1
8.	36	44.5	118	57	62.5	50	41	128	65	68	23	24.5	59.7
9.	65	11.5	10.5	104.5	49.5	90	198.5	33.5	15	22	28	14.5	57.7
10.	122	29.5	10.5	143	303	26	79	49.5	165	15	29.5	66	85.6
Mean	69.3	38.1	46	79	260.1	42	142.1	70.1	97	105.3	63.8	57.8	—

C.D. (0.01) : For Columuns – 5.2 : For Rows – 65.2 ; For the Table – 268

Natural population of *H. indicus* in the region : 0–118 (av.21) / 250 g of soil.

Crop patterns : 1. Ragi–Mung–Cotton+Rice, 2. Cotton–Arhar, 3. Wheat–Mung–Rice 4. Ragi–Rice–Wheat, 5. Arhar–Ragi–Rice, 6. Rice–Cauliflower–Groundnut, 7. Cauliflower–Pumpkin–Lady's finger–Radish, 8. Cotton+Groundnut, 9. Rice–Ragi–Potato–Maize–Mung, 10. Rice–Mung–Potato–Maize.

ANOVA

Source	D.F.	S.S.	M.S.	F	Ft
Months	11	840191.57	76381.5	4.19**	2.4
Rotations	9	369390.50	41043.4	2.25**	2.5
Months × Rotations	99	1422074.58	143657.3	7.89**	1.3
Error	120	2182877.25	18190.64		
Totol	239	4814533.90			

others except for the last rotation, Maize-Rice-Mung-Potato. Lowest numbers were observed for the crop sequence, cauliflower-Pumpkin-Lady's finger-Radish. It appears that higher counts were in the crop combinations having more of favourable hosts, whereas, grouping of less desirable hosts or nonhosts, and possibly longer fallow periods (Chawla and Prasad, 1973), produced low numbers of nematodes. Similar differences in effect due to various crop rotations have also been noted by previous workers like Oostenbrink (1960), Mukhopadhyaya and Prasad (1969), Nusbaum and Barker (1971), but others have related this influence to be more due to interactions of crop rotations and fertilizer treatments (Hesling, 1959 ; Collins and Rodrigues-Kabana, 1971 ; Chawla and Prasad, 1973).

Interestingly enough, a highly significant rise in population density of lance nematodes was found during the month of May, which is usually the hottest

part of the year (Table I). This suggests that the test nematode species may be favoured by warm temperatures and thrives well at the higher soil temperature range of 28–34.3°C in the 15 to 30 cm horizon. However, there was an unusually high recovery of the nematode in the month of May after the ragi crop (823/250 g of soil) after the crop pattern of Arhar-Ragi-Rice. Explaining for such lack of uniformity, and high build-up of certain nematode populations, in respect of time and space, Wallace (1973) was of the opinion that such phenomena are quite natural because unusual aggregation of eggs in masses and excessive colonization of nematodes at a particular spot around a rootlet, or oxygen pocket, do frequently occur.

Soil is a complex ecosysten in which various microbial communities constantly attempt to establish biological relationships and adjust to other environmental factors, both biotic (Sayre, 1971) and abiotic (Wallace, 1971), for survival and sustenance. Therefore, it is not possible to make generalizations, particularly in the absence of precise sampling techniques (Barker and Nusbaum, 1971) and adequate knowledge of nematode behaviour. However, for better pest management practices (Oostenbrink, 1964), it would be safer to avoid favourable hosts like ragi, rice, cotton and maize around the month of May; as these host types and soil temperatures, apparenthly favour the lance nematode population.

Thanks are due to Dr. A. Mishra, Head of Agronomy Depratment and Sri H. K. Mishra, Lecturer in Agronomy for their cooperation and Dr. S. Mohanty, Head of Statistics Department for his assistance in analysing the data.

References

Barker, K. R. and Nusbaum, C. J., 1971, Diagnostic and Advisory programs. *In: Plant Parasitic Nematodes*–1 Ed. B. M. Zucksman, W. F. Mai, and R. A. Rohde. Academic Press, New York and London. pp. 345.

Chawla, M. L. and Prasad, S. K., 1973, Multiple cropping and nematodes : I – Effect of fertility management and intensive rotations on nematode populations and crop yield. *Indian J. Nematode.*, 3 : 34–49.

Collins, R. J. and Rodrigues–Kabana, 1971, Relationship of fertilizer treatments and crop sequence to population of lesion nematode. *J. Nematol.*, 3 : 306–307.

Hesling, J. J., 1959, Some observations on the cereal root celworm population of field plots on cereals with different sowing times and fertilizer treatment. *Ann. appl. Biol.*, 47 : 402–406

Mukhopadhyaya, M. C. and Prasad, S. K., 1969, Nematodes as affected by rotations and their relation with yield of crops. *Indian J. agric. Res.*, 39(4) : 366–385.

Nusbaum, C. J., and Barker, K. R., 1971, Population dynamics. In : *Plant Prasitic Nematodes*–I Fd. B. M. Zuckerman, W. F. Mai, R. A. Rohde. Academic Press, New York and London, 345 pp.

Oostenbrink, M., 1960, Population dynamics in relation to cropping, manuring and soil disinfection. In: *Nematology* Ed. J. N. Sasser and W. R. Jenklins. Univ. N. Carolina Press, Chapel Hill, N. C.

OOSTENBRINK, M., 1964, Harmonious control of nematode infestation. *Nematologica*, **10** : 49–56.

SAYRE, R. M., 1971, Biotic influences in soil environment. In : *Plant Parasitic Nematodes*–I. Ed. B. M. Zuckerman, W. F. Mai and R. A. Rohde. Academic Press, New York and London, 345 pp.

SCHINDLER, A. F., 1961, A simble substitute for a Baermann funnel. *Plant. Dis. Reptr.*, **43** : 747–748.

WALLACE, H. R., 1971, Abiotic influences in the soil environment. In : *Plant Parasitic Nematodes*–I. Ed. B. M. Zuckerman, W. F. Mai, and R. A. Rohde. Academic Press, New York and London, 345 pp.

WALLACE, H. R., 1973, Nematode ecology and plant diseases. *Edward Arnold* (Publishers) Ltd., London, 228 pp.

Distribution of Earthworms in Relation to Soil Conditions in Bangalore

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ABSTRACT

Earthworm population studies made within a radius of 15 km around Bangalore City have shown a wide range of distribution of six different species of earthworms namely *Megascolex mauritii, Pheretima elongata, Pontoscolex corethrurus, Octochaetoides beatrix* and *Perionyx excavatus*. The soil types in these regions are red and black clay loams and the nature of distribution of these earthworm species showed a definite pattern. Hence, studies were directed at finding out the limiting factors influencing their distribution. Moisture content, salinity and organic matter concentration were the principal factors controlling the distribution and bionomics of the earthworm population.

INTRODUCTION

From the time of Darwin (1881) earthworms, one of the major fauna of soil have been considered as the farmer's friend. But to what extent the farmer himself accepts this statement is an important question to be answered in this region.

There is an extensive literature available regarding the earthworms of Europe and the Australian region. The genus *Lumbricus* of Europe has been considered to be the major animal clearing the winter leaf fall of these regions (Satchell, 1958, 1963 ; Edwards & Lofty, 1973) and the extensive work of Wood (1974) has given the distribution pattern of megascolicid earthworms of the Australian region.

With regard to the chemical changes that take place in the worm-activated soil Nye (1955); Satchell (1958, 1963) and Abaturov (1972). Atlavinyte and Vana gas (1973), Krivolutski and Pokarzhevskii (1974), have shown the importance of earthworms in bringing about changes in soil components by means of their feed. ing and defecation of soil particles. They have shown the increase in the available Ca^{++}, K^{+}, phosphorus and nitrogen in worm-activated soils. Most of these studies carried out by using castings of the worms have shown greater variations in the levels of these elements in the castings to that of surrounding soil.

Very little information is available regarding the distribution and the seasonal activity of oriental earthworms. Gates in his paper (1961) has recounted the seasonal activity of some of the earthworms of the humid tropics of Burma and India. Nijhawan and Kanwar (1952) have compared the physico-chemical properties of the castings of two genera of earthworms and mentioned that the castings of earthworms with calciferous glands were rich in available calcium and no such change was observed in the constituents of the castings of earthworms without calciferous glands. Bhat *et al.* (1974, 1975) discussed the selective feeding and migratory habits of earthworms. The preferential feeding and settlement of earthworms, in the laboratory studies in glass cages and their role in changing the chemical constituents of the soil had been observed earlier in this laboratory (Kale *et al*,, 1976). These worms feed selectively on rich organic matter. Furthermore, when provided with different concentrations of organic matter, the feeding activity was in regions with high concentrations of organic matter and thep colonized regions with low concentrations of organic matter. Moreover, they had drifted the fine particles of this matter into the burrows in the ion colonization and the variation in chemical composition in this strata was higher than in other regions. In the same way, the degree of humification varied in the soils mixed with different leaf matter and animal matter after the activity of earthworms. These interesting results in the laboratory, regarding the feeding activity and settlement zones in glass cages of these different genera of earthworms, led us to study in detail their distribution pattern in and around the city within a radius of 15 km.

Material and Methods

Earthworm population counts were taken by a hand sorting method. Population density in the areas was estimated by Quadrat sampling method where population $(N) = \frac{\text{Area of the plot} \times \text{Total No. of worms collected}}{\text{Actual area dug} \times \text{No. of quadrats considered in the plot}}$

The organic matter content in the soils of different areas was estimated according to the method of Walkely-Black (1947). The salinity content of the soils was estimated titrimetrically by Harvey's method. One gram soil samples

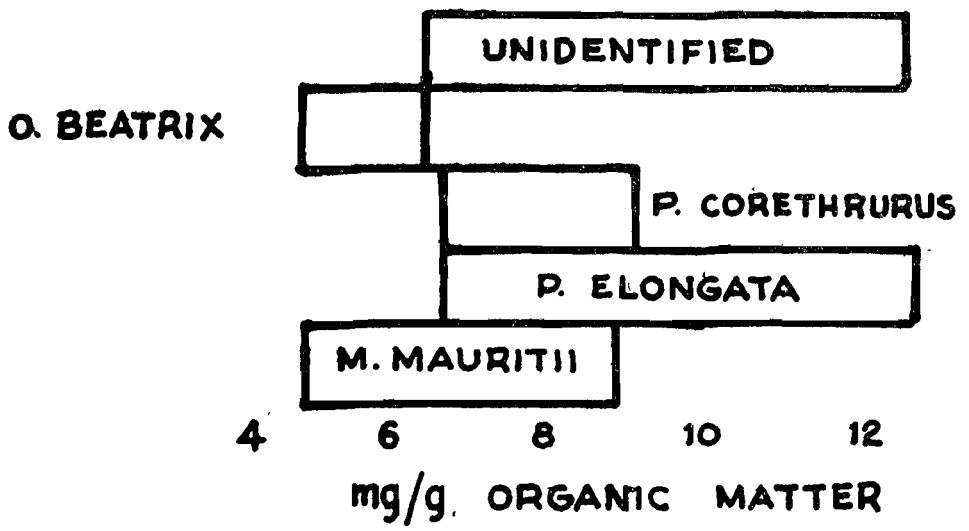
from the area were accurately weighed and dried in a hot air oven at 120°C for 24 hr and reweighed to determine the percentage moisture content in the soil.

Results and Discussion

In our studies, we have found representatives of 6 different genera of earthworms. These are *Pheretima elongata, Megascolex mauritii, Pontoscolex corethrurus, Perionyx excavatus, Octochaetoides beatrix* and one unidentified species. The commonest type of soil in this city is red or black clay loam, the nature of distribution of the available earthworms showed a definite pattern (Table I). Such a niche distribution shown by these different genera of earthworms inspired us to investigate the factors limiting their distribution.

For this reason, the moisture content, salinity and organic matter concentration of their habitat soil was determined to find out their influence on the distribution of earthworms of this region.

Megascolex mauritii like *Lumbricus terrestris* is a common species appearing in barren land, grass lands and areable land. The density of populations is very high in pastures and barren lands compared to cultivated areas. As has been mentioned by Lewis and Taylor (1968) the decreased numbers in areable land might be due to frequent soil disturbances or irregular use of fertilizers and pesticides. The moisture content of the soils in their different habitats showed that this species has a greater tolerance for variations in moisture. The degree of tolerance of this species to salinity and available organic matter is greater when compared to other species studied (Figs. 1, 2 & 3). Because of this, this species has a wide spread distribution in this area.



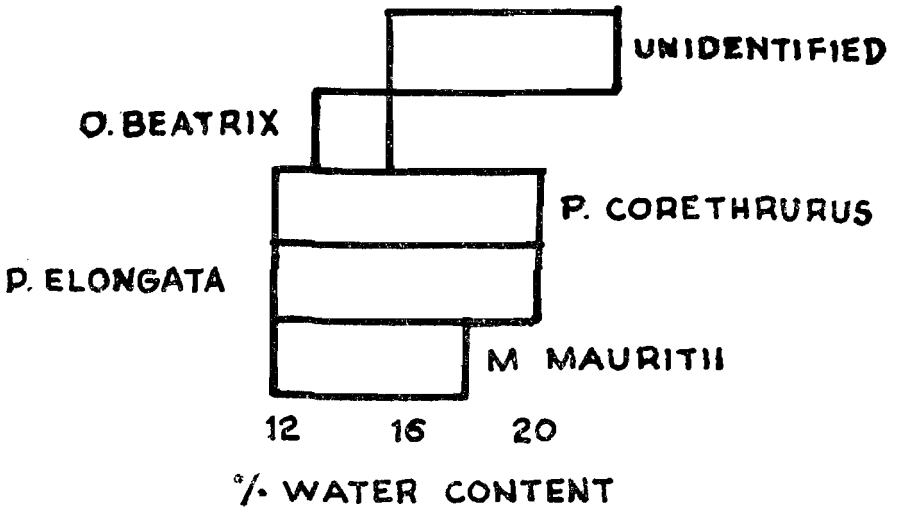
1. Distribution of earthworms in relation to organic matter concentration of soil.

TABLE

Number of earthworms in different sites
No/100 Sq. Ft.

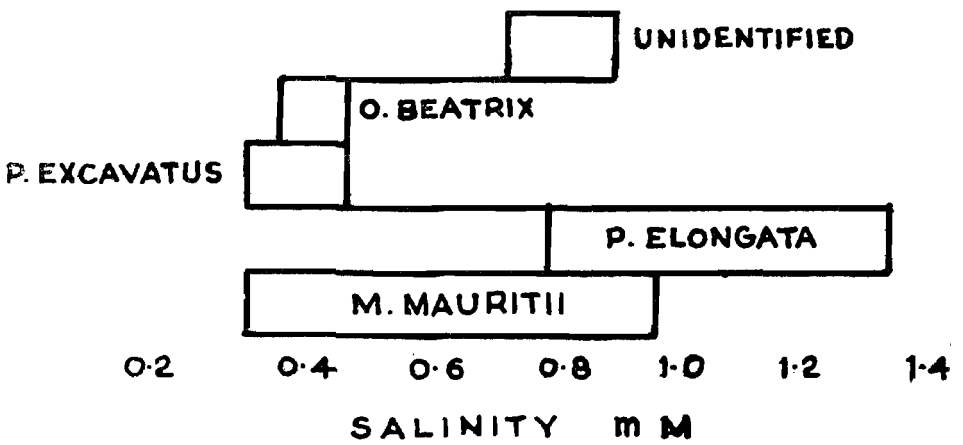
	GRASS LAND					ORCHARDS					ARABLE LAND			BARREN LAND			
	Sanky tank	Binnaman-gala tank	Hebbal tank	Chalagatta tank	Banasavadi tank	Miller's Rd. garden	Lalbhag	Forest research lab	Unversity campus	Kodihalli vineyard	Bennigana-halli	Hebbal fields	Thyagara-janagar	Indian Oxygen Ltd	Krishna-rajapura	Peenya	Laksmipura
M. MAURITII				260		206	826	250	833	355	350	1388	470	1288	1400	1466	
P. ELONGATA	1009	233	1000								1250						
P. CORETHRURUS						373	2466	1150	2750		950		4				
O. BEATRIX							1200	2066	250				8				
P. EXCAVATUS									75								3700
UNIDENTIFIED				2833	8700												

Phretima elongata is of common occurrence in the low grasslands adjacent to tanks in hard and sticky soils. This species is a great burrower and is found to a depth of 14 cm in these hard soils. It is an inhabitant of water-logged soils contaminated with sewage effluents. As such, they require rich supply of water, high salinity and high level of organic matter for their survival (Figs. 1, 2 & 3).



2. Distribution of earthworms in relation to moisture content of soil.

Pontoscolex corethrurus a lumbricid worm of this area is restricted to garden soils. They are found in subsurface soil of the shady regions. They are highly selective in their habitat and are found in soils which contain very low salinity and high organic matter (Figs. 1, 2, and 3).



3. Distribution of earthworms in relation to salinity of soil.

Populations of *Octochaetoides beatrix* are very restricted and we found this species associated to a large extent with *Pontoscolex*, in the Hebbal, Lalbagh

and Forest Research Laboratory areas. The conditions essential for these forms is almost the same as those for *Pontoscolex*.

Perionx excavatus, behaves like the manure worm *Helodrilus foetidus* in the American soils. Its usual habitat is near cow-sheds where compost heaps are found. This is also very active and adaptable to any kind of habitat. They are highly gregarious and found in aggregations in the crevices. The excreta of this species are not left in mounds but are loosely scattered on the surface.

With this information regarding the nature of their distribution, some, experiments on temperature tolerance, metabolic rate and excretory pattern were conducted in the laboratory to find out the degrees of relationship of these results to their natural habitats. From this it was found that the temperature tolerance of *M. mauritii*, was greatest, ranging from 8–32°C, of *P. corethrurus*, was 12–30°C, *P. elongata* 15–32°C and *P. excavatus* 7–27°C, *P. excavatus* is highly ammoneotelic (Urea/NH_3 = 0.2). *P. elongata* 3.8 and *P. corethrurus*, *M. mauritii* and *O. beatrix* with the ratio of 4.4 and 4.9 respectively.

From our knowledge regarding the feeding activity and soil humification by these earthworms and their distribution pattern in this area, we shall concentrate our further studies on two types of earthworms (i) *Pontoscolex corethrurus* and (ii) *Megascolex mauritii*. This is because our laboratory studies have shown that *Pontoscolex* is the most active species in helping in the mobilization of the mineral nutrients in the soil as are the Lumbricidae in the other regions of the globe. We must see to what extent it is possible to introduce them to cultivated lands, spread their distribution and improve soil fertility.

The common genus *Megascolex* will be used in continuing our studies in relation to the effects of fertilizers and pesticides on soil fauna.

References

Abaturov, B.L., 1972, The role of burrowing animals in the transport of mineral substances in the soil. *Pedobiologia*, **12**: 261–266

Atlavinyte, O. and Vanagas, J., 1973, Mobility of nutritive substances in relation to earthworm numbers in the soil. *Pedobiologia*, **13**: 344–352.

Bhat, J. V., 1974, Suitability of experimental diets for earthworm culture. *Curr. Sci.*, **43**: 266–268.

Bhat, J.V., Uma Bai and Subbannayya, K., 1975, A simple and elegant technique to ascertain food acceptability and migratory habits of earthworms. *Curr. Sci.*, **44**: 654–656.

Darwin, C. 1881, The formation of Vegetable mould through the action of worms, with observation on their habits. *Murray*, London.

Edwards, C.A. and Lofty, J.R., 1973, Biology of earthworms. *Chapman and Hall Ltd.*, London.

Gates, G.E., 1961, Ecology of some earthworms with special reference to seasonal activity. *Am. Midl. Nat*, **66**: 61–86.

KALE, R.D., BANO, K. AND KRISHNA MOORTHY, R.V., 1976, Feeding zones and interspecific zonations in earthworms. *Curr. Sci.* (In press).

KRIVOLUTSKI, D.A. AND POKARZHEVSKII, A.D., 1974, Rol 'pochvennykh Zhivotnykh V biogennoi migratsii Kal' tsiya Strontsiva–90. *Zhobshchbiol,* 35: 263–269.

LEWIS, T. AND TAYLOR, L.R., 1968, Introduction to experimental ecology. pp 211–218. *Academic press,* Lond, LNY.

NIJHAWAN, S.D. AND KANWAR, J.S., 1952, Physico-chemical properties of earthworm castings and their effect on the productivity of soil. *Indian J. agric. Sci.,* 22: 357–373.

NYE, P.L., 1955, Some soil forming processes in the humid tropics. IV. The action of the soil fauna. *J. Soil Sci.,* 6: 73–83.

SATCHELL, J.E., 1958, Earthworm biology and Soil fertility. *Soil Fertil.,* 21: 209–219.

SATCHELL, J.E. 1963, Nitrogen turnover by a woodland population of *Lumbricus terretris.* In soil organisms. J. Doeksen and J. Van der Drift (eds) North Holland, Publishing Co., Amsterdam, pp. 60–66.

WOOD, R. G., 1974, The distribution of earthworms (Megascolicidae) in relation to soils, vegetation and altitude on the slopes of MT KOSCISKO, Australia. *J. Anim. Ecol,* 43: 87–106.

Thermobiology of the Tropical Earthworm, *Perionyx excavatus*

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ABSTRACT

Lethal temperatures (LT–50) and influence of thermal acclimation on lethal temperatures of the earthworms was studied. Normal earthworms had a 24–hour median heat and cold-tolerance of 39.5° and 16.3°C respectively. Cold acclimation (19.0°C) depressed and enhanced the 24-hour heat and cold-tolerance respectively up to 12 days. Whereas, warm acclimation (37.0°C) increased and lowered the 24-hour median heat and cold-tolerance respectively within 12 days. Thermal acclimation beyond 12 days had no effect on lethal temperatures. Young and immature earthworms displayed greater susceptibility to high and low temperatures than their adolescent and mature brethren. The ecophysiological significance of these results is discussed.

INTRODUCTION

TROPICAL animals are not usually exposed to such rigours of temperature as their temperate counterparts but they are not free from environmental thermal fluxes. The information about lethal temperatures and the relationships between lethal and acclimation temperatures are largely restricted to vertebrates,

especially fish ; in comparison to fish, the thermal physiology of invertebrates has been less studied (Nagabhushanam and Kulkarni, 1970).

Grant (1955) had demonstrated that the heat tolerance of *Pheretima hupeiensis* increased 0.3°C per 1°C rise in conditioning temperature. The remaining reports on the temperature relations of earthworms have been chiefly concerned with the temperature preferenda, lethal temperatures and effects of ambient temperature on different biological processes (Wolf, 1938 ; Dowdy, 1944 ; Hogben and Kirk, 1944 ; Hopp, 1947 ; Evans and Guild, 1948 ; Graff, 1953 ; Michon, 1954 ; Kollmannsperger, 1955 ; Miles, 1963 ; Duweini and Ghabbour, 1965a, 1965b ; Satchell, 1967 ; Madge, 1969). Study of the above mentioned papers revealed that very little is known about the effect of thermal acclimation on temperature tolerance of earthworms. Since scant information is available about the thermal relations of *P. excavatus*, the present study was undertaken to investigate its (1) heat and cold tolerance and (2) effect of thermal acclimation on heat and cold tolerance.

Material and Methods

Adult, fully mature and clitellate (except otherwise specifically stated) earthworms of the species, *P. excavatus* were collected from the outskirts of the Marathwada University Campus, Aurangabad. In the laboratory, the worms were maintained in glass vessels filled with sufficient moist soil brought from their natural habitat. The worms were conditioned to total darkness (except for brief exposure while moistening or replacing the soil) to eliminate possible photoperiodic influences The ambient temperature these worms were kept at fluctuated between 25° to 28°C.

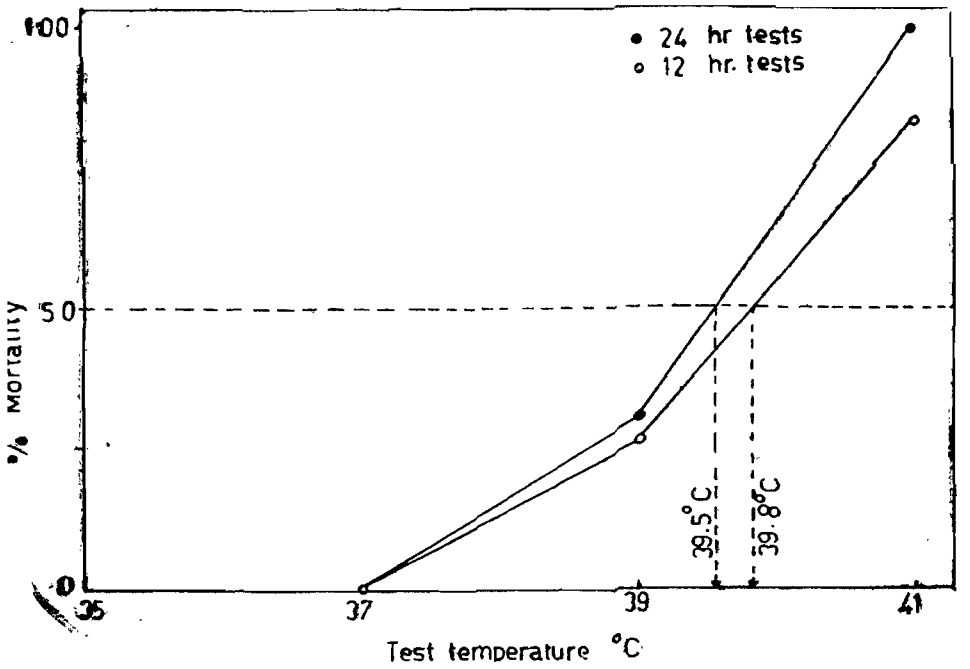
For acclimation, groups of 15 to 50 worms were selected randomly from the laboratory populations and were put into smaller glass jars containing soil and positioned inside incubators at 37.0±0.5°C (Warm-acclimated) or 19.0±0.5°C (cold acclimated), for different time intervals. Initially, the animals were brought to the desired acclimation temperature by adopting the 'slow induction of thermal stress' pattern. Every day, the glass jars were replenished with fresh moist soil already brought up to the appropriate acclimation temperature.

The lethal temperatures of experimental and control animals were determined by exposing the animals to 15°, 17°, 19°, 37°, 39° and 41°C for 24 hours (except otherwise specifically stated). The earthworms were tested in groups of ten, in the small glass vessels. After exposure to the test temperature for the designated period the animals were counted as dead if no response to mechanical stimulations could be seen or if they haemorrhaged.

Observations

I. Temperature tolerance

(i) *Heat-tolerance of normal worms*: Normal earthworms conditioned in the laboratory (25–28°C) for a week, when exposed to 37°C survived indefinitely. However, at 39°C they could survive maximally for only four days and none of them could sustain a 41°C temperature for 24 hours. Their percentage mortalities after 12 and 24-hour exposures to these three temperatures are summarized In Fig. 1. The 12-hour median heat tolerance (or LT-50 after 12 hours) was in the proximity of 39.8°C and that for 24 hours 39.5°C.



ig. 1. Per cent mortality of *P. excavatus* conditioned at temperature range of 25–28°C and tested at 15°, 17° and 19°C

(ii) *Loss of heat tolerance*: After twelve days of cold acclimation, the 24 our median heat-tolerance of the earthworms dropped to 36.5°C, with no urther decline even after three months (cited as final temperature in Table I) of cclimation.

(iii) *Gain of heat-tolerance*: The heat-tolerance of normal worms which ras eclipsed during cold acclimation, recovered quite rapidly when the worms vere withdrawn from the cold acclimation. Thirty worms maintained at 19.0± .5°C for two weeks were warmed slowly up to laboratory temperature (25°C) nd then they were kept at this temperature for twelve hours. Theteafter, these nimals were exposed to 39°C; 20 per cent died after 12 hours and 40 per cent ied after 24 hours. Obviously, their heat tolerating capacity was well within

TABLE I

Loss of heat-tolerance of P. excavatus *after acclimation to cold (19.0±0.5°C)*

Acclimation period in days	24 hr. median heat-tolerance °C*
1	39.3
2	39.3
3	39.0
4	38.8
5	38.4
6	37.9
7	37.4
10	36.6
12	36.5
15	36.5
Final (3 months)	36.5

* Graphical values derived from the experimental data. For every observation three test (10 animals/test) were carried out.

the range of the heat-tolerance of normal worms. Another aspect is that the rate of gain of heat-tolerance is conspicuously quicker than the rate of loss, the tolerance lost during two weeks at 19.0±0.5°C, was regained in not more than 24 hours.

(iv) *Effect of warm acclimation on the heat-tolerance:* Twelve days after warm acclimation, the 24-hour median heat tolerance of the worms was elevated to 41.5°C which surprisingly did not increase even three months (cited as final temperature in Table II) after the acclimation.

TABLE II

Effect of acclimation to warmth (37.0±0.5°C.) on 24-hour median heat-tolerance of P. excavatus

Acclimation period in days	24 hour median heat-tolerance °C.*
1	40.0
2	40.2
3	40.5
4	40.7
5	40.7
6	40.7
7	41.0
10	41.2
12	41.5
15	41.5
Final (3 months)	41.5

* Graphical values derived from the experimental data. For every observation three tests (10 animals/test) were carried out.

(v) *Cold-tolerance of normal worms* : Normal earthworms were able to endure a 19°C temperature indefinitely; at 17°C they lived for five days but none of them could tolerate 15°C temperature for even 24 hours. Percentage mortalities of normal worms at these three temperatures are summarized in Fig. 2. The 12-hour median cold-tolerance was 16°C and that for 24 hour was 16.3°C. Comparison of Figs. 1 and 2 reveal that *P. excavatus*, is more susceptible to cold

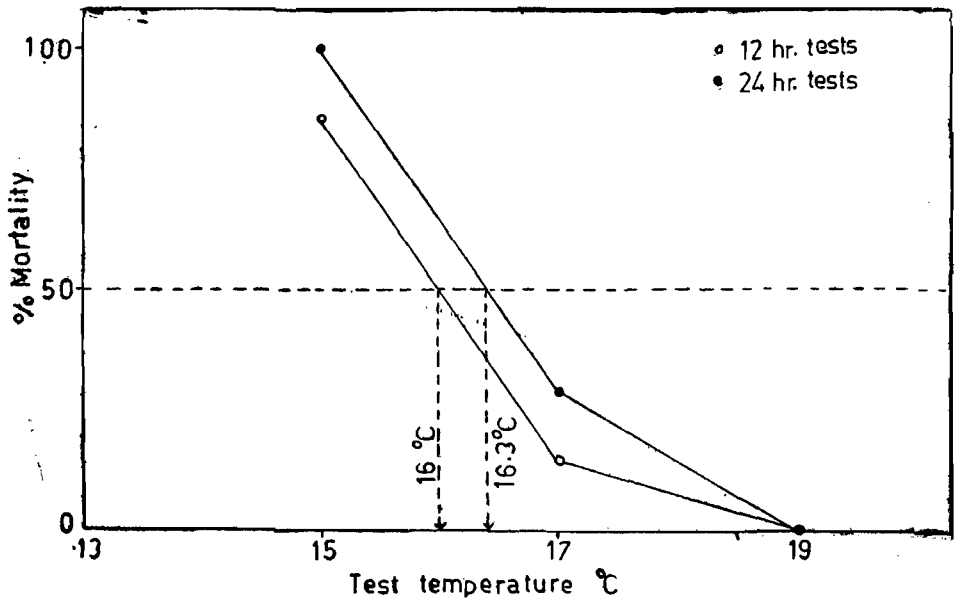


Fig. 2 Per cent mortality of *P. excavatus* maintained at temperature range of 25–28°C and tested at 15°, 17° and 19°C.

than to heat because its 24-hour median cold tolerance was about 9°C, below the conditioning temperature, whereas its heat-tolerating capacity is about 14°C above of its normal thermal regime.

(vi) *Loss of cold-tolerance* : There was a dramatic fall by about 6°C in the 24-hour median cold-tolerance of the normal worms from 16.3°C to 22.6°C after twelve days of warm acclimation (Table III). However, even acclimation for a period of three months (cited as final temperature in Table III) could not decrease their cold-tolerance to any further extent.

(vii) *Gain of cold-tolerance*: The cold-tolerance deprived during warm acclimation recovered quite rapidly when the earthworms were moved from the warm acclimating vessels. Thirty worms conditioned at 37.0±0.5°C for two weeks (during which their 24-hour cold-tolerance would have decreased to 22.6°C, Table III), were cooled down to the laboratory temperature slowly for 12 hours. When these earthworms were given a survival test at 17.0±0.5°C 40 per cent and 60 per cent mortality was recorded after 12 and 24 hours respectively.

TABLE III

Loss of cold-tolerance of P. excavatus *acclimated to warmth (37.0±0.5°C)*

Acclimation period in days	24 hour median cold-tolerance °C.*
1	18.0
2	18.5
3	19.0
4	19.5
5	20.1
6	20.4
7	20.9
10	21.7
12	22.6
15	22.6
Final (3 months)	22.6

* Graphical values derived from the experimental data. For every observation three tests (10 animals/test) were carried out

(viii) *Effect of cold acclimation on cold-tolerance* : When the normal worms were acclimated to cold, their cold tolerance capacity was raised by nearly 2°C (Table IV) at the end of twelve days. However, any further continuous acclimation (even 3 months period : cited as final temperature in Table IV) did not advance their 24–hour cold-tolerance below 14.5°C.

TABLE IV

Effect of acclimation to cold (19.0±0.5°) on 24-hour cold-tolerance of P. excavatus

Acclimation period in days	24 hour median cold-tolerance C.*
1	16.0
2	15.8
3	15.8
4	15.6
5	15.4
6	15.1
7	15.0
10	14.9
12	14.5
15	14.5
Final (3 months)	14.5

* Graphical values derived from the experimental data. For every observation three tests (10 animals/test) were carried out.

(ix) *Effect of body size on temperature tolerance* : Worms were sorted into three groups according to their body weights : (1) small group (average body weight 0.3 to 0.5 g) consisted of mostly young immature worms, (2) medium group (average body weight 0.6 to 0.9 g) consisted of young but adolescent worms

and (3) large group (average body weight 1.0 to 1.5 g) consisted of only adult, fully clitellate worms. Their percentage mortality at different test temperatures is summarized in Table V which reveals that at cold (19.0°C and 17.0°C) and warm (37.0°C) temperatures, worms from the small group were killed more readily than animals belonging to both the medium and large groups; in the physiological vocabulary the smaller (young immature) worms were more sensitive and susceptible to the temperature than the older ones.

TABLE V

Per cent mortality of P. excavatus *of different body weight groups (conditioning temperature 25–28°C)*

Test temperature °C.	No. of tests	No. of animals/test	% mortality after 24 hour exposure of Small group	Medium group	Large group
15	3	20	100	100	100
17	3	20	60	50	30
19	3	30	20	00	00
37	3	20	10	00	00
39	3	20	50	40	30
41	3	20	100	100	100

DISCUSSION

Investigations on the thermal relations of poikilotherms display that the lethal temperature of a species is not an absolute value but is associated with the immediate thermal history of the organism. Consequently, figures for median heat and cold-tolerance are not significant unless acclimation temperatures are also cited. Moreover, acclimation influences not only the upper and lower lethal temperatures, but also the duration of exposure to a lethal temperature that an animal can withstand (McWhinnie, 1967). These relationships were confirmed by the data obtained in the present investigation on the earthworm *P. excavatus.*

The data presented led to the conclusion that the earthworm, *P. excavatus* exhibited a simple pattern of acclimation in relation to lethal temperatures (median heat-and cold-tolerance). Firstly, the decline in heat-and cold-tolerance was appreciably greater following cold and warm acclimation, respectively, as opposed to the increase in temperature-tolerating capacity after thermal acclimation. Secondly, the effect of high temperature raised both the upper (both physiological and numerical increase) and lower (only numerical elevation) lethal temperatures, whereas low temperature lowered both (only numerical decline in case of cold-tolerance). Thirdly, the fully acclimated state, whether to high or low temperatures, seemed to be approached asymptotically (as occurs for isopods, *Porcellio laevis* and *Armadillidium vulgare* : Edney, 1964) and achieved in about ten to twelve days.

Miles (1963) recorded an upper lethal temperatures of 33.3°C for *Eisenia foetida* and 25.7°C for *Allolobophora terrestris*, which were acclimated to 15°C for several weeks. However, his figures are based on a 12 hour exposure, leaving 80 per cent of the animals still alive after the end of experimentation (LT-20). The slug, *Laevicaulis alte* had a 24-hour median heat tolerance of 34.5°C when it was conditioned at 25-30°C (Nagabhushanam and Kulkarni, 1970). Edney (1964) recorded an upper lethal temperature (after 30 minutes exposure) of about 38.5°C for *P. laevis* and 39.5°C for *A. vulgare* maintained at 20°C. In this context the 24-hour median heat-tolerance of 39.5°C of *P. excavatus* suggests a capability to sustain higher temperatures for a longer period, even though it has a rapidly transpiring soft skin surface.

On the contrary, the 24-hour cold-tolerance of *P. excavatus* (16.3°C) reflects its poor ability to endure the cold compared to terrestrial isopods, *P. laevis* and *A. vulgare* which have low lethal temperatures of about -0.6°C and 1.6°C respectively (Edney, 1964). Kale and Rao (1973) mentioned that lowest temperature that could be tolerated by *P. excavatus* (collected at Bangalore) was 9± 1°C whereas in the present experiment the same species (collected at Aurangabad) was unable to withstand a 15°C temperature for 24 hours. The exact reason for this discrepancy is not known but probably can be accounted to the ecological variations of the two populations.

Interestingly, it is only after three days of cold acclimation that 24-hour median heat-tolerance of normal earthworms deviated markedly from the original value; this parallels other poikilothermic vertebrates and invertebrates. This brief latent period before the initiation of loss of heat-tolerance suggests that this may be a normal behavioural peculiarity of the animals. As demonstrated by Hutchinson (1961) for salamanders and certain other animals, this earthworm species is also has a faster rate of gain of heat-tolerance than that of cold-tolerance These two aspects (greater heat-tolerating capacity and a more rapid gain of heat-tolerance) are probably adaptively significant and might be due to its tropical habitat with high temperature.

It is well-established that an increment in acclimation temperature can elevate the median heat-tolerance (within the genetic limit of species) very rapidly whereas acclimation to low temperature entails a loss in heat-tolerating ability. The present observations reveal that *P. excavatus* is no exception to this. Additionally, this report corroborates the view of Spoor (1955) and Nagabhushanam and Kulkarni (1970) that though there exists a quantitative variation in the exentt and rate of acclimation, qualitatively there is a coherent, fundamental unity of design of temperature acclimation among different animal groups.

Alterations in heat-and cold-tolerance limits in response to acclimation indicate that in earthworms there can be a substantial anticipatory adjustment

in their lethal temperatures (temperature-tolerating abilities), as has been suggested for other poikilotherms by Fry and Hochachka (1970). This faculty is a great asset to earthworms in protecting their homeostasis while combating imposed thermal stresses during summer and winter.

In some species, young or smaller individuals are more sensitive to temperature than the older or larger animals (Vernberg, 1963). The greater thermal susceptibility of smaller worms than the larger worms observed in the present probe may be attributed to the non-development of such mechanisms.

We are grateful to the University Grants Commission, New Delhi for financial assistance in the form of Junior Research Fellowship.

References

Dowdy, W. W., 1944, Influence of temperature on vertical migration. *Ecology of invertebrates inhabiting different soil types*, **25** : 449–460.

Duweini, A. K. and Ghabbour, S. I., 1965a, Population density and biomass of earthworms in different types of Egyptian soils. *J. appl. Ecol.*, **2** : 271-287.

Duweini, A. K. and Ghabbour, S. I., 1965b, Temperature relations of three Egyptian oligochaete species. *Oikos*, **16** : 9–15.

Edney, E. B., 1964, Acclimation to temperature in terrestrial isopods. I. Lethal temperatures. *Physiol. Zool.*, 37 : 364-377.

Evans, A. C. and Guild, W. J. Mc.L., 1948, Studies on the relationship between earthworms and soil fertility. IV. On the life cycles of some British Lumbricidae. *Ann. appl. Biol.*, **35** : 471-484.

Fry, F. E. J. and Hochachka, P. W., 1970, In : *Comparative Physiology of Thermoregulation* Vol. I. (Whittow, G. C., ed.) *Academic Press*. New York, 79-134.

Graff, O. Die Regenwurmer Deutschlands. 1953, Schrift Forsch. Land. *Braunschweig-Volk.*, 7: 81.

Grant, W. C., 1955, Temperature relationships in the megascolid earthworms, *Pheretima hupeiensis. Ecology*, **36** : 412–417.

Hogben, L. and Kirk, R. L., 1944, Body temperature of worms in moist and dry air. *Proc. R. Soc.*, **132**b: 239–252.

Hopp., H., 1947, The ecology of earthworms in cropland. *Soil Sci. Soc. Am. Proc.*, **12** : 503-507.

Hutchinson, V. H., 1961, Critical thermal maxima in salamanders. *Physiol. Zool.*, **34**: 92–125.

Kale, R. D. and Rao, K. P., 1973, Studies on neurohumoral induction of compensatory mechanisms in thermal acclimation of poikilotherms. I. Effect of injection of CNS extract on the metabolism of two species of earthworms. *J. exp. Biol.*, **59** : 655–664.

Kollamannsperger, F., 1955, Uber Rhythmen bei Lumbriciden. *Decheniana*, **180** : 81–82.

Madge, D. S., 1969, Field and laboratory studies on the activity of two species of tropical earthworm. *Pedobiologia*, **9**: 188-214.

McWhinnie, M. A.. 1967, In : *Thermobiology* (A. H. Rose, Ed.). *Academic Press*, New York, 535–553.

Michon, J., 1954, Influence de l'isolement a partir de la maturite sexuelle sur la biologie dos Lumbricidae. *C. R. Acad. Sc. Paris*, **238** : 2457-2458.

MILES, H. B., 1963, Heat death temperature in *Allolobophora terrestris* f. *longa* (Ude) and *Eisenia foetida* (Sav.). *Nature*, **199** : 826.

NAGABHUSHANAM, R. AND KULKARNI, A. B., 1970, Studies on the temperature tolerance in the slug, *Laevicaulis alte*. *Marathwada Univ. J. Sci.*, **9** : 77–81.

SATCHELL, J. E., 1967, In: *Soil Biology* (A. Burgess and F. Raw, eds.) *Academic Press*, New York, 259–322.

SPOOR, W. A., 1955, Loss and gain of heat-tolerance by the crayfish. *Biol. Bull.*, **108** : 77–87.

VERNBERG, F. J., 1963, Temperature effects on invertebrate animals. *Temperature–its measurement and control in Science and Industry*, **3** : 135–141.

WOLF, A. V., 1938, Studies on the behaviour of *L. terrestris* to dehydration ; and evidence for a dehydration tropism. *Ecology*, **19** : 233–242.

Some Observations on the Earthworm Population and the Biomass in a Sub-Tropical Pine Forest Soil

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ABSTRACT

Monthly fluctuations in the biomass and population density of earthworms in a pine forest soil of Shillong, North-Eastern India were studied during the period April-September, 1976. The earthworms were extracted both by the wet formalin method and by handsorting, to ensure adequate sampling and to avoid underestimations of population size. The population size was related to soil pH and moisture. Maximum abundance was recorded in July and minimum in April, 1976. The high and low values in population size coincided with the maximum and minimum levels in soil moisture during this period. The soil pH was on the acidic side (5.80 to 6.25) which explains the comparatively small earthworm population in this soil. Relationships of population size to soil pH and moisture were tested statistically and significant correlations were established and discussed.

INTRODUCTION

EARTHWORMS form a major proportion of the invertebrate biomass in the soil particularly in temperate regions. The pioneering work of Darwin (1881) on earthworms sparked off a great upsurge of interest in these animals during the late 19th and early 20th century, even though the work was on morphology and detailed histology rather than on basic biology and ecology. The earthworms are secondary decomposers and their role in fragmentation and breakdown of dead plant and organic material is well established. (Raw, 1959, 1962; Health and King, 1964; Satchell and Lowe, 1967; Pearel *et al.*, 1966; Barley

and Keining, 1964 and Medge, 1966). The part, these organisms play in humification of leaf litter and organic debris has been extensively studied (Guild, 1955 ; Barley, 1961 ; Satchell, 1967 ; Raw, 1962 and Van Rhee, 1963). As an attempt to study the earthworm population structure, Block and Banage, 1968 ; El-Duweini and Ghabbour, 1965 ; Guild, 1951, 1952 ; Nakamara, 1968 ; Raw, 1960 : Van Rhee and Nathans, 1961 ; Svendsen, 1955 : Waters, 1955 and Zicsi, 1962 ; have estimated population densities in different ecosystems.

In India, ecological observations on earthworms are few, and even these investigations have been mostly on damage caused by earthworms to agricultural crop and measures of control (Puttarudraiah and Sastry, 1961). This investigation considers some aspects of earthworm population and biomass in the pine (*Pinus khasya* Royle) forest soil of Meghalaya.

Study area : The study was confined to one of the cultivated pine forests of the Government of Meghalaya in Shillong (25.34°N and 91.56°E) at an elevation of 1250 m. The dominant undergrowths of the forest were *Eupatorium* and *Artemisia.*

Material and Methods

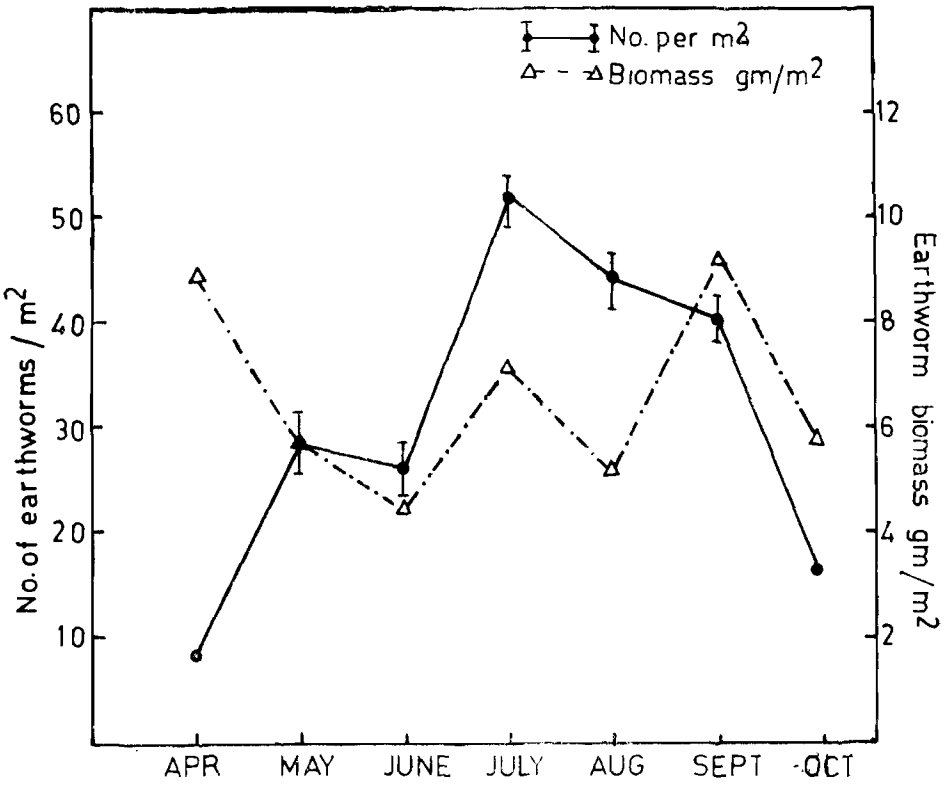
Population and biomass estimates were made every month from April to November 1976. The litter and surface twigs were removed in five randomly selected patches of 625 cm^2 area. A dilute solution of formalin (0.55 per cent) was sprayed on each quadrat until the soil was saturated. The earthworms were picked up as they appeared over a period of twenty minutes. The worms were washed immediatly and stored in polythene bags along with some soil. After extracting the worms with formalin, the soil in each quadrat was carefully dug up to a depth of 10 cm. This soil was thoroughly examined and any worms present in it were hand-picked. This was done to ensure thorough sampling of each quadrat. In the laboratory the earthworms were once again washed in water, dried with blotting paper and weighed fresh and the biomass per unit area was calculated (standing crop). The worms were relaxed by adding drops of rectified spirit and the length of the stretched worms were recorded. The worms were preserved in 10 per cent formalin for taxanomical investigation.

For statistical parameters, methods outlined by Woolf (1968) were followed.

Results and Discussion

It has been seen that the members of the family Lumbriculidae and Acanhodrillidae were the most dominant in the study area. It can be seen from Fig. 1 that the highest density of worms (52/m^2) occurred in July and the minimum density (8.8/m^2) in April. This corresponds to the maximum and minimum levels in soil moisture. A significant correlation between soil moisture

and earthworm abundance was established (Table II). Moisture levels in the soil microenvironment are governed by macro environmental factors namely rainfall.



ig.1 Monthly variation in numbers and biomass of earthworms experimental forest site.

TABLE I

Coefficient of correlation values between pH, moisture and earthworm populations

Metric traits	Coefficient of correlation
Body length and body weight	0.978
Earthworm population and moisture (soil)	0.925
Earthworm population and pH (soil)	0.988
Soil moisture and soil pH	0.988

All the values are significant at 1 per cent probability level.

pH limits earthworm distribution (Petrov, 1946, and Edwards and Lofty, 1972). The forest soil under the present study being acidic, the abundance of these earthworms was less (Table II).

It is well known that earthworm density and activity fluctuates during annual cycles. However, Gates (1961) observed that earthworms were mainly

TABLE II

Climatological data for the study area with per cent of total earthworms extracted

Months	Per cent of total earthworms	Moisture	pH
April	4.52	20	5.85
May	14.07	30	5.95
June	13.07	25	5.80
July	26.13	35	6.25
August	22.11	28	5.95
September	20.10	28	6.15

active during May to October in both monsoon tropical climate of Burma and the humid sub-tropical climate of India. Cocoon production also seem to be seasonal even in the sub-tropical climate of India Bahl (1922) reported that although *Pheritima* sp. produce cocoons throughout the year, peak production occurred between March to June, before the rain in July and August. Cocoon production was lowest during these rainy months.

The experimental area always has undecomposed litter on the surface. This was only to be expected when acidity of the soil restricts earthworm population to low densities. Although the bulk of the humification process is due to microorganisms and microarthropods of the soil, the process is accelerated by the passage of the organic material through the guts of earthworms (Edwards and Lofty, 1972). They have shown that most species of litter mites are incapable of feeding on raw litter and they change from fungal-feeding to litter-feeding only when the litter has reached a certain stage of decay. Moreover, soil microarthropods can complete the process of mineralisation as essential for nutrient recycling, only when the litter is fragmented and incorporated by the earthworms. Earthworms form an important link in this series of events by breaking down the organic matter, thus enhancing the mineralisation process. This study on the population density and biomass is useful for further work on the role of earthworms in pine litter decomposition.

The authors are thankful to Prof. R. G. Micheal and Prof. P. S. Ramakrishnan, Heads of the Zoology Department and Botany Department respectively for providing necessary facilities. They are also thankful to North Eastern Hill University and University Grants Commission for financial assistance.

REFFRENCES

BAHL, K. N., 1922, On the development of the enteronephric type of nephridial system found in the Indian earthworms of the genus. *Pheritima. Q. Jl. Micros. Sci.*, 66 : 49-103.

BARLEY, K. P. AND KLEINIG, C. R., 1964, The occupation of newly irrigated lanes by earthworms. *Aust. J. Sci.*, 26 (9) : 290.

BLOCK, W. AND BANAGE, C. W., 1968, Population density and biomass of earthworm in some Uganda soils. *Rev. Ecol. Biol. Soil*, 5 (3) : 515-521.

EDWARDS, C. A. AND LOFTY, J. R., 1972, Biology of earthworms. *Chapman and Hall edit.*, 268 p.

DARWIN, C., 1881, The formation of vegetables mould through the action of worms with observations of their habits. *Murry*, London, 326 pp.

EL-DUWEINI, A. K. AND GHABBOUR, S. I., 1965, Population density and biomass of earthworms in different types of Egyptian soils. *J. appl. Ecol.*, **2** : 271–287.

GATES, G. E., 1961, Ecology of some earthworms with special reference to seasonal activity. *Am. Midl. Nat.*, **66** : 61-86.

GUILD, W. J. MC. L., 1951, The distribution and population density of earthworms (Lumbricidae) in Scottish pasture field. *J. Anim. Ecol.*, **20** (1) : 88–97.

GUILD, W. J. MC. L., 1952, Variation in earthworm numbers within field populations. *J. Anim. Ecol.*, **21** (2) : 169.

GUILD, W. J. MC. L., 1955, Earthworms and soil structure. In *Soil Zoology*, D. K. Mc. E. Kevan (ed). *Butterworths*, London, pp. 83–98.

HEATH, G. W. AND KING, H. G. C., 1964, The palatability of litter to soil fauna. *Proc. VIII Int. Congr. Soil Sci.*, Bucharest, pp 979–986.

MEDGE, D. S., 1969, Field and laboratory studies on the activities of two species of tropical earthworms. *Pedobiologia*, **9** : 113–115.

NAKAMARA, Y., 1968, Population density and biomass of terrestrial earthworm in the grassland of three different soil types near Sappora. *Jap. J. appl. Ent. Zool.*, **11** : 164–168.

PAREL, T. S., KARPACHEVSKII, L. O. AND YEGOROVA, S. V., 1966, Experiments for studying the effect of earthworms on the litter horizon of forest soil. *Pedobiologia*, **6** : 269–276.

PETROV, B. C., 1946, The active reaction of soil (pH) as a factor in distribution of earthworms. *Zool. Jour.*, **25** (1) : 107–110.

PUTTARUDRAIAH, M. AND SASTRY, K. S. S., 1961, A preliminary study of earthworm damage to crop growth. *Mysore agric. J. Sci.*, **36** : 2–11.

RAW, F., 1960, Earthworms population studies : a comparison of sampling methods. *Natur*, Lond., **187** (4733) : 257.

RAW, F., 1962, Studies of earthworm population in Orchards. I Leaf burial in apple orchards. *Ann. appl. Biol.*, **55** : 342–343.

RHEE, J. A. VAN, 1963, Earthworm activities and the breakdown of organic matter in agricultural siol. In : *Soil organisms*, J. Doeksen and J. van der Drift (eds). *North Holland Publishing Co.*, Amsterdam, pp. 55–59.

RHEE, J. A. VAN AND NATHANS, S., 1961, Observations on earthworm populations in orchard soils. *Neth. J. Agric. Sci.*, **9** (2) : 94-100.

SATCHELL, J. E. AND LOWE, D. G., 1967, Selection of leaf litter by *Lumbricus terrestris*. In : *Progress in Soil Biology.*, O. Graff and J. E. Satchell (Eds.) *North Holland Publishing Co.*, Amsterdam, pp. 102–119.

SVENDSEN, J. A., 1955, Earthworm population studies : a comparison of sampling methods. *Nature, Lond.*, **175** : 864.

WATERS, R. A. S., 1955, Number and weight of earthworms under a highly productive pasture. *N. Z. J. Sci. Technol.*, **36** (5) : 516–525.

WOOLF, CHARLES, M. 1968, Principles of Biometry. *Von. Nostrand Co. Ind.*, London.

ZICSI, A., 1962, Determination of number and size of sampling unit for estimating Lumbricid populations of arable soils. In : Progress in soil Zoology, P. W. Murphy (ed.). *Butterworths*, London, 68–71.

Annelids as Pests of Paddy Crop

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Abstract

Annelids, particularly earthworms, have long been considered beneficial as they improve the soil condition. Patel and Patel (1959) were probably the first who reported that earthworms retard germination, growth and root development of tobacco plants in Gujarat. During August-September, 1975 and 1976 severe infestation of annelids in paddy crop was noticed in Surat and Bulsar district of Gujarat. These annelids were different from the common earthworms. They are commonly known as Oligocahetes. The infestation of this pest was heavy in some of the field where roots of a single paddy plant harboured as many as 80 worms on an average. The infestation was particularly harmful during the early stage of the crop growth when it adversely affected tillering and vigour of the plants. The infested plants first gave symptoms of burning and then withered. Such damage has been also reported from Punjab by Verma *et al.* (1975) for annelids belonging to family Naididae and Tubificidae for paddy crop. Further work is in progress at this Institute for its biology and control measures.

References

Patel, H. K. and Patel, R. M., 1959, Preliminary observations on the control of earthworms by soapnut (*Sapindus launfolius*) extract. *Ind. J. Ent.*, **21** (IV) : 251–255.

Verma, A. N., Tiwari, C. B. and Gupta, D. S., 1975. Annelids as pest of paddy crop and their control. Estratto da. Rivista II Rise-Anno XXV Gennio pp. 81–84.

Occurrence and Characteristics of Hoplochaetella with Particular Reference to *H. suctoria*

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Abstract

Hoplochaetella is a rare species of earthworms confined to India, are seen in the subsoil of only a few localised regions. This species has now been observed and identified in different regions of South Kanara. Very little information is available regarding this genus especially of *H. suctoria.* The clitellum is present for only a short time and occurs between segments XIII to XVI. The inner contents of the calciferous glands are crystalline, colourless spherical structures containing calcium carbonate. These worms feed on

organic matter and are commonly seen below the cashew, jack, and Eugenia, trees. *H. suctoria* casts small oval pellets of about 2–5 mm. The body is brittle, readily breaks off and caudal regeneration takes place rapidly. The life cycle is in two distinct phases, an active phase and a dormant phase.

Introduction

Hoplochaetella is a unique genus of Indian earthworm belonging to the family Octochaetidae. Beddard (1890) first gave the genus the name *Hoplocheata.* But Michaelson (1900) changed it to *Hoplochaetella.* At present the distribution of these earthworms, seems to be restricted to India. Even in the Indian subcontinent they are rare and seen only in a few localised regions.

Gates (1940), gave a good account of eleven species of these worms and drew attention to the sparse information that is available on them. Perhaps this may be due to the paucity of materials or due to the poor conditions of the few preserved worms studied. In fact some of the *Hoplocheatella* species are known only from macerated specimens. Species such as *Hoplocheatella suctoria* Stephenson (1917) are recorded from the study of only a few immature and aclitillate specimens. This would explain why the segmental position of the clitellum has not yet been recorded. Hence a close biological study of these worms was considered interesting and worthwhile. The presence of these worms in and around Moodabidri prompted us to undertake a study of some aspects of their biology. Special attention was given to *H. suctoria.* Unless otherwise stated, the observations and results relate only to this species. The results presented in this paper are based on extensive field and laboratory studies over three consecutive years.

Material, Methods and Observations

A large number of worms from different localities, in and around Moodabidri, South Kanara District, Karnataka State, were collected by a hand-sorting method. The collecting was done throughout the rainy season, from June to the end of October. Selected worms were killed and preserved.

To study their habits a few random specimens were kept in glass cages constructed of two sheets of glass slotted into a wooden frame with a space of 2 cm apart and filled in with soil mixed with small amount of cowdung to serve as food.

Earthworm cultures were maintained for long periods in soil mixed with cowdung, kitchen waste etc., as described by Bhat and Khambata (1957). Since the worms were mostly collected from cashew farms, some decaying cashew leaves and a pinch of calcium was also incorporated in the cultures. Fifteen worms were maintained in each pot, care being taken to prevent water-logging or drying. Autotomy, excess of worm castings, death of worms etc., on the

surface area were considered to indicate unfavourable conditions in the habitat and the medium was therefore changed often.

Distribution : Gates (1940) has reported that all species of *Hoplochaetella* appear to be restricted to lowlands. Stephenson (1923) and Gates (1940) have recorded the presence of *H. suctoria* only from Sanvardem (Goa). Detailed observations have now revealed its presence in different parts of South Kanara District, especially in Moodabidri, Udupi and Coondapur. Aswathapura, a place about eight km from Moodabidri, seems to be an ideal habitat for it. From the present study, it would appear, that *Hoplochaetella* species earthworms may may have a localised distribution along the western parts of India.

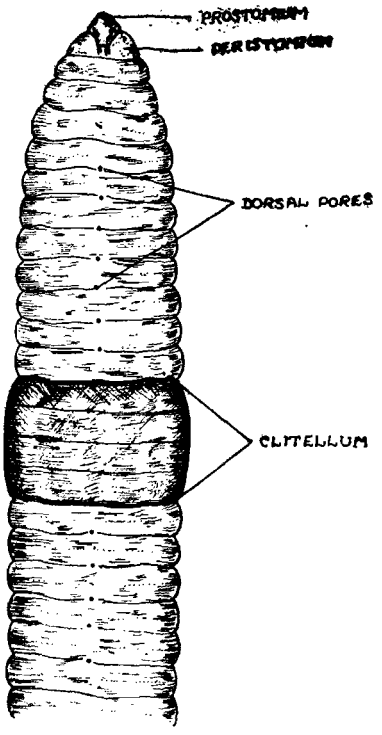
Description of H. suctoria : The length of a fully grown, clitellate worm varied from 150–300 mm and its weight from 6–12 g. The diameter in front of the clitellum was 5–10 mm. The number of segments was found to increase in proportion to the length of the body. A worm measuring 150 mm had as many as 76 segments and a worm of 220 mm had 98 segments and one of 280 mm had 140 segments. The body colour of mature clitellate specimens was light brown, with darker median strips located dorsally the ventral side being somewhat whitish. The anterior region of the body is more pointed than the posterior region. The hind end is somewhat enlarged, a possible indication of production of casts above ground. In a fully matured specimen, the hind end of the body became brittle. The anus is a longitudinal slit, at the posterior end.

As stated by Stephenson (1923) the prostomium is epilobic and the tongue extends 2/3 of the length of the first segment. The dorsal pores is observable from 4/5 (Fig. 1). Setae are perichaetine, commencing from II segment and they are 60–66 in number, on each segment. Though displaced setae are observable on the ventral part of segment VII to IX, (Fig. 2) they can not be considered as a diagnostic feature, because they vary, not only from specimens of different localities, but also in individuals from the same region. A close comparative study of 6 specimens revealed much diversity in number and positions of setae in these regions (Table I).

Gates (1940) reported these displaced setae to be in fairly straight transverse rows, but this has not been always observed. Two pairs of intrasegmental spermathecal pores in the form of minute transverse slits are however present ventrally in segment VIII (Fig. 2).

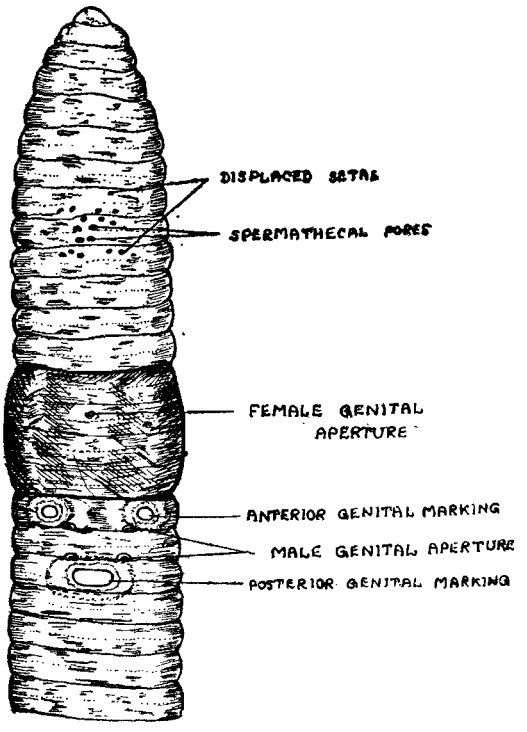
The clitellum becomes observable (Fig. 2) for only a short period during the reproductive cycle. Our observations reveal that the region from XIII to XVI segments becomes thickened to form the clitellum, during October each year. When the clitellum is fully developed, it becomes a sharply demarcated glandular annular, less-pigmented, somewhat whitish structure (Fig. 3). In the clitellate region setae and dorsal pores are seen. Contrary to the belief that these worms

burrow very deep during clitellum formation for reproduction, we found that they remain in the superficial soil. They tend to come above the surface, when the clitellum is formed, probably for copulation.



DORSAL VIEW

Fig. 1 External-features *Hoplochaetella Suctoria*



VENTRAL - VIEW

Fig. 2

TABLE I

Displaced setae

Specimen Sl. No.	No. of displaced setae		
	7th segment	8th segment	9th segment
1	3	1	4
2	5	3	5
3	3	6	5
4	3	4	3
5	3	2	5
6	4	4	8

As reported by Stephenson (1923) and Gates (1940) the male field extends from XVII to XIX segments ventrally. Setae are lacking in this region. The two pairs of male pores, minute, eliptical in outline, are located transversely in 17/18 and 18/19 (Fig. 2). In all the specimens collected from different localities

three large deeply marked whitish, sucker-like, genital markings were observed with a triangular form (Fig. 3). One pair of these genital markings seen in XVII segments, was always a circular ring-like structure. Further, in all the specimens studied, the solitary genital marking was transversely placed in the middle line of XIX segment, just below the two male pores of 18/19, and it had the appearance of an elongated oval depression (Fig. 2). In juveniles, these genital markings were lacking. A single minute, mid-ventral presetal female pore was apparent in XIV segment in a clitellate worm.

Fig .3 A normal healthy *H. suctoria*

The calciferous glands, are located in X–XIII segments. The 3rd and the 4th pair of these glands are bigger than the first two and all the 4 pairs appear as ventro-lateral outgrowths from the posterior portion of the oesophagus. In appearance they are reinform, and anterio-posteriorly flattened. In our observation of freshly killed and dissected specimens these glands contained large number of spherical or oval, colourless crystalline structures. Chemical tests have revealed them to be made up of calcium carbonate.

Sphermathecae are somewhat oval and as stated by Stephenson (1923) and Gates (1940), they have short ventrally directed digitiform diverticula. Much importance has been given to these diverticula, for identification and classification of different species of *Hoplochaetella*. The majority of the specimens examined had 15 diverticulae and a few had 18, arranged in a somewhat circular fashion. Gates (1940), in the key to species of *Hoplochaetella*, has stated that the circle of diverticulae is uninterrupted in *H. suctoria*. But in a few specimens

observed by us showed displacement of diverticulae. In one of the specimens the diverticulae comprised of two groups of 4 and 11. Variations in the diverticular number and arrangement was evidenced even when the four spermathecae taken from a single specimen were compared. Below each spermatheca covered by a thin membrane, one or two pairs of club-shaped accessory glands of 1 mm length were always observed. Prostrate glands were yellowish during breeding season.

Habits and Habitats : Although some work has been done on the morphological aspect of these worms, nothing is known about their ecological habits. A study of the habitats of these worms reveals that they are common during the rainy season in certain localised regions of South Kanara. They are entirely or mostly confined to organic matter, such as heaps of compost manures, dumps of dung, decaying leaves, sites receiving kitchen drainage, ditches having waste effluents etc. They appear to flourish well in black loamy soil having a pH in the vicinity of 7.0. It appears that laterite derived red soils is not congenial to them ; hence they are very rare in these soils. Since they need abundant organic matter they congregate around old-dung pats or other similar food sources. When they are in soils with low organic matter content, they seem to be attracted to animal droppings. Agricultural land, where chemical fertilizers or pesticides are often used, seem to be unsuitable places for them to thrive.

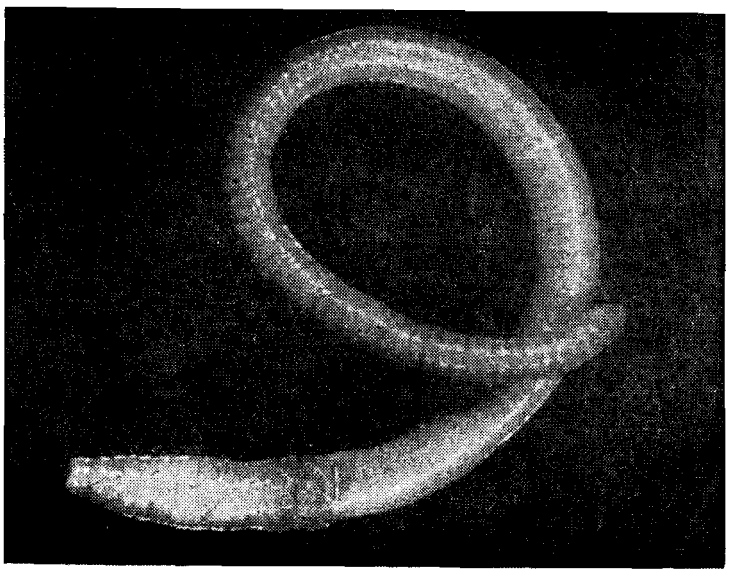


Fig. 4 Discuasal *H. suctoria*

Our field observations and population studies have revealed that they are commonly seen below *Anacardium occidentale* (Cashew), *Artocarpus integrifoli* (Jack fruit) and *Eugenia corymbosa,* trees having decaying leaves. Laboratory

observations have also tended to support this view. They were rarely encountered in paddy fields.

By nature, these worms are surface feeders and can be seen picking up food materials, generally below the dry leaves even during day time. These surface working species generally confine themselves to the top few cm of the soil profile during rainy season. It appears that as long as an adequate food supply and a cover are present on the surface soil they do not generally prefer to burrow. Perhaps, whenever there is scarcity of food or water, they are stimulated to burrow.

Generally, their burrows are curved having "U" shape. However, sometimes they are only simple straight tubes, or "Y" shaped burrows, with one or two openings. It has been observed that these worms are in the habit of keeping their posterior within the burrow and retreating at the slightest vibration on the ground.

Faeces, in the form of castings, are deposited above the soil, perhaps to prevent the burrow system from being blocked. The castings of *H. suctoria* were in the form of small pellets, about 2–5 mm in size and excreved individually. Due to this, the castings near the burrow generally appeared as little heaps of small oval pellets each distinct from the others.

In general they emerge from soil during late hours in the evening and crawl under the dry leaves. It appears that they remain very active during night. It is during this period they generally try to change their habitat against adverse factors.

Enemies and method of escape: Apart from natural enemies the man is a hazard. The majority of the farmers who have been interviewed expressed their hostility to these worms. Since they find them in their compost manure or other decaying organic matter, they conclude that they feed on manure and thus rob the plants of their nutrients. Using different methods, they kill these worms in large numbers. Detailed observations on their activity make us to believe that these worms may play an important role in the incorporation of organic matter, in the upper layers of the soil, and hence they can be treated as humus-forming agents.

Extensive field observations have revealed that these worms have three methods of escape from their enemies: (i) to remain motionless, (ii) to burrow themselves deep in to the soil very quickly and (iii) to wriggle and break their body at the hind end. In the latter method it is always the detached posterior tail end which twists and wriggles violently, thus focussing the attention of the enemy, while the anterior region, can burrow deeper and escape. This method of escape seems to be a common method in adult worms. If the worms are picked up by

the tail, they break off the tail and escape. Perhaps the autotomy of the tail region is stimulated due to the warmth of the hand. When a piece of wood or other objects which are generally cooler than the hand are used, they usually do not break off their tails. Juveniles, when picked up, usually prefer to escape by a sudden jerk and spring of the hand.

Regeneration: *Hoplocheatella* species of worms exhibit a remarkable regenerative capacity. Laboratory observations have revealed that the anterior region of the body is capable of regenerating the caudal region, but the caudal region incapable of regenerating the anterior portion. During caudal regeneration the wounded surface heals itself rapidly, and a long slender appendage appears. For a long period the regenerated region is clearly demarcated. This region is less pigmented and is narrow.

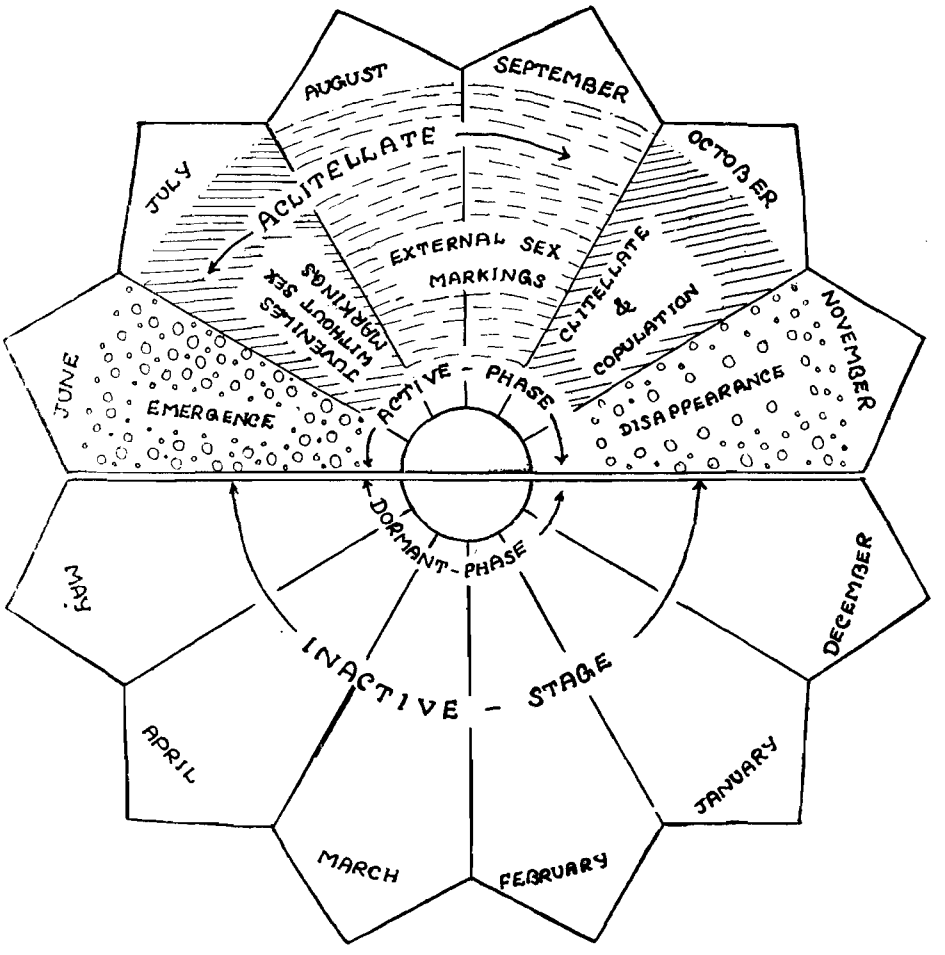
Life Cycle : The rainy season is the period of activity of these species. Detailed observations have revealed that they are not continuous breeders, but breed seasonally. Their annual cycle of activity is found to coincide with the monsoon months of the year. This means their activity is restricted to 4–6 months of the monsoon period and accordingly their life history exhibits two distinct phases, *i.e.*, an active phase and a dormant phase (Fig. 5).

(a) *Active phase* : During June soon after the advent of the rains these worms emerge from the deep soil, and appear in large numbers on the surface. Generally, it is the young ones that emerge out in large numbers, especially near the sides of water channels, ponds, ditches, etc. From this one may infer that the majority of the adults die during the adverse period. During heavy rains and when the earth is flooded they migrate to nearby suitable regions where there are ample amounts of decaying materials for them to feed upon and grow.

The young worms which emerge during June are about 2–6 cm in length. They are less-pigmented and their body wall is somewhat transparant so that their blood vessels, intestin etc., are visible. They are pale red in colour. Genital markings and reproductive apertures are not clearly visible until they reach maturity. From June until September they continue to be very active, feeding and increasing their body size and weight very rapidly. External genital markings appear generally during the months of August. Clitellar development starts or is completed during early October. However, the appearance of the recognizable epidermal differentiations does not confirm that the worm is ready for breeding.

The breeding period becomes marked by the appearance of a pale red colour around the genital pore regions. A definite date for the beginning of breeding season could not be established, however in majority of cases it occurred during late October. In rare instances copulation was also noted during

the early part of November. In the field, as well as in the laboratory, copulation has been observed. It generally occurs late in the evening or early in the morning, below dry leaves. During copulation, the worms lie with their anterior

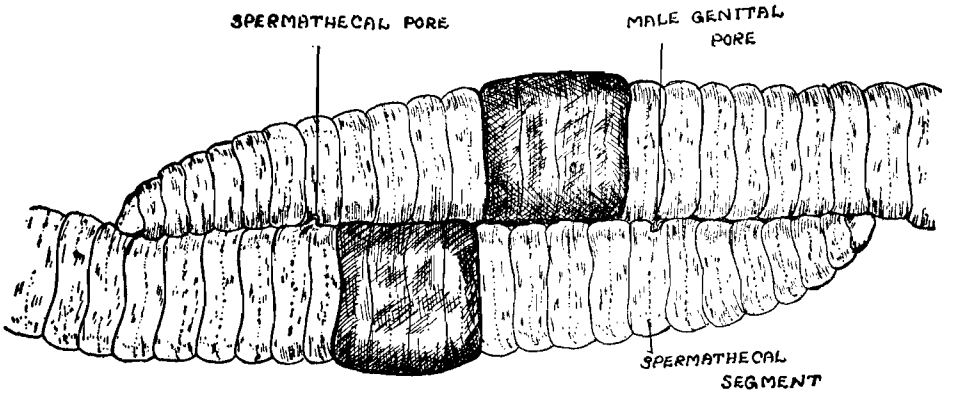


DIAGRAMATIC REPRESENTATION OF THE LIFE - CYCLE OF HOPLOCHAETELLA SUCTORIA

Fig. 5

ventral surface firmly attached with their heads in opposite directions as shown in Fig. 6. The male pores of each comes in to contact with the spermathecal pores of the other. Small tube like protruberancss from the male generative aperture make contact with the spermathecal openings. This can be seen clearly from the sides. Copulating worms keep close together for about 15–30 minutes. During copulation, they do not seem to respond readily to any external stimuli such as light or touch. When one of the copulating worms was lifted by its

tail, the other came with it still copulating. The copulation process can easily be observed by keeping the two partners on a tray. Attempts at preserving them



COPULATION IN HOPLOCHAETELLA SUCTORIA

Fig. 6

in the process of copulation however ended in failure as they suddenly got separated themselves when put into chloroform.

From all these observations, it appears that the reproductive life of these worms is short, spanning only a month or two and occurs only once in a year. As the rainfall decreases, during September, much more soil had to be dug over to secure fewer worms of these species, than was possible in the July and August months. This gives an indication that the annual cycle has a bearing on the species water relations. During the end of October these worms begin to crawl and migrate on the surface. They seemingly migrate to the nearby restricted sites where more of moisture becomes available. The migration may well be due to a microscopically recognizable peculiar disease they seem to suffer from during October. Moisture, food and congenial temperatures seem to be the primary factors in their life. Generally, cocoons are laid deep in the soil only in certain well protected and selected areas at the end of the rainy season.

There seems to be considerable variation in the size of the population of these worms from site to site. Population studies undertaken in a cashew garden near Mahaveera College, Moodabidri, during different months, by a hand sorting method (Table II) revealed that large number of juveniles existed during early monsoon and adults emerge at the end of monsoon period.

(b) Dormant Phase : During the end of November, the soil that is not kept moist artificially dries. As the soil becomes hardened, these worms disappear, presumably by vertical migration, tunnelling deep into the soil. Paucity of these worms in many field observations during subsequent months, in several regions of soils examined (which were marked for these worms during rainy season) clearly indicated their cessation of activities. Thus the period between December

and May becomes the inactive dormant period, during which they withdraw themselves to unknown depths (Fig. 5).

TABLE II

Month	No./m²		g/m²	
	Juvenile	Aclitellate	Clitellate	Total wt.
June	168	1	0	19.8
July	57	19	0	43.7
August	08	24	0	88.62
September	02	28	0	140.00
October	00	09	16	208.00
November	00	02	09	118.00

Due to the drought, the embryonic development is probably interrupted, without detrimental effects. All attempts to obtain resting adult individuals of these large worms were in vain even though considerable depths were dug over. At least, in some or other sites, their presence is very probable. However, when the deep soil, taken out during the digging of wells, was closely examined during the dry season of summer; a few resting juvenile individuals in diapause condition, suspected to be that of *H. suctoria*, were encountered. They were reddish in colour, having a mucus covering and their body coiled into a ball-like structure, taking 2 or 3 knots, with the two ends inserted inside. It appears that the young ones which have already hatched out avoid the lethal effects of drought, by cessation of normal activities and undergoing diapause. Since cocoons were not deposited in captivity in cultures maintained in the laboratory, further study on this aspect was not possible.

Further, it appers from all our detailed observations in the laboratory that they do not respond to the artificially supplied moisture. Thus, even when they were maintained in cultures in favourable conditions in large containers (with sufficient amount of moisture, food etc.) they could not survive after December.

It appears that all the essential functions of life, *i.e.*, feeding, growth, maturity and reproduction occurs during the active phase, restricted to the monsoon period, and that during the dormant phase they remain completely inactive taking an obligatory diapause.

The mortality rate of these worms at the end of the rainy season seems to be rather very high. Perhaps many adults die after laying cocoons, due to one or other adverse factors. A common unknown disease in these worms itself caused the death of a large number of adults. Due to the high mortality rate, it is natural that during the next rainy season most of the worms that emerge are the young ones. Further investigations will be directed to ascertain more about the disease they are prone to and their exact phases of life.

We are thankful to Dr. T. M. A. Pai, Registrar, Academy of General Education, Manipal, Dr. Krishna Rao, Dean of Kasturba Medical College, Manipal and Mr. U. Srinivasa Upadhyaya, Principal, Sri Mahaveera College, Moodabidri for their keen interest and facilities provided by them for this work.

We have great pleasure in recording our gratitude to Dr. G. E. Gates for the valuable suggestions. We are also grateful to the staff of Zoological Survey of India, especially Dr. G. C. Rao for the accurate identification. We also thank Miss M. Aruna Kamath, for the help given in the preparation of illustrations.

References

Edwards, C. A. and Lofty, J. R., 1972, Biology of earthworms. *Chapman and Hall*, London.

Bahl, K. N., 1960, The Indian Zoological Memoirs 1. Pheretima. reprint of 4th Edn. *Lucknow Pub. house*, Lucknow.

Bhat, J. V. and Kambata, S. R., 1957, The survey of the microflora of soils in relation to their structure and the role of earthworms in alteration of microflora of soils. Final report submitted to *Indian Council of Agricultural Research*, New Delhi.

Gates, G. E., 1940, Indian Earthworms, XII, The genus *Hoplochaetella*. *Rec. Indi. Mus.*, **42** (2): 199–252.

Gates, G. E., 1961, Ecology of some earthworms with special reference to seasonal activity. *Am. Midl. Nat.*, **66** : 61–86.

Stephenson, J., 1923, Oligochaeta, in fauna of British India. *Taylor and Francis*, London.

Tembe, V. B. and Dubash, P. J., 1961, The earthworm a review. *J. Bombay nat. Hist. Soc.*, **58** (1) : 171–201.

A Contribution to the Knowledge of Millipedes (Diplopoda : Arthropoda) of Karnataka State II

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Abstract

During the period of current investigation on the species of millipedes that occur in Karnataka, three species of millipedes *viz.*, *Arthrosphaera* sp. belonging to the family Sphaeropoeidae of the order Oniscomorpha ; *Chondromorpha severini* Silvestri and *Telodrepanum* sp. belonging to the family Paradoxosomatidae of the order Polydesmida were collected and information on these species is provided. The millipede, *Telodrepanum* sp. is recorded for the first time in Karnataka.

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Introduction

Millipedes have so far received comparatively less attention from zoologists than many other groups of arthropods in India. The earlier work of Pocock (1892), Silvestri (1916) and Attems (1936) was confined mostly to morphological descriptions of some of the oriental millipedes.

Millipedes are generally recognised as feeders on dead and disintegrating plant material. They live mostly in uncultivated forest areas either in the litter or in the surface soil and are known to help in the formation of the soil (Blower, 1955). Many species of millipedes are known to feed on plants (Theobald, 1904; Metcalf and Flint, 1962; Ramakrishna Ayyar, 1963 ; Puttarudraiah, 1958; Rangaswamy, 1969a). Rangaswamy and ChannaBasavanna (1969) reported seven species of millipedes *viz.*, *Chondromorpha kelaarti* (Hubert), *Streptogonopus jerdani* (Pocock), *Polydrepauum* sp. belonging to the family paradoxosomatidae ; *Diopsiulus* sp. belonging to the family Stemmiulidae ; *Scaphiostreptus* sp. belonging to the family Spirostreptidae ; *Phyllogonostreptus nigrolabiatus* (Newport) belonging to the family Harpagophoridae and *Aulacobolus* sp. belonging to the family Pachybolidae from the then Mysore State.

With a view to listing the different species of millipedes occurring in various parts of Karnataka and assessing their importance in agriculture the present study was undertaken.

Results and Discussion

During the course of the present study three species of millipedes *viz.*, *Arthrosphaera* sp., *Chondromorpha severini* Silvestri and *Telodrepanum* sp. were collected and the information available on them is furnished.

Order Oniscomorpha

Family Sphaeropoeidae (= Sphaerotheridae)

Arthrosphaera sp. : Individuals of *Arthrosphaera* sp. were collected from coffee estate in Balehonnur, Chikkamagalur Distric, Karnataka during the month of October, 1969.

The adult measured 5.1 mm in length and 2.3 mm in width and was yellowish-brown in colour. Head, collum and antennae were dark brown in colour.

Of two species of Sphaeropoeidae known to occur in Karnataka *Arthrosphaera zebraica* (Butler) has been reported from different places of North Karnataka and this species is known to harbour in its enteric canal a gregarine, *Hyalosporina zebraica* (Karandikar and Rodgi, 1955). Chowdaiah (1966 c) collected this species from Sorab Taluk, Shimoga District and studied its cytology. Chowdaiah (1966 c) also collected an unidentified species of *Arthrosphaera* from coffee plantations of Sakleshpur, Hassan District on which he worked out both cytology as well as the male reproductive pattern.

ORDER POLYDESMIDA

FAMILY PARADOXOSOMATIDAE (= STRONGYLOSOMATIDAE = STRONGYLOSOMIDAE)

Chondromorpha severini Silvestri

1897. *Chondromorpha severini* Silvestri, *Ann. Soc. Ent. Belgique*, XLI, p. 356, figs. 38–40.

Specimens of *Chondromorpha severini* were collected in large numbers from the betelvine garden on Agricultural College Campus, Dharwad, Karnataka during the months of June and July, 1976. They were very active during morning hours and large number of mating pairs were encountered in the field. During the sunny hours of the day they concealed themselves under fallen leaves and in cracks in soil.

This species is chestnut or black in colour. It consists of 19 segments and measures 30 mm in length. The prozonites and metazonites measure 2 mm and 3 mm respectively (Attems, 1936).

This millipede was first collected from Gokak, Belgaum District, Bombay Presidency and Sagar, Shimoga District, Mysore State (Attems, 1936). Karandikar and Rodgi (1955) made periodical collections of this species from various places in Bombay and the Karnataka area and recorded four species of gregarines, *Hyalosporina froilanoi, H. rayi, Monoductus lunatus* and *M. tubulosus* from its enteric canal.

of the seven species of Paradoxosomatidae known to occur in Karnataka *Chondromorpho mammifera* Attems has been recorded from the Bombay Presidency (Attems, 1936) and also near Bangalore (Chowdaiah, 1966 b); *C. severini* Silvestri throughout South India (Attems, 1936; Karandikar and Rodgi, 1955); *C. kelaarti* (Humbert) in various places of Bombay, Karnataka (Karandikar and Rodgi, 1955) and Nandi Hills, Kolar District (Rangaswamy and ChannaBasavanna, 1969); *Strongylosoma* sp. from Hambi, Bellary District (Chowdaiah, 1962); *Streptogonopus jerdani* (Pocock) and *Polydrepanum* sp. from Dharwad (Rangaswamy and ChannaBasavanna, 1969).

The remaining species of the family was collected during the course of present investigation and is treated elsewhere in this paper.

Telodrepanum: A few specimens of an unidentified species of *Telodrepanum* have been collected from tree trunks of *Mallotus philippinensis* in Botanical Garden, Karnatak University, Dharwad, Karnataka during the month of August, 1975.

The adult male measured 37 mm in length and 4.5 mm in width. The number of segments was 19. The species is uniformly deep chocolate-brown in colour except the antennae and legs which are light brown.

The only described species in this genus is *Telodrepanum bedaga* Carl from Nilgiris (Carl, 1932). The genus and this unidentified species of the genus are recorded for the first time from Karnataka.

The three species of millipedes encountered during the course of the present study were determined by the authorities of the British Museum (Natural History), London for whom the authors are grateful. The authors are also thankful to Dr. S. V. Patil, Director of Instruction (Agri), College of Agriculture, Dharwad-580 005, for constant encouragement and providing facilities.

References

Attems, C., 1936, Diploda of India. *Mem. Ind. Mus.*, **11** : 133–323.

Blower, J. G., 1955, Millipedes and Centipedes as soil animals. *In Soil Zoology*, Butterworth Publication, London.

Carl, J., 1932, Diplopoden aus sudindien und Ceylon, 1. Teil, Polydesmoidea. *Rev. Suisse. Zool.*, **39** : 458.

Chowdaiah, B. N., 1962, Unpublished Thesis. Mysore University.

Chowdaiah, B. N., 1966 b, Cytological studies on some Indian Diplopoda (Myriapoda). *Cytologia, Int. J. Cytology*, **31** : 294–301.

Chowdaiah, B. N., 1966 c, Chromosome studies in two species of Pillmillipedes (Diplopoda : Myriapoda). *Caryologia*, **19** : 135–141.

Karandikar, K. R. and Rodgi, S. S., 1955, Gregarines from the millipedes of Bombay-Karnataka. *J. Univ.*, Bombay, **24** : 11–37.

Metcalf, C. L., and Flint, W. P., 1962, Destructive and useful insects. *McGraw Hill Book Co.*, New York and London.

Pocock, R. I., 1892, Report upon two collections of Myriapoda sent from Ceylon by Mr. Green and from various parts of Southern India by Mr. Edgar Thurston, of the Government Central Museum, Madras. *J. Bombay Nat. Hist. Soc.*, **7** : 131–174.

Puttarudraiah, M., 1958, Millipedes damage crops. *Mysore Agric. J.*, **33** : 130–132.

Ramakrishna Ayyar, T. V., 1963, *Handbook of Economic Entomology for South India*. Government Press, Madras.

Rangaswamy, H. R., 1969a, A millipede *Phyllogonostreptus nigrolabiatus* (New port) as a pest of crops. *Sci. Cult.*, **35** : 342.

Rangaswamy, H. R. and ChannaBasavanna, G. P., 1969, A contribution to the knowledge of millipedes (Diplopoda :Arthropoda) of Mysore State. *Mysore J. agric. Sci.*, **3** : 7-12.

Silvestri, F., 1916, Four new species of *Aulacobolus* Poc. (Diplopoda : Spirobolidae) from India. *Rec. Indian Mus.*, **12** : 41-48.

Theobald, F. V., 1904, *Second Report on Economic Zoology*. British Museum (Natural History), London, pp. 1-197.

Progress of Research on Diplopoda in Karnataka

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ABSTRACT

In Karnataka, *Arthrosphaera zebraica, A. gracilis, A. disticta, A. dalyi, A. bicolor, A. hendersoni, A. craspendota* and *Arthrosphaera* sp. of the family Sphaeropoeidae of the order Oniscomorpha; *Chondromorpha mammifera, C. severini, C. kelaarti, Streptognopus jerdani, Polydrepanum* sp., *Strongylosoma* sp. and *Telodrepanum* sp. belonging to the family Paradoxosomatidae of the order Polydesmida; *Thyropygus* sp., *Phyllogonostreptus nigrolabiatus, Spirostreptus asthenes, Gongylorrhus* sp., *Ktenostreptus costulatus, Ktenostreptus* sp., *Harpurostreptus robustior* and *Harpurostreptus* sp., belonging to the family Harpagophoridae and *Scaphiostreptus* sp., belonging to the family Spirostreptidae of the order Spirostreptida; *Diopsiulus* sp. belonging to the family Stemmiulidae of the order Chordeumida; *Aulacobolus levisstmus, A. variolosus* and *Aulacobolus* sp. of the family Pachybolidae of the order Spirobolida, occur in various places and the information available on these millipedes has been presented in this paper.

INTRODUCTION

ORDER ONISCOMORPHA FAMILY SPHAEROPOEIDAE (=SPHAEROTHERIDAE)

Arthrosphaera zebraica (Butler)

1872. *Zephronia zebraica* Butler, *Ann. Mag. Nat. Hist.*, **4**: 356, Pl. XVIII, fig. 4.
1899. *Arthrosphaera zebraica* Pocock, *J. Bombay Nat. Hist. Soc.*, **12**: 275.

Distribution: North Mysore (Karandikar and Rodgi, 1955), Sorab Taluk, Shimoga District (Chowdaiah, 1966 c). *A. zebraica* has been known to harbour a gregarine, *Hyalosporina zebraica* in its enteric canal (Karandikar and Rodgi, 1955). Chowdaiah (1966 c) studied the cytology of this species and reported that the diploid chromosome number is 26 and the sex mechanism is XY.

Arthrosphaera gracilis Attems : Chowdaiah and Kanaka (1974) studied the cytology of this species and reported that the diploid chromosome number is 28 and the sex mechanism is XY.

Arthrosphaera disticta Pocock : Chowdaiah and Kanaka (1974) studied the cytology of this species of millipede according to whom the diploid chromosome number is 28 and the sex mechanism is XY.

Arthrosphaera dalyi Pocock : The cytology of this species has been worked out by Chowdaiah and Kanaka (1974) and the diploid chromosome number is 30 and the sex mechanism is XY.

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Arthrosphaera bicolor Pocock : 1895. *Arthrosphaera bicolor* Pocock, *Ann. Mag. Nat. Hist.*, (6) XVI, 411. 1899. *Arthrosphaera bicolor* Pocock, *J. Bombay Nat. Hist. Soc.*, **12**: 278.

Chowdaiah and Kanaka (1974) stated that the diploid chromosome number of this species is 30 and the sex mechanism is XY.

Arthrosphaera hendersoni Pocock

1895. *Arthrosphaera handersoni* Pocock, *Ann. Nat. Hist.*, (6) XVI, 411.

1899. *Arthrosphaera hendersoni* Pocock, *J. Bombay Nat. Hist. Soc.*, XII: 277.

According to Chowdaiah and Kanaka (1974), the diploid chromosome number of this species is 30 and the sex mechanism is XY.

Arthrosphaera craspedota Attems : Kanaka and Chowdaiah (1974) studied the male reproductive organs of this species and according to them they consisted of 2 vasa deferentia uniting anteriorly in a short median duct which forks into two long transverse branches running to the external apertures. These two ducts run almost up to last segment and are widely separated and end blindly posteriorly. The transverse connections which represent the ladder system are completely absent. Testislobes are usually 16 pairs which are similar externally and globular and lobulated and attached to vasa deferentia by short and thick stalks.

Atrhrosphoera sp. - *Distribution* : Forest area, Mysore State (Chowdaiah, 1969), Sakleshpur, Hassan District (Chowdaiah, 1966 c), Balehonnur, Chickmagalur District.

The cyptology of an unidentified species of *Arthrosphaera* was studied by Chowdaiah (1966 c) according to whom the diploid chromosome number is 30 and sex mechanism is XY.

Chowdaiah (1969) collected an undetermined species of *Arthrosphaera* and observed the occurrence of first meiotic chromatid bridges of a low frequency in the testes.

Order Polydesmida

Family Paradoxosomatidae (=Strongylosomatidae=Strongylosomidae)

Chondromorpha mammifera Attems

Distribution: Puri, Jowar fields of the then Bombay Presidency (Attems, 1936), Bangalore (Chowdaiah, 1966 b).

Chowdaiah (1966 b) studied the cytology of the species in detail and reported that the diploid chromosome number is 14 and the mechanism of sex is XY.

Chondromorpha severini Silvestri.

1897. *Chondromorpha severini* Silvestri, *Ann. Soc. Ent. Belgique*, XLI, P. 356, figs. 38–40.

Distribution: Gokak, Belgaum District, Bombay Presidency; Sagar, Shimoga District (Attems, 1936), Bombay Karnatak (Karandikar and Rodgi, 1955), Dharwar, Karnataka. Karandikar and Rodgi (1955) have recorded four species of gregarines, *viz. Hyalosporina froilanoi, H. rayi, Monoductus lunatus* and *M. tubulosus* in the enteric canal of this millipede. We have made observations on the breeding habit of this millipede according to whom during copulation the male and female lay side by side and the duration of copulation lasted for 14 minutes.

Chondromorpha kelaarti (Humbert).

1866. *Polydesmus kelaarti* Humbert, *Mem. Soc. Geneve*, **18**: 23, Pl. II, fig. 7.

1892. *Paradesmus kelaarti* Pocock, *J. Bombay Nat. Hist. Soc.*, **7**: 149, Pl. X, fig. 12.

1898. *Prionopeltis kelaarti* Attems, *Denk. Ak. Wiss. Wien.*, **67**: 358, Pl. V, figs. 99, 100.

1902. *Prionopeltis kelaarti* Carl, *Rev. Suisse Zool.*, **10**: 593.

1936. *Chondromorpha kelaarti* Attems, *Mem. Ind. Mus.*, **11**: 212–213.

Distribution: Various places in Bombay Karnatak (Karandikar and Rodgi, 1955), Nandi Hills, Kolar District (Rangaswamy and ChannaBasavanna, 1969).

This species has been known to harbour in its enteric canal seven speeies of gregarines viz. *Stenophora ovoidalis, S. tubulosus, Monoductus kelaarti, M. lunatus, M. tubulosus, Hyalosporina froilanoi* and *H. rayi* (Karandikar and Rodgi, 1956).

Streptogonopus jerdani (Pocock).

1892. *Strongylosoma jerdani* Pocock, *J. Bombay Nat. Hist. Soc.*, **7**: 22.

1936. *Streptogonopus jerdani* Attems, *Mem. Ind. Mus.*, **11**: 216.

Distribution: Dharwar, Mysore Srate (Rangaswamy and ChannaBasavanna, 1969).

Rangaswamy and ChannaBasavanna (1969) recorded this millipede for the first time in Karnataka and reported that the female millipede usually carried the male during its movements. The reproductive pattern of both male and female millipedes has been studied by Rangaswamy *et al.* (1976). The male reproductive system is of primitive type which consists of paired vasa deferentia, 30 connecting tubes of vasa deferentia and 23 pairs of stalked lateral lobes and the female reproductive system has a pair of vulvae, uteri and a single distended sac like ovary.

Polydrepanum sp.

Distribution: Dharwar (Rangaswamy and ChannaBasavanna, 1969).

An unidentified species of *Polydrepanum* was collected in Karnataka by Rangaswamy and ChannaBasavanna (1969).

The adult measures 18 mm in length and 2 mm in width. The female is paler while the male is uniformly dark brown in colour. The number of segments is 19. A deep constriction is present between the pro and metazonite of each segment. A shallow transverse groove is present on the dorsum of the metazonite in most of the trunk segments, the groove extending of the lateral longitudinal ridge on each metazonite. A blunt caudal spine is present.

Rangaswamy (1973) made observations on the breeding habits of this millipede. During copulation the male and female lay side by side and no coiling was involved and the copulation lasted for nearly 27 minutes.

Strongylosoma sp.

Distribution: Hampi, Bellary District (Chowdaiah, 1962), Bombay Karnatak (Karandikar and Rodgi, 1955).

Karandikar and Rodgi (1955) recovered two species of gregarines *viz. Stenophora nematoides* and *S. spiroboli* from the enteric canal of an unidentified species of *Strongylosoma*, Chowdaiah (1966 a) worked out the cytology of an unidentified species of *Strongylosoma* which exhibited the diploid chromosome number of 24.

Telodrepanum sp.

Distribution: Dharwar (Rangaswamy *et al.*, Unpublished).

We collected an unidentified species of *Telodrepanum* from the tree trunks of *Mallotus philippinensis* in Botanical Garden of Karnatak University, Dharwar during the month of August, 1975. This is the first record of the genus *Telodrepanum* in Karnataka. The adult male measures 37 mm in length and 4.5 mm in width. The number of trunk segments is 19. The species is uniformly deep chocolate brown in colour except the antennae and legs which are light brown.

Order Spirostreptida

Family Harpagophoridae

Thyropygus sp.

Distribution: Bangalore (Chowdaiah, 1966 b), Bombay Karnatak (Karandikar and Rodgi, 1955, 1956).

Karandikar and Rodgi (1955, 1956) recovered a gregarine, *Stenophora karnataki*, a ciliate, *Nyctotherus thyropygus* and a flagellate, *Metastephanonympha karnataki* from the enteric canal of this millipede. Chowdaiah (1966 c) studied the cytology of an undetermined species of *Thyropygus* and reported the diploid chromosome number as 24 and sex mechanism as XY.

Phyllogonostreptus nigrolabiatus (Newport).

[= *Thropygus nigrolabiatus* (Newport)] .

1844. *Spirostreptus nigrolabiatus* Newport, *Ann. Mag. Nat. Hist.*, **13**: 269.

1892. *Spirostreptus nigrolabiatus* Pocock, *J. Bombay Nat. Hist. Soc.*, **7**: 159, Pl. i, fig. 7, Pl. ii, fig. 5.

1918. *Phyllogonostreptus nigrolabiatus* Carl, *Rev. Suisse Zool.*, **26**: 426.

Distribution: Bombay Karnatak (Karandikar and Rodgi, 1955, 1956), Dharwar (Rangaswamy and ChannaBasavanna, 1969).

P. nigrolabiatus has been reported to harbour in its enteric canal a gregarine, *Stenophora papillata*, a ciliate, *Nyctotherus diplopodae* and a flagellate, *Metastephanonympha karnataki* (Karandikar and Rodgi, 1955, 1956).

Rangaswamy (1969 a) observed this millipede feeding on *Sorghum vulgare*, *Crotalaria juncia*, *Dolichos lab lab*, *Vigna sinensis*, *Amaranthus paniculatus* and *A. gangeticus* at Dharwar. Observations on the breeding habits of this millipede were made by Rangaswamy (1969 b) who reported that the male coiled tightly round the female and the copulation lasted for nearly 1 hour and 11 minutes.

Rangaswamy and ChannaBasavanna (1973) recorded an unidentified species of a mite, *Heterozercon* belonging to the family Heterozerconidae on the body of this millipede. The mites were found moving freely all over the body of the millipede and the average number was 8 per millipede. No apparent ill-effect was noticed on the millipede due to the infestation by the mites.

Spirostreptus asthenes Pocock

1892. *Spirostreptus asthenes* Pocock, *J. Bombay Nat. Hist. Soc.*, **7**: 161.

Chowdaiah and Kanaka (1970) studied the cytology of the species according to whom the diploid chromosome number in Spermatogonial metaphase is 16 and the sex mechanism is XY.

Gongylorrhus sp.

Distribution: Bombay Karnataka (Karandikar and Rodgi, 1956).

Work done: This millipede has been reported to harbour a ciliate, *Nyctotherus gongylorrhus* in its enteric canal (Karandikar and Rodgi, 1956).

Ktenostreptus costulatus (Attems)

1913. *Ktenostreptus costulatus* Attems, *Denkschr. Ak. Wiss. Wien.*, LXXXIX, P. 684, figs. 14–16.

1930. *Ktenostreptus scaberrimus* Verhoeff, *Zool. Anz.*, LXXXIX, P. 202, figs. 6–9.

Kanaka and Chowdaiah (1974) have worked out the male reproductive pattern of this millipede.

Ktenostreptus sp.

Distribution: Jagalur, Chitaldrug District (Puttarudraiah, 1958; Chowdaiah 1966 b).

Puttarudraiah (1951) observed an unidentified species of *Ktenostreptus* damaging chillies heavily. It was also found feeding on cotton seedlings, coriander, blackgram, wild brinjal, Ipomea weeds and onions exposed from the soil. Puttarudraiah and Shivashankara Sastry (1959) studied the bionomics of this millipede. Eggs were laid in earthen cells and were 0.2 mm wide with an incubation period that varied from 63 to 74 days with an average of 66.8 days· The cytology of on unidentified species of *Ktenostreptus* was studied by Chowdaiah (1966 b) who reported that the diploid chromosome complex consisted of 20 chromosomes of which two were sex chromosomes (XY).

Harpurostreptus robustitor (Humbert)

The male reproductive pattern of this species has been worked out by Kanaka and Chowdaiah (1974).

Harpurostreptus sp.

Distribution: Bangalore (Chowdaiah, 1966 b)

The cytology of this unidentified species of millpede was studied by Chowdaiah (1976 b) according to whom the spermatogonial metaphase consisted of 12 chromosomer and the sex mechanism as XY.

FAMILY SPIROSIEPTIDAE

Scaphiostreptus sp.

Distribution: Dharwar (Rangaswamy and ChannaBasavanna, 1969).

The adult female measures 80 mm in length and 8 mm in width with 50 trunk segments, uniformly dark brown in colour except the antennae and legs which are pale brown. There appears to be no previous record of this genus in India (Rangaswamy and ChannaBasavanna, 1969).

ORDER CHORDEUMIDA

FAMILY STEMMIULIDAE

Diopsiulus sp.

Distribution: Balehonnur, Chickmagalur District (Rangaswamy and ChannaBasavanna, 1969).

Individuals of this unidentified species of *Diopsiulus* were collected from soil in Balehonnur, Karnataka during the month of December, 1966. The genus was recorded for the first time for Karnataka. It measured 22 mm in length and 2.1 mm in width with 37 trunk segments. The antennae were pale white in colour while the head, collum and last two trunk segments were pale

brown. Head was punctate, Legs short, pale white. Prozonites punctate and broader than metazonites (Rangaswamy and ChannaBasavanna, 1969).

Order Spirobolida

Family Pachybolidae

Aulacobolus levissimus Attems

Kanaka and Chowdaiah (1974) studied the male reproductive pattern of this millipede according to whom the male reproductive pattern of this millipede represents further simplification in the progression of evolutionary changes from the reticular-type to the ladder type.

Aulacobolus variolosus (Silvestri)

1916. *Aulacobolus variolosus* Silvestri, *Rec. Ind. Mus.*, XII : 46.

The male reproductive pattern of this millipede has been studied by Kanaka and Chowdaiah (1974) according to whom the basic plan of the male reproductive pattern in *A. variolosus* is a considerable simplification of the typical ladder system of *Ktenostreptus costulatus*.

Aulacobolus sp.

Distribution: Nandi Hills, Kolar District (Rangaswamy and Channa-Basavannna, 1969).

Rangaswamy and ChannaBasavanna (1969) collected specimens of an unidentified species of *Aulacobolus* from tree trunks on Nandi Hills (4,850 feet), Kolar District, during July, 1967, The specimen measured 45 mm in length and 3.4 mm in width and trunk consisted of 42 segments. Prozonites were brown with longitudinal oblique streaks irregularly arranged which extend to the entire width of segments ventrally. Metazonites were paler. The brown colour gradually deepened from the anterior to posterior end of the body. Head pale brown, legs and antennae pale white in colour. Antennae short, face flat. A single ventral seta on each segment of the leg. Eyes composed of 45 ocelli arranged in seven thansverse rows. This was the first record of this genus in Karnataka.

Chowdaiah and Kanaka (1970) studied the cytology of an unidentified species of *Aulacobolus* according to whom it has 26 diploid chromosomes and the sex mechanism is of XY type.

References

Attems, C., 1937, Diplopoda of India. *Mem. Ind. Mus.*, **11** : 133–323.

Cowdaiah, B. N., 1966 a, Cytological investigations on some Indian Diplopoda (Myriapoda). *Nature*, **210** : 847.

Chowdaiah, B. N., 1966 b, Cytological studies on some Indian Diplopoda (Myriapoda). *Cytologia. Int. J. cytology*, **31** : 294–301.

CHOWDAIAH, B. N., 1966 c, Chromosome studies in two species of Pill-millipedes (Diplopoda–Myriapoda). *Caryologia*, **19** : 135–141.

CHOWDAIAH, B. N., 1962, Unpublished thesis, Mysore University.

CHOWDAIAH, B. N., 1969, A note on the occurrence of chromatid bridges in the male of *Arthosphaera* sp., a pill-millipede. *Curr. Sci.*, **38** : 169–170.

CHOWDAIAH, B. N. AND KANAKA, R., 1969 (1970), Cytological studies of Indian diplopoda II (Myriapoda). *Bulletin Du Museum National D' Historie Naturelle.* 2e serie-Tome 41-supplement n°2, pp. 43–47.

CHOWDAIAH, B. N. AND KANAKA R., 1974, Cytological studies on six species of Pill-millipedes (Diplopoda-Myriapoda). *Caryologia*, **27**: 55–64.

KANAKA, R. AND CHOWDAIAH, B. N., 1974, Studies on the male reproductive pattern in some Indian Diplopoda (Myriapoda). *Symp. Zool. Soc. London*, **32**: 261-272.

KARANDIKAR, K. R., AND RODGI, S. S., 1955, Gregarines from the millipedes of Bombay-Karnatak. *J. Univ. Bombay*, **24** : 11–37.

KARANDIKAR, K. R. AND RODGI, S. S., 1956, Ciliates and flagellates from the millipedes of Bombay-Karnatak. *J. Univ. Bombay*, **24**: 1–11.

PUTTARUDRAIAH, M., 1958, Millipedes damage crops. *Mysore Agric. J.*, **33** : 130–132.

PUTTARUDRAIAH, M. AND SHIVASHANKARA SASTRY, K. S., 1959, A preliminary note on the bionomics of a millipede damaging crops in Mysore. *Proc. First All-India Congr. Zool.*, 393-398.

RANGASWAMY, H. R., 1969 a, A millipede *Phyllogonostreptus nigrolabiatus* (Newport) as a pest of crops. *Sci. Cult.*, **35**: 342.

RANGASWAMY, H. R., *1969 b, Observations on the breeding habit of the millipede Phyllogonostreptus nigrolabiatus. Sci. Cult.*, **35**: 480–481.

RANGASWAMY, H. R., 1973, Observations on the breeding habit of the millipede *Polydrepanum* sp. *Mysore J. agric. Sci.*, **7**: 328–330.

RANGASWAMY, H. R. AND CHANNABASAVANNA, G. P., 1969, A contribution to the knowledge of (Diplopoda: Arthropoda) of Mysore State. *Mysore J. agric. Sci.*, **3**: 7–12.

RANGASWAMY, H. R. AND CHANNABASAVANNA, G. P., 1973, A new species of *Heterozerconid* mite (Mesostigmata: Heterozerconidae) from India. *Mysore J. agric. Sci.*, **7** : 134–136.

RANGASWAMY, H. R. AND GOVINDAN, R. AND VISWANATH, B. N., Observations on the breeding habit of the millipede *Chondraomorpha severini* Silverstri (Diplopod: Arthropoda) (Unpublished).

RANGASWAMY, H. R., GOVINDAN, R. AND VISWANATH, B. N., A contribution to the knowledge of millipede (Diplopoda: Arthropoda) of Karnataka State II (Unpublished).

RANGASWAMY, H. R., JAYARAMAIAH, M. AND PUTTASWAMY, 1976, The reproductive pattern of the millipede *Streptogonpus jerdani* (Pocock) (Diplopoda:Arthropoda) *Mysore. J. agric. Sci.*, **10**: 255–259.

The Role of the Millipede Jonespeltis *Splendidus* (Verhoeff) in soil Humification

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ABSTRACT

Millipedes are important macrofauna of the woodland soil. The flat back millipede *Jonespeltis splendidus* (Verhoeff) had a diurnal rhythm of activity. Humification of the soil occurred during its passage through the gut, which harboured a number of microorganisms. Humification of the soil was studied by incubating cultured gut flora in control soil. The fungi present in the gut humified the soil. The survey of digestive enzymes of the millipedes showed that the lipolytic digestion may be entirely due to symbiotic relationships. The excrements contained nitrogenous excretory material in the form of ammonia, urea and uric acid. Biochemical changes and rate of humification by the millipede was studied in four different soils namely brown loam, brown clay loam, black loam and black clay loam. Preference of millipedes for different types of soils and organic matter was also observed by choice experiments. In addition expulsion of HCN through the repugnatorial glands of the millipede was also noted.

AMONG soil animals millipedes are important macrofauna of the soil in woodland. (Wallwork, 1970). They are found to inhabit arable land and garden soils too. They are saprophagous, fungivorous and coprophagous and contribute much to the formation of soil (Kuhnelt, 1966), Millipedes are known to be the mull formers (Romell, 1935, Jacot, 1940; and Eaten, 1943). They comminute the litter and effect the mixing up of this with the soil minerals (Kubiena, 1955). Their excrements affect soil structure by the formation of soil aggregates, which provide good aeration and drainage (Kubiena, 1955).

The millipede *Jonespeltis splendidus* (Verhoeff) is a common flat-back millipede in peninsular India. It weighs about 100 mg and has 19 body segments. It is found to inhabit cool and well-aerated manure, compost heaps, garden soils and forest floors in large numbers. From earlier work, it is understood that the feeding and excretory activity is established in a diurnal rhythm, with a peak of activity in the morning hours of the day (Bano *et al.*, 1976). There is a considerable increase in the humus content of the soil in the excrements of the millipede (Table I) (Bano *et al.*, 1976). The humification of the soil is related to the passage of the food through the gut, which can harbour about 14 genera of fungi and a large number of bacteria belonging to gm^{+}, gm^{-}, cocci and Bacilli (Table II) (Bano *et al.*, 1976). It is known that microbial activity in soil increases its humus content, Fungal and bacterial isolates of the gut populatton were incubated with soils in vitro and it was found that the fungal isolates of the

TABLE I

Humification of the soil during excretion by Jonespeltis splendidus

Humus		Incidence of change on excretion
Soil consumed	Soil excreted	
1.358±0.056	8.422±2.56	t = 6.169 p <0.001, increase

Values are mean ± S. D. of 5 observations.

TABLE II

Survey of the occurrence of microflora in the digestive tract of the millipede Jonespeltis splendidus

Genera	Presence of the organism		
	Soil consumed	Foregut Stomodeal	Hindgut Proctodeal
A : Fungi			
1. Fusidium	—	P	P
2. Cladosporium	—	P	P
3. Trichoderma	P	—	—
4. Fusarium	P	—	—
5. Helminthosporium	P	—	—
6. Non-sporulating white mycelium	P	—	—
7. Phoma	—	P	—
8. Monosporium	—	P	—
9. Diplocladium	—	P	—
10. Mucor	—	P	—
11. Non-sporulating brown mycelium	—	—	P
12. Cylindrocephalum	—	—	P
13. Torula	—	—	P
14. Aspergillus	P	P	P
B : Bacteria			
1. Cocci	P	P	P
2. Bacilli	P	P	P
3. Gram+ve	P	P	P
4. Gram−ve	P	P	P
5. Spore−formers	P	P	P
6. Non—spore formers	P	P	P

— indicates the absence of the organism and P indicates the presence.

gut helped in humifying the soil (Table III) (Bano *et al.*, 1976). The ratios of humic to fulvic acid in the extracts of defaecated soil indicated that, it contained condensed substances similar to fulvic acid.

The occurrence of symbiotic fungi and bacteria in the gut of the millipede prompted us to check whether the animal is dependent on symbiotic activity for some of its digestive functions like the termites, (Hungate, 1943). The gut of the

TABLE III

In vitro *humification of the soil by the fungal isolates of the millipede–gut*

(The control soil had 1.43 per cent of humus)

Genera	Per cent of humification by 10^6 organisms per day
1. Control soil (without any organisms)	0.00
2. Helminthosporium	2.10
3. Aspergillus	20.20
4. Cladosporium	56.80
5. Trichoderma	45.40
6. Fusarium	0.00
7. Fusidium	1.96
8. Non-sporulating brown mycelium	90.80
9. Phoma	75.20

millipede secretes proteases, and carbohydrases such as amylase, in nature. Cellulase is absent from the gut. The animals were deflorated by administering antibiotics and antifungal agents through filter paper feeding. The fungi were eliminated by feeding millipedes with 0.2 per cent antifungal agent Dithane M-45 (Rohm & Hoas Co. Philadelphia, USA) and the bacteria were eliminated from the animals by feeding 0.2 per cent antibiotic Dicrysticin (Sarabhai Chemicals Pvt. Ltd.). The deflorated animals lost the secretions of lipase entirely, suggesting that the symbionts help in the digestion of dietary fats for the host. The dietary proteins and carbohydrates are partially digested by the symbionts (Bano *et al.*, unpublished observation).

The pH of the digestive tract suggested that the stomodeal region of the millipede is acidic and the proctodeal region is alkaline. The humification of the food during the passage through the gut from the anterior to posterior regions showed a relative degree of humification from the stomodeal region to the proctodeal region. It could be suggested by these observations that the hind part of the gut provides a congenial microhabitat for the microbial flora which humify the soil (Bano *et al.*, unpublished observation). However, it should be ascertained whether any pH-specific symbiotic microbes exist in the gut.

Experiments on the occurrence of ammonia, urea, and uric acid in the excrements indicated that more ammonia and urea are excreted into the soil by the animals than uric acid (Table IV). The increase in ammonia content is associated with the autolytic degradation of symbiotic microbes. It is suggested that these millipedes are *ureotelic* like other soil animals (Bano *et al.*, 1976).

Biochemical changes brought about by the feeding activity of the millipede in four different soils namely brown loam, brown clay loam, black loam and black clay loam were studied (Bano and Krishnamoorthy).

TABLE IV

Analysis of soil consumed and excrements of Jonespeltis splendidus

Constituent	μg/day/individual		Incidence of change on excretion	
	Soil	Excrement		
1. Total nitrogen content (4)	26−2	25−3	t=0.5547, p 0.1	no change
2. Total organic matter (6)	356−26	186−32	t=7.392, p 0.001	decrease
3. Total ammonia (6)	0.005−0.001	0.34−0.11	t=7.491, p 0.001	increase
4. Total urea (6)	0.005−0.001 (traces)	0.16−0.06	t=6.276, p 0.001	increase
5. Water content (mg) (8)	21.4−2.16	1.92−0.29	t=31.27, p 0.001	decrease

Values are mean − S. D. of observations given in parenthesis.

It was concluded that the defaecation had increased the humus content (Table V) and also had enriched the soil with minerals by conversion from inavailable form to available form, thus increasing the availability of the mineral nutrient in the soil (Bano and Krishnamoorthy).

TABLE V

Changes in per cent humus of the soils due to defaecation by the millipede J. splendidus *($\bar{x}$ — SD of n=7)*

	SOIL TYPES			
	Brown loam	Brown clay loam	Black loam	Black clay loam
Soil	1.19−0.12	2.25−0.44	1.75−0.11	1.45−0.02
Excrement	2.44−0.28	7.64−0.27	8.45−0.74	4.96−0.27
Incidence of change on defaceation	Increase t=6.0964	Increase t=20.9485	Increase t=20.4443	Increase t=17.8624

Millipedes were tested for their preference for different types of soils and different percentages of organic matter by providing choice. They showed greater preference for soil with high percentage of leaf litter at a suitable stage of decomposition. They eat away all the soft parts of the leaf leaving the veins as mesh. Among the soils tested it was found that the millipedes preferred black clay loam soil. Among the animal organic matter, they had greater affinity and attraction towards farmyard manure than to dead animal tissues (Bano *et al.*, unpublished observations).

In addition to soil humification, we would like to emphasize the defensive secretions of this millipede. The millipede has repugnatorial glands situated in pairs on some of their segments. These glands expel HCN, which repels ants, termites and cockroaches. Quantitative estimation of the gas was ascertained by aeration, and collecting it into ammonial silver iodide and estimated turbidometrically. *J. splendidus* expelled 23±4 μ moles of gas per animal per discharge (Bano and Krishnamoorthy, 1976).

References

Bano, K., Baghyaraj, J. D., Krishnamoorthy, R. V., 1976, Feeding activity of the millipede *Jonespeltis splendidus* (Verhoeff) and soil humification. *Proc. Indian acad. Sci.*, **83** B, No. 1, 1976, pp 1–11.

Bano, K., Krishnamoorthy, R. V., 1977Changes in the composition of soils due to defaecation by the millipede *Jonespeltis splendidus* (Verhoeff) Accepted for publication in *Mysore J. agri. Sci.* (1977).

Bano, K., Krishnamoorthy, R. V., 1976, Alarm secretion in a soil feeding millipede and its ecological significance. Abstract published in 5th annual conference of the Ethological Society of India.

Eaton, T. H., 1943, Biology of the mull forming millipede *Apheloria coriacea* (Koch). *Amer. Midl. Nat.*, **29** : 713–723.

Hungate, R. E., 1943, Cellulose fermentation in termite protozoa. *Ann. Ent. Soc. Amer.* **34**: 467.

Jacot, A. P. 1940, The fauna of the soil. *Quart. Rev. Biol.*, **15** : 28–58.

Kubiena, W. L., (1955) Animal activity in soils as a decisive factor in establishment of humus forms. pp 73–82, in *soil zoology*, D. K. McE Kevan.

Kuhnelt, W., (1961) *Soil Biology with special reference to the animal kingdom.* (English ed., trans. Walker, N.), Faber, London. 397 pp.

Romell, L. G., 1935, An example of Myriapods as mull formers. *Ecology*, **16** : 67–71.

Wallwork, J. A., 1970, *Ecology of Soil Animals.* Mc Graw-Hill, London, pp 283.

Observation on the Mating Habit of the Millipede *Chondromorpha severini* Silvestri (Diplopoda: Arthropoda)

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Abstract

Observations made in the laboratory, on the mating habit of the millipede, *Chondromorpha severini* Silvestri revealed that mating took place during the months of June and July. The male was aggressive and seized the gnathochilarium of the female. It charged its gonopods into the female genital pore and the copulation lasted for fourteen minutes. No coiling was involved during copulation. Large number of mating pairs were observed in the field.

THE adults of *Chondromorpha severini* Silvestri are chestnut or black with the posterior half of the antennae and legs pale yellow, and measure 30 mm in length with the width of the metazonites and prozonites being 3 mm and 2 mm

:espectively (Attems, 1936). Rangaswamy *et al.* (1974) have studied the male reproductive pattern of *C. severini* and according to them the genital region in this species consisted of the first seven segments. The paired genital opening was located on the sternum of the second segment and the seventh segment bore the gonopods ventrally in place of first pair of legs. The presence of gonopods distinguished the male from the female.

Adults of *C. severini* were collected during the months of June and July from the betelvine garden on the Agricultural College campus, Dharwad, Karnataka. They were kept in petri dishes containing humus and moist soil in the laboratory to study their breeding habits. The sexes could be easily distinguished because the male was slenderer than female (Fig. 1).

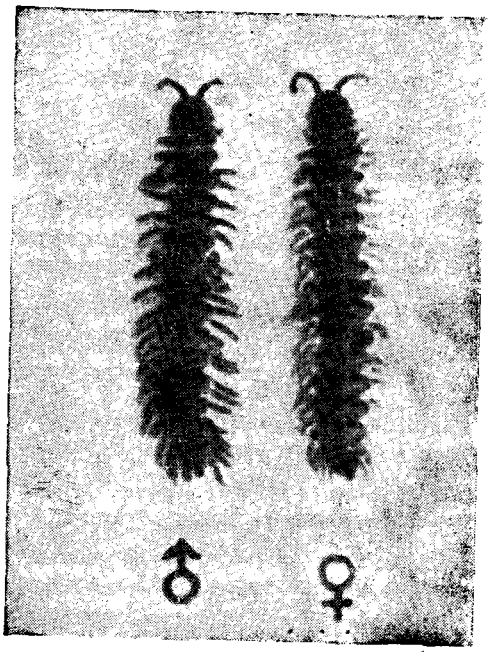

Fig. 1

Mating took place during June and July. The male was aggressive and followed the female from behind and crept along the back of the female until the head of the female was reached. Then it immediately turned towards the ventral side of the female and siezed the gnathochilarium of female with its mandibles. This hold was retained until the body of the female throughout its length was embraced in the broad grasp of the male. In this position the last six segments of the female lay outside and the remaining segments were firmly embraced by male during copulation (Fig. 2). The male inserted its gonopods into the female genital pore and copulation on an average lasted for 14 minutes. Soon after copulation, the male released the gnathochilarium of the female and

lifted its head up along with the anterior part of the trunk during which time the female started to creep forward. Then the male crept backwards. Large number of mating pairs were encountered in the field during the period of investigation.

The position assumed by male and female during copulation varies in different species. In *Phyllegonostreptus nigrolabiatus* (Newport) the male has

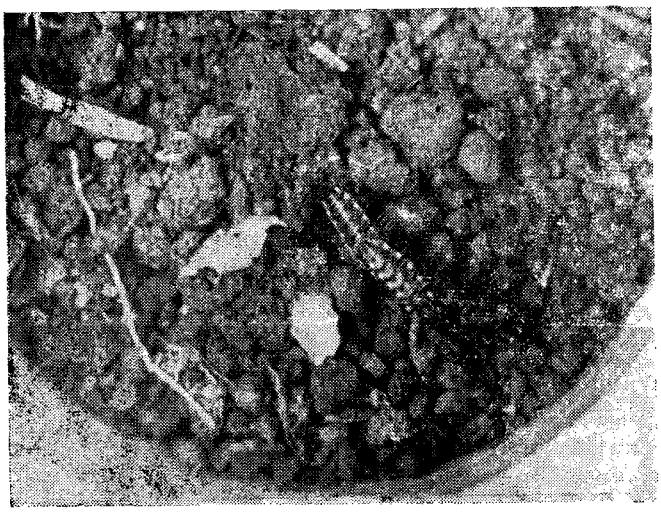

Fig. 2

been reported to coil round the female (Rangaswamy, 1969 b) while in *Polydrepanum* sp. the male and female lies side by side and no coiling was involved during copulation (Rangaswamy, 1973).

In *C. severini* the male and female were also observed to lie side by side and coiling was not involved during copulation.

The authors are thankful to Dr. S. V. Patil, Director of Instruction (Agri), College of Agriculture, Dharwad, for his constant interest and encouragement.

References

Attems, C., 1936, Diplopoda of India. *Mem. Ind. Mus.*, **11** : 133–323.

Rangaswamy, H. R., 1969 b, Observations on the breeding habit of the millipede *Phyllegonostreptus nigrolabiatus* (New port). *Sci. Cult.*, **35** : 480–481.

Rangaswamy, H. R., 1973, Observations on the breeding habit of the millipede *Polydrepanum* sp. *Mysore J. agric. Sci.*, **7** : 328–330.

Rangaswamy, H. R., Viraktamath, C. A. and Vijayalakshmi, S., 1974, The male reproductive pattern in *Chondromorpha severini* Silvestri (Diplopoda : Arthropoda). *Curr. Res.*, **3**: 6–7.

Distribution of Oribatid Mites (Acari) in India

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Abstract

An idea of the species of oribatid mites occurring in five States of India *viz.*, West Bengal, Bihar, Uttar Pradesh, Madras (Tamil Nadu) and Sikkim is given. The total number of species described and reported from India at present stands at 119, distributed through 64 genera and 40 families. Genera and species reported and described from West Bengal alone are 34 and 53 respectively. A strategraphical division of mites has been attempted. Of the 119 species 87 species belonging to 41 genera are known to occur in the plains of West Bengal, Bihar and Uttar Pradesh. Two species under one genus have been described from the Nilgiri Hills. South India and 30 species distributed over 23 genera have been described and reported from Sikkim Himalaya and Himalaya of Central Asia. About 9 per cent of the genera are exclusively restricted to the temperate high altitude regions, 9 per cent occur both in high altitude and plain lands and the remaining 68 per cent have been found only in the plain lands. An attempt is made to draw a correlation between the occurrence of oribatid mites in India and the ecology and biogeography of the subcontinent.

Introduction

Oribatid mites form a complex group of the order Acarina, frequently designated as "beetle" or "moss" mites. According to Noordam and DeVlieger (1943) and Van der Drift (1951) Oribitadal are the predominating inhabitants of forest litter. They are primarily fungivorous, algivorous or saprophagous and occur in soil litter, humus, compost heaps, in moss, lichens growing over tree stumps, in twigs and leaves, in nests of birds (Aoki, 1966), in caves (Moritz *et al.*, 1971), in lava caves (Yamamoto and Aoki, 1971), pasture soil, coniferous taiga forest, arctic tundra (Bregetova, 1965) and even in Antarctic zones (Wallwork, 1971). A few species are slightly hydrophilic and some inhabit the sea (Willman, 1931). Thus, they occur in almost all ecological niches, especially where vegetative materials decay with sufficient moisture and are penetrated by fungal mycelia.

In recent years, attention has been paid to this group owing to their economic importance. Many species of oribatid mites act as intermediate hosts of certain anoplocephaline cestodes and are responsible for the transmission of various helminth diseases of cattle and other domesticated animals (Stunkard, 1937, 1941; Kates and Runkel, 1948; Anantaraman, 1951). Oribatid mites belonging to the families Carabodidae, Liacaridae, Pelopidae, Galumnidae, Oribatulidae, Notaspidae and Haplozetidae have been reported as vectors of

various tapeworms. Anantaraman (1951) described a new species of oribatid mite, *Scheloribates madrasensis* from Madras, India which was known to act as intermediate host of *Moniezia*, the large tapeworm of domestic ruminant.

It is claimed by oribatidologists that the Oribatidae may be instrumental in decomposing organic material in or on the soil and promote soil fertility. Sellnick (1928) believed that they contribute considerably to the fertility of the forest soil. Jacot (1930) pointed out that the bodies, bristles, legs and mouth parts of many species of oribatid mites are infested with spores of fungus and help in the spread of fungal infection to plants as move from one plant to another. Rockett and Woodring (1966) found a new species of *Pergalumna* that fed (in all stages except larval) on both saprophytic and plant parasitic nematodes. It was suggested that normally saprophytic oribatids may constitute an important regulator of soil nematode populations. Therefore, in view of importance of these mites in veterinary, soil zoology and agriculture, their taxonomy should be understood.

More than five thousand species of oribatid mites belonging to over 735 genera under 135 families have been described from the world.

Indian oribatid mites are known through the works of Pearce (1906), Ewing (1910), Jacot (1933), Baker (1945), Anantaraman (1951), Prasad (1965), Aoki (1965), Bhaduri and Raychaudhuri (1967, 1968), Singh and Mukherjee (1971), Chakrabarti and Bhaduri (1972), Kardar (1972, 1974), Chakrabarti, *et al.* (1972, 1973), Banerjee (1972), Bhaduri *et al.*, (1974), Bhattacharya *et al.* (1974), Bhaduri *et al.* (1975) and Singh and Pillai (1975).

The total number of species of oribatid mites described and reported from India is 119 belonging to 66 genera and 40 families. All these species has been reported and described from five states of India *viz.*, West Bengal, Bihar, Uttar Pradesh, Tamil Nadu (Madras) and Sikkim. Oribatid mites of other Indian states have still to be explored.

From a total of 119 species described and reported from India 87 species have been reported and described from the tropical plains of West Bengal, Bihar and Uttar Pradesh, 2 species were reported from the Nilgiri Hills, South India and 30 species from temperate high altitude regions of Sikkim Himalaya.

It is interesting that certain genera are restricted to the temperate high altitude regions only and have not been recorded from the tropical plain lands. The occurrence of the genera *Hypochthonius* C. L. Koch, 1836, *Nothrus* C. L. Koch, 1836, *Heminothrus* Berlese, 1913, *Platynothrus* Berlese, 1913, *Tyrhypochthonius* C. L. Koch, 1836, *Hermannia* Nicolet, 1855, *Cepheus* C. L. Koch, 1836,

Ommatocepheus, Berlese, 1896, *Cymbacremasus*, Berlese, 1896, *Unduloribates* Balogh, 1943 in the temperate high altitude regions (4,000–8,000 ft) of Sikkim where the average annual temperature and rainfall vary from 4°C–15.5°C and 120″–180″ respectively and their absence from tropical plain lands of West Bengal, Bihar and Uttar Pradesh where the annual temperature and rainfall vary from 10°C–46.11°C and 25–60″ suggests that these genera are adapted to the bioecological conditions of high altitude area. Some of these genera had been previously reported from Europe, Japan and some of them from Greenland, Canada and U.S.A. Their occurrence in Sikkim and Himalaya of Central Asia may speak of their adaptation to temperate and extreme cold climates.

The genera *Tectocepheus* Berlese, 1913 and *Oribatula* Berlese, 1896 have been reported from Sikkim Himalaya as well as from the tropical plains of Aligarh and Varanasi. Similarly, two other genera *Eupelops* Ewing, 1917 and *Chaunoproctus* Pearce, 1906 are known to occur in Sikkim and the gangetic plains of West Bengal. The genus *Schelonibates* Berlese, 1908 has been reported from the plains of West Bengal (Bhaduri, 1971 ; Deb, 1974, Chakrabarti, 1975) and Kerala (Haq, 1975) *Lamellobates* Hammer, 1958 and *Paralamellobates*, Bhaduri and Raychaudhuri, 1968 from West Bengal.

Recently a survey of soil oribatid mites undertaken by Bhaduri and Raychaudhuri in Darjeeling, Sikkim, Manipur and Nagaland in 1973–74 and in the coastal regions of West Bengal in 1975 also reported the above-mentioned genera. Therefore, the occurrence of these oribatid genera in the temperate high altitude regions as well as in tropical plain lands and in coastal regions show their tolerance to diverse ecological niches.

The senior author is grateful to Dr. D. B. Dutta, Teacher-in-charge, Vidyasagar College, Calcutta, for providing laboratory facilities.

References

Anantaraman, M., 1951, The development of *Moniezia*, the large tapeworms of domestic Ruminants. *Sci. Cult.*, **174** : 155–157.

Aoki, J., 1965, Oribatid mites (Acarina:Oribatei) from Himalaya with descriptions of several new species. *Jour. Coll. Arts and Sciences*, Chiba, **4** : 289–302.

Aoki, J., 1966, Oribatid mites from Bird'r nests on Midway Island (Acari:Craptostigmata). *Pacific Ins.*, **8** : 770–776.

Baker, E. W., 1945, *Scheloribates chauhani*, a new species of oribatid mites from India (Acarina: Ceratdozetidae). *Jour. Wash. Acad. Sci.*, **35** : 386–388.

Balogh, J., 1943, Conspectus Oribatorum Hungariae Matem. *Teroness. Koztem.*, **39** : 1–193.

Berlese, A., 1896a, Acari, Myriapoda et Scorpiones hucusque in Italia reperta, 79 (1–12).

Berlese, A., 1896b, Acari, Myriapoda et Scorpiones hucusque in Italia reperta. Ordo Cryptostigmata (Oribatidae) (Cryptostigmata II), Portici.

Berlese, A., 1913, Acari nuovi. Manipoli - VII–VIII. *Redia*, **9** : 77–111.

BHADURI, A. K., 1971, Faunistic survey of the soil oribatid mites (Acari) of Calcutta and suburbs. Ph.D. thesis, University of Calcutta.

BANERJEE, S., 1972, Microarthropods and Humus Formation. *J. Indian Soc. Soil Sci.*, **20**: 403–405.

BHADURI, A. K. AND RAYCHAUDHURI, D. N. 1967, A note on soil oribatis mited from Calcutta, West Bengal. *Sci. Cult.*, **33** : 450.

BHADURI, A. K. AND RAYCHAUDHURI, D. N., 1968, Studies on the oribatid mites of Calcutta and suburbs. *Oriental Ins.*, **2** : 195–200.

BHADURI, A. K., CHAKRABARTI, D. K. AND RAYCHAUDHURI, D. N., 1974, A new species of the genus *Basilobelba* (Aceri, Oribatei) from Calcutta, India. *Acta. Arachnol.*, **25** : 86–89.

BHADURI, A. K., BHATTACHARYA, T. AND CHAKRABARTI, D. K., 1975, Two new species of oribatid mites (Acari) of the genus *Chaunoproctus* Pearce, from Calcutta. *India Mitt. Zool. Mus.*, Berlin.

BHATTACHARYA, T., BHADURI, A. K. AND RAYCHAUDHURI, D. N., 1974, Soil Oribatid mites of Santiniketan, Birbhum, West Bengal I (Acarina:Lohmanniidae). *Oriental Ins.*, **8** : 281–289.

BREGETOVA, N. G., 1965, Acarology in the U.S.S.R. In: Advances in Acarology, Vol. II, Naegele, J. A. ed., *Comstock Publishing Associates, Corneal Universiiy Press,* New York.

CHAKRABARTI, D. K., 1975, Faunistic Survey of the Soil Oribatid Mites (ACARI) from the districts of Nadia and 24–Parganas, West Bengal. Ph.D. Thesis, University of Calcutta.

CHAKRABARTI, D. K. AND BHADURI, A. K., 1972, New records of soil oribatid mites (Acari, Oribatei) from the districts of Nadia and 24 Parganas, West Bengal. *Sci. Cult.*, **38** : 499–500.

CHAKRABARTI, D. K., BHADURI, A. K. AND RAYCHAUDHURI, D. N., 1972, One new species and a new subspecies of Oribatid mites (Acari, Oribatei) from West Bengal, India. *Acta Arachnol.*, **24** : 86–90.

CHAKRABARTI, D. K., BHADURI, A. K. AND RAYCHAUDHURI, D. N., 1973, A new subspecies and a few new records of soil Oribatid mites (Acari, Oribatei) from West Bengal. *Sci. Cult.*, **39** : 365–366.

DEUB, D. C., 1974, Taxonomic studies of soil oribatid mites (Acari) from 24–Parganas, West Bengal. Ph.D. Thesis, University of Calcutta.

DRIFT, J. VAN DER, 1951, Analysis of the animal community in a Beech forest floor. *Tijdschr. Ent.*, **94** : 1–168.

EWING, H. E., 1910, New Acarina from India. *Trans. Acad. Sci.*, St. Louis, **19** : 113–121.

HAFEEZ–KARDAR, M. A., 1972, A new species of Lohmanniidae (Acarina:Oribatei) from India. *Oriental Ins.*, **6** : 61–64.

HAFEEZ-KARDAR, M. A., 1974, Two new species of Tectocepheidae (Acari: Oribatei) from India. *Oriental Ins.*, **8** : 51–54.

JACOT, A. P., 1930, Moss-mites as a spore bearers. *Mycologia*, **22** : 94–95.

JACOT, A. P., 1933, Two winged Moss-mites of the Nilgiri Hills. *Rec. Ind. Mus.*, Calcutta, **35** : 371–374.

KATES, K. C. AND RUNKEL, C. E., 1948, Observations of Oribateid Mite Vectors of *Moniezia expansa* on Pastures, with Report of several new vectors from the United States. *Proc. Helm. Soc. Wash.*, **15** : 18–33.

KOCH, C. K., 1836, Deutschlands Crustacean, Myriapoden und Arachniden. 1836. Vols. 1–9.

MORITZ, M., BROEN, B. V., MESSNER, B. AND MOHRIG, W., 1971, Beitragege Zur Arthropodenfauna aus Grosshoehlen des Harzes und des Kyffhaeusers v. Oribatei (Acarina). *Olsch. Entomol. Z.*, **18** : 133-144.

PEARCE, N. D. F., 1906, On some oribatidae from Sikkim Himalaya. *Jour. Roy. Micr. Soc.*, **1906** : 269-273.

PRASAD, V., 1965, Soil mites of Sabour (Bhagalpur). *Sci. Cult.*, **31** : 495-496.

ROCKETT, C. L. AND WOODRING, J. P., 1966, Oribatid mites as predators of Soil Nematodes. *Ann. Ent. Soc. Amer.*, **59** : 669-671.

SINGH AND MUKHERJEE, 1971, Qualitative composition of soil Arthropods in some fields at Varanasi (India). *Oriental Ins.*, **5** : 487-494.

SINGH AND PILLAI, 1975, A study of soil micro-arthropod communities in some fields. *Rev. Ecol. Biol. Sol.*, **22** ; 579-590.

STUNKARD, H. W., 1937, The life cycle of *Moniezia expansa*. Science, **86** : 312.

STUNKARD, H. W., 1941, Studies on the life history of the anoplocephaline cestodes of hares and rabbits. *Jour. Parasitol.*, **27** : 299-325.

WALLWORK, J. A., 1973, Zoogeography of some terrestrial Microarthopods in Antarctica. *Biol. Rev.*, **48** : 223-259.

WILLMANN, C., 1931, Moosmilben order Oribatiden (Cryptostigmata) in : Dahl, Die Tierwelt. *Deutschlands*, **22** : 79-200.

YAMAMOTO, Y. AND AOKI, J., 1971, The fauna of the lava Caves around Mt. Fujisan VIII. Maloconothridae (Acari, Cryptostigmata). *Bull. Nat. Sci. Mus.*, Tokyo, **14** : 579-513.

Some Aspects of the Taxonomy of Oribatid Mites from the Soils of Kerala

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ABSTRACT

The awareness of the importance of oribatid mites in the biology of the soil has led to a great deal of work on these animals in recent years in different parts of the world. Although taxonomic studies of the oribatid mites from India were started in the year 1910 by Ewing, only very few studies on the oribatid fauna of India have been carried out since then. From South India, only a single species of *Sheloribates* (Anantharaman, 1951) and three species of *Galumna* (Jacot 1933, Anantharaman 1951) are known. Oribatid mites have not been reported from Kerala in taxonomic studies. As a result of the faunistic studies of the oribatid mites by various authors, a total of 64 species and 35 genera are unown now from India. In the present work, 25 species were studied. Among these, 13 are new to science and 9 others are new additions to Indian fauna. Only three species found in the present collection were recorded earlier from India.

The system of Oribatei is divided into two groups *viz.*, 'Oribatei inferiores' and 'Oribatei superiores' in which a total of twenty-five superfamilies are included. Oribatei inferiores are primitive forms (Macropylene) comprising only seven super-families. The major character with distinguishes 'Oribatei inferiores' from 'Oribatei superiores' is the nature of the propodosoma which can be closed like the blade of a pen-knife to the hysterosoma. 'Oribatei superiores' are higher forms (Brachypylene) containing eighteen superfamilies. Here the propodosoma cannot be closed like the blade of a pen-knife to the hysterosoma. There are also a few other well-defined characters by which these two groups could be distinguished. 'Oribatei superiores' is divided into two different subcategories, the Pycnonoticae and the Poronoticae. In the Pycnonoticae there are no areae porosae on the notogaster and the pteromorphae are absent. Lamellae may or may not present in these mites. In the Poronoticae, areae porosae, sacculi or pori are present on the notogaster in addition to pteromorphae and lamellae.

Out of the twenty-five species in the present study, twelve species representing six families and eleven genera belong to 'Oribatei inferiores' and thirteen specie representing seven families and thirteen genera belong to 'Oribatei superiors. Methodology of collection, preservation, mounting, and taxonomic features of the thirteen new species and the revelant terminology are discussed.

Introduction

The recognition of the importance of oribatid mites in the biology of the soil led to much work on these animals in recent years in different parts of the world. Although taxonomic studies of the oribatid mites from India has a history of seventy years, it is a fact that no comprehensive work on the oribatid fauna of India has been carried out during the past years. Scrutiny of the literature on the oribatid fauna of India reveals that some work has been made from North India. From South India only a single species of *Sheloribates* (Anantharaman 1951) and three species of *Galumna* (Jacot 1933. Anantharaman, 1951) are known. Obviously, oribatid mites were not reported from Kerala in taxonomic studies. As a result of the faunistic study of the oribatid mites by various authors, a total of 119 species and 66 genera are known from India so far. Even though a number of species have been collected from different habitats in the Southern-most districts of Kerala, only seven species are included in the present paper. These seven species are collected from the Trivandrum and Quilon districts of Kerala State and they belong to seven genera and seven families representing both Oribatei inferiores and Oribatei superiores.

Material and Methods

Material for the present study was obtained largely from soil samples collected from different localities of Trivandrum district. The soil samples were extracted within twenty four hours of their collections in a series of modified Tullgren funnels. Animals were collected in test tubes containing 80 per cent alcohol. Oribatid mites were separated and transferred to small vials containing equal proportions of 90 per cent alcohol and lactic acid for two to three weeks.

Most specimens cleared within this period, depending on the degree of sclerotization. Permanent slides were prepared in Hoyer's medium, which was found to be satisfactory and was prepared by mixing the ingredients at room temperature from the formula given by Baker and Whartod 1952.

Description of species: 1. *Annectacarus trivandricus* n. sp (Figs 1–2)

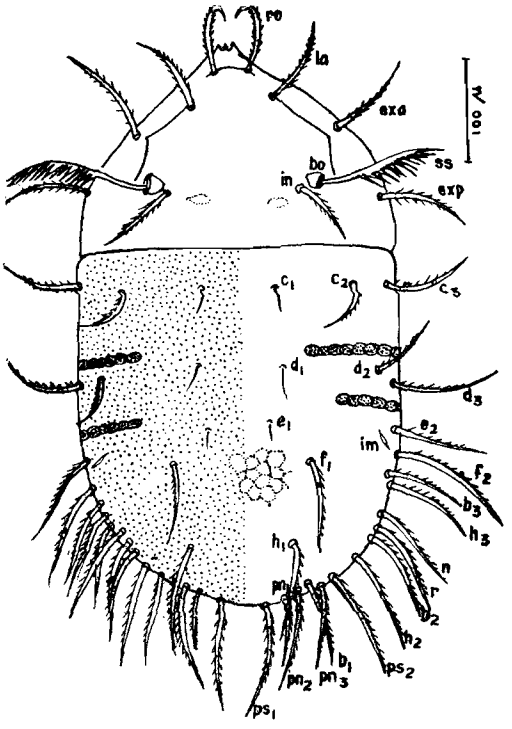

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Fig. 1

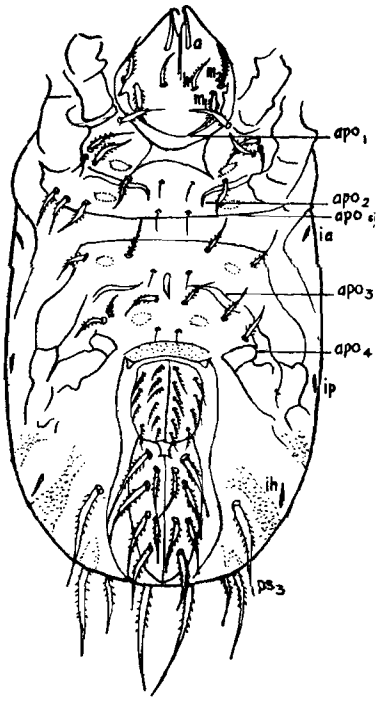

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Fig.2

Material examined: forty three adults aollected from the litter and soil of the museum garden on 12-10-1973.

Measurements: Holotype: Length 530.4 µm, Width 280.8 µm

Paratypes: Length 478.4µm -540.8µm
Width 249.6µm -280.8 µm

Body yellowish-brown in colour. Microsculpture of the integument clearly seen as fine punctuation together with reticulations of polygone on the notogaster.

Prodorsum: Rostral tectum with two incisions at the anterior most region. All prodorsal setae distinctly barbed (70 µm=90µm) long. Rostral setae inwardly curved and inserted on a ridge, behind the anterior end of the rostrum. Bothridium cup-shaped and sensillus pectinate with 12 to 14 branches. A pair of areae porosae found between the interlamellar setae.

Notogaster: Notogastral neotrichy is present, 24 pairs of notogastral setae are counted of which c_1, d_1, and ee_1 are comparatively small narrow and smooth while others are long, lanceolate and barbed. Length of various notogastral setae are as follows :

c_1, d_1, e_1	–	18 μm
c_2, e_2, f_2, n, b_1, b_3, pn_1	=	65 μm – 80um
c_3, d_2, d_3, b_2, r	–	80 μm – 95 μm
f_2, h_2, pn_3, ps, ps_2, ps_3	–	95 μm—105 μm

In well sclerotized and newly mounted specimens two notogastral bands could be detected corresponding to $band_3$ and $band_5$. These are composed of large circular areae porosae rather than clear areas. Fissure im alone is seen in dorsal view, below or on the level with the insertions of setae e_2. Fissure ia, lp and ih are visible on ventral views as in *A. insculptus.*

Ventral region : Three pairs of leaf-like adoral setae present (Not shown in the figure). Setae on infracapitulum consist of a, m_1, m_2, and h arranged in the usual manner. Each coxisternum bears an area porosa and there is coxisternal neotrichy. Paraxial setae and a single pair inserted antiaxially on coxisterna 1 are smooth and short while others are long and barbed. Aggenital plates small and triangular and located anterolaterally to each genital plate. Genital plates are without transverse sutures and with ten pairs of distinctly barbed setae of which six shorter pairs are distributed paraxially and four longer pairs are distributed antiaxially. Preanal plate is small, the lateral and posterior sides of which are concave in appearance. Adanal anal plates are fused and a total of six pairs of anoadanal setae are present, their formula being (4+2). All these setae are finely barbed.

Leg : Characters of the legs similar to *A. insculptus.*

Variations : Three paratypes show variation in the arrangement of genital setae. Only five genital setae are found on the right paraxial row of one specimen, possibly g_4 is lacking. In the other two cases the paraxial setae are not distributed in a line. Setae g_2 to g_5, in one case and g_2 and g_3 in another case, are inserted exterior to the line of their arrangement.

Distriburion in Kerala : Trivandrum

Remarks : The genus, *Annectacarus* was errected by Grandjean (1960) with *A. mucronatus* as the type for the genus. The generic characters include the presence of neotrichy, entire genital plate and fused anoadanal plate with formula (4+2). Two other species from Ghana, *A. insculptus* and *A. sejugatus* were also included in this genus by Wallwork (1962a). Conspicuously thickened, fairly barbed and comparatively longer nature of the notogastral setae c_2, d_2, f_1,

b_1, b_2 and b_3 than c_1, d_1, e_1 are the distinguishing characters of *A. insculptus* from *A. mucronatus* where these setae are longer than c_1, d_1, e_1 ; *A. sejugatus* can be identified from the above two species by the shorter nature of the notogastral setae b_1, b_2 and b_3 and the absence of neotrichy on the infracapitulum. Bhattacharya *et al.* (1974) described *A. longisetosus* from North India based on the very long nature of the notogastral setae except c_1, d_1 and e_1. *A. trivandricus* described above agrees in the long nature of the notogastral setae of *A. longisetosus* but differs with the Ghanian and the North Indian species in having greater number of notogastral setae *i.e.*, 48 instead of 42 of the former and 46 of the latter. The additional pairs of setae which are more than in *A. insculptus* are found at the posterior region of the notogaster in between ps_1 and ps_2 and they are named as pn_1, pn_2 and pn_3 to mean posterior neotrichial setae and are shown in Fig. 1. In *A. logisetosus* additional pairs of setae are unnamed and are found above and below to e_2. Of the three notogastral bands (lacking in *A. logisetosus*) of *A. insculptus*, the anterior most is lacking in the new species which is a condition observed in *A. sejugatus* also. In the absence of notogastral band corresponding to $band_2$, presence of incised rostral tectum and the very long nature of the notogastral setae, *A. trivandricus* possesses combination of characters of other known species of *Annectacarus*. The most diagnastic feature of the new Indian species is the presence of 48 setae on the notogaster which is the largest number known in *Annectacarus*.

2. *Cyrthermannia bicornuta* n. sp (Figs. 3-4).

Material examined: 11 adults; 8 collected from the soil around the grasses of museum garden and three collected from the soil and litter of Nagaroor on 4-4-1973 and 21-12-1973 respectively.

Measurements: Holotype: Length 530.4 μm, Width 208.0 μm, Paratypes: Length 530.4 μm-546.0 μm Width 208.0 μm-270.0 μm.

Body brown in colour. The prodorsum medially ornamented with very fine punctuations which extend from the base of the prodorsal apophysis to the anterior end of the prodorsum. In between the interlamellar setae, this region bears few rounded circles which may vary in positions in different specimens.

Prodorsum: Anterior margin of the prodorsum rounded and bears the rostral setae. They are thick, smooth and strongly curved. Their mutual distance is lesser than the length of a single rostral seta. Lamellar setae inserted well behind the rostral setae are thin and smooth and longer than rostral setae. Interlamellar setae situated little behind in between bothridia as long as lamellar setae. Each prodorsal apophysis with two branches which in some cases are unequal in size. In certain cases, the branches of the apophysis overlap the anterior margin of the notogaster. A faint transverse ridge is noticed just above the lamellar setae.

Notogaster: Broad with three pairs of lateral tubercles on its posterior half. Width of the notogaster is minimum at the posterior most region. Notogaster has 15 pairs of setae, all of which are smooth. The whole surface of the notogaster is provided with foveolae of different dimensions. They appear to be more rounded in dorsal view.

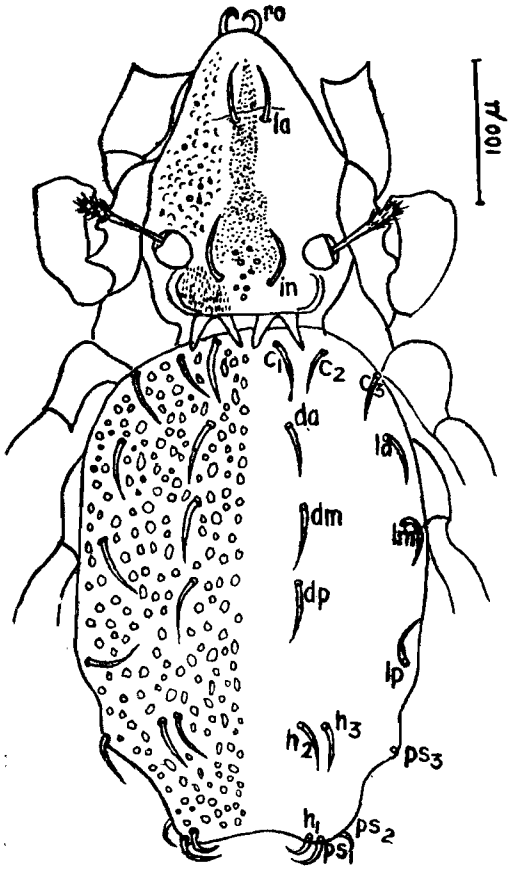

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Fig. 3

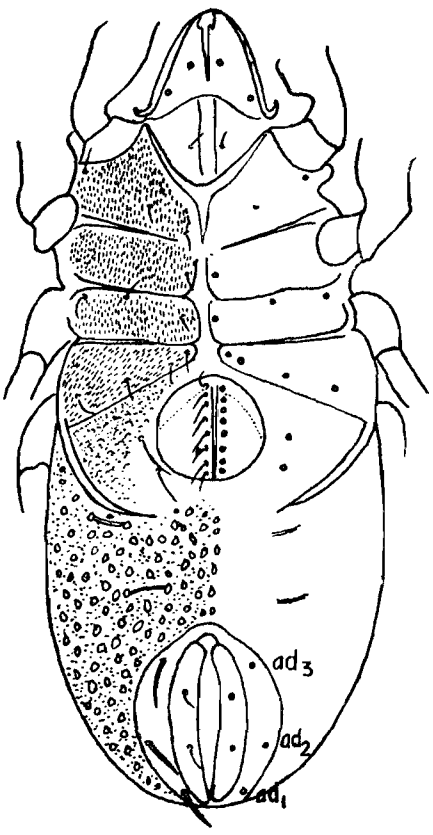

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Fig. 4

Ventral region: The gnathosoma consists of 3 pairs of setae h, m_1 and a. All the four coxisterna are well-developed. Each coxisternum, as in the case of median region of the prodorsum, is minutely punctured. Epimeral setal formula is 3–1–3–4. Margin of the genital aperture is distinct with each plate bearing eight smooth setae. Anal aperture is bigger than genital aperture. There are two anal setae in each plate and they are smooth and short. Each adanal plate bears three smooth setae which are longer than anal setae. The hysterosoma is foveolated throughout.

Distribution in Kerala: Trivandrum and Nagaroor.

Remarks: The new species described above can be easily distinguished from *C. tuberculata*, *C. stellata* and *C. vicinicornuta* by the bibranched nature of each of its prodorsal apophysis, sculpture of the prodorsum and in the presence of three setae on the gnathosoma. In this respect it shows resemblance to *C. parallela*. However, in *C. parallela* the branches of the apophysis are not so distinctly demarcated when compared with *C. bicornuta* and they are broader than longer. In addition the measurements of the body show that the size is between *C. stellata*, *C. vicinicornuta*.

3. *Allonothrus giganticus*: n. sp. (Figs. 5-6).

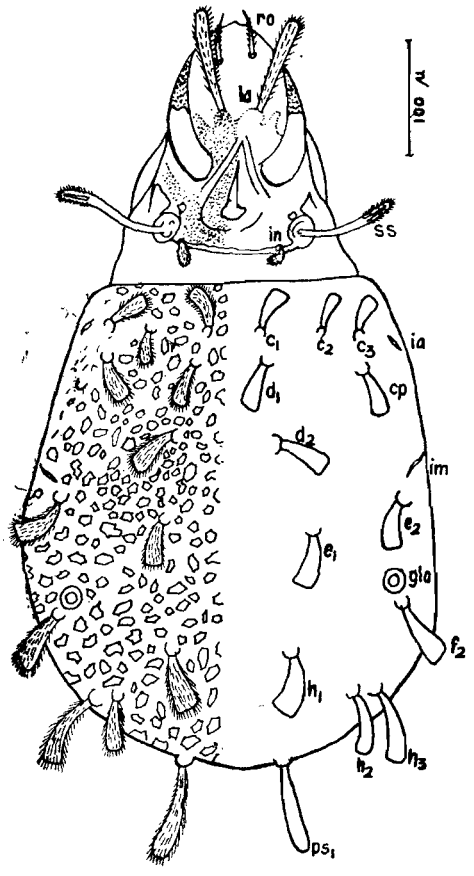

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Fig. 5

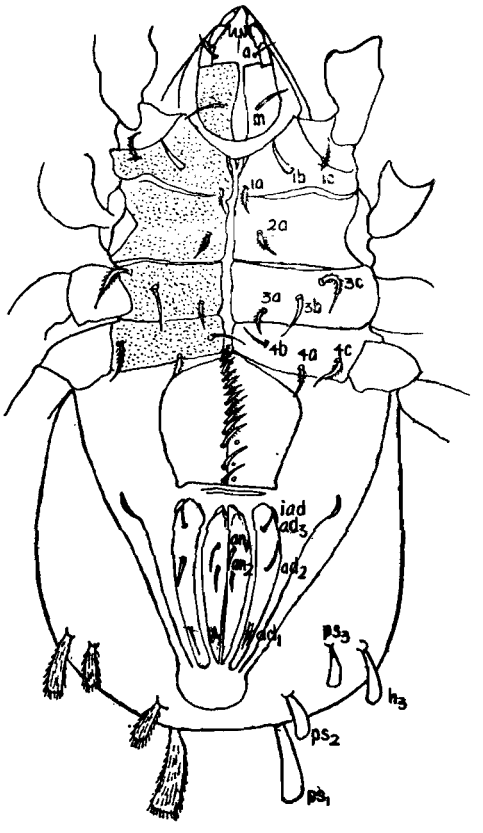

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Fig. 6

Material examined: 11 adults collected from the soil of an open grass field, Zoo garden on 14-7-1973 and 3 adults collected from the soil of Parassala.

Measurements: Holotype : Length 644.2 µm, Width 374.6 µm.

Paratypes: Length (range 634.4 μm–705.2 μm)
Width (range 332.8 μm–384.8 μm)

Older adults reddish-brown whereas young adults light yellowish-brown. Most older adult specimens were found with lot of detritus adhering to the body. Therefore, repeated cleaning and prolonged clearing was necessary before the specimens could be mounted on slides.

Prodorsum: Has very minute punctuations except for the regions where the chitinised ridges are present. A pair of very prominent, basally broad well chitinised lateral ridges seen extending from the middle of the prodorsum to the lateral margins. Central ridges less prominent and narrow and placed in between the lateral ridges as the two sides of a triangle which meet below the insertions of lamellar setae. Presence of an inner ridge which is pyramidal in shape is also observed towards middle of the prodorsum, in between central ridges. A transverse ridge as in *A. russeolus* extends only in between bothridia. Rostral setae barbed about 41 μm long. They are longer than their mutual distance. Lamellar setae are longer among prodorsal setae about 91.0 μm, long and club-shaped. Interlamellar setae are the smallest, about 13 μm long, and leaf-like. They are placed in the transverse ridge in prominent insertions, just before the ridge joins with the bothridium on either side. This ridge is continuous in most cases and never curved posteriorly. Exobothridial setae lacking and the existence of their insertions also could not be confirmed. The bothridium and sensillus of the usual type as in other species of *Allonothrus* except that the head of the sensillus is not much swollen.

Notogaster: Broad and beautifully ornamented with areolae of polygonal appearance which extend over the whole surface except for the anterolateral region. There are 15 pairs of fan-shaped notogastral setae, arranged dorsolaterally of which c_2 is the smallest. Seta f_1 is lacking. Fissures ia and im are visible in dorsal aspect, the former being located just below and lateral to the level of insertion of seta c_3 and the latter just above the insertion of seta e_2. Aperture of the lateral abdominal gland is represented by a very distinct chitinised ring just above the seta f_2.

Ventral region: The gnathosoma bears two pairs of smooth setae, the anterior a and posterior m. The posterior pair is longer than the anterior pair. The gnathosomal and epimeral regions are ornamented with fine punctuations. Epimeral setal formula is 3–1–3–3 of which setae 1 b, 3 b and 4 b are smooth, Genital aperture is wider than longer and each genital plate bears 13 setae. They could, however be counted accurately in young adults which do not have much debris on their body. The anterior pairs of genital setae grouped close together than the posterior pairs of which the posterior most two pairs are well-spaced and smooth. The margin of the genital aperture is distinct and a curved spur

can be clearly seen on each plate, posterolaterally. Aggenital hairs are absent. Anal aperture about thrice longer than its width and two pairs of smooth setae inserted close together at the anterior halves of the plates. Anal and adanal fissures present, but the former one is difficult to differentiate from the anterolateral margins of the anal plates.

Leg: Each leg is provided with three claws and tarsus I is similar to *A. russeolus*.

Remarks: Presence of a transverse ridge at the posterior region of the prodorsum and 13–14 pairs of genital setae are the distinguishing characters of *A. russeolus* Wallwork (1960) from Ghana. Recently (1968) Bhaduri and Chaudhuri collected specimens belonging to the above species, in addition described *A. indicus* from Calcutta. *A. indicus* differs from *A. monodactylous* Wallwork (1960) in having strongly-curved lateral ridges on the prodorsum, 10 pairs of barbed genital setae, and three pairs of smooth adanal setae. The species mentioned above from South India shows closer resemblance to *A. russeolus* than to any other known species of *Allonothrus* in possessing three pairs of prodorsal ridges (lateral, central, transverse) number, nature and arrangement of lamellar, interlamellar, notogastral, epimeral, genital, anal and adanal setae and in the triclawed nature of their legs. But differences were noticed in certain other details, which include, the fairly large body, presence of an additional inner ridge on the middle of the prodorsum, continuous nature of the transverse ridge in between bothridia without lateral posterior curving and polygonated ornamentation of the notogaster. The present species differs from *A. monodactylus* and *A. indicus* in having 13 genital setae instead of seven of the former and ten of the latter and for the tridactylous nature of the leg instead of monodaetylous.

4. *Eremobelba nagaroorica*: (Figs. 7–8)

Material examined: 12 adults; 9 collected from the mixed forest floor of Nagaroor on 16–12–1974 and 3 from the reserve forest of Madathara on 28–6–1974.

Measurements: *Holotype*: Length 499.2 μm. Width 332.8 μm

Paratypes: Length 468.0 μm–561.6 μm
Width 312.0 μm–353.6 μm

Prodorsum: The surface of the prodorsum is unevenly granulated. The granules at the posterior region of the prodorsum, just above the bothridia, form an arched elevation. Midlateral regions of the prodorsum are devoid of granulations where dense punctuation are more pronounced. Rostral setae are smooth and curved. Lamellar state are provided with distinct insertions and are straight and smooth. Interlamellar setae are found on the posterior elevation

with well projected insertions. These setae finely pointed. Minute barbs are occasionaly found on them. Sensillus is long, flagellate and bears thick minute barbs on its upper side. A pair of circles are seen in between bothridia in few specimens.

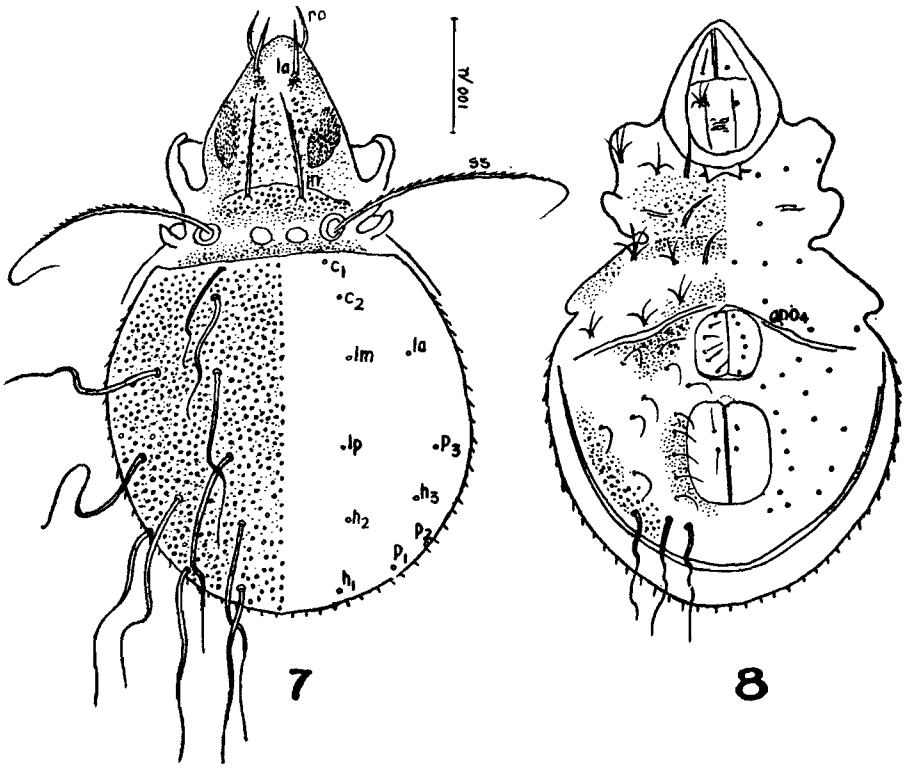

Fig. 7 Fig. 8

Notogaster: Broad, posteriorly rounded and with straight anterior margin. Anterolateral margins of the notogaster is slightly elevated forming a short projection. 11 pairs of notogastral hairs are present all of which are flagellate. All these hairs extend well beyond the insertional points of the succeeding transverse line of hairs. There appears to be a backward shift in the insertions of the outer series of setae. Small granules are present on the notogaster throughout.

Ventral region: Infracapitulum with two pairs of haris, a and h of which h is branched. Epimeral region consists of setae of two kinds, smooth and branched. Epimeral setal formula is 3-1-3-3. Setae 1a, 2a and 3a are smooth while all others are branched. As on the prodorsum and notogaster granules are unevenly present on the ventral regions of the body also. Their accumulation in certain regions makes it difficult to observe the locations of the hairs and its insertions on the ventral plate. 16 pairs of setae are found on the ventral plate

all of which appear to be smooth. Of these setae, the last three pairs are long and flagelliform. Genital plates bear 6 and anal plates bear 2 pairs of smooth setae.

Variation: Variations are observed in three paratypes where 4a also appears to be smooth. The number and locations of ventral setae show differences and a maximum of seventeen and a minimum of 14 setae are noticed among paratypes. Asymmetrical distribution of setae is found only in one specimen where the right plate bears 14 setae and left plate bears 15 setae. Anterior pairs of 1–3 ventral setae are branched in two specimens collected from Madathara.

Distribution in Kerala: Madathara and Nagaroor.

Remarks: Five species of *Eremobelba, E. capitata, E. mahunkai, E. breviseta, E. japonica* and *E. bellicosa* have been reported from the Oriental region. The present species can be easily separated from the first three species in having a scattered cerotegument. In this respect, they more closely resemble *E. japonica* and *E. bellicosa* described from Japan and Vietnam respectively. But additonal characters such as the barbed nature of the interlamellar hairs, sensillus, thick nature of rostral and lamellar setae, the branched nature of more than five hairs on the epimeral region, and the flagelliform nature of the three posterior most setae on the ventral plate are characters which help in the recognition of the species.

5. *Multioppia indica*: n. sp. (Fig. 9–10)

Material examined: 6 adults collected from Madathata reserve forest on 14-6-1973.

Mesurements - Helotype: Length 384.8 μm. Width 197.6 μm

Paratypes: Length 374.4 μm – 416 μm. Width 176.8 μm - 208 μm

Prodorsum: Somewhat triangular in outline. The rostrum is entire and more or less pointed anteriorly. Rostral setae are found at the anterior region of the rostrum, far above the transverse ridge. They are smooth and slightly curved. Lamellar setae are located in between the anterior tips of the lamellae. They are slightly longer than rostral setae and are barbed. Interlamellar setae are inserted near the posterior margin of the prodorsum, between the bothridia. They are the longest among prodorsal setae. Lamellae thin, convergent anteriorly and reach about one third of the length of the prodorsum. Lateral to the lamellae, pale circular areas varying in number, are arranged anteroposteriorly. They are usually four in number extending from the anterior margin of the bothridium to above the level of insertions of lamellar setae. Two rows of closely packed pale areas, three in number in each row are also seen in between the bothridia. Bothridium is directed dorsolaterally. Sensillus has a compressed head which bears seven or eight long but unequal branches which are progressively shorter

from proximal to distal region of its length. The appearance of the sensillus is subject to change depending on the orientation of the specimen at the time of observation. Exobothridial setae are not observed in any case.

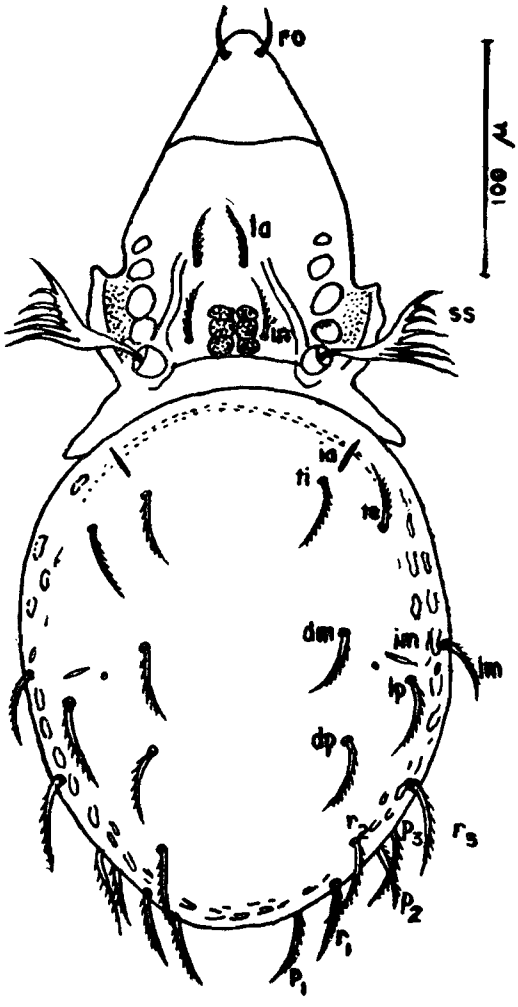

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Fig. 9

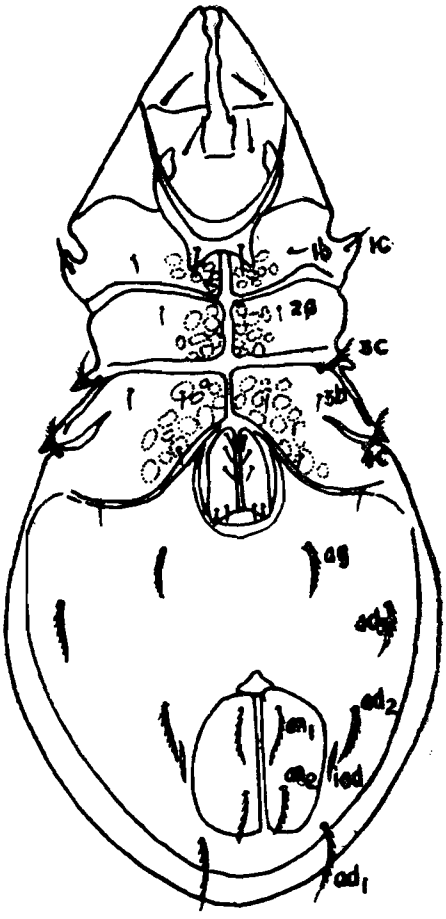

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Fig. 10

Notogaster: Oval in shape. 12 pairs of notogastral setae are present which are distinctly barbed. Notogastral fissures ia and im are clearly seen. Fissure ia is obliquely located anterolateral to setae ti and im is located more or less transversely anterior to seta lp. Periphery of the notogaster, except for the more anterior region, is provided with smaller pale areas.

Ventrual region: Gnathosoma has two pairs of setae a and h. All the apodemes, except apo. III are well developed. Apodeme IV is strongly curved.

Epimeral setal formula is 3-1-3-3. All the epimeral setae except for 3c and 4c are smooth. Epimeral region is ornamented with reticulate microsculpture which is well developed on epimeral field IV. Genital aperture is rounded in appearance. Five setae are found on each genital plate of which 3 are distributed at the anterior half of each plate whereas the other two are located posteriorly. All these setae are smooth and small. A pair of barbed agenital setae are present. Anal aperture is longer than genital aperture. Each anal plate bears two barbed setae which are longer than genital setae. There are three pairs of adanal setae and all of them are barbed. Adanal fissures are located near the lateral margins of each anal plate.

Leg: All tarsi are monodactylous. Setae on tarsus I are 18.

Distribution: Trivandrum.

Remarks: Hammer (1961, 1962) described 3 species of *Multioppia viz.*, *M. radiata* (Peru), *M. stellifera* (Peru) and *M. australis* (Chile) from the Andes Mountains of South America. These 3 species can be disinguished from one another mainly by the form of the sensillus and in the distribution pattern of setae on the notogaster. However, several characters are found to be common to all of them. Aoki (1964) reported *M. wilsoni* from Hawaiian Islands which resembles to *M. laniseta* described by Moritz (1966) from Germany in the ornamentation of the prodorsum and the chaetotaxy of the notogaster. Mortiz (1971) described two species of *Multoppia.* viz., *M. glabra* and *M. excisa* from Europe. *M. glabra* differs from *M. laniseta* in the comb like nature of the sensillus and in the interbothridial thickening of the posterior region of the prodorsum. These two species differ from *M. excisa* in the nature of the rostrum. Littlewood and Wallwork (1972) obtained and reported two species of *Multioppia*, *M. pulchra* and an unidentified species of *Multioppia* from two widely separated and apparently distinct sites in Western Britain. Of these *M. pulchra* shows closer resemblance to *M. australis* in the distribution pattern of setae on the notogaster and for the faint traces of lamellar ridge on the prodorsum. But the nature of the sensillus in both the species differs. Moreover in *M australis* the peripheral ring of pale areas is absent.

The new species described above is more closely related to *M. laniseta* than to any other species mentioned above, in the nature of prodorsum, distribution pattern of setae on the notogaster, number of setae on the genital plates and in the ornamentation of the epimeral region. However, pointed nature of the rostrum, small and smooth nature of the rostral setae, absence of exobothridial setae, position of setae ip just below im and the two pairs of setae on the gnathosoma are chatacters which would help to distinguish this species from *M. laniseta.* The presence of thin but clear lamellar ridge is the most distinguishing character of this new species.

6. *Suctobelba semiplumosa indica* n. sub sp (Figs. 11-12)

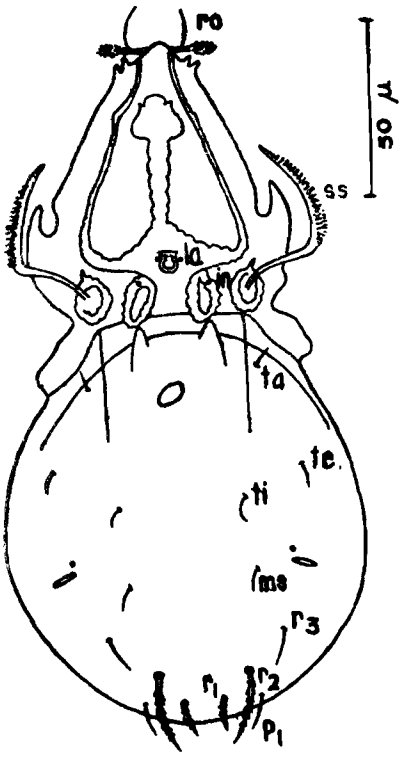

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Fig. 11

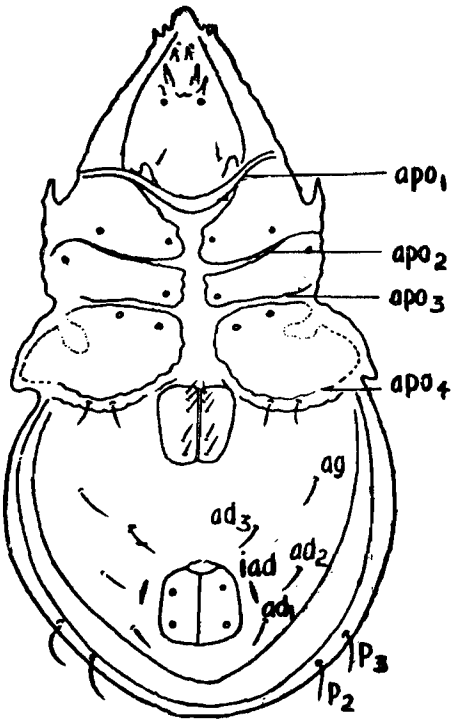

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Fig. 11

Material examined: 13 adults collected from the soil of museum siol garden on 24-7-1973.

Measurement: *Holotype*: Length 190.0 μm Width 111.8 μm Paratypes: Length 187.2 μm - 200.2 μm Width 100.8 μm - 111.8 μm.

Prodorsum: The sculpture of the prodorsum is more or less similar to that described for *Suctobelba semiplumosa simplex*. Rostral setae are very prominent and placed at the anterior most region of the prodorsum, above the rostral teeth. They are pectinate. Insertions of lamellar and interlamellar setae are found on raised ridges (knobs) at the posterior region of the prodorsum. Lamellar ridge is single, square in appearance and situated in between and adove the interlamellar ridges. Interlamellar ridges are irregular and elongated and found in between bothridia. Sensillus is thickened at the middle portion and finely barbed at the posterior margin.

Notogaster: Oval with straight anterior margin. Notogaster possesses two pairs of condyles (also called spur) at its anterior region, one submedian and the other more or less lateral in position. The outer pair is more pointed and its inner margin extends down well into the notogaster. Ten pairs of notogastral setae are present of which the last two pairs are plumose.

Ventral region: Gnathosoma posteriorly bears a pair of knobs at its lateral region. A pair of gnathosomal setae is inserted just above these knobs. Epimeral ridge IV is irregular and strongly curved. Epimeral setal formula is 2-2-2-2. Anal aperture is long as the genital aperture. Each genital plate bears five pairs of setae of which the first three pairs are inserted close together at the anterior region of the plate. The last two pairs are found at the posterior region of the plate and these setae are slightly longer than the anterior pairs. Each anal plate bears two pairs of setae which are represented only by their insertions, at the anterior and posterior region of the plate. A pair of adanal fissures is seen at the anterolateral region of each plate.

Distribution in Kerala: Trivandrum

Remarks: The new subspecies described above has a position in between the subspecies *S. s. semiplumosa* and *S. s. simplex*. *S. s. semiplumosa* has four pairs of plumose setae, where as *S. s. simplex* has no plumose setae on the notogaster. The present species has two pairs of plumose setae on the notogaster.

7. *Dolicheremaeus indicus* n. sp. (Figs. 13–14)

Material examined: 6 adults collected from a bamboo field, museum garden on 21-9-1974.

Measurements: Holotype: Length 800. 8 μm Width 312.0 μm Paratypes: Length 780.0 μm - 884.2 μm Width 312.0 μm - 395.2 μm.

Body is light to fairly yellow in colour. It is convex with well-spread body setae.

Prodorsum; Lateral margins of the prodorsum without teeth. Cerotegment is restricted only at the middle of the prodorsum, in between the lamellae. Lateral lamelliform (spa. 1) expansion are weakly developed. Lamellae are slender and not strictly parallel but are gradually converging anteriorly. Tutorium (tu) appears to be moderately developed. Rostral and lamellar setae are about 94 μm and 104 μm respectively. The former is more strongly curved and thickly barbed than the latter. Both are unilaterally barbed. Interlamellar setae have a similar shape to anterior notogastral setae but it appear to be smooth. They are about 135 μm long. Bothridia directed laterad and the opening of each is small. Dorsal bothridial plates (tbd) weakly chitinised and less distinguishable where as ventral bothridial plates (tbv) are more clear and

rounded. The elbowed sensillus with fusiform head. Exobothridial setae short and conspicuous. Median prodorsal condyles (co. pm) broadly rounded. Lateral prodorsal condyles (co. pl) are slightly angulate.

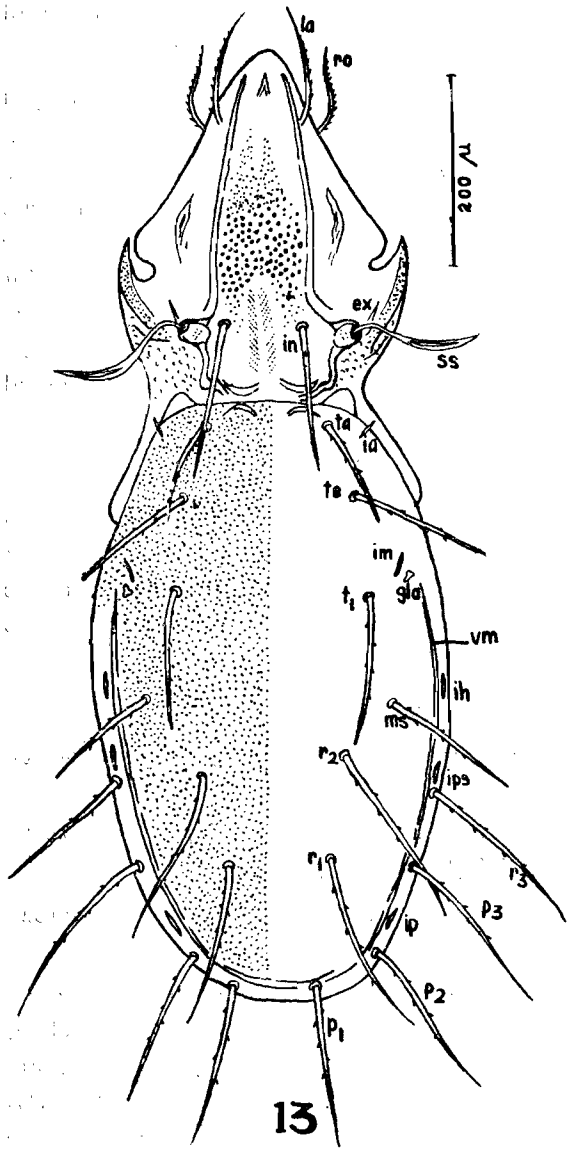

Fig. 13

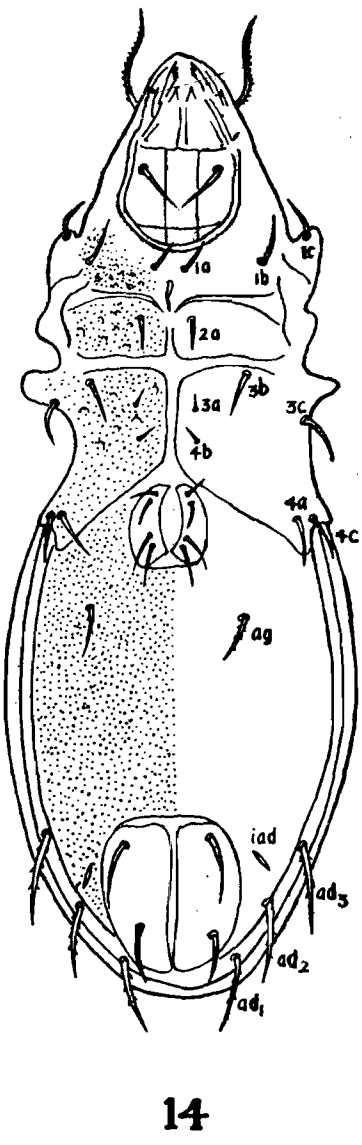

Fig. 14

Notogaster: Well-elongated, fusiform and more than one and a half time as long as its width. The centromedian region of the notogaster is well raised than the remaining part. Anterior region is more or less straight with the whole surface minutely and densely punctured. There are ten pairs of notogastral setae of which the anterior pairs ta, te, ti and ms are with blunt tips where as

the posterior pairs r_1, r_2, r_3, p_1, p_2 and p_3 are with flagelliform tips. Seta ta is the smallest and p_3 is the longest among the notogastral setae. All the notogastral setae are occasionally and minutely barbed. The measurements of these setae are as follows: ta–40 μm, te–51 μm, ti–50 μm, ms–45 μm, r_1 65–70 μm, r_2 70 μm, r_3 55–60 μm, p_1 60 μm, p_2 60 μm, p_3 75 μm. Five pairs of notogastral fissures are seen at the lateral aspect of the notogaster. Fissures ia and im are aligned obliquely, the latter being situated anterior to gla, ih and ips are anterior to r_3 and ip is in between p_2 and p_3. Marginal ridge (vm) is irregular and extends up to gla. Lateral notogastral condyles (co. nl) are well projected above the anterior margin of the notogaster. Median notogastral condyles (co. nm) are less pronounced.

Ventral region: A single pair of setae is inserted somewhat in the middle if the infracapitulum. They are relatively long and smooth. Epimeral setae are smooth and arranged in the formula 3-1-3-3. The paraxial row of epimeral setae are smaller than the antiaxial row of setae. The whole ventral region punctured. Genital aperture wider at the middle region. Four pairs of genital setae of which two pairs inserted posteriorly. Posterior pairs are longer than anterior pairs. Aggenital condyles absent. Anal aperture is longer than its width and wider anteriorly than posteriorly. Of the two pairs of anal setae the anterior pair is longer than the posterior pair. Adanal fissures distinct, obliquely located on either side of the anal plate just below the level of an_2. All the three pairs of adanal setae barbed.

Distribution in Kerala: Madathara

Remarks: The present species shows some resemblance to *Dolicheremaeus africanus* (1962) in the form of pseudostigmatic organ, nature of lamellae, number and differentiation of notogastral setae into two types *i.e.*, short barbed bristles with blunt tips and long minutely-barbed bristles with fine flagelliform tips, and for the absence of rounded fissures lateral to genital aperture. The small and elongated nature of the body, very prominent lateral notogastral condyles, absence of undulation of notogastral margin, presence of tutorium and five pairs of notogastral fissures are some of the useful characters for the recognition of the above new species.

References

Anantharaman, M., 1951, The development of *Moniezia*, the large tapeworm of domestic ruminants. *Sci. Cult.*, **174**: 155–157

Aoki, J., 1964, Some Oribatid mites (Acarina) from Laysan island. *Pacific Insects*, **6**: 649–694.

Baker, E. W. and Wharton G. W. 1952, An introduction to Acarology. *MacMillan Co.*, New York.

Bhaduri, A. K. and Raychwudhri, D. N., 1968, Studies on the Oribatid mites of Calcutta and suburbs – I. *Oriental Insects*, **2**: 195–200

BHATTACHARYA, T., BHADURI, A. K. AND RAYCHWUDHURI, D. N., 1974, Soil Oribatid mites of Santinikethan, Birbhum, West Bengal I. (Acarina : Lohmanniidae) *Oriental Insects*, **8** : 281-289.

GRANDJEAN, F., 1950, Etude Sur Ies Lohmannidae (Oribates Acariens). *Archiv. Zool. Explt. Generale.*, 87 : 95-162.

HAMMER, M., 1961, Investigation of the Oribatid fauna of Andes Mountain II Peru. *Biol. Skr. Dan. Vid. Selsk*, 13 : 1-157.

HAMMER, M., 1962, Investigation of the Oribatid Fauna of the Andes Mountain III. *Chile. Biol. Skr. Dan. Vid. Selsk*, 13: 1-96.

JACOT, A. P., 1933, Two winged Moss-Mites of the Nilgiri Hills. *Records of Indian Museum*, **35** : 371-374.

LITTLEWOOD, C. F. AND WALLWORK, J. A.,1972, A new species of *Multioppia* (Acari : Cryptostigmata) from St. Kilda with notes on another member of this genus from Wales. *Acarologia*, 14 : 479-483.

MORITZ, M., 1966, Neue Oribatiden (Acari) aus Deutschland II. *Multioppia laniseta* n. sp. *Zool Anz.*, 176 : 127-132.

MORITZ, M., 1971, Beitrage Zur Kenntnis der Oribatiden (Acari) Europas IV *Multioppia excisa* n. sp. und *Multioppia glabra* (Miheleie, 1955) (Oppidae). *Mitt. Zool. Mus. Berlin Band*, 47 : 99-107.

WALLWORK, J. A., 1960, Some Oribatei from Ghana : Two new species of the genus Allonothru, (Vander Hammen). *Acarologia*, 11 : 568-574.

WALLWORK, J. A., 1962a, Some Oribatei from Ghana X. The family Lohmanniidae. *Acarologia*. **4** : 457-487

WALLWORK, J. A., 1962b, Some Oribatei from Ghana. VIII The genus Tetracondyla Newell 1956. (Ist series). *Acarologia*, **4** : 274-291.

Studies on the Biology of *Galumna flabellifera* Hammer, 1958 and its Role as Fungal Spore Carrier

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ABSTRACT

Galumna flabellifera Hammer, 1958 is a widely distributed mite from Rajasthan soils. It was originally described by Hammer (1958) from the Andes Mountains (S. America) and later Aoki (1964, 1964a) reported it from Thailand and Laysean Islands. Reddy (1972) recorded it for the first time from Rajasthan soils. The present paper is concerned with the biology and description of its immature stages. Although they are fungivorous and saprophagous in under field conditions, various test foods were also

tested under laboratory conditions. Yeast was the most preferred food. The feeding specificity and its relative effect on egg production, duration of development of larval and nymphal stages have also been discussed. Fungi belonging to eight different species were isolated from the gut and body surface of *G. flabellifera* and their role as fungal spore carrier is also discussed.

Material and Methods

Soil samples were collected from three different biotopes, Plot-A was just by the side of a water reservoir with moisture always persisting on the soil surface; plot-B cultivated land with *Pennisetum typhoides* (Ver. Bajra) as the standing crop at the time of sampling, and plot-C undisturbed litter under bushes of *Nerium* sp. Both plots A and B were located in the Birla Agricultural Farm which is about 2 kms from the Zoology Dept. and the plot C was in the Botanical Garden of the Institute itself.

Soil samples of volume 10 × 10 × 5 cm were collected from the above sites fortnightly from July, 1970 to March, 1971. Materials were transported to the laboratory in air-tight polythene bags. Modified Tullgren funnels (Haarlov, 1947) were employed to extract mites. Both adult and nymphs were isolated and transferred to culture chambers maintained in the laboratory.

Modified Plaster of Paris charcoal based specimens tubes as illustrated by Rhodes (1956) were used for rearing adults and the immature forms. However, for mass culturing, specimen jars (dia. 5 cm and height 125 cm) with a base of 7.5" thick Plaster of Paris and 5 cm finely sieved soil manure mixture (1 + 2 ratio) above it as two separate layers. This allows the mite to have free vertical movements in response to the varying microclimatic factors. Culturing and rearing were at 25°C (±2) in the laboratory. Both culturing and rearing chambers were watered every day.

For microscope examination, mites were killed, cleared in Nesbett's solution[1] and mounted in Hover's media[2]. For temporary observations, mites were cleared in cold lactic acid as recommended by Balogh (1958). Mites were preserved in Oudemans medium.

During routine microscopic examination fungal spores and hyphae were noticed on the surface and in the guts of the mites. Fungi from the external surface of the mite were obtained by gentle brushing into a cavity slide in

1. Nesbett's solution : Chloral hydrate : 25 g
   Dist. water : 25 ml.
   HCl (Conc) : 2.5 ml.
2. Hover's media (mounting) : Dist. Water : 50 ml.
   Gum arabic : 30 g
   Chloral hydrate : 200 g
   Glycerol : 20 ml.

distilled water. Pteromorphs and legs were dissected out and washed with distilled water to free the fungi. For collecting the fungi from the guts of the mite, mites were surface sterilised by dipping in 0.01 per cent mercuric chloride for two to three minutes to check the growth of the fungi present on the body surface and later washed in distilled water thoroughly. These surface-sterilised mites were then dissected by sliding the notogaster from the hysterosoma. The gu_t contents along wlth faeces were collected into the tube. The suspensions thus obtained were further diluted in distilled water and later poured into melted potato dextrose agar medium (PDA) of pH 5.6 in a petri dish and placed in the incubator at 25° C. After four days of observation, fungi were isolated. To obtain purecultures fungi were isolated from the colony and transferred to PDA slants in test tubes. The fungi were stained in 1 per cent cotton blue or 1 per cent lactofuchisn and were mounted in lactophenol for observations and identification. Fungi were identified by Dr. A. K. Sarbhoy, Mycologist, Division of Mycology and Plant Pathology, I.A.R.I, New Delhi.

Mite in the culture jars were fed mainly on dry yeast powder. Mites and immature forms were also offered different food such as, *Asperigillus variecolor*, moss, organic matter, a mixture of finely sieved soil with 2 parts of animal manure, dry leaves (not powdered) and green leaf choffings of *Nerium*. Both cultures and Plaster of Paris-charcoal cultures were moistened daily in the morning. Great care was taken not to add excess water. The testing food was sprinkled 15 minutes after watering the chambers. Care was taken to remove mold from the jars as it would tangle the mites. Yeast powder when sprinkled on the wet surface of the chambers became paste which was attractive to either juvenile or adult mites.

Observation and Discussion

LI. Biology—Description of development stages: A general description of the adult *G. flabellifera* is given by Hammer (1958). Hence only characters that supplement Hammers descriptions are given below together with a full description of the immature stages.

Sexual dimorphism is not very distinct in *G. flabellifera* except that the area between the genital and anal plates is lesser in males than females and males are alway smaller in size.

Eggs: Transluscent, oval, four to six eggs laid at one time either singly or in clusters. When in clusters, are glued to the yeast pellets. Eggs measuring an average 220μ to 240μ in length and about 90–95μ in width.

Larva: Length 240μ rostal hairs (RO) straight and as long as lamellar hairs (LH). The distance between LH is half to the distance between INLH, which are longer than other prodorsal hairs. All prodorsal setae are distinctly barbed·

Pseudostigmatae cup-shaped and laterally directed, sensillus (SS) short with a thin stalk and club-shaped head with fine bristles. Exostigmatic setae (EXO) present and lateral to the pseudostigmata. Notogastral setae 8 pairs, epimeral sta l formula 2-1-2-0. Genital aperture absent. Anal aperture slit-like without any anal setae, two pairs of setae present at the adanal region. 3 pair, of legs, all legs monodactylus. Trochanter of third leg devoid of seta.

Fig. 1

Protonymph: Length 245-260μ, with four pairs of monodactylus legs, 8 pairs of notogastral setae, genital aperture still not very distinct, without adgenital setae. Epimeral setal formula 2-1-2-1. 2 pairs of setae at the adanal region (Fig. 1).

Deutonymph: About 265-280μ in length; 4 pairs of legs, all legs monodactylus. Genital aperture slit-like and distinct. Genital and anal plates area slightly demarcated, each with 3 pairs of setae on their lateral margins, one pair of adgenital setae and 2 pairs adanal. Epimeral setae 2-1-2-1.

Tritonymph: About 300-325μ in length; all legs monodactylus, genital and anal plates demarcated, genital plate with 5 pairs setae and one pair of adgenital setae. Two pairs of anal and three pairs of adanal setae present. Adanal fissure posterior to Ad 3. Ten pairs of notogastral setae, short and glabrous. Abdominal glands distinct, situated laterally in between setal pores or 3 and cp. Two pairs of area porosae are also present. Sensillus much elongated with distally barbed clavate head. Both LH and INLH are densely barbed. Lamellar carinae laterally situated and shoulder patches (the future pteromorphs) are also demarcated from the notogaster. Tritonymphs undergo quiscent for at least a day to two before moulting to preadult and adult.

Adults: About 300-350μ notogaster rounded posteriorly, notogastral setae absent but ten pairs of setal alveoli present. Four pairs of area porosae are present. The relative size of area porosae are $A_0 > A_3 > A_1 > A_2$. Abdominal gland lateral to the area porosae Al and slightly posterior to setal pore r3. Pteromorphae are large, broadly rounded anteriorly with a V-shaped groove and a *ta* setal pore. Genital plate with 6 pairs of setae, three pairs anteriorly situated in a transverse plane; anal plate with 2 pairs of setae and two pairs of adanal setae. All legs tridactyl and hetero-dacty! the lateral claws remarkably thinner. Tarsus 1-4

slender than the remainder. Chelicerae normal with strong dentate chela and the cheliceral setae barbed. Tragardh organ well-developed. Pedipalp five segmented (Fig. 2).

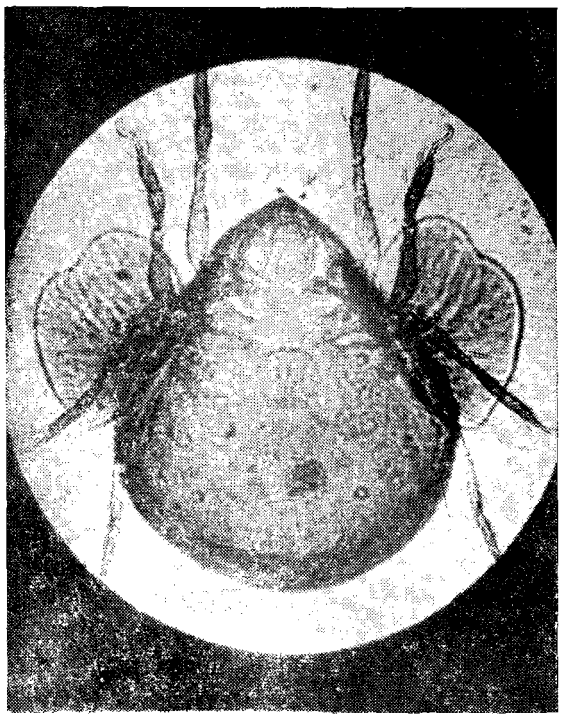

Fig. 2

Reproductive activity under field conditions: Reproductive activity varies both in time of occurrence and duration from species to species. Harding (1967) observed *Rhysotritia duplicata* to breed throughout the year suggesting that the Phthiracaridae have no restricted breeding period. Rocket and Woodring (1966) observed *Pergalumna omniphagous* laying eggs singly during winter and in clumps of four during the spring, suggesting that temperature changes, acting directly on the metabolic rate, may influence ovarian activity. Reproductive activity in *G. flabellifera* varied considerably in field conditions. Mites collected from the sampling plot A and C with sufficient moisture enough to keep the mites active included immature stages and adults throughout the season. Whereas the samples from plot B which was cultivated land showed remarkable variations both in density and occurrence of immature stages. During dry spells mites were not only fewer but the immature stages were rarely found. Generally, the oribatid distribution in cultivated soils is sparse. Surprisingly, when samples were collected during the Spring both immature and adult forms were obtained from the soils. Adult mite laid an average of 2–4 eggs during the

August–Sept. period and during off-season rarely one in cultivated land. The gravid adults were found throughout the sampling period where moisture and organic content was available (plots A and C). Therefore, it is likely that the onset of reproductive activity of *G. flabellifera* starts with availability of moisture on the grounnd surface and the duration of development depends on the availability of food as will be seen later in this chapter.

Food and duration of development in C. flabellifera*:* It is difficult to estimate the time required to complete the development from egg to adult under field conditions. Mites were reared in the laboratory with various test foods. Woodring (1965) fed some species of *Glumna* and other oribatids on mushrooms. Sengbusch (1954) reared 3 sps. of *Galumna* on *Protococcus*, a green alga, in the laboratory. Shaldybina (1970) reared about 20 species of oribatid superiores on potato and dry leaves. Shereef (1976) reared *Multioppia* sp. successfully on *Asperigillus flavus*. Hartenstein (1962a) suggested food was an important factor in determining the rate of development of *Belba kingli*. *Trichoderma koningi*, a fungus, and a soil water extract furnished sufficient nutritional requirement for *Belba* sp. and took 63–76 days for the development of all strges from egg to adult.

In the present studies, *G. flabellifera* was reared in the laboratory at 25°C with various test foods and the results are summarizad in Table I with duration of development recorded. The results obtained were in general agreement with observations reported by other authors when temperature at which mites were reared in the laboratory was taken into consideration. It should be noted that duration of development varied with different food. It was rapid taking 48 days to complete the life cycle when mites were fed on yeast and a maximum of 67 days required when they fed on organic matter (this can be taken as field condition but at constant temperature). Development of larvae never occurred when the mites were fed on dried and green leaves. When mites were fed on

TABLE I

Food and the average duration (in days) of the developmental stages of G. flabellifera

Food	Emergence of larva	Emergence of proto-nymph	Emergence of deuto-nymph	Emergence of trito-nymph	Emergence of adult	Total days
Yeast	11	8	9	5	15	48
Asperigillus veriecolor	11	11	13	7	15	57
Moss	11	13	11	7	23	65
Organic matter	11	17	13	9	17	67
Dried leaves	11	12	Failed to survive	—	—	—
Green leaves	11	Failed to survive		—	—	—

A.variecolor (a fungus) and moss, they required about 57 and 65 days respectively to complete their cycle.

Food and egg production: Woodring and Cook (1962) suggested the nutritional state of animal was an important factor for egg production in *Certozetes cisalpinus* Sdtchell (1967) related the feeding activity of earthworms to the cocoon production. In the present study the feeding activity of mites on the nutritious protein containing food, yeast, increased the egg production. The egg production ranged from 4 to a maximum of 8 with an average of 6.5 eggs per adult when fed on yeast alone. *Asperigillus variecolor* and moss as food produced 2 to 5 eggs with an average of 3 per adult; organic matter produced 3-5 eggs per mite and has no preference for dried and green leaves with just one egg per mite. The suitability and food preference of adult mite was estimated by the ability of adults to lay viable eggs (Table II).

TABLE II

Food preference and its relative effect on egg production and survival of the adult mite and developmental stages of G. flabellifera

Test food	Preference to food	Eggs laid	Larva introduced	Emergence of Proto-nymph	Deuto-nymph	Trito-nymph	Adult	% of reaching adult
Yeast	+++	6.5	10	8	8	8	8	80
A. variecolor	++	3	10	8	5	3	3	30
Moss	++	3	10	4	4	4	4	40
Organic matter	++	3.5	10	5	4	4	4	40
Dried leaves	NF	1	10	2	FS	FS	FS	0
Green leaves	NF	1	10	FS	FS	FS	FS	0

Note: + denotes degree of preference
NF – not preferred

Food and its effect on the development of larval and nympal stages: Restriction to one particular source of food is rare among soil animals (Wallwork, 1970). Woodring and Cock (1962) showed in culture experiments that the larvae of *Ceratozetes cisalpinus* would not survive if they were prevented from feeding on fungal hyphae soon after hatching, suggesting that the immatures may be more selective feeders than the adults. A series of experiments were conducted in order to study the feeding specificity of adult and immature stages and to determine the relative attractiveness of various test foods to newly-emerged larvae. Ten freshly-emerged larvae were introduced into each container with test foods. Preference of the food by the larvae was confirmed by the percentage of larvae that survived to become adults. The information obtained is summarised in Table II. It should be noticed that the larvae outstandingly preferred yeast. The larvae were attracted little to dried and green leaves. With the former only 2 larvae survived became protonymphs. Yeast is not only a

preferred food of adults but all the larval and nymphal stages because 80 per cent of the larvae fed an yeast survived and grew to adults. Moss and organic matter attracted immature and adults with 40 per cent of larvae becoming adults. *A. variecolor*, the fungus, was a principal food for larvae but not for nymphal stages as it could be noticed that of the 8 larval that moulted to protonymph stage finally only 3 reached the adult stage. Therefore, it could be that the food preferred by adult need not be preferred by the larvae, on the contrary, on the food preferred by larvae and nymphs the adults seemed to thrive. The immature stages preferred the more nutritious and protein-rich food during their development. Further work with varying combinations of protein, carbohydrate and vitamins etc., may throw light on this.

Isolation of fungi from G. flabellifera : Jacot (1930) reported the occurrence of fungal spores on the body surface of *Galumna* and *Neolides* spp. and suggested the importance of these mites as fungal spore carriers from soil surface to plant parts by their migratory movement. Moskacheva (1961) also isolated certain pathogenic and non-pathogenic fungi from the body and gut content of oribatid mites. In the present study, fungal spores from *G. flabellifera* were isolated, cultured in the laboratory and identified. The findings are tabulated in Table III.

TABLE III

Fungi isolated from the body surface and guts of the mite, G. flabellifera *and its developing stages*

Fungal species	Adult		Tritonymph		Deutonymph		Proto-nymph		Sampling sites		
	S	G	S	G	S	G	S	G	A	B	C
Asperigillus flavus	+	−	+	−	+	−	−	−	+	+	+
A. fumigatus	+	−	+	−	−	−	−	−	+	+	+
A. niger	−	+	−	+	−	−	−	−	+	+	+
A. nidulans	−	+	−	−	−	−	−	−	+	+	+
A. variecolor	+	+	+	+	+	+	+	+	+	+	+
Curvularia lunata	+	+	+	+	+	+	+	+	+	+	+
Helminthosporium specitirum	+	+	+	−	−	−	−	−	+	+	−
Memnoniella echinata	−	+	−	+	−	−	−	−	+	−	+

Note: + denotes present ; −denotes absent; S is for surface and G for gut content of mite.

Eight fungal spores were recorded from the mites. Of the eight fungi recorded, five species, were isolated from the surface and six from the gut content of the adult mite. *A. vareicolor, Curvularia lunata* and *Helminthosporium specitirum* were more frequently found on the body and in the guts of the adult. The presence of only three fungal forms on the surface and two in the gut of deuto-nymphs and two fungi on the surface and only one in the gut of protonymphs shows their inability to ingest organic matter with poorly developed

chelicerae and pedipalp. The species of *Helminthosporium* are reported to cause leaf spots on Graminae (Sprague, 1950; Dickson, 1956). In the present study, *H. specitirum* was isolated from the body and guts of the adult and larval forms of *G. flabellifera*. *Aspergillus flavus*, an important pathogenic fungus which causes 'X'–disease among turkeys in England by its ability to produce aflotoxin (Spensley, 1963) was also isolated from the adult and trito- and deutonymphal stages. Further, the occurrence of *C. lunata* and *A. niger* and other species of *Aspergillus* on the mite and their presence on the plants suggests that these mites transmit the fungal disease to plants by their movements from plant to soil. Their role as carriers of these fungal spores in spreading fungal diseases to plants can only be ascertained through an understanding of the extent the fresh plants are inoculated by the oribatid mite under controlled canditions and to what extent the fungal spores are utilised by the mite as food.

The authors acknowledge their thanks to Dr. A. K. Sarbhoy, Mycologist, Division of Mycology and Plant Pathotogy, I.A.R.I., New Delhi for kindly identifying the fungal forms. We are also thankful to the Director, B.I.T.S., Pilani for providing facilities in carrying out this work in the Department of Biological Sciences.

References

Aoki, J., 1964, Oribatiden in Thailand. I. Nature and life in South-east Asia, **4** : 129–193.

Aoki, J., 1964a, Some oribatid mites (Acarina) from Laysan Island. *Pac. Insects* (Hawaii), **6** : 649-664.

Balogh, 1958, On the preparation and observation of oribatids. *Acta. Zool. Acad. Sci. Hung.*, **5** (3–4) : 241-253.

Hammer, M., 1958, Investigations on the oribatid fauna of Andes Mountains I. The Aregentine and Bolivia. *Biol. Sjr. Dan. Vid. Selsk*, **10** (1) : 1-129.

Harding, D. J. L., 1967, referred from Ecology of Soil Animals by Wallwork, J. A., 1970, *McGraw Hill Publ. Co.*

Hartensiein, R.. 1962, Soil Oribatei. I. Feeding specificity amoung forest soil Oribatei. (Acarina). *Ann. Ent. Soc. Ame.*, **55** (2) : 202-206.

Hartenstein, R., 1962a, Soil Oribatei. II. Belba kingi, new species (Acarina:Belbidae) and a study of its life history. *Ibid.*, **55** (4) : 357-361.

Jacot, A. P., 1930, Oribatid mites of subfamily Phircarinae of the northeastern United States. *Proc. Boston. Soc. Nat. Hist.*, **39** (4) : 209-261.

Moskacheva, E. A., 1961, The microflora of testaceous ticks. (Oribatei) *Zhur. Bio.*, **12** B : 281

Reddy, A. S., 1972, Studies on the Oribatid Fauna of Rajasthan. Thesis submitted to Dept· Biological Sciences, B.I.T.S., Pilani.

Rhodes, C. J., 1956, A modification of the plaster charcoal techniques for rearing of mites and other small Arthropods. *Ecology*, **37**: 843–844.

Rocket and Woodring, 1966, Biological investigations on a new species of Ceratozetes and of Pergalumna (Acarina:Cryptostigmata). *Acarologia*, **8** : 511-520.

Sengbusen, H. G., 1954, Studies on the biology of three oribatid mites wt with observations on other species. *Ann. Ent. Soc. Amer.*, **47** : 646–67.

SHALOYBINA, E. C., 1970, Biological investigations on a new Ceratozete Oribatid mites superfamily Ceratozetoidea. Synopsis of thesis Ds. C. (in russian).

SATCNELL, J. E., 1967, "Lumbricidae" in Burges N. A. and Roy F. C. Edrs *Soil Biology*, 259-322.

WALLWORK, J. A., 1970, Ecology of Soil Animals. *McGraw-Hill publs. Co.*

WOODRING AND COOK, E. F., 1962, The biology of Ceratozetes cisalpinus Berl. Scheloribates laevigatus Kocn, and Oppia neerlandica Oudemans (Oribatei) with a description of all stages. *Acarologica*, 4: 101-137.

WOODRING, 1965, The biology of five new species of oribatids from Louisiana. *Acarologia*, 7: 564-576.

SHEREEF, G. M., 1976, Biology of two oribatid species in Giza region. *Acarologia*, 18(1): 1976.

A New Polyaspid Mite (Acarina: Mesostigmata) from West Bengal, India

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ABSTRACT

This paper embodies a description of a new Polyaspid mite *Polyaspis bengalensis* under a new subgenus *Adyscritaspis*.

INTRODUCTION

WHILE examining soil mesostigmatid mites collected from Parganas, West Bengal, a new species *bengalensis* was erected under a new subgenus, *Adyscritaspis* in the genus *Polyaspis* Berlese, 1881. The new subgenus differs from the subgenus *Dyscritaspis* Camin, 1953 in having the metasternal shield free from genital shield. Again in this character the new subgenus agrees with the main genus but differs in having metasternal seta placed outside the metasternal shield.

Adyscritaspis subgen. nov. (Figs. 1-4).

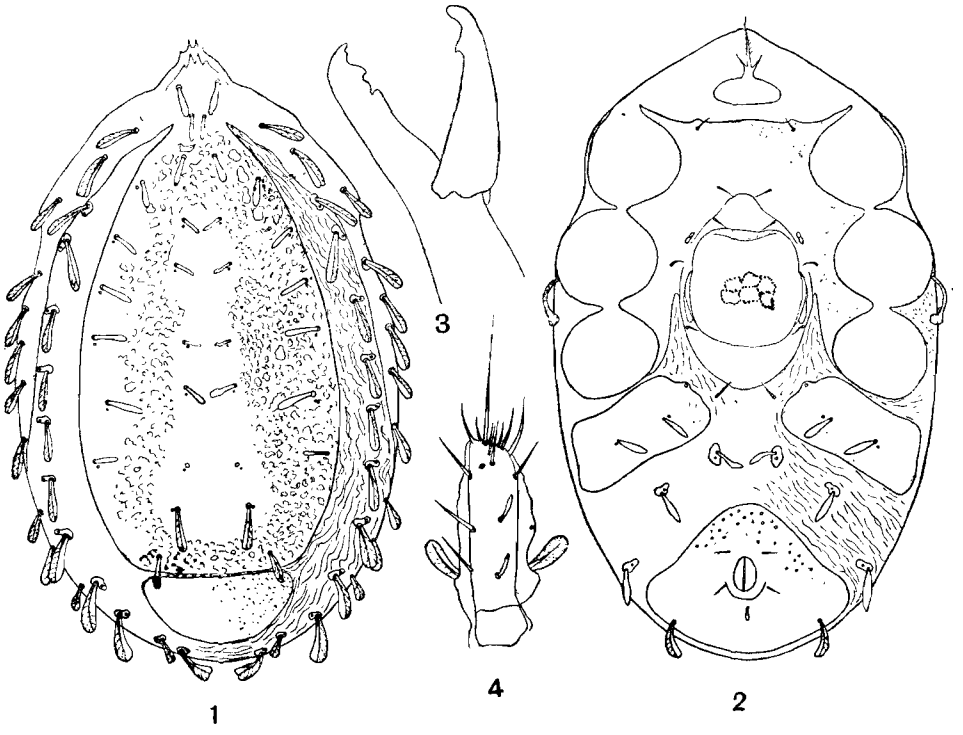
The new subgenus is characterised by a free metasternal shield bearing no setae, metasternal seta placed on integument at the postero-lateral side of the genital shield and metapodal shield free from exopodal-peritrematal shield.

Type species: *Polyaspis (Adyscritaspis) bengalensis* sp. nov.

Female: Body 0.492 mm – 0.504 mm long and 0.324 mm – 0.336 mm wide, dark brown, rough and fimbricate anteriorly; anterior dorsal shield large,

0.420 mm – 0.432 mm long, 0.240 mm – 0.252 mm wide, covers most of the dorsum, covered by nyphal skin excepting the median longitudinal area and carries peg-like or leaf-like setae (Fig. 1); posterior dorsal shield triangular, small and without setae; all setae surrounding anterior and posterior dorsal shields leaf-like, of these inner marginal setae on small isolated platelets.

Tritosternum with broad triangular base and three branched laciniae (Fig. 2). Sternal shield fused with endopodal, exopodal, peritrematal and ventral shields. Perigenital rim raised into crescentic hood-like structure at the anterior margin of genital aperture and almost surrounding the genital aperture. Sternal setae I and II lies on sternal shield and of equal length, sternal setae III within the perigenital rim, pseudosternal setae placed lateral to the perigenital rim and a pair of small platelets present at the level of anterior margin of coxae III. Genital shield almost square with rounded corners and covered with scale-like sculpturing. Metasternal shield small, elongated and free from genital shield: metasternal seta lying on integument below the metasternal shield. Large and oblong metapodal shield free from exopodal-peritermatal shield, with a rounded pore at inner anterior margin and with one pair of leaf like setae. Anal shield triangular, relatively smooth, with two pairs of



Figs. 1-4. *Polyaspis (Dyscritaspis) bengalensis* Pramanik and Raychaudhuri, female.
1. dorsum of idisoma; 2. venter; 3. chelicera; 4. tarsus of leg I.

setae excluding para-anal and post-anal setae; post-anal setae knob-like; anus lying on rudder-like projection. Peritreme short and recurved; stigma lying between coxae III and IV.

Gnathosoma with 4 pairs of hypostomal setae and of these the first and third setae longer, others spiny. Corniculus blade-like and long, reaching beyond distal ends of palp femur. Salivary styli long and cross each other medially. Movable digit of chelicera unidented, fixed digit bidentate and with a pocket receiving tooth of movable digit (Fig. 3). Leg I without claws and ambmlacrum; tarsus as in Fig. 4.

Locality: Holotype: Female from decaying leaves of *Casuarina* sp., Frazzergunge, 24 Parganas, West Bengal, 2. VI. 1973, M. M. Pramanik; Paratypes: 3 females, collection data as holotype.

We wish to express our thanks to Dr. D. N. Ganguly, Head of the Department of Zoology, University of Calcutta, for laboratory facilities in his department.

REFERENCES

BERLESE, A., 1881, *Atti. Ist Venet. Sci*, 8: 35.
CAMIN, J. H., 1953, *Bull. Chicago Acad. Sci.*, 9 (17): 335-385.

* Not seen in Original

Breeding Biology of Oribatid Mites

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ABSTRACT

The present paper embodies the results of laboratory experiments on the breeding biology of two species of oribatid mites *viz.*, *Lepidacarus ornatissimus* and *Archegozetes longisetosus*. Successful rearing of the mites was of primary importance in the study of breeding biology and the techniques of rearing are described. Under laboratory conditions, females of *A. longisetosus* laid eggs on the sixteenth day, after the fourth moult. The eggs were smooth and laid in batches. Average incubation period of the eggs was 5.7 days. *L. ornatissimus* eggs were laid singly and the egg shell was covered over by hooked hairy outgrowths. The incubation period of the egg was 15 to 16 days. The larva emerging from the egg, subsequently underwent four moults and passed through protonymphal, deutonymphal and tritonymphal stages, before reaching the adult stage. The duration of each of these developmental stages varied and an increase in size of body was noticed in both the species. After a prolonged period of active feeding, at every stage they entered into an inactive period known as *quiescent period* or the

premoult period. Before the initiation of this period, nymphs of the same stage of *A. longisetosus* were found to aggregate in a place in the culture vessel. The premoult period in *A. longisetosus* was shorter, ranging from 2 to 3 days but for *L. ornatissimus* it was much longer ranging from 9 to 10 days. The newly moulted animal was seen to rest for some time. This is known as the *hardening period.*

L. ornatissimus was comparatively smaller, about half of the length of *A. longisetosus*. However, the length of time required to complete the development of *L. ornatissimus* was five-fold the time taken by *A. longisetosus*. This observation was contrary to the general contention that smaller species have shorter developmental times than larger species. From the time taken to complete the life cycle under laboratory condition, it is possible to arrive at a conclusion that *L. ornatissimus* would have a single generation per year, whereas *A. longisetosus* would have seven generations per year. Morphological changes noticed in both the species in the course of postembryonic development are described.

Introduction

This paper submits the results of the laboratory experiments on the breeding biology of two species of oribatid mites, namely *Lepidacarus ornatissimus* and *Archegozetes longisetosus*. The study was attempted in order to obtain information on the duration of life cycle and the chaetotoxic and other morphological changes occurring during post-embryonic development. The first aspect would help in the study of the ecology of these species and the latter in the study of systematics.

Laboratory studies on the biology of oribatid mites involved the difficult task of culturing them. The minute size of the animal, its cryptic behaviour, dearth of information on the food requirements and artifical foods that could be easily provided in the laboratory hinder their rearing. Yet, another difficulty is that the study of the biology often demands constant observations of all developmental stages and requires maintenance of a population surviving indefinitely in laboratory conditions. The rearing and culturing techniques employed in the present study was based on those of Rhode (1956, 1959) and Sengbusch (1963) with certain modifications for better contrast of the eggs, easy manipulations of the larvae and nymphs and for convenient microscopic examination.

Material and Methods

The materials for the present study were obtained largely from samples collected from the field during monsoon season. A Berlese-Tullgren funnel method was used for extraction from soil. The mites collected were separated into species and then transferred to acclimatisation chambers. These chambers were made of circular plastic boxes of 6 cm diameter and 4 cm height with lids. The lids were perforated with small holes for air circulation. The boxes were half filled with plaster of Paris/charcoal mixture in the ratio 4 : 1 which

proved to be excellent base for the culturing chambers. The dark colour of the base after moistening, gave good contrast to the white shiny eggs. Plant debris and different species of fungi were provided as food. As soon as eggs were seen they were transferred immediately to specially–prepared culture rings. Commercially available glass rings measuring 2 × 1 cm were found suitable for culturing. Petri dishes measuring 15 × 2 cm were filled to one third their depth with a plaster of Paris/charcoal mixture. Before the mixture hardened, the culture rings were embedded in it vertically to half their height and at a distance of 2.5 cm from each other (Fig. 1). The mouth of the glass ring was closed with a cover glass of 2 cm diameter. The inner surface of the glass rings and the cover glasses were coated with a thin film of plaster of Paris/charcoal mixture to avoid unnecessary condensation of water inside. The culture base was moistened periodically to provide necessary moisture conditions. An average relative humidity of 94.7 per cent and a temperature of 30±1°C were maintained throughout the investigation. Precautions were taken by regular cleaning of the culture cells to avoid contamination. Observations were carried out three times a day at equal intervals.

Observations and Dicussion

Under laboratory conditions, mating was not observed either for *A. longisetosus* or for *L. ornatissimus* and spermatophores could not be detected. In the laboratory, females of *A. longisetosus* laid eggs on the sixteenth day after their fourth moult. Gravid females (Fig. 2) could be recognised easily by observing the presence of eggs, through their transparent bodies. The eggs were small, smooth, shiny and oval in shape. They were laid in batches (Fig.3) along with some fluid, which appeared to be sticky, keeping the eggs adhering together. The average incubation period of the eggs was 5.7 days. Eggs of *L. ornatissimus* were laid singly (Fig. 4) and intermittently covered over by hooked hairy out-growths. The average incubation period of these eggs was 15.16 days. At the end of incubation period, the eggs of both species appeared to be transparent when kept in a film of water. The hatching of the larvae of *L. ornatissimus* was initiated by the splitting of the egg case followed by a break at the one-third region. The break extended deep, but never encircled the egg shell completely (Fig. 5). Through the break, the first pair of legs protruded out initially and then by subsequent movements, the larva emerged. Egg cases were seen in culture vessels without disintegration for a long time after the emergence of the larvae of L. *ornatissimus* but they were not observed for *A. longisetosus*. The larvae (Fig. 6 and 7) emerging from the egg subsequently moulted four times and passed through protonymphal, deutonymphal (Fig. 6) tritonymphal stages, before becoming adults. The duration of each of these developmental stages varied and an increase in size of the body if both the species was noticed. After a period of active feeding at every stage in the development these

mites entered into an inactive period, known as the *quiescent period* or *pre-moult period.* During this period no feeding was noticed and the mites did not

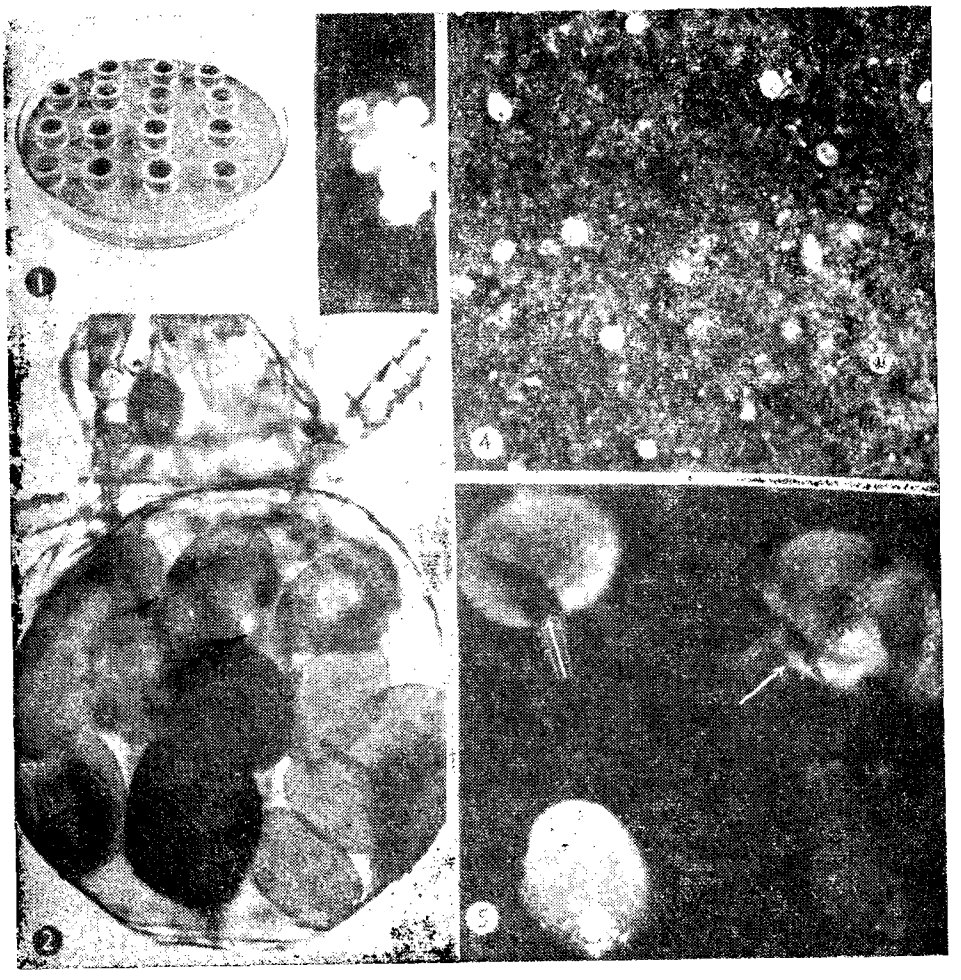

Fig. 1 Culture chamber employed in the rearing of *Lepidacarus ornatissimus* and *Archegozetes longisetosus* X5

Fig. 2 Gravid female of *Archegozetes longisetosus* X100

Fig. 3 Egg cluster of *Archegozetes longisetosus*

Fig. 4 Solitary eggs of *Lepidacarus ornatissimus* X7

Fig. 5 Discarded egg cases of *Lepidacarus ornatissimus* showing the line of break-arrow X400

move even when they were violently disturbed. This period in *A. longisetosus* was relatively short, ranging from 2 to 3 days but for *L. ornatissimus* it was comparatively long ranging 9 to 10 days. Before the initiation of this period, nymphs of the same stage of *A. longisetosus* were found to aggregate in the culture vessel (Fig. 8). But this was not observed for *L. ornatissimus*. The

tendency to aggregate was especially seen in larvae and protonymphs. Moulting of *L. ornatissimus* was found to start with the appearance of a small break along the ventrolateral suture (Fig. 9). The break then extended from the posterior region of the hysterosoma to fourth pair of legs. The movements of the animal inside the old skin helped in the separation of the old cuticle and the emergence of the animal. On splitting of the old cuticle (Fig. 10), the new individual was emerged partly and was seen resting for a further period of about three hours. This is known as the *hardening period.* Moulting of *A. longisetosus* could not be observed in detail. The exuviae left on the substratum formed a group (Fig. 11) and could often be detected on leaves collected from the field.

It was suggested by earlier workers (Wallwork, 1970 and Butcher *et al.*, 1971) that smaller species have shorter developmental time than larger species. *L. ornatissimus* was 500μ long whereas *A. longisetosus* was 950μ long. The length of time required to reach the adult stage was 176 days for *L. ornitissimus* which was five times as long as *A. longisetosus.* The egg deposition of the two species exemplified the patterns observed by earlier workers (Wallwork, 1970). The egg shell of *L. ornatissimus* was found to be covered over by numerous hooked hairy outgrowths and these were thought to be an additional advantage in anchorage. In *A. longisetosus*, on the contrary, the egg shell was smooth and the eggs were laid in clusters. It was found that the entire egg mass was attached to the substratum by some sticky fluid which held the eggs together in a cluster. Two different mechanisms were thus evolved by the two species apparently for the same purpose.

The tendency to aggregate before the premoult period observed in *A. longisetosus* was a unique phenomenon. Possibly, some aggregating substance was released but attempts to test this in the laboratory were not successful. This kind of aggregation at the time of molting was observed by Joosse (1966) in Collembola. It is interesting to note that such gregarious behaviour generally disappeared in these mites in the older stages and the tritonymphs sometimes moulted individually. An important anatomic al feature of the larva was the absence of sensillus which appeared only in the protonymph. Perhaps this has some part in this peculiar behaviour.

A progressive increase in the body size from larva to the adults was noticed in the two speciees. However, the percentage increment was not uniform for all the stages. In both species the increase in size of the protonymph was more striking than in any other succeeding stages. In *A. longisetosus* it was very impressive that the protonymph attianed a size about one and a half times that of the larva. Such remarkable increments in growths were also noted for *Damaeus clavipes* by Block (1965). There is very little differene in the duration of life between protonymph and deutonymph of *L. ornatissimus* but for *A. longisetosus* the duration of life of the protonymph was 15 per cent longer than that of

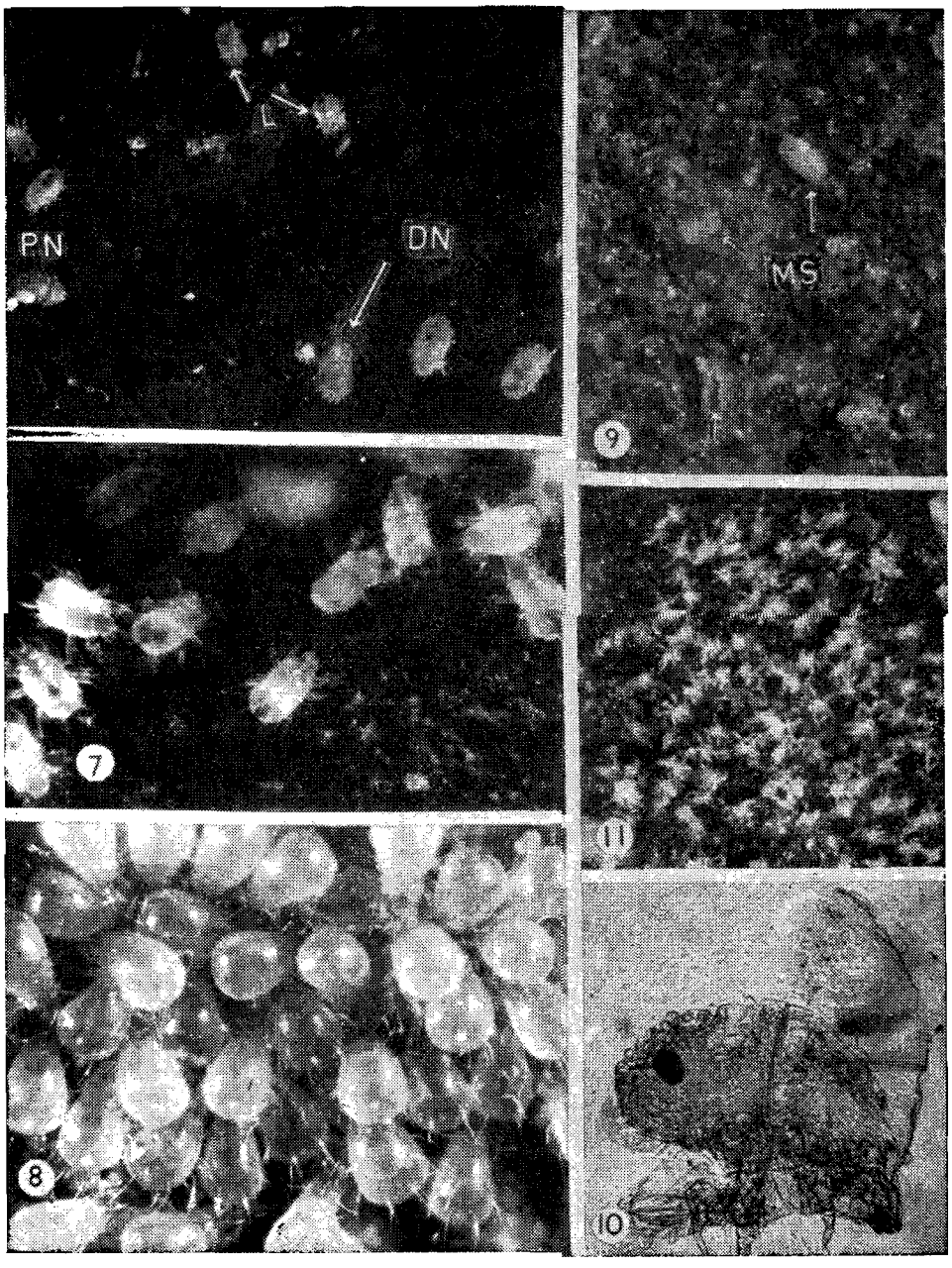

Fig. 6 Larvae (L), protonymphs (PN) and Deutonymphs (DN) of *Lepidacarus ornatissimus* X7
Fig. 7 Larva of *Archegozetes longisetosus* X20
Fig. 8 Aggregation of protonymphs of *Archegozetes longisetosus* before quiescent period X60
Fig. 9 Tritonymph of *Lepidacarus ornatissimus* (arrow below) showing the line of break on the ventrolateral notogastral suture just before moulting M. S. Exuviae of *Lepidacarus ornatissimus* X26
Fig. 10 Emergence of tritonymph of *Lepidacarus ornatissimus* X60
Fig. 11 Exuviae of larvae of *Archegozetes longisetosus*

the deutonymph. For both the species the larval complement of notogastral setae was retained in the adult and there was only addition to the basic number in the course of development.

From the point of view of chaetotoxy, tritonymph of *A. longisetosus* was exactly similar to the adult. In *L. ornatissimus*, on the other hand, the apodemal setae and the genital setae were fewer in the tritonymph than the adult. The determination of the species by examining the tritonymph would be possible only in the former species whereas for the latter species such determination, even if possible, would not be completely reliable.

The average time taken by *A. lognisetosus* to complete its life cycle was 50 days so that *A. logisetosus* can have a maximum of seven generations per year if conditions are favourable. *L. ornatissimus*, on the other hand took more than 176 days to complete the life cycle, so it is possible that the species has only two generations per year. But adults which lived in the laboratory for about three months after emergence did not lay eggs. If this happens in nature, then the species is likely to have only one generation per year.

References

Block, W., 1965, The life histories of *Plantinothrus peltifer* (Koch 1839) and *Damaeus clavipes* (Hermann 1804) (Acarina: Cryptostigmata) in soils of Pennine moorland. *Acarologia*, **7**: 735-743.

Butcher, J. W., Snider, R. and Snider, R. J., 1971, Bioecology of Edaphic collembola and Acarina. *Annual Review of Entomology*, **16**: 249-288.

Joosse, E. N. G., 1966, Some observations on the biology of *Anurida maritima* (Guerin) (Collembola). *Z. Morph. Okol.*, Tiere **57**: 320-328.

Rhode, C. J., 1956, A modification of the plaster-charcoal technique for the rearing of mites and other small arthropods. *Ecol.*, **37**: 843-844.

Rhode, C. J., 1959, Studies on the biologies of two mite species, predator and prey, including some effects of gamma radiation on selected developmental stages. *Ecology*, **40**: 572-579.

Sengbusch, H. G., 1963, Methods recommended for the preparation and culture of Oribatei, Advances in Acarology 1. *Cornell University Press*, N. Y. pp. 181-190.

Wallwork, J. A., 1970, Ecology of soil Animals. *McGraw-Hill Publishing Company Limited* Maidenhead-Berkshire-England. pp. 283.

Distribution of Collembola in Accordance with Different Vegetation at Eden Gardens, Calcutta

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ABSTRACT

Five distinct vegetational sites viz., (i) grassy plot, (ii) bamboo plantation, (iii) banana plantation, (iv) *Ixora* plantation and (v) *Sansivieria* plantation were selected for this study at the Eden Gardens, Calcutta, including an atypical site, namely, drainage of the garden which remains covered with the foliage litter of *Polyalthia longifolia* Benth & Hook. f. for almost all the year round. Altogether, 450 soil samples were taken by using stainless steel samplers having an inner cross-sectional area of 8.55 sq cm. Those samples were extracted with an expedition funnel apparatus as devised by Macfadyen (1953) with certain modifications.

RESEARCHES in soil biology are in the process of blooming in tropical countries. Its advancement in comparison to the progress made in other parts of the world, specially in temperate countries, is negligible in view of the fact that sound and relatively complete taxonomic work, as emphasized by Christiansen (1970), is lacking even for major groups of soil animals occurring in those countries. Of all the soil organisms, Collembola in general have attracted the greatest attention of soil zoologists since they are among the commonest soil insects (Pearse, 1946), remaining associated with almost all types of soil and exhibiting distinct morphological specialisations in accordance with their distribution in different strata of soil.

The object of the present investigations has been to study the distribution pattern of Collembola in five distinct vegetational sites, *viz.*, (i) grassy plot, (ii) bamboo plantation, (iii) banana plantation, (iv) *Ixora* plantation and (i) *Sansivieria* plantation, at Eden Gardens, Calcutta, including an atypical site, namely, drainage of the garden which remains covered with the foliage litter of *Polyalthia longifolia* Benth. & Hook. f. for almost round the year.

Characteristics of Sampling Sites

I. Grassy plot: The existence of a thick mat of grass, representing the species *Cynodon dactylon* Pers, characterises this plot. Characteristic seasonal plant species, *viz., Commelina obliqua* Ham. (commelinaceae), *Vernonia cinerea* Less. (Compositae), *Digitaria adscendens* (H.P.K.) Henr. (Gramineae), *Eupatorium odoratum* Linn. (Compositae), appeared in this plot mostly during the monsoon season.

II. *Bamboo plantation*: This site, having the plantation of *Bambusa arundinacea* Willd., is almost 40 cm higher from the ground level. The soil surface of this site was with a thick, dry litter, composed of the leaves of *B. arundinacea* throughout the period of investigations. Characteristic seasonal plant species, appearing mostly during monsoon months, were represented by *Echinochola colonum* (Linn.), Link (Gramineae), *Typhonium* sp. (Araceae), *Euphorbia hirta* Linn. (Euphorbiaceae), *Amaranthus viridis* Linn. (Amaranthaceae) and *Eclipta alba* Hassk. (Compositae).

III. *Banana plantation*: The plantation is represented by *Musa sapientum* Linn. It supported the characteristic seasonal plant species like *Murraya koenigii* Spreng. (Rutaceae), *Jasminum sambac* Ait. (Oleaceae), *Canna* sp. (Cannaceae) and *Codiaeum variegatum* Bl. (Euphorbiaceae).

IV. *Ixora plantation*: The plantation is represented by *Ixora* sp. Characteristic seasonal plant species like *Ageratum conyzoides* (Compositae) and occasionally the *Cynodon dactylon* (Gramineae) occurred in this plot during monsoon months.

V. *Sansivieria plantation*: This plot is represented by the *Sansivieria* sp. Characteristic seasonal plant community in this plot is represented by *Panicum* sp. (Gramineae), *Achyranthes aspera* Linn. (Amaranthaceae), *Oplismenus* sp. (Gramineae) and *Trema orientalis* Bl. (Ulmaceae).

IV. *Drainage*: The soil of the drain is compact and dark, remaining covered with a thick layer of foliage litter, resulting from the caste leaves of *Polyalthia longifolia* Benth. & Hook f., located nearby. *Lantana camara* Linn. (Verbenaceae) and *Fleurya interrupta* Gaud. (Urticaceae), appeared seasonally during monsoon and remaining restricted to this site, also contributed to the litter element of the drainage system of this garden which remained water-logged during most of the months under observation.

Besides the specific plant communities mentioned above for each of the sites, the following species, not restricted to any of the particular sites under observation, were found to occur seasonally: *Coccinia cordifolia* Cogn. (Cucurbitaceae), *Synedrella nodiflora* Gaertn. (Compositae), *Scoporia dulcis* Linn. (Scrophulariaceae) and *Ruellia tuberosa* Linn. (Acanthaceae).

Material and Methods

Each plot was sampled with stainless steel samplers each having an inner cross sectional area of 8.55 sq cm. Soil samples were taken to a depth of about 3 cm and were placed inverted in an expedition funnel apparatus (Macfadyen, 1953). Since the extraction was carried out in the laboratory, an electric bulb (40 W) was employed as the source of heat instead of hot water bath, as used by

Macfadyen, resulting in a temperature of 39°C inside the apparatus. Altogether, 450 soil samples were taken from the six plots during the period of June, 1975 to November, 1975, *i.e.*, at the rate of 3 samples from each plot every week.

Results

Abundance and changes of Collembolan populations : A quantitative analysis of the total number of Collembola obtained from the six vegetational sites reveals that the banana plantation supported the highest population (22. 50 per cent) followed by other sites, namely, bamboo (22.38 per cent), *Ixora* (17.38 per cent), grassy plot (16,02%), *Sansivieria* (12.27 per cent) and drainage (9.45 per cent) (Fig. 1).

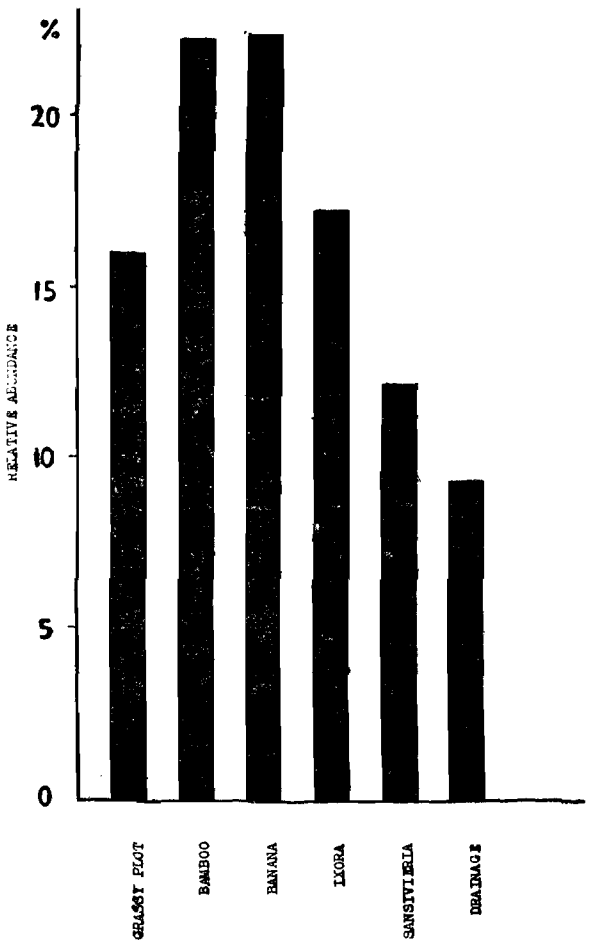

Fig. 1 Relative abundance of collembolan population at six vegetational sites

Further, it was noted that the monthly changes in the collembolan populations were not uniform and were found to differ from one site to another. Thus, the grassy plot had a population maximum in July and a minimum in November, the bamboo plantation had a maximum in September and minimum in November; maximum population for banana plantation occurred during July-August and minimum in November, for *Ixora* a maximum during the months of October and a minimum in November in for *Sansivieria* a maximum during the months of September October and a minimum in June. Drainage site had a peak population in June and its lowest was recorded during August.

Population composition of Collembola : Qualitatively, the grassy plot yielded the largest number of genera/species (20) and the lowest was recorded from the bamboo plantation (13). Out of the total 30 genera/species, occurring in these sites, *Cyphoderus albinus* (Nicolet), *Megalothorax minimus* Willem, *Folsomides*

parvulus Stach., *Isotomina* (*Cryptopygus*) *thermophila* (Axelson), *Arrhopalites* sp., *Pseudosinella* sp., *Sphaeridia* sp. and *Lepidocyrtus* sp. occurred in all sampling sites. These species, therefore, are to be considered as ubiquitous. Further, the specificity was noted in the distribution of certain genera/species of Collembola according to vegetational sites under study. Thus, *Sinella (Sinella)* sp., *Pseudochorutes* sp. *Tullbergia* (*Stenaphorura*) sp., *Lepidocyrtus* (*Lepidocyrtus*) sp. and *Salina bengalensis* Mitra remained restricted to the grassy plot only. *Dicyrtomina* (*Calvatomina*) sp. occurred only at the bamboo plantation, while *Folsomina onychiurina* Denis at the banana plantation. *Sminthurinus* sp. and *Dicyrtomina* (*Pseudodicyrtomina*) sp. were obtained only from the samples drawn from *Ixora* plantation, while *Proisotoma* sp. from the *Sansivieria* plantation. The drainage area of the garden, which remained water-logged during most of the months under observation, represented two characteristic species, namely, *Subisotoma fitchioides* (Denis) and *Sminthurides (Sminthurides) appendiculatus* Imms.

The highest frequency of appearance of *M. minimus* was in the soil samples, taken from three vegetational sites, *viz.*, the banana plot, *Ixora*, *Sansivieria* while that of *C. albinus* was in the samples from the grassy plot and the bamboo plantation and that of *I. thermophila* was in the samples from the drainage area. Both *Lepidocyrtus* sp. and *Sphaeridia* sp. appeared in the highest frequency at the site of *Ixora* while, *Pseudosinella (Pseudosinella)* sp. at the grassy plot. So far as the dominance of the species is concerned, the following species were found to dominate the population in each plot under study: *Psuedosinella* sp. in the grassy plot; *M. minimus* in the bamboo plantation, banana and *Sansivieria*; *C. albinus* in the site of *Ixora* and *I. thermophila* in the drainage area. Out of the total number of genera/species, obtained from each plot, the grassy plot shared the largest (20) followed by *Ixora* (19), *Sansivieria* (18), banana (17), drainage (16) and bamboo (13).

The following genera/species not restricted to any of the vegetational sites and not mentioned above, were also obtained from soil samples extracted during this investigation: *Stenognathellus* sp., *Entomobrya* sp., *Isotomurus ciliatus* Stach, *Isotomiella minor* (Schaeffer), *Sminthurus* sp., *Sinella (Coecobrya)* sp., *Tullbergia* (*Tullbergia*) sp., *Katianna sp.*, *Drepanura* sp,, *Isotomodes* sp., *Brachystomella* of *curvula* Gisin, *Willemia* sp., *Dicyrtoma* sp. and *Calx* sp.

Conclusion: The results, presented above, clearly indicate the influence of plant communities on both the quantitative and qualitative distribution of the collembolan fauna. Quantitatively, the banana area supported the highest population while qualitatively the grassy plot yielded the largest number of genera and species. Restriction of certain genera/species to a particular vegetational site may be ascribed to the specific rhizospheric effect of the plant

community occurring at that particular site. The observations presented here support the views of Nosek (1959), Dunger (1964), Christiansen (1964), Choudhuri and Roy (1972) and Mitra *et al.* (in press) on the effects of macroflora in the quantitative and qualitative distribution of collembolan fauna.

Thanks are due to the Director, Zoological Survey of India, Calcutta for facilities.

REFERENCES

CHOUDHURI, D. K. AND ROY, S., 1972, An ecological study on Collembola of West Bengal (India). *Rec. Zool. Surv. India*, **66** : 81–101

CHRISTIANSEN, K., 1964, Bionomics of Collembola. *Ann. Rev. Ent.* **9**: 147–178.

CHRISTIANSEN, K., 1970, The scope and direction of contemporary soil arthropod research. "Pesticides in the Soil". Intern. Symposium, 144.

DUNGER, W., 1964, Tiere in Boden. Ziemsen verlag, Witenberg Lutherstad. 265 pp.

MACFADEN, A., 1953, Notes on methods for the extraction of small soil arthropods.- *J. Anim. Ecol.*, **22**: 62–77.

MITRA, S. K., HAZRA, A. K. AND SANYAL, A. K., Dynamics in quantitative and qualitative composition of Collembola in Gangetic alluvium of West Bengal (India) in relation to relative humidity and temperature. In: Lohm, U. & Persson, T. (eds) Soil Organisms as components of Ecosystems. Proc. VI. International Soil Zoology Colloquium. *Ecol. Bull.* (Stockholm), **25** (In press).

NOSEK, J. 1959, Die Untersuchung der Bodenfauna als ein Teil der Waldbiozonoseforschung (mit), Bemerkungen zur Bodenfauna vom Standpunkt der Bodenbiologie. *Biol. Works Slovakr. Acad. Sci.*, **3** : 156.

PEARSE, A. S. 1946, Observations on the microfauna of the Duke Forest. *Ecol. Mongr.* **16** (2): 127–150.

Some Preliminary Observations on the Life History of *Entomobrya Sp.* (Collembola : Entomobryidae)

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ABSTRACT

An *Entombrya sp.* is very abundant in the surface litter layer of Delhi region. Soil samples were taken from 5 different sites of a small garden in South district and Collembola specimens were extracted from the soil samples by Tullgren funnels. *Entomobrya sp.* were reared in petri dishes 10 cm in diameter and 2 cm high with a 0.5 cm thick layer of plaster of Paris in the bottom. All cultures were maintained at a room temperature of $32 \pm 2°C$. At regular intervals water was added in order to keep the plaster of paris layer moist. Only dry yeast was introduced as food which seems to be quite favoured by these collembolans.

Sexual dimorphism could not be observed in *Entomobrya sp.* but suspected females were maintained at a random on the basis of their short, hevay and bluntly pointed abdomen. The eggs were laid in clusters, sometimes singly in linear fashion, in some protected place, like crevices, inside the holes in the plaster layer, beneath the fungus moulds or even under small glass particles. One peculiar feature observed in *Entomobrya sp.* was that they form a reticulate nest-like structure from the yeast spores and lay eggs in the interspaces. After oviposition, the eggs are left unattended. Females lay eggs two or three times in their life span of about 3 months, with the total number of 30–35 eggs per oviposition.

Eggs, when laid, are white in colour, small (0.13–0.15 mm) and smooth. On the second day they become larger (0.20–0.25 mm) by absorbing moisture. The appearance of some hair-like structures had been observed all around the egg chorion. Though the real function of these structures is not known, it is believed that they help in anchoring the eggs. On the third day two eye spots are visible which become darker on the subsequent days.

Hatching starts on 5th day but sometimes it is delayed till the 7th or 8th day. The movements of the embryo inside the egg could be observed on the last moment prior to the hatching and on emergence the head comes out first.

The 1st instar is similar to the adults in appearance except that it is white in colour, has darker eye spots and a clearly visible digestive tract. Its body length is about 0.25 mm (excluding head and furcula), whereas the 12th instar which seems to be the last, measures about 1.5 mm. Sexual maturity is attained in the 5th instar which measures about 0.8 to 0.85 mm. Although the maximum number of intar stages is 12, the insect continued to moult throughout its life without any increase in body measurement. The whole life cycle takes about 23–26 days for completion.

Temperature is said to influence the time required for the development as well as oviposition. As all the observations were made at room tempurature, the effects of the wide range of temperature could not be seen. Experiments for these observations are planned for future. However, the amount of food and population density are the other factors which influence the production of eggs.

In *Entomobrya* sp. parthenogenesis seems to be common. About 10 suspected females were picked out and kept individually in different dishes. 7 out of 10 laid eggs. The females were immediately transferred to the other dishes after oviposition. Eggs hatched in the usual time of 5 days and all the instars were transferred individually to the different dishes. About 50 pert cent of them laid eggs after attaining sexual maturity and the new instars came out after hatching.

Introduction

Soil biologists have paid little attention to the role played by Collembola in litter decomposition and soil formation. For better understanding of these problems, the life histories of Collembola under various conditons and in different areas should be investigated. Few workers have worked on the Collembola taking the applied, ecological and taxonomical ascepts all into consideration.

The present report is one of a series aimed at understanding the life histories of Collmebola.

Material and Methods

This species of *Entomobrya* although not yet fully identified is very much abundant in the surface litter layers of the Delhi region. Soil samples were taken from five different sites of a small garden in the South district of Delhi and Collembola specimens were extracted from the soil samples in Tullgren's funnels. The insects were reared in petri dishes 10 cm in diameter and 2 cm high with a 0.5 cm thick layer of plaster of Paris in the bottom. All cultures were kept at room temperature of $32 \pm 2°C$. At regular intervals, water was added to the plaster layer to keep it moist. Only dry yeast was introduced as food and this seemed to be suitable for nearing Collembola.

Sexual dimorphism : Like other Collembola, this species is ametabolous. It was quite difficult to identify the sex of this species because there were no external genital organs visible in this genus. However, it was sometimes possible to pick out the females from the mass culture on the basis of their shorter and more distended abdomen than those of the males, so that the body of females was more bluntly pointed and short.

Sperm transfer: There seems to be very little known about the sperm transfer in Collembola. The author was unable to observe this mechanism with certainity but found it definitely different from the method described by Wigglesworth who reported that males smear the sperms on the mouth parts and the sperm are transferred to the genital pore of the females. In the present observations the young specimens were placed in different dishes as soon as they hatched and kept isolated until they were sexually mature. As soon as the animals in two dishes were mixed together, those suspected to be females seemed to be quite excited. They ran about restlessly touching the head and antennae on to the plaster layer, then moved forward till the posterior end of their abdomen reaches the spot where the males might have deposited spermatophores. Then they moved forward within seconds after touching their abdomen up and down on the spot to receive spermatophores. This method of sperm transfer agrees with the method described by Strebel.

Oviposition: This species laid eggs usually in batches but sometimes singly or in a linear fashion with a little distance between them. They usually laid eggs in crevices, under fungus moulds and even under small glass particles. However, if no protection was available they simply laid eggs in open areas. After oviposition, the eggs were left unattended. One peculiar feature observed was that they usually formed some reticulate structures out of the yeast spores and laid eggs underneath, or in the interspaces of these.

Eggs: Eggs were spherical, smooth, white and about 0.13–0.15 mm in diameter. At first they were small and half the size of those one or two days old. They became larger on the second day by absorbing moisture and on the same day, some very prominent hairy growths were observed arround the egg chorion. The function of these structure is not known but it is presumed that they help in anchoring eggs to the surface after oviposition.

Temperature is a very important factor influencing the time required for the development in Collembola. Because the present studies were made at room temperature only, the effects of temperature on the development could not be observed. However, temperature experiments are now in progress at our laboratory.

Hatching: The eggs have pigmentation of the two eye spots which increases on subsequent days and which appeared first on the third day after oviposition. Hatching started on the fifth day but sometimes was delayed until the seventh day. Total hatch of the eggs was about eigty five per cent. The movements of the embryo inside the eggs could be seen immediately prior to hatching and on emergence the head came out first.

Instars: The first instar was 0.25 mm in length (excluding head and furcula) and white in colour. It was very similar to the adult in appearance except it was white in colour, had darker eye spots, fewer hairs on the body and a clearly visible digestive tract. It continued to moult throughout the life cycle without any metamorphosis. At the maximum, twelve instars were observed for this genus, but, moulting continued to take place even after this but without any subsequent change in the body length. The total number of moults after the twelth instar was 4–6. Moulting was influenced by various factors *viz.*, variation in temperature, humidity, quality and amount of food. The effects of these physical factors are still being recorded in our laboratory. Sexual maturity was attained by the fifth instar after seventeen days when it was about 0.80–0.85 mm in length (excluding the head and furcula). Females laid eggs about 3–5 times (up to the eigth instar) in thier life span of about three months. The average number of eggs laid by a female at a time was thirty five. After the eigth instar oviposition was inhibited but growth continued. The twelfth instar, which is the last, measured 1.5 mm in length (excluding head and furcula). It was estimated that 23–26 days were required to complete the life cycle from eggs to adult.

Fecundity: The number of eggs laid by the females have been estimated from the average number of eggs in all batches. On average thirty five eggs were laid by each female. Females laid eggs 3–5 times during their life span of about three months at 5–7 days intervals. Temperature effects did not seem to influence the fecudity but generally it change the time intervals between the ovipositions

rather than the number of eggs per oviposition. The population growth of Collembola was estimated, not only by the total number of eggs laid per female but also from the method of egg laying.

Fecundity is also affected by the amount and kind of food, humidity and population density. These effects of physical factors have been described by Green. We are conducting experiments to study the effects of these physical factors in details.

Parthenogenesis: Parthenogenesis seemed to be common. About ten suspected females were selected and kept individually in different dishes. Seven out of ten laid eggs. The females were immediately transferred to other dishes after oviposition. Eggs hatched in the usual time of five days and all the instars were transferred individually to the different dishes. Fifty per cent of them laid eggs after attaining sexual maturity and eighty per cent hatched.

My sincere gratitudes are due to Dr. H. S. Vishnoi, Reader, Dept. of Zoology for his constant encouragement and guidance. Thanks are also due to Dr. M. R. N. Prasad, former Head of Zoology Department for providing facilities and Dr. P. N. Lawrence of British Museum (Natural History) for identifying the specimens for me. The help of Mr. Subhash Prabhaker is also acknowledged for typing the whole manuscript.

References

Britt, N. W., 1951, Observation on the life history of Collembolan Achorutes armatus. *Trans. Amer. Micr. Sec.*, **70** : 119–132.

Choudhary, D. K., 1960, Influence of temperature on the development of Onychuirus furciferus and its mathemetical representation. *Proc. Zool. Soc.* Calcutta, **13** : 123–128.

Choudhary, D. K. 1961, Influence of temperature on the sex ratio of Onychuirus imperfectus Devis. *Sci. Cult.* Calcutta **27** : 48–49.

Choudhary, D. K., 1963(a), Temperature and its effects on the three species of the genus Onychuirus (Collembola). *Proc. Zool. Soc.* Calcutta, **16** : 97–117.

Choudhary, D. K., 1963b, Effects of some physical factors on the genus onychuirus (Collembola). *Proc. National, Sci.*, India, Section B **33** : 538-546.

Green, C. D., 1964, The effects of crowding upon the facundity of Folsomia candida (Willem) var. distincta (Bagnell). *Ent. Exp. Appl.*, **7** : 62-70.

Green, C. D., 1964, The life history and facundity of Folsomia candida (Willen) var distincta (Bagnell) (Collembola-Isotomidae). *Proc. Roy. Ent. Soc.*, Lond (A), *39* : 125-128.

Joosse, ELS, N. G. and Ellen Veltkamp, 1970, Some aspects of growth, moulting and reproduction in five species of surface dwelling Collembola. *Netherlands Journal of Zoology*, **20 (3)** : 315–328.

Marshall, V. G. and McE Kevan, D. K., 1962, Preliminary observations on the biology of Folsomia candida Willem. 1902. *Can. Ent.* **94** : 575–586

Nijima, K., 1973, Experimental studies on the life history fecundity and growth of Sinella curviseta. *Pedobiologia*, **13** : 186–204.

*STREBEL, O., 1932, Beitrage zur Biologie, okologie und physiologie einhemischer Collerbolen. *Zool. Jb. Syst.*, 78 : 506-525.

**WALTERS, M. C., 1964, A study of *S. viridis* (L) in the western cape province. *Ent. Memoirs* 16 : 1-99.

WIGGLESWORTH, V. B., 1942, The principles or insect physiology. *Methuen and Co. Ltd.*, London, 434 p.

*Not seen in original. Quoted from Joosses ELS. N. C.
**Quoted from Nijima, K.

Soil Factors Governing the Distribution of Collembola (Insecta) in the Grave Yard of Berhampore, Murshidabad District (West Bengal)

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ABSTRACT

To study the probable role of different soil factors on the distribution of subterreanean Collembola, soil samples were taken from three plots at Berhampore grave yard campus, Murshidabad district, each plot five metres square, uncultivated, undisturbed and thickly vegetated. Altogether, 108 samples were taken, 36 from each plot at monthly intervals over a period of three consecutive years (from January, 1971 to December, 1973).

1,925 Collembola belonging to ten genera were collected. The genus *Lepidocyrtus* was the dominant one, comprising 14.29 per cent of the total population. Population density varied considerably from month to month usually with maxima in July–August (monsoon months) and minima in May (summer month) and was found to be soil factor-dependent.

Vertical distribution studies showed larger populations in the upper-most layer (0–3 cm depth) invariably associated with the phenomenon of aggregation of juvenile forms.

Regression studies of collembolan population and soil factors revealed : (a) positive correlation of some factors namely, nitrate, moisture, organic carbon and relative humidity with the population, (b) weak negative correlation of phosphate with the population and (c) no association of some other factors such as temperature, pH and calcium carbonate with the population.

Further, statistical analysis of variance showed the existence of both qualitative and quantitative differences between years and also between months of year, although the pattern of seasonal distribution appeared to be reasonably constant in all the three years under consideration.

INTRODUCTION

QUALITATIVE and quantitative ecology of the collembolan population in different habitats has been studied by numerous workers (Murphy, 1953), Bellinger (1954),

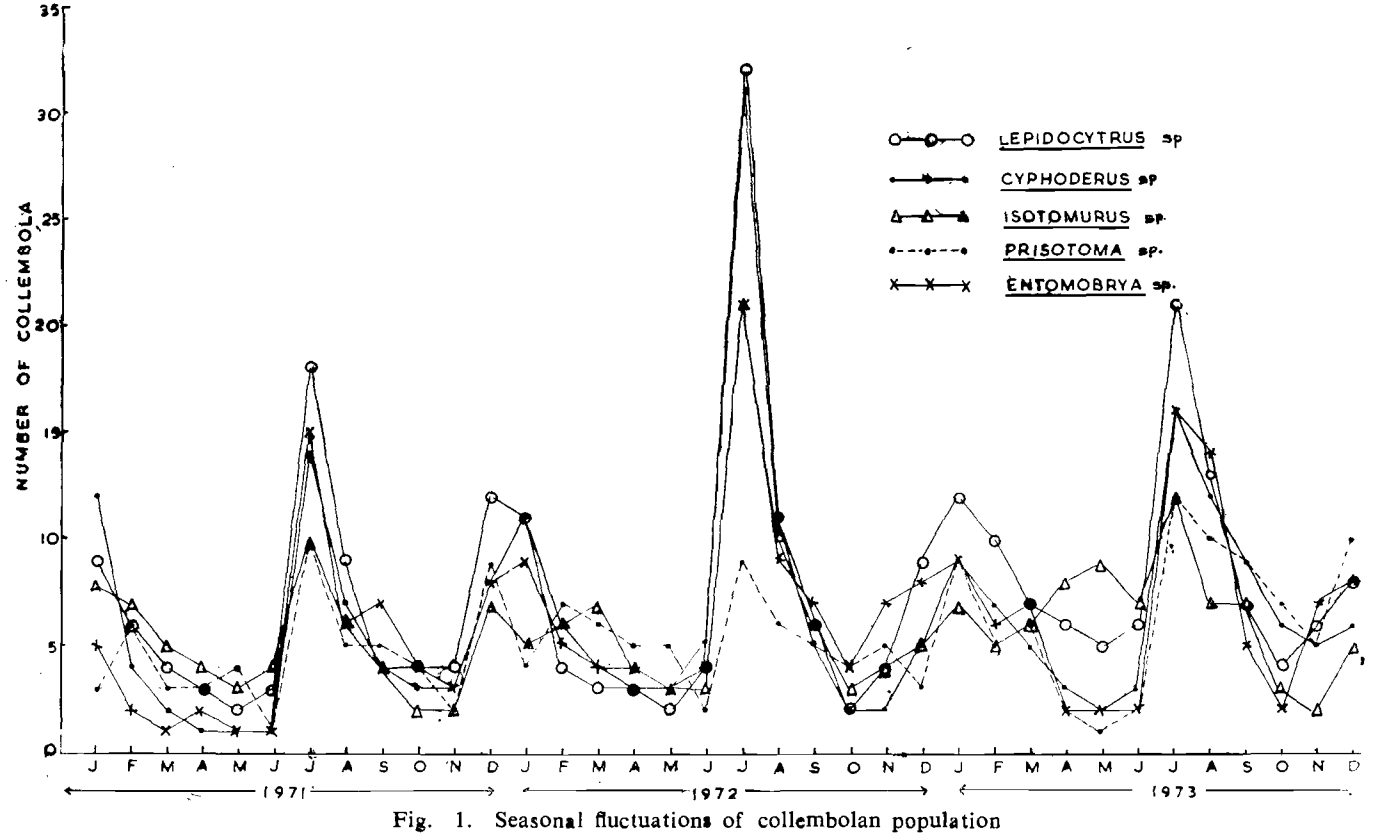

Fig. 1. Seasonal fluctuations of collembolan population

Sheals (1957), Haarlov (1960), Christiausen *et al.* (1961), Poole (1961), Dhillon and Gibson (1962), Milne (1962), Davies (1963), Rapoport and Najt (1965), Choudhuri and Roy (1965, 1966, 1967, 1971a and b, and 1972), Choudhuri and Banerjee (1975) and Choudhuri and Bhattacharya (1975) in different parts of the world. There are reasons to believe that the animal life of the soil plays a significant role in its economy, and the activity of the micro-fauna is of great importance in the determination of the character and fertility of the soil. In view of this, studies on the collembolan fauna of Murshidabad, West Bengal were made.

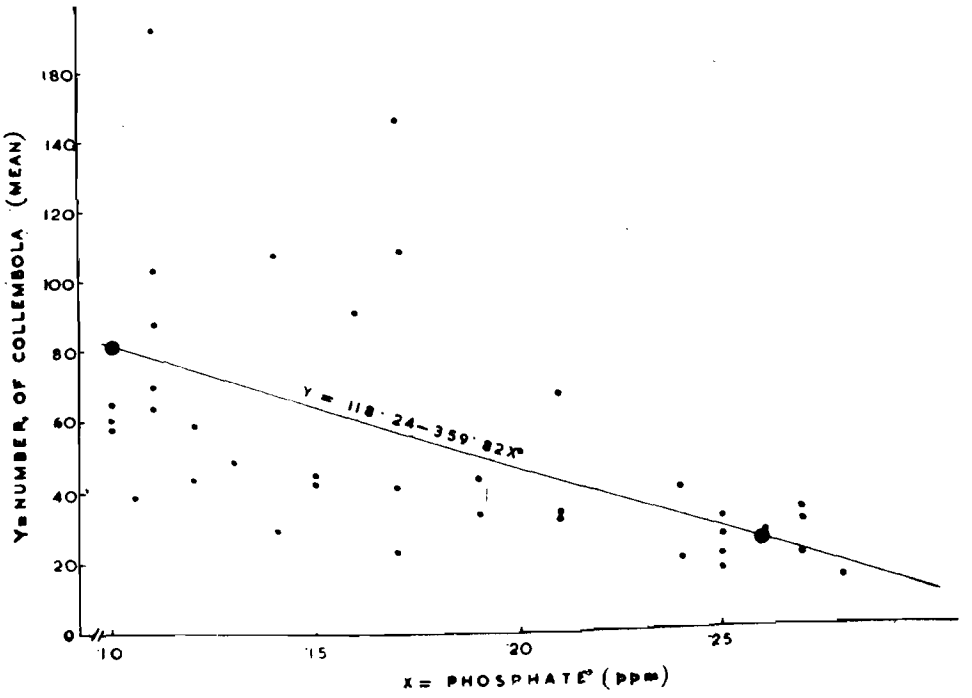

Fig. 2a Regression line with scatter diagram of collembolans on phosphate (ppm)

Material and Methods

108 soil samples were collected from the site, 36 from each of the three plots at monthly intervals for a period of three consecutive years (from January, 1971 to December, 1973). These were taken by means of a sampling corer designed by Auerbach and Crossley (1960) and the cores were extracted by Tullgren funnels of the type used by Murphy (1962). Soil factors studied were temperature, pH, moisture content, organic carbon, phosphate, nitrate, calcium carbonate and water-holding capacity. A calorimetric method for nitrate and phosphate and an oven-drying method for moisture determination as described by Dowdeswell (1959) were followed. A rapid titration method for calcium carbonate and Walkley and Black's method (Piper, 1942) for organic carbon detection were followed. The pH was determined from soil suspension by an

electric pH meter and Keen's Box method (Piper, 1942) for detection of water-holding capacity was followed. Relative humidity and temperature were determined by a dial-hygrometer and a soil-thermometer respectively.

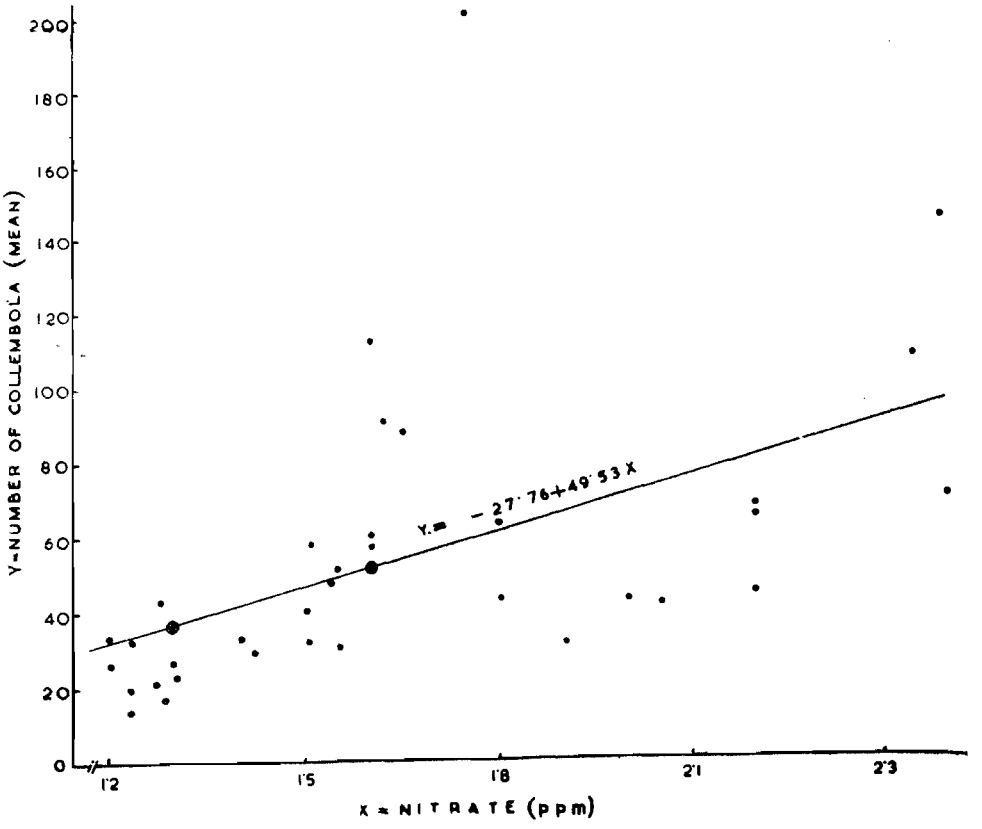

Fig. 2(b) nitrate (ppm)

Observations and Discussion

Location and characteristics of sampling sites: The sampling site was located at the Grave-yard campus of Berhampore town in Murshidabad district of West Bengal adjacent to National Highway No. 34. This site included three plots, each 5 metre square, uncultivated, undisturbed, and thickly-vegetated with herbs and shrubs of different plant families and soil-surface was covered with debris of fallen leaves and dried twigs from trees such as *Casurina* sp. and *Mangifera indica*.

Edaphic factors: Soils of these plots were alluvial in nature, greyish in colour and clay loam in texture with a mean water-holding capacity of 49.14 per cent. Soil pH ranged from 7.0–7.6. In April and May, the moisture content of the soil was 7 per cent and 6.5 per cent. respectively in 1971 ; 8 per cent and 7.5 per cent, respectively in 1972 ; and 10 per cent and 8.5 per cent,

TABLE I

Mean values for soil factors and Collembola populations in different months (January, 1971 – December, 1971)

Month	Collembola (mean)	Phosphate (ppm)	Nitrate (ppm)	Moisture (%)	Temp. (°C)	pH	Organic carbon (%)	Calcium carbonate (%)	Water-holding capacity (%)	RH (%)
Jan.	5.7	0.10	1.60	10.5	20.0	7.6	2.15	6.5	51.32	66.5
Feb.	33	0.21	1.40	9.2	23.5	7.4	1.92	6.3		66.0
Mar.	20	0.24	1.23	7.5	29.5	7.69	1.93	6.3	46.41	65.5
Apr.	21	0.25	1.27	7.0	33.5	7.33	1.90	5.6		65.0
May.	14	0.28	1.23	6.5	39.5	7.15	1.88	6.8	45.23	64.0
June	17	0.25	1.28	7.5	34.5	7.25	1.91	7.3		67.0
July	113	0.11	1.60	17.5	32.0	7.15	2.13	3.2	52.53	87.5
Aug.	58	0.12	1.50	15.5	30.0	7.20	1.20	3.1		86.0
Sep.	48	0.13	1.56	12.5	29.5	7.22	1.10	4.5	50.68	82.5
Oct.	33	0.19	1.20	11.2	29.0	7.50	1.00	4.6		74.5
Nov.	23	0.17	1.30	11.0	28.0	7.35	1.10	3.2	51.24	72.0
Dec.	87	0.11	1.65	12.0	21.0	7.20	1.12	4.0		68.5
(January, 1972 – December, 1972)										
Jan.	63	0.11	1.80	10.0	20.5	7.25	2.34	6.2	49.63	67.5
Feb.	40	0.24	1.50	9.0	22.5	7.30	1.97	6.5		66.5
Mar.	33	0.27	1.23	9.5	29.5	7.45	1.95	6.0	44.79	65.0
Apr.	26	0.25	1.20	8.0	32.5	7.20	1.92	5.8		64.0
May	21	0.27	1.27	7.5	37.5	7.29	1.87	6.5	46.77	63.5
June	27	0.26	1.30	8.5	35.0	7.50	1.91	7.2		66.0
July	202	0.11	1.75	15.5	32.5	7.30	2.42	5.6	51.68	91.5
Aug.	90	0.16	1.62	13.5	31.0	7.40	1.87	5.3		78.5
Sep.	51	0.20	1.55	13.0	29.5	7.00	1.41	4.8	52.64	74.5
Oct.	29	0.14	1.42	12.5	29.0	7.10	1.25	3.8		72.5
Nov.	43	0.12	1.28	12.0	27.5	7.30	1.12	3.7	50.63	71.0
Dec.	60	0.10	1.60	10.5	20.0	7.35	2.20	6.3		69.5
(January, 1973 – December, 1973)										
Jan.	69	0.11	2.4	11.5	21.5	7.4	1.38	7.5	48.58	71.5
Feb.	44	0.15	2.2	11.2	25.5	7.2	1.0	6.5		69.0
Mar.	43	0.19	1.8	10.5	30.0	7.5	1.0	6.0	46.29	68.5
Apr.	32	0.21	1.5	10.0	30.5	7.3	0.98	8.2		67.5
May	30	0.27	1.55	8.5	38.5	7.2	0.96	7.8	46.24	66.0
June	31	0.25	1.9	9.5	36.5	7.3	1.20	9.0		67.0
July	145	0.17	2.4	16.5	32.0	7.0	2.58	8.5	49.75	93.5
Aug.	107	0.14	2.35	15.5	32.5	7.2	2.42	7.0		92.0
Sep.	67	0.21	2.2	15.0	31.0	7.4	1.32	6.5	51.68	78.5
Oct.	42	0.15	2.0	13.0	30.3	7.3	1.34	5.5		76.5
Nov.	41	0.17	2.05	10.5	29.5	7.2	1.42	6.3	48.46	74.5
Dec.	64	0.10	2.2	11.5	20.5	7.1	2.20	6.0		72.0

respectively in 1973 (Table II). The month of July in each sampling year had the maximum water content (17.1 per cent in 1971, and 15.5 per cent in 1972 and 16.5 per cent in 1963). In May 1971, other soil factors such as phosphate, nitrate, content temperature, organic carbon. calcium carbonate and relative humidity were 0.28 ppm, 1.23 ppm, 39.5°C, 1.88 per cent, 6.8 per cent and 64 per cent, respectively; 0.27 ppm, 1.27 ppm. 37.5°C, 1.87 per cent, 6.5 per cent and 63.5 per cent respectively in 1972; and 0.27 ppm, 1.55 ppm, 38.5°C, 0.96 per cent, 7.8 per cent and 66 per cent, respectively in 1973. Amounts of organic carbon at a maximum in July–August for the whole sampling period. However, in January, 1971 the content of organic carbon (2.15 %) was slightly higher. Mean values of soil factors (Table I) revealed almost identical edaphological characteristics of the plots. Mechanical analysis of soil sampled showed relatively high percentage of clay (Table II).

TABLE II

Mechanical analysis of soil

Coarse sand (3%)	Fine sand (%)	Silt (%)	Clay (%)
16	37.5	5.46	44.5

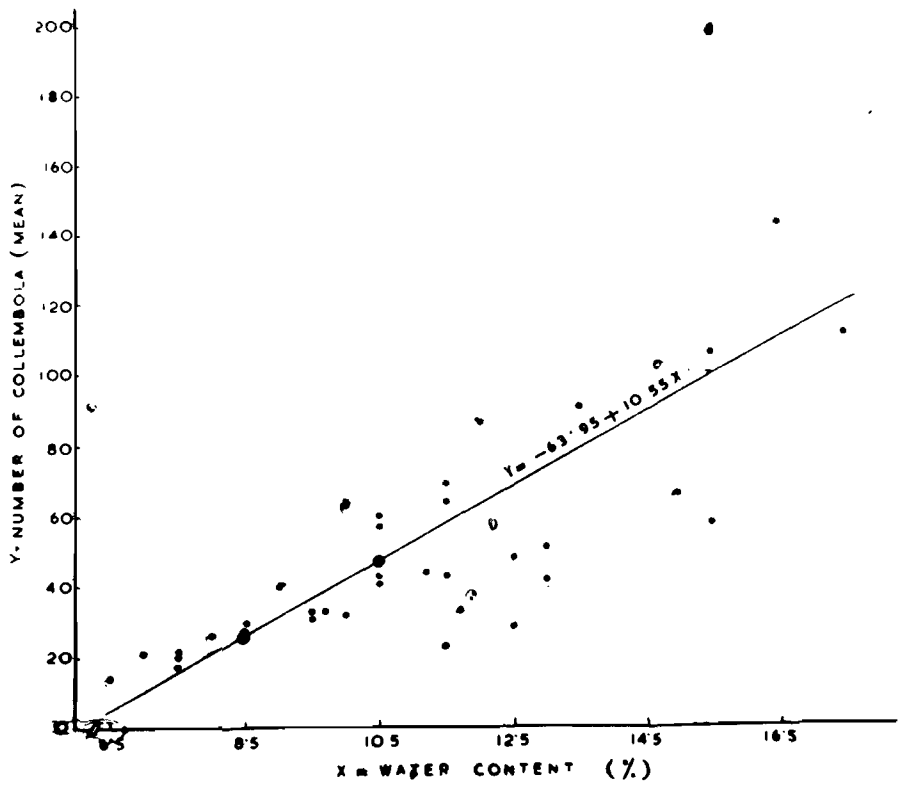

Fig. 2 (c) water content (per cent)

Faunal composition: Collembolan fauna obtained in this site belonged to :en genera; *Salina, Lepidocyrtus, Pseudosinella, Megalothorax, Isotomurus, 'sotomina, Cyphoderus, Sphaeridia, Entomobryo* and *Proisotoma* (Table III). The

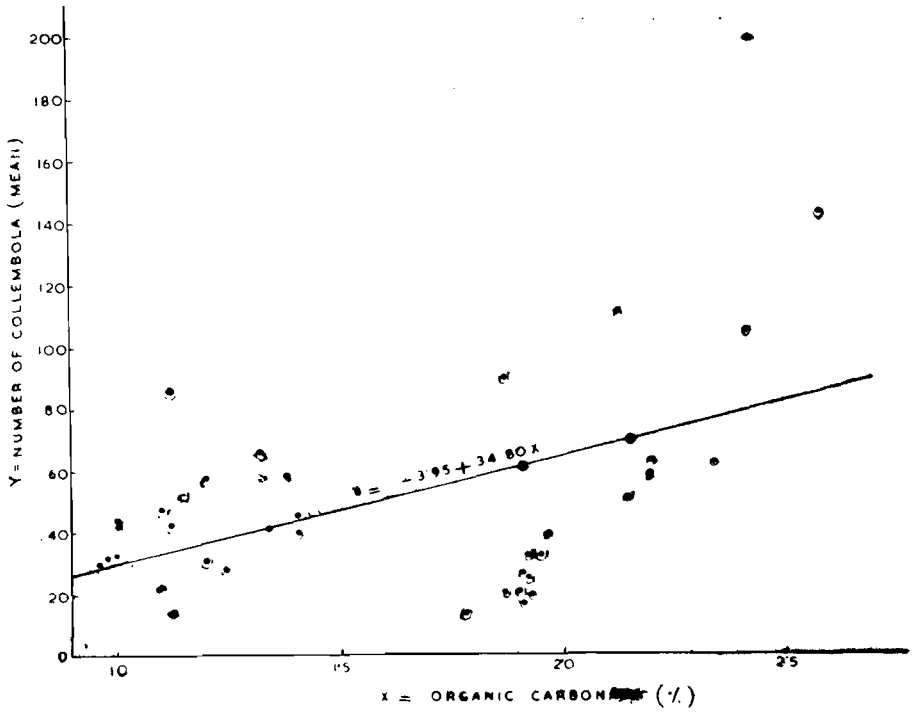

Fig. 2 (d) Organic carbon

genus *Lepidocyrtus*, was dominant being found in all samples and comprising 14.3 per cent of the total population followed by *Cyphoderus* sp. comprising 12.00 per cent, *Entomobrya* sp. comprisng *Isotomurus* sp. comprising 11.3 per cent and *Proisotoma* sp. comprising 10.5 per cent. Populations of the other fiive genera and species such as *Salina indica, Pseudosinella* sp., *Megalothorax* sp., *Isotomina* sp. and *Sphareidia* sp. were small and very irregular in distribution pattern. Mean numbers of Collembola obtained in each month (Table III) showed maximum populations in July when edaphic factors like moisture, organic carbon, nitrate and relative humidity were at a maximum. A partial increase of population in December and January as observed might be due to occurrence winter maxima of a few species of Collembola.

Seasonal variation: Predominant forms of Collembola obtained from this site exhibited an irregular trend of fluctuation. During the sampling period January, 1971 to December, 1973 they were maximum in July – August (monsoon months), minimum in May and more or less constant in December – January. They actually exhibited a gradual increase from the 1st week of June and

TABLE III

Species of Collembola and their monthly population counts

(January, 1971 – December, 1971)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Salina indica	—	—	—	—	—	2	15	7	5	3	2	13
Lepidocyrtus suborientalis	9	6	4	3	2	4	18	9	4	4	4	12
Pseudosinella sp.	4	—	—	—	—	—	9	4	3	2	1	9
Megalothorax sp.	6	3	2	3	1	2	7	5	7	3	2	11
Isotomurus ciliatus	8	7	5	4	3	4	10	6	4	2	2	7
Isotomina sp.	7	5	3	5	2	2	8	4	3	4	2	6
Cyphoderus sp.	12	4	2	1	1	1	14	7	4	3	3	8
Sphaeridia sp.	3	—	—	—	—	—	7	5	6	4	2	4
Entomobrya sp.	5	2	1	2	1	1	15	6	7	4	3	8
Proisotoma minuta	3	6	3	3	4	1	10	5	5	4	2	9
Total:	57	33	20	21	14	17	113	58	48	33	23	87

(January, 1972 – December, 1972)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oet.	Nov.	Dec.
Salina indiac	—	—	—	—	—	2	22	12	7	3	5	7
Lepidocyrtus suborientalis	11	4	3	3	2	4	32	11	6	2	4	8
Pseudosinella sp.	—	—	—	—	—	—	16	7	4	2	3	6
Megalothorax sp.	6	5	4	3	2	3	18	8	3	2	5	7
Isotomurus ciliatus	5	6	7	4	3	3	21	10	6	3	4	5
Isotomina sp.	7	7	5	4	3	4	17	9	4	3	3	4
Cyphoderus sp.	11	6	4	3	3	5	31	11	5	2	2	5
Sphaeridia sp.	10	—	—	—	—	—	15	8	4	3	5	7
Entomobrya sp.	9	5	4	4	3	4	21	9	7	4	7	8
Proisotoma minuta	4	7	6	5	5	2	9	6	5	4	5	3
Total:	63	40	33	26	21	27	202	91	51	29	43	60

(January, 1973 – December, 1973)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Salina indica	—	—	—	—	—	1	18	15	8	5	4	7
Lepidocyrtus suborientalis	12	10	7	6	5	6	21	13	7	4	6	8
Pseudosinella sp.	—	—	—	—	—	—	12	9	6	3	2	4
Megalothorax sp.	8	6	5	4	3	4	14	8	5	4	3	6
Isotomurus ciliatus	7	5	6	8	9	7	12	7	7	3	2	5
Isotomina sp.	6	5	7	7	8	6	13	10	6	5	5	7
Cyphoderus sp.	9	7	5	3	2	3	16	12	9	6	5	6
Sphaeridia sp.	10	—	—	—	—	—	11	9	5	3	2	3
Entomobrya sp.	9	6	7	2	2	2	16	14	5	2	7	8
Proisotoma minuta	8	5	6	2	1	2	12	10	9	7	5	10
Total:	69	44	43	32	30	31	145	107	67	42	41	64

attained a peak in July followed by a gradual decline up to end of November and a partial higher peak during December – January.

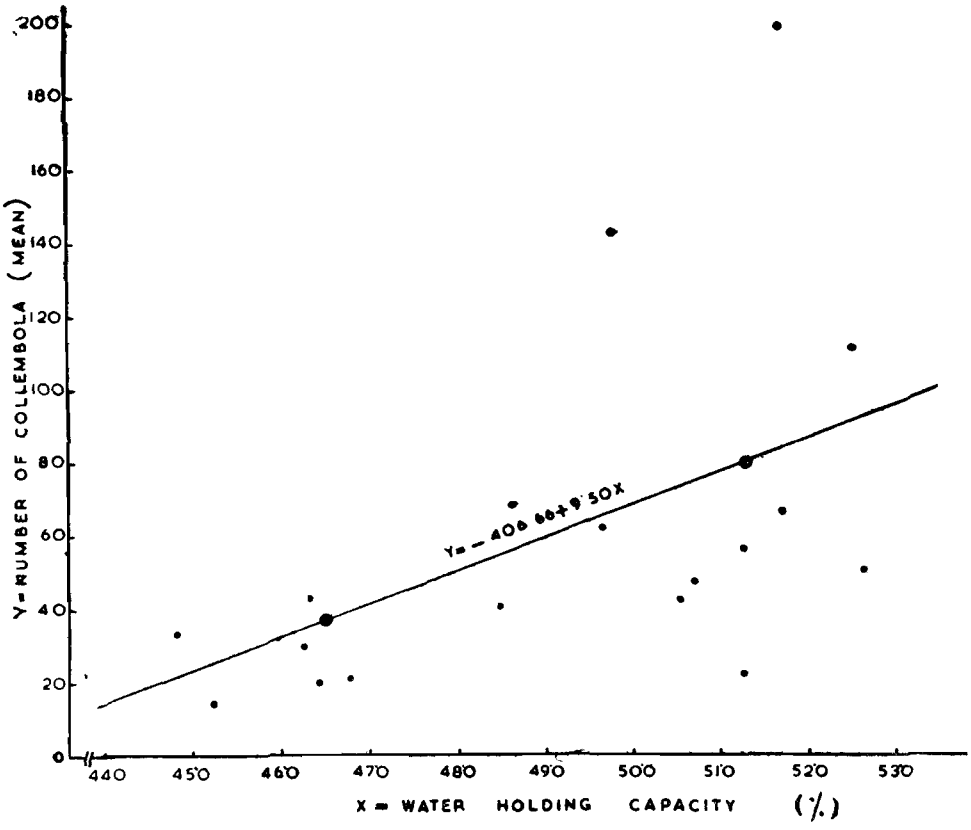

Fig. 2 (e) Water-holding capacity (per cent)

Vertical distribution: Mean populations of Collembola obtained per sample from three different layers (0–3 cm, 3–6 cm and 6–9 cm) are given in Table IV, with the collembolan fauna inhabiting the uppermost layer (0–3 cm) constituing about 78.9 per cent of the total population and outnumbering that of other two layers. The minimum number was recorded from the lowermost layer (6–9 cm). It was interesting, to note that the relative abundance of Collembola in the topmost layer was invariably associated with preponderance of juvenile forms.

TABLE IV

Vertical distribution of Collembola (Mean value of 50 samples)

Depth	0–3 cm.	3–6 cm.	6–9 cm.
Number	56	11	4

Correlation between collembola numbers and soil factors: Data on soil factors and population density of Collembola were statistically analysed to find out possible regressions on correlations and dependance of numbers of Collembola (Y) on each of the nine variables (edaphic factors) considered here. First, by means of a statistical test it was verified whether relationships between number of Collembola (Y) and different variables remained same throughout (Table V). This test revealed identical relationships throughout the sampling period. Regression lines were obtained from data for all three years. These combined regression lines darwn along with respective scatter diagrams are given in Figures 2a to 2f. Studies of correlation coefficients (second column of Table V) indicated that of the nine variables, temperature, pH and calcium carbonate seemed to have no association with Collembolan populations. In respect to other variables, the correlation coefficient was significant for Nitrate, moisture, organic carbon and relative humidity with positive correlation whereas phosphate showed negative correlation with population density.

There was a difference between sampling years and between months of a sampling year and (b) seasonal pattern or monthly variation was reasonably constant throughout.

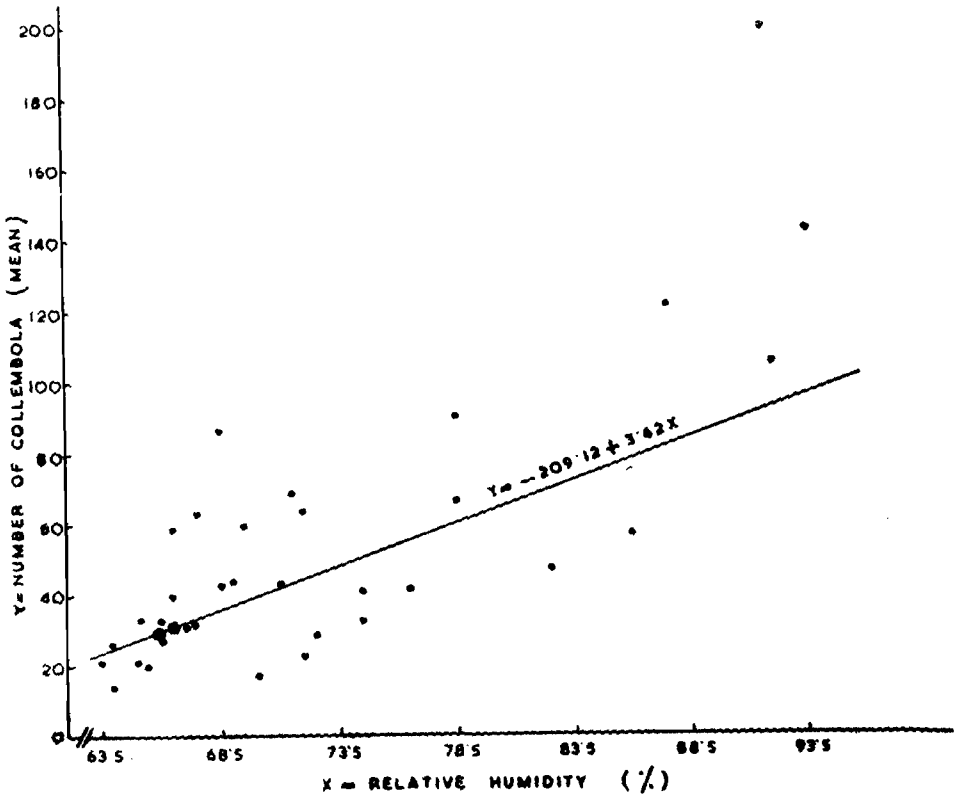

Fig. 2 (f) Relative humidity

TABLE V

Showing relationships between collembolan populations and soil factors

	Mean	Correlation coefficient between no. of collembola and different factors	Regression line of No. of collembola (Y) on different factors (X) Y= a + bx
Y : No. of Collembola	53.47		
Phosphate	0.18	-0.5645**	Y=118.24-359.82X
Nitrate	1.64	0.5046**	Y=-27.76+ 49.56X
Water content	11.13	0.7672**	Y=-63.95+ 10.55X
Temperature	29.31	-0.1210	
pH	7.29	-0.2449	
Organic carbon	1.65	0.4466**	Y=- 3.95+ 34.80X
Calcium carbonate	5.94	-0.0509	
Water-holding capacity	49.14	0.5119**	Y=-406.66+ 9.50X
Relative humidity	72.54	0.7944**	Y=-209.12+ 3.62X

** Significant at 1% level

TABLE VI

Analysis of variance

	Year	Month	Error	Total
Degree of freedom	2	11	22	35
Sum of squares	692	44722	6852	52266
Mean square	346.00	4065.64	311.45	
Frequency	1.1109	13.0539**		

** Significant at 1 % level.

The work is a part of the research project financed by the University of Burdwan, West Bengal to one of the authors (A. K. H.). The authors are thankful to Dr. S. K. Mitra of Zoological Survey of India for identifying the Collembolan specimens.

REFERENCES

AUERBACH, S. I. AND CROSSLEY, D. A., 1960, A sampling device for soil microarthropods. *Acarologia*, 2 : 279-287.

BELLINGER, P. F., 1954, Studies on soil fauna with special reference to Collembola. *Bull Conn. agric. Exp. Stn.*, 583 : 1-65.

CHOUDHURI, D. K. AND ROY. S., 1965, The role of edaphic factors on the dirtribution of subterranean collembolan fauna of West Bengal. Part I. *Proc. 1st Latin Am. Colloquium. Soil Biol.*, 391-403

CHOUDHURI, D. K. AND ROY, S., 1967, Qualitative composition of collembolan fauna of some uncultivated fields in Nadia district (West Bengal) with a correlation between monthly population and individual soil factor. *Rev. Ecol. Biol. Sol.*, 4 : 507-515.

CHOUDHURI, D K. AND ROY, S., 1971a, Distribution of collembola in relation to soil conditions in the district of Jalpaiguri, West Bengal (India). *Annales de Zoologie* (France), 1 : 289-296.

CHOUDHURI, D. K. AND ROY, S., 1971b, The collembola (Insects) of the uncultivated fields in Burdwan district (West Bengal), with remarks on correlation between monthly population and certain soil factors. *Proc. Zool. Soc.* Calcutta, **24** : 33–39.

CHOUDHURI, D. K. AND ROY, S., 1972, An ecological study on collembola of West Bengal, India. *Rev. Zool. Surv.* India, **66** : 81–101.

CHOUDHURI, D. K. AND BANERJEE, S., 1975, Qualitative and quantitative composition of Acari and Collembola in relation to soil organic matter-microbes complex. *Oriental Ins.*, **9** : 313–316.

CHOUDHURI, D. K. AND BHATTACHARYA, B., 1975, The effects of temperature and humidity on the development and hatching of eggs of *Lobella* (*Lobella*) *maxillaris* Yosii, 1966. *Rev. Ecol. Biol. Sol.*, **12** : 643–647.

CHRISTIANSEN, K., WILLSON, M AND TECKLIN, J., 1961, The Collembola of Hunter cave, with a preliminary study of microarthropod ecology of Hunter cave. *Bull. natn. speleol. Soc.*, **23** : 59–69.

DAVIS, B. N. K., 1963, A study of microarthropod communities in mineral soils near Carby, Northants. *J. Anim. Ecol.*, **32** : 49–71.

DHILLON, B. S. AND GIBSON, N. H. E., 1962, A study of the Acarina and Collembola of agricultural soils. *Pedobiologia*, **1** : 189–209.

DOWDESWELL, W. H., 1959, Practical animal ecology. Methuen London.

HAARLOV, N., 1960, Microarthoropods from Danish soils. ecology and phenology. *Oiko.* (suppl.), **3** : 1–176.

MILNE, S., 1962, Phenology of a natural population of soil Collembola. *Pedobiologia*, **2** : 41–52.

MURPHY, P. W., 1962, The split funnel extractor – A modified Tullgrenfunnel Progress in soil zoology. (*Ed. by P. W. Murphy*), *Butterworths*, London, pp 178.

PIPER, C. S., 1942, Soil and plant analysis. Mongr. *Waita Agric. Res. Inst., Univ.* Adelaide, South Australia.

Ants of India – A Brief Review

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ABSTRACT

The tribe Heterogyna, of the suborder Aculeata of Hymenoptera consists of one family Formicidae, to which the social insect ants belong.

Some of the earliest work in India dates back to 1890, where some good notes on some important ants are given by Rothney (1890). Later, a still further detailed paper by Wroughton (1892) on different ants found in different parts of India is available. He listed more than 40 genera comprising of more than 100 species from different parts of India. Bingham (1903) describedi n detail 488 species of ants from 79 genera:

under 5 subfamilies *viz.*, Dorylinae, Ponerinae, Myrmecinae, Dolichoderinae and Camponotinae, comprising 2, 26, 30, 7 and 14 genera respectively. Subsequent faunistic studies are very few. In an entomological survey of the high altitude Nival zone of N. W. Himalayas, Mani and Singh (1962) found that Formicidae constituted 40.63 per cent of the Hymenoptera from that region, while other families were far fewer. It is reasonable therefore to expect a rich ant fauna in some parts of our country.

The ant fauna varies very much with vegetation and climate, generally they are dense under moist forest conditions (Malozemova, 1972). Nests of ants are of diverse kinds, varying from temporary occupation below stones, logs etc., as with Dorylinae, to the crater and mound nests of *Myrmica, Prenotepis, Formica* etc., and the more complex suspended nests of *Oecaphylla* and *Polysachis* (Wheeler, 1965).

With special reference to agriculture and economic importance, it would be worthwhile considering that some of our important ants such as *Dorylus orientalis* whose status as a pest was controversial, was recently confirmed by Roonwal (1975) as a serious pests of potato tubers. Ghosh (1934) reports this species as an enemy of honeybees. Pruthi and Singh (1950) recorded *D. labiatus* Shuck as an important household pest besides reporting *Monomorium indicum* and *Camponotus compressus* as household pests attacking masonay and wood work. Pruthi (1969) added *Monomorium gracillinum* to the lists and suggested control measures like carbon-bisulphide fumigation, baits and barriers. Ayyar (1963) reported *Oecophylla smaragdina* known to disperse scales and mealybugs on fruit trees, *Myrmicaria brunnea* as a household pest and *Solenopsis geminata* as a pest of brinjal and in households.

Solenopsis sp. has been reported as a menace in a poultry farm near Bangalore, and a *Monomorium* sp. infested a wheat plot inoculated with *Rhizobium* (Veeresh, 1976).

The actual status of many of our ants under different ecological conditions is still unknown. The role of ants as a factor in the spread and stabilization of many of our homopterus pests, is still not clear. Considering the dual role that ant can play, suitable ant management programmes have yet to be evolved. Studies on pheromone communication and other behavioural aspects are still needed. A thorough faunastic study throughout the country and a revision of existing taxonomic notes merits consideration. Work on ants is urgently needed.

Introduction

Ants are among the most fascinating insects and are well-known for their social habits. They are found everywhere except in frozen wastes of Arctic and Antarctic. They established their orderly communities nearly 30 million years before men appeared on earth. However, scientific study of them began only in the middle of the 18th century when Rene Antoine ferchault de Reaumur, William Gould and Gilbert White made careful observations. Sir John Lubbock of England, Auguste Ford of Switzerland and Gottfried Adlerz in Sweden are other past stalwarts in myrmecology or the science of ant study (Newman and Dalton. 1968).

The tribe Heterogyna, of the suborder Aculeta of the order Hymenoptera consists of only one family Formicidae-to which the ants belong.

One of the earliest studies in India dates back to 1890, where some good notes on some important ants were given by Rothney. Later (1892), a still detailed paper on different ants found in different parts of India by Wronghton was published. He listed 47 genera comprising of more than 100 species from different parts of India. In 1903, Bingham described in detail 488 species of ants from 79 genera, and 5 subfamilies *viz.*, Dorylinae, Ponerinae, Myrmecinae, Dolichoderinae and Componotinae, comprising 2, 26, 30, 7 and 14 genera respectively. Lal (1939) listed 13 species of ants from Delhi which was later augmented by Menon and Punjabi (1960). In an entomological survey of the high altitude Nival zones of N. W. Himalayas, Mani and Singh (1962) found that Formicidae constituted 40.63 per cent of the Hymenoptera from that region, while other families were far fewer in numbers. It is reasonable therefore, to expect a rich ant fauna in other parts of our country.

Although ants in general are adaptable to all habitats, they vary much with the vegetation and climate and are denser under moist forest conditions and sparsely distributed under dry conditions (Malozemova, 1972).

Ants are primitively carnivorous, but this is not general, except for the subfamily Ponerinae and Dorylinae. However, the food of ants is varied and, in general, ants are omnivorous. Exceptions are like the genus *Atta* which is specific to fungus hyphae (Wheeler, 1965).

Nests of ants are of diverse kinds ranging from temporary occupation below stones, logs etc. *e.g.*, Dorylinae, to the crater and mound nests of *Myrmica, Prenolepis, Pheidole Formica* etc., and to the more complex suspended nests of *Oecophylla* and *Polyrachis.* Ants also nests in cavities of plants and inside houses (Wheeler, 1926).

Ants have been known to nest in cavities of plants, for instance, in India Mani (1939) has recorded such instances. *Cremastogaster subnuda* Mayr was found occupying the hollow cavities of old shoot galls of *Acacia leucopholoea* produced by the weevil *Sphadosmus braminus* in Tanjore (Tamil Nadu). Hingston (1925) gave an interesting account of the nesting, food, pastoral activities, communication etc., of the cremastogaster ant.

Camponotus compressus and *Tapinoma indicum* Forel live in galls such as those of *C. subnuda. Leptothorax* sp. occupies the hollow shoot galls on *Tephrosia purpurea* produced by the gelechid moth, *Dactylethra canadida.* The ants remove the pupae and making use of the gall cavity for their own need (Mani, 1938).

The main formicary *of Polyrachis simplex* Mayr is on the ground, but when soil gets saturated the ants take refuge on trees, by building a nest around the stem using extraneous material. This differs from *Oecophylla smaragdina*

which uses surrounding leaves to build a globular nest; with silk used as a connecting medium to secure the edges unlike the former where silk is used to interweave and line the interior. Moreover, *O. smaragdina* nests permanently on tree (Hingston, 1924). In case of the gipsy ant, *Prenolepis* sp, there is no settled home and *Tapinoma melanocephalum* (Fabi) nests under stones (Wronghton, 1892).

Details of important ants found in India, are as follows :

Oecophylla smaragdina Fabr is found throughout India except in arid and mountainous tracts and is especially abundant in South India. They nest on foliages and forage day and night, winter and summer. The lycaenid *Zesius chrysomallus* is maintained by this ant, also coccids such as *Lecanium hesperidum*, *Icerya* sp. etc., and various membracids (Hingston, 1924a, 1924b). Ullah (1939) and Ayyar (1963) reported that this ant occupied trees in orchards and plantations, spread noxious scales and mealybugs, and stung walkers severly making harvesting difficult.

Camponotus compressus Fabr. is the common black ant of South India. Ayyar (1935) has summarized the detailed biology and economic status of this ant. Nests are abundant in loose sandy soil. It is associated with the ragi aphid, *Tetraneura*, builds its nest at the base of the plant, imparing its growth. Adult syrphid flies predating on these aphids are caught and killed by these ants. In maize fields they are responsible for the spread of cholam shoot bug, *Pundaluoya simplicia* Dist. (Fulgoridae); In cotton fields mound nests of this ant are abundant, associated with the harmful cotton aphid, *Aphis gossypii* Glov Adults of coccinellid predators and *Chrysopa* adults are usually attacked and dragged away from the aphids. However, larvae of these coccinellids, probably because of their spiny bodies, are never touched by these ants. In pulse fields such as lablab and redgram, it is associated with *Aphis medicaginis*, *Ceroplastodes cajan* and caterpillar of *Catachrysops cnejus*, as a result often causes severe damage and failure of the crop. It occurs also on different avenue and ornamental trees, in association with homopterans. The House Crow, *Corvus splendens* Viellot preys on this ant (Ayyar, 1935). Rao (1943) reports it as a menace in sugarcane fields on account of its association with the serious mealybug, *Pseudococcus saccharicola* Takh. It is known to attack termites (Rothney, 1890). This ant does immense damage to the woodwork of old buildings. (Pruthi and Singh 1950). *C. rubripes* (Drury) and *C. mitis* (Smith) are known to associate with lycaneid larvae (Wroughton, 1892). According to Khan and Rao (1956) the abundance of 2 pests, Jowar shootbug (*Pundaluoya simplicia* Dist) and groundnut aphid (*Aphis craccivora* Koch) are directly related with the presence of the ant (*C. compressus*) near the field. The roots of jowar were clipped by the ants according to them, and eventually the plants lodged and dried.

Solenopsis geminata Fabr is an important household pest. It causes damage to bainjal plants (Ayyar, 1963). Although known to be a pest, Negi (1933) points out some uses of this ant; it destroys the predators and parasites of lac insect, destroys termites and bed bugs. By collecting loose earth from its nest and encouraging its nesting near lac colonies and termatoria its usefulness could be exploited.

A serious menace of a *Solenopsis* sp was reported from South Bangalore, Karnataka in June 1974. These ferocious ants invaded a poultry farm, in large numbers attacking the birds and workers, as a result the farm had to be abandoned. It was belived that some meat pieces and bones (fed to the farm dogs) scattered around were attracting these ants (Veeresh, 1976).

Camponotus compressus is a menace in sugarcane fields, because it is associated with the pest species *Pseudococcus saccharicola* Takh (Rao, 1943).

Monomorium indicum Forel is an omnivorous ant, nesting near foundations and walls of building. They forage indoors all the year round, and are known to attack woodwork and masonary (Pruthi & Singh, 1950). *M. gracillinum* Smith attacks flour and fats inside houses and attends on mealy bugs, infecting plants for their secretion (Pruthi, 1969). A *monomirium* sp was attracted to sweet *Rhizobium* inoculated wheat, and started nibbling at the roots. Their presence was not detected as they used subterranean tunnels from their nests to the field (Veeresh, 1976).

Dorylus orientalis Westw. is found all over India except in the extreme north and northwestern parts. Its synonyms include *D. curtisi* (Shuckard), *D. fuscus* Emery, *D. longicornis* (Shuckard) *D. oberthueri* (Emery). The economic status of this ant has been much in controversy. In 1899 Barlow reported it as a pest of potato, but Forel (1899 and 1923) considered it to be carnivore. Forel's view was supported by Mukerji (1934) who said the workers were seen feeding on grubs and earthworms, and did eat vegetable food when offered. But many workers have reported it to be a pest on vegetables including potatoes (Stebbing, 1905, 1908; Lefroy, 1906-9; Dutt, 1912; Fletcher, 1917; Pruthi, 1960). Roonwal (1975) has recently confirmed this as a serious pest of potato in Dehra Dun, in the months February to April. Ghosh (1936), and Cherian and Ramachandran (1943) reports this ant as attacking beehives and their broods.

D. labiatus Schuck are bright red brown, highly polished, shiny and smooth ants with minute dot like pits on their bodies. This species is found throughout India. It builds its nests outside the house, the workers go foraging in the house (Pruthi and Singh, 1950). It is considered as a relentless enemy of the termite *Microtermes mycophagus* by Sharma and Bhora (1968); it gathers around the hole of the termite and attacks while swarming.

Plagiolpis longipes caused serious havoc in an irrigated tract by tunnelling (up to 150 cm) and affecting irrigation, during 1973–74, in Pandavapura Taluk, Madya district, Karnataka. About 150 ha were affected and to control them nearly Rs. 65,000 was spent by the Department of Agriculture (Gubbaiah, 1976). There are also other ants of lesser economic importance. *Myrmicaria brunuea* Saunders is the odoriferous brown anta household pest (Ayyar, 1963). *Formica compressa* Fabr. attacks termites (Rothney, 1890). *Holcomyrmex scabriceps* (Maya) carried away grains, seeds etc, from houses and fields *Plaglolepis exigua* Forel is a serious pest in fields and houses in Western India (Lal, 1939). *Messor barbarus* Lin, *Phedologeton affinis* Jerden and *Pheidole grayi* Forel are other harvester ants, (Pruthi, 1969). *Tapinoma* sp and *Pheidole* sp have been found to be useful predators on the larva of *Plutella maculipennis* in Hebbal, Bangalore (Jayarathnam, 1976). *Iridomyrmex anceps* Roger is useful in killing lac enemies; *Lobopelta ocellifera* Roger attackes termites (Negi, 1933). *Monomorium salomonis* (Lin) and *M. yastator* (Smith) are known to be household pests (Wronghton, 1892). Pruthi (1969) reports that eggs of red ants are used by some tribals as a cure for Malaria. *Cremastogaster dohrni* Mayr and *Cataulacus taprobanae* Smith build hard shelters for coccids like *Lecanium formicarii* Green (Pruthi, 1969).

Aitkins (1889) reports *Camponotus smaragdinus* as being relished as food by jungle people in Canara district. As he says it is entirely arboreal, the ant probably referred to is *Oecophylla smaragdina*. Moreover, Bingham (1903) has not referred to this species at all. Butler (1895) reported the above ant, *C. smaragdinus* as being used as medicine. The tribals rub the ant, and inhale the ammonia-like fumes from the crushed insect, said to relieve them from severe colds.

Control: Pruthi (1969) has given the following control measures. Nest holes should be injected with carbon bisulphide, petrol or kerosene or treated with calcium cyanide flakes. Dusting with 10 per cent BHC or 5 per cent chlordane powder or spraying with 2 per cent chlordane suspension in and around the nest gives effective control. In case ant nest cannot be detected he has suggested baiting in places frequented by the ants. According to him, the baits are prepared by boiling 5 kg of sugar + a table–spoonful of honey + 8 g of sodium arsenate or thallium sulphate in 56 litres of water. The ant barrier which he suggested was a string or lampwick dipped in a saturated solution of corrosive sublimate (mercuric chloride) or just an application of corrosive sublimate, which can be prepared by dissolving 20 g of corrosive sublimate in 60 cc of ethyl alcohol to which 31 gm of orange shellac is added. Ayyar (1962) suggests the use of an exterminator which is used for termites.

For *Dorylus orientalis* the following control measures were given, which may prove effective for other ants also:

Soil treated with the fumigant paradichlorobenzene at 1.03 to 1 sq yd of soil, gave good control. Soil sprayed with 30 per cent E.C. of aldrin, 2 per cent E.C. heptachlore or 20 per cent E.C. gamma benzene hexachloride all at a rate of 3 litres in 1000 litres of water/acre controlled the ants effectively (Roonwal, 1975). In the case of *Oecophylla smaragdina* burning the nest with torches gave the best control. Banding trees with tar or sticky paste prevents ants going up the tree (Ayyar, 1963).

Ant mimics: There is a coreidbug, *Dulchius inflatus* which is a perfect mimic of ant, and moves around with them (Viraktamath, 1976). Kunhikannan (1915) reports the spider *Synomasyna formica* as imitating *Oecophylla smaragdina*. A beetle *Formicomus indicus* (Anthicidae) mimicks the ant *Monomorium salomonis indicum,* and lives in the neighbourhood of this species, as reported from Coimbatore by Fletcher (1913).

Conclusion

Wilson (1963) has made it clear that much ants behaviour is stimulated by pheromones; work in this line is still sparse in India. There is a report on the mating behaviour and colony fission in the ant *Monomorium gracillimum* Smith by Soans and Soans (1970, 1971a). Soans and Soans (1971b) reports an absence of colony-specific pheromones in the ant, *Technomyrmex albipes* Smith. A thorough understanding of the communication in ants may go along way in control programmes.

It is quite clear that ants are harmful in some situations but useful in others. An excellent example of this is *Solenopsis geminata* mentioned before. Considering that they are excellent predators, work in biological control programmes must be initiated with more vigour. Soans and Soans (1971c) describes an interesting incident in which *Anoplolepis longipes* emigrated to the base of a mango tree and replaced a well-established colony of *Oecophylla smaragdina* on the mango tree. This leaves the question as to whether *Anoplolepis* could be used to control *Oecophylla.*

However, when biological control of pest homopterans are considered, ants must be regarded as antibiological control agents. Ants protect these from predators and parasites, help in their spread, and introduce a hygenic condition by removing their excretions like honeydew. So ants must be controlled before considering biological control programmes (Dick, 1969). Clearly, detailed work on the biology and ecology of all economically important ants is necessary to carry out suitable management and biological control programmes. Advances in ecological aspects, especially of *Oecophylla smaragdina, Camponotus compressus* and *Myrmecocystus setipes* have been made thanks to the commendable work of Dr. C. S. Gupta (1963, 1964, 1966, 1968a, 1968b, 1968c, 1970a, 1970b).

More work on faunistic studies and revision of existing taxonomic notes merits consideration. As ants are a very fascinating group of insects, their study would be of immense interest not only to professionals but also to amateurs.

References

Aitkins, E. H., 1889, The Red Ant. *Journal Bom. Nat. Hist. Soc.*, **4**: 151.

Ayyar, P. N. K., 1935, The biology and economic status of the common black ant of South India. *Camponotus compressus* Latr. *Bull Ento Research*, **26**: 575–585.

Ayyar, T. V. R., 1963, Handbook of Economic Entomology for South India. Govt. of Madras.

Barlow, E., 1899, Notes on insect pests from the Entomological Section, Indian Museum. *Indian Museum Notes.*, **4** (4): 180–221.

Bingham, C. T., 1903, Fauna of British India including Ceylon and Burma. *Hymenoptera*, **11**: 414. (Published under the authority of the secretary of State for India in Council).

Butler, A. L., 1895, Red ants as smelling salts. *Journal Bom. Nat. Hist. Soc.*, **10**: 330.

Cherian, M.C. and Ramachandran, S., 1943, Bee enemies. *Indian farming.*, **4** (5): 251–253.

Dick, J., 1969, The mealybug of sugarcane. Pests of sugarcane. 343–65 Amsterdam: Elsevier 568 pp.

Dutt, G. R., 1912, Life histories of Indian insects (Hymenoptera). *Mem. Dept. Agric.* India (Ent.), **4** (4): 247.

Fletcher, T.B., 1913, Ant-mimicry by a *Formicomus* (Coleoptera: Anthicidae). *Journal Bom. Nat. Hist Soc.*, **22** (2): 415.

Fletcher, T. B. (Ed. by), 1917, Cruciferous crops. *Proc. znd ent. meet.* (Pusa, Feb. 1917). Calcutta: P. 281.

Forel, A., 1899, Notes on *Dorylus orientalis* (in E. Barlow). *Indian Mus. Notes*, Calcutta, **4** (4): 189.

Forel, A., 1923, Les Monde Social des fourmis du globe 5. *Genera Sec.*, P. 17.

Ghosh, C. C., 1936, Bee-keeping (3rd Revised Ed.). *Misc. Bull. Imp. Counc. agric Res.*, Delhi, No. 6 vi + 91 + 8 P.

Gubbiah, 1976, Personol Communication.

Gupta, C. S., 1963, Ecological studies on *Camponotus compressus* Fabr. (Formicidae: Hymenoptera). *Agra Univ. J. Res.* (Sci), **12** (3): 45–52.

Gupta, C. S., 1964. Studies on the ecology and population pattern of *Oecophylla smaragdina* Fabr. (Formicidae: Hymenoptera) during spring in Hardwar. *Agra Univ. J. Res.* (Sci), **13** (2): 59–66.

Gupta, C. S., 1966, Effect of temperature on *Oecophylla smaragdina* Fabr. (Formicidae: Hymenoptera). *Trop. Ecol.*, **7**: 125–135.

Gupta, C. S., 1968a, Studies on the population structure of the nests of the Indian 'Red Ant'– *Oecophylla smaragdina* Fabr. (Formicidae: Hymenoptera) P. 187–198, in *Proc. Symp. Recent Adv. Trop. Ecol., Intl. Soc. Trop. Ecol.*, Varnasi, India.

Gupta, C. S., 1968b, Studies on the effects of light, wind, and moisture on *Oecophylla smarag dina. Fabr. Trop. Ecol.* **9** (2): 131–139.

Gupta, C. S., 1968c, Observations on tandem-running, Indian Red Ant, *Oecophylla smaragdina. Fabr. Trop. Ecol.* **9** (2): 194–200.

GUPTA, C. S., 1970a, Studies on marriage flights, behaviour of sexes, and tenacity of two species of ants, *Myrmecocystus setipes* Forel and *Camponotus compressus* Fabr. *G.K.V.J. Sc. R.*, **2**: 49-57.

GUPTA, 1970b, Ecological studies on the ant. *Myrmemocystus setipes* Forel. *G.K.V.J. Sc.R.*, **2**: 134-148.

HINGSTON, R.W.G., 1924, The Red Ant. Part I. The Nest. *Journal Bom. Nat. Hist. Soc.*, **29** (1 & 2): 362-372, 681-693.

HINGSTON, R.W.G., 1925, The Cremastogaster Ant. *Journal Bom. Nat. Hist. Soc.*, **30** (3&4): 541-550

JAYARATHNAM, K., 1976, Personal communication.

KHAN, M. Q. AND RASO, A. S., 1956, The influence of the Black ant (*Camponotus compressus* F) on the incidence of Two Homopterous Crop Pests. *Indian J. Ent.*, **18** (2): 199-200.

KNIGHT, W. J., 1973, A new species of *Hishimonus Ishihara* (Hom. Cicadellidae) attacking *Terminalia* spp in India, with comments on the relationship of the genus to cestive distant. *Ann. Ent. Fenn.* **39** (4): 153-156.

LAL, K. B.. 1939, Ants of Delhi. *Indian J. Ent*: **1** (1-2)., 107.

LEFROY, H. M., 1906, Indian Insect Pests. Calcutta, pp. 231-132.

LEFROY, H. M., 1907, The more important insect injurious to Indian Agriculture. *Mem Dept. Agric. India.* Calcutta, **1** (2): 128.

LEFROY, H. M., 1909, Indian Insect Life. Calcutta pp. 227-228.

MALOZEMOVA, L-A., 1972, Ants of steppes forests their distribution by habitats and prospects for their use in forest protection in Norrth Kazakhstan. *Zoologicheskii Zhurnal*, **51** (1): 47-68.

MANI, M. S., 1939, Ant tenants of plant galls. *Indian J. Ent.*, **1** (1-2): 94.

MANI, M. S. AND SINGH, S., 1962, Entomological Survey of Himalaya. Part XXVI. A contribution to our knowledge of the geography of the high attitude insects of the Nivalzones from the North West Himalayas. *Journal Bom. Nat. Hist Soc.*, (Part 3) **159** (1): 77-99.

MENON, M. G. R. AND PUNJABI, G.M., 1960, Some observations and new records of Ants from Delhi. *Indian J. Ent.*, **22**: 133-135.

MUKERJI, D., 1934, On the anatomy of the worker of the ant, *Dorylus* (Alaopons) *orientalis*· *W. Zool. Anz. Leipzig.*, **105**: 97-105.

NEGI, P. S., MISRA, M. P. AND GUPTA, S. N., 1930, Ants and lac insect. *Journal Bom. Nat. Hist. Soc.*, **34**: 182-188.

NEGI, P. S., 1933, The small red ant, *Solenopsis geminata* sub sp. *rufa*. Jerdon, and its usefulness to Man. *Journal Bom. Nat. Hist. Soc.*, **36** (3&4): 1018-1025.

NEWMAN, L. H. AND DALTON, S., 1968, Ants from closeup. *Cassell and company Ltd.*

PRUTHI, H. S., 1969, Text book on Agricultural Entomology. ix + 1 + 977 New Delhi (I.C.A.R.).

PRUTHI. H. S. AND SINGH, M., 1950, Pest of stored grain and their control. pp. 25-27. Issued by I.C.A.R. and Publ. by Manager of Publications, Delhi.

RAO, S. R. M., 1943, Life history and Economics of *Pseudococcus saccharicola* Takh—a new pest of sugarcane in India. *Proc. Indian Acad. Sci*, (B) **16**: 79-85.

ROONWAL, M. L., 1954, On the structure and population of the nest of the common Indian tree ant-*Cremastogaster dohrni rogenhoteri* Mayr. *J. Bombay Nat. Hist. Soc.*, **52**: 354-364.

ROONWAL, M. L., 1975, Plant-Pest status of root eating ant, *Dorylus orientalis* with notes on taxonomy, distribution and habits (Insecta : Hymenoptera). *Journal Bom. Nat. Hist. Soc.*, **72** (2) : 305-313.

ROTHNEY, G. A. J., 1890, Notes on Indian Ants. *Trans Ent. Soc.*, London, 347-374.

SHARMA, S. K. AND BOHRA, O.P, 1968, A new record, *Dorylus lubicus* Shuck. (Hymenoptera : Formicidae) as a predator of *Microtermes mycophagus*. (Isoptera : Termitidae). *Indian J. Ent.*, **30** (1) : 243.

SOANS, A. B. AND SOANS, J. S., 1970, Observation on mating behaviour in the ant *Monomorium gracillimum* Smith (Hymenoptera : Formicidae) *Journal Bom. Nat. Hist Soc.*, **67** (3) : 350.

SOANS, A. B., AND SOANS, J. S., 1971a, Colony fission in the ant *Monomorium gracillimum* Smith. (Hymenoptera : Formicidae). *Journal Bom. Nat. Hist. Soc.*, **68** (3) : 849-850.

SOANS, A. B. AND SOANS, J. S., 1971b, Absence of colony specific pheromones in the Ant *Technomyrmex alhipes* Smith (Hymenoptera : Formicidae). *Journal Bom. Nat. Hist. Soc.*, **68** (2) : 483.

SOANS, A. B. AND SOANS, J. S., 1971c, A case of intergeneric completion and replacement in the ants. *Oecophylla smaragdina* Fab. and *Anoplolepis longipes* Jeedon (Hymenoptera : Formicidae) *Journal Bom. Nat. Hist Soc.*, **68** (1) : 289.

SOANS, A. B. AND SOANS, J. S., 1971d, Proximity of the colonies of the tending ant species as a factor determining the occurence of aphids. *Journal Bom. Nat. Hist. Soc*, **68** (3) : 850-851.

SOANS, A. B. AND SOANS, J. S., 1972, Some observation on the habits of the ant *Harpegnathus saltator* Forel (Hymenoptera : Formicidae). *Journal Bom. Nat. Hist. Soc.*, **69** (3) : 668.

STEBBING, E. P., 1905, Insect life in India and how to study it, etc., *Journal Bom. Nat. Hist. Soc.*, **16** : 683.

STEBBING, E.P., 1908, A Manual of Elementary Forest Zoology for India. Calcutta, pp. 72-73 and pl. XXIII.

ULLAH, G., 1939, Red ant's nest. *Ind. J. Ent.* (1-2) p. 109.

VEERESH, G. K., 1976, Persoual Communication.

VIRAKTAMATH, C. A., 1976, Personal Communication.

WHEELER, W. M., 1926, Ants. *Columbia Univ. Press*, New York.

WILSON, E. O., 1963, Social Biology of Ants. *A.R.E.*, **8** : 345-361.

WROUGHTON, R. C., 1892, Our Ants. *Journal Bom. Nat. Hist. Soc.*, **7** : 13-16.

Soil Dwelling Hemiptera

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ABSTRACT

The majority of species of living organisms are arthropods, so it is not surprising that a high proportion of soil animals belong to this phylum. The most important arthropods are the mites, myriapods, the springtails and insects such as termites,

beetles, ants, flies and bugs. Although Hemiptera live in the soil, they are in no way important in soil formation and are not known to play an important part in the soil economy. But a large number live underground on roots, many being quite serious pests of crops. The contribution made to the soil by Hemiptera is confined to the residues accumulating from the plants they kill, to the faeces and secretions they produce and to their own remains. A few soil-inhabiting species are found in the following families.

HOMOPTERA

Family : *Cicadidae*

Cicadas are the commonest of the soil inhabiting Homoptera. After hatching, the nymphs crawl to the ground. They then begin a subterranean life feeding upon the roots of various plants and also make extensive galleries in the soil as they move between roots. Their entire nymphal existence is then spent below the ground and can last for several years. On reaching maturity, the nymphs leave the soil, and some species construct earthen "chimneys" above ground for their exit. The nymphs are most peculiar insects, pale in colour, awkward in movements and characterised by the large, toothed, fossorial fore-legs. A large number of adults may emerge simultaneously in an area to produce incredibly noisy swarms, hence the pseudonym "locust". The 17-year locust of N. America (periodical cicada) *Tibicen septendecim* (= *Magicicada septendecim* (Linn.) is an outstanding example (Mani, 1973). Very little is known of the life history of Indian species and Distant (1906) enumerates 148 species. The only common species are *Platypleura octoguttata and P. mackinnoni* found in the hills and plains of Bihar (Lefroy and Howlett, 1909). *Gudaba marginata* Distant and *Terpnosia psecas* Walk. have been recorded from Karnataka (Usman and Puttarudraiah, 1955).

Family : *Cercopidae*

Many species of frog-hoppers spend their immature stages under ground, often in frothy masses (cuckoo spit). The common European *Cercopis vulneratae*, whose nymphs suck the sap from grass roots down to a depth of 15 cm is an example and the notorious sugarcane frog-hopper *Aeneolamia varia saccharalis* (= *Tomaspin saccharalis*) of Trinidad is another which attacks only partly exposed roots. *Triecophora* sp. (= *Cercopis*) has been reported feeding on the roots confined to top soil from Europe (Kuhnelt, 1976).

Family : *Cixiidae*

The members of this family include the most primitive fulgorids. It is a fairly large family distributed throughout the world. The nymphs are primarily root feeders. The nymphs of *Oliarus felis* Kirk. feed underground on the roots of grass in Australia (Hacker, 1925; C.S.I.R.O. 1970). A number of *Oliarus* have been recorded from India as infesting roots of grasses (Lefroy and Howlett, 1909).

Family : *Aphididae*

Many species of aphids live in the soil and feed on the roots of many plants. They have complicated life cycles, some generations being confined to roots, and invariably they are apterous forms. *Rhopalosiphonimus latysiphon*, the bulb and potato aphid is commonly found underground on potato tubers and bulbs, in addition to having generations on surface vegetation (Keva, 1962). *Anuraphis maidis radicis* is an important root aphid pest on corn in America. Other root aphids are *Pemphigus bursarius* and *P. betae* on lettuce and sugar beet respectively (Essig, 1942). A few species of root aphids have been reported from India. For example, *Tetraneura nigriabdominalis* (ragi root aphid), which is a minor pest of *Eleusine coracana* and *Sorghum vulgare* has been reported from Karnataka and Tamil Nadu. The detailed biology has been worked out by Gadiappanavar (1970). This species is entirely confined to root systems.

Phylloxeridae

The grape phylloxera, *Viteus vitifolii* may pass part of its life cycle underground. In the latter part of the 19th century, it was a pest of great importance in European viticulture. They feeding on roots, stimulates the production of root galls. The life cycle is complex. Fertilized females lay overwintering eggs under rough bark on the vine rods and then the nymphs migrate to the foliage and develop into parthenogenetic females, which lay eggs on the galled leaves. Several further generations of parthenogenetic egg-laying females, some of which are winged and fly to other plants follow; eventually some of these females migrate to the roots, where they stimulate the production of further galls. Towards the end of the year, a mixed generation of male and female winged forms develop in the root galls and these migrate to the stems. Their progeny become wingless males and females (Kevan, 1962).

Family : *Eriosomatidae*

This group includes a number of root-feeding aphids. The life cycle is similar to that of other root aphids. Many are economically important pests of crops in the Western countries. The examples are pear root aphid *Eriosoma laniginosum* and the woolly apple aphid *Erisoma lanigerum*. The latter species is also found on apple, pear and crab-apple in India in districts of Uttar Pradesh and Himachal Pradesh. It infests apple throughout the year, but is most active during March-September. The life history has been worked out (Lal and Singh, 1947; Atwal, 1976). During the winter aerial colonies migrate below the soil. *Aploneura lentisci* and *Geoica lucifuga* live on the roots of grasses and sugarcane. *Smynthurodes betae* has been reported on the roots of dicotyledons (C.S.I.R.O., 1970) and the same species is found

to infest the roots of French bean (*Phaseolus vulgaris*) in Bangalore, (Channa-Basavanna, 1958, 1962). A similar subterranean form *Tribidaphis gossypii* Kulkarny has been reported from cotton (Kulkarny, 1956) from Dharwad, Karnataka.

Family : *Margarodidae* (Cottony cushion scales).

Margarodidae contain some of the largest coccids, some females having a body length of 35 mm. The cysts of *Eumargarodes* and *Paramargarodes* are called ground pearls, and are used as beads in some parts of the world. They are an additional immature stage capable of long periods of quiescence during unfavourable conditions. The females emerging from the cysts, have greatly enlarged fore legs modified for digging but the other legs are normal. Legs and antennae are present in the first instar of Margarodini, absent from the middle instar, and appear again in adults. The species *Margarodaes vitium* Giard, has been reported to feed on the roots of grapes in Chile and Venezuela (C.S.I.R.O., 1970). The mango mealy bug *Drosicha stebbingi*, a serious pest of mango in north India, spends part of its life in the soil. The females come down to the soil to lay eggs under the trees and they eventually die in the soil. The eggs are laid at a depth of 5-15 cm. After hatching, the nymphs climb the host plant and congregate on growing shoots. The mealy bug attacks a number of hosts, such as banyan, guava, papaya, jack fruit. The detailed biology has been worked out by Sen and Prasad (1956) and Atwal (1976).

Family : *Pseudococcidae*

This family includes the familiar mealy bugs. Many species feed above the ground and cause economic losses to commercial fruit and ornamental plants. As well as these, many subterranean species are known. The important species are the Rhode grass mealy bug *Antonina graminis* which is a serious pest on rhode grass in the U.S.A. and *Rhizoecus kondonis* attacking the roots of alfalfa. *Geococcus coffeae* is a serious pest of coffee in S. America. *Dysmicoccus brevipes* (Pineapple mealy bug) is confined generally to the crown of pineapple but sometimes infests roots. A few hypogeic mealy bugs have been reported from India. From Karnataka, Sekhar (1964) reported *Planococcus lilacinus* on the roots of arabica coffee, *Planococcus citri* on roots of coffee and cacao and *Cataenococcus* sp. on robusta coffee. *Antonina maxitima* and *Rhizoecus cynodontis* infest the roots of cynodon grass (Ayyar, 1930). Das and Ganguli (1961) have reported *Cataenococcus thaecola* on the roots of tea from Darjeeling. The pineapple mealy bug, *Dysmicoccus brevipes* has also been reported from south India. The genus *Geococcus* which contains hypogeic mealy bugs which feed on the roots and cause considerable damage. For example, *Geococcus citrinus* and *G. coffeae* have been reported on the roots of piper betal and sweet potato respectively, from Tamil Nadu by Muthukrishnan *et al.* (1958).

Heteroptera

Family : *Cydnidae*

This family is closely related to Pentatomidae. The members are small to medium-sized species. Some species burrow into soil and in these the fore-legs and also the middle legs are fossorial. The black cydnid. *Sehirus buctuores* is a common species found in the soil in Europe (Kevan, 1962). The following species have been recorded by Lefroy and Howlett (1909) from India. *Stibaropus molginus* has been recorded on the roots of a palm from South India, and *S. callidus* is very common in the loamy soils of Bengal. The geranium bugs *Cydnus indicus* and *C. varians* are also common species. Their normal habitat is on or in the soil but at certain seasons, especially the rainy months, they come out in great abundance and are considered a nuisance. The smallest species, *Chilocoris nitidus* which measures about 3 mm also breeds on the roots of grass. Ayyar (1940) has reported a cydnid bug *Stibaraopus tabulatus*, a medium-sized reddish brown flattish bug as attacking roots of tobacco from Coimbatore. The external indication of the presence of the pest in the field is the gradual fading of some plants as a whole and stunted growth in others.

Family : *Pentatomidae*

A few species of these shield bugs are known to confine themselves to roots in the soil. *Scaptocoris talpa* (central American mole bug) feeds upon the roots of sugarcane and banana in Central America. The nymphs show structural modifications for subterranean life, the legs being modified for burrowing. *Odontoscelis* spp. are known to occur in sandy soils (Tiamonin, 1958).

Family : *Gelestocoridae*

Among the semi-aquatic bugs, the carnivorus terrestrial toad bugs *Mononyx terrestris* feed on soil-inhabiting insects in Trinidad. They usually live at the margins of ponds or streams (Keven, 1962 ; Miller, 1956).

References

Ayyar, T.V. and Ramakrishna, 1930, Contribution to our knowledge of South Indian Coccidae. *Bull. Agric. Res. Inst. Pusa*, **197** : 31.

Ayyar, T. V. and Ramakrishna, 1940, *Hand book of Economic Entomology for South India*. Govt Press, Madras, 528 pp.

Atwal, A. S., 1976, *Agricultural pests of India and South East Asia*. Kalyani Publishers, Delhi, 501 pp.

ChannaBasavanna, G. P., 1958, *Smynthurodes betae* Westw. (*Trifidaphis phaseoli* Pass), a new aphid pest of French beans in Mysore, India. *FAO Pl. Prot. Bull.* Rome, **6**: (May, 1958).

ChannaBasavanna, G. P., 1962, A note on the identity of *Smynthurodes betae* Westw. (*Trifidaphis phaseoli* Pass.) (Aphididae : Hemiptera). *Indian J. Ent.*, **24** : 80-85.

Commonwealth Scientific and Industrial Research Organisation, Melborne, 1970, *Insects of Australia.* 102 pp.

DAS, G. M. AND GANGULI, R. N., 1961, Coccids on tea in North East India. *Indian J. Ent.*, **23** (4): 246–256.

DISTANT, W. L., 1906, Rhymehota III. Fauna of British India. *Taylor and Francis,* 503 pp.

ESIG, E. O., 1942, *College Entomology.* Macmillan, N. Y., 900 pp.

GADIAPPANAVAR, R. D., 1970, Faunistic study of Aphids of Mysore and biology of Ragi root aphid *Tetraneura nigriabdominalis* (Sasaki) (Homoptera: Aphididae). M.Sc. thesis, UAS, Bangalore.

HACKER, H., 1925, The life history of *Oliarus felis* Kirk (Homoptera). *Mem. Qd. Mus.*, **8**: 113–114.

KEVAN, D. K. McE., 1962, *Sail Animals.* H. F. & G. Witherby Ltd. London, 237 pp.

KUHNELT, W., 1976, *Soil Biology with special reference to the animal Kingdom.* Faber & Faber, London, 483 pp.

KULKARNY, H. L., 1956, *Tribidaphis gossypii* sp. nov. (Family Aphididae) a new specics of aphid pest on cotton in Bombay Karnatak. *Curr. Sci.*, **25**: 21.

LAL, K. B. AND SINGH, R. N., 1947, Seasonal history and field ecology of wolly aphis in Kumaon hills. *Indian J. agric. Sci.*, **17**: 211–218.

LEFROY, H. M. AND HOWLETT, F. M., 1909, *Indian Insect Life.* 786 pp.

MANI, M. S., 1973, *General Entomology.* Oxford & IBH, New Delhi, 597 pp.

MILLER, N. C. E., 1956, *The biology of Heteroptera.* Leonard Hill Ltd., London. 162 pp.

MUTHUKRISHNAN, T. S., NAGARAJA RAO, K. R., SUBRAMANYAN, T. R., JANAKI, I. P. AND ABRAAM, E. V., 1958, Brief notes on a few crop pests noted for the first time in Madras. *Madras Agic. J.*, **45**: 363–64.

SEKHAR, P. S., 1964, Pests of coffee in *Entomology in India.* Entomological Society of India. 530 pp.

SEN, A. C. AND PRASAD, D., 1956, Biology and control of mango mealy bug (*Drosicha mangiferae* Green). *Indian J. Ent.*, **18**: 127–140.

TIAMONIN, M. I., 1958, *Scaptocoris talpa* on roots of banana and other plants in Honduras. *FAO Pl. Prot. Bull.*, **6**: 174–175.

Termites and Soils

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ABSTRACT

Termites are one of the predominant groups of soil-living organisms. They have put the soil to various uses and in the process enhance soil fertility, mainly through their feeding habits and associated symbiotic relationships. Termites aid in soil formation and also influence the nature of the landscape and the vegetation in many parts of the world. Termite soils have important uses for man and the abudance of termite mounds in certain areas creates serious problems.

Although termites are generally better known for their destructive role as pests less than 10 per cent of the termite species have actually been recorded as pests. The beneficial roles played by them have not always received the serious attention and recognition they deserve. The necessity for more intensive studies in India on all aspects of the life and activities of termites is stressed.

Introduction

Termites from a dominant group among soil-living organisms in all the warmer regions of the world between latitudes 42°N and 42°S of the equator. Over 2200 species of termites are known, grouped under about 170 genera and 6 families. Termites live in well-integrated colonies or societies, some in chambers hidden from view below the surface of the soil with little or no indication of their presence, while others build conspicuous nests or mounds.

The uses of soil by termites

Termites make use of the soil for various purposes. Some primitives harvester termites excavate elaborate nests in the soil consisting of systems of chambers and communicating galleries without ingesting any soil. Such soil is carried to the surface where it forms dumps of earth. The smaller genera of the fungus-growing termites *(Microtermes, Ancistrotermes* and some *Odontotermes)* also live in subterranean and diffuse chambers and deal with the excavated soil in a somewhat similar manner. The larger fungus growers *(Macrotermes, Pseudacanthotermes* and some of the larger *Odontotermes)* usually utilize the excavated soil for the construction of mounds of varied sizes and architectural complexity characteristic of the species. This habit may have arisen from the necessity for disposing of the soil excavated in the construction of their large compact nest systems.

A second group of termites, principally of the subfamily Termitinae, feed on vegetable residues in the soil, and in the process large quantities of soil pass through their alimentary canals, leaving them with much earth to be disposed off. This they do by constructing small mounds (*Cubitermes* and allies) or by enclosing their subterranean nests in hard envelopes of a distinctive pattern *(Apicotermes)*.

A third group of termites feeds principally on woody material with a high proportion of ligneous matter, and as only a portion of the cellulose is digested, these too produce a large quantity of excreta which they use for building purpose *(Amitermes, Microcerotermes, Nasutitermes, Syntermes)*. Their nests are compact masses of small cells constructed of carbon (excreted cellulose and lignin) with a little soil. When these are above ground they are enclosed in a thick layer composed of ingested soil material cemented with excreted lignin. Such nests when arboreal *(Nasutitermes)* are enclosed in a thin envelope of ligneous matter.

The fungus-growing termites bring up large quantities of subsoil when constructing the covered passage ways between their nests and food supply, and for making earth sheets over wood that is being attacked so that they may work protected from the sun and desiccating air currents. They also use a lot of soil to replace the wood removed from inside logs or building timber and thus preserve some little strength in the structures until they have completed their task. Occasionally along road sides and in the forest one sees a whole trunk or branch, sometimes almost an entire tree so covered over in red mud that it completely conceals the bark.

Termites and soil fertility

Drummond (1886) suggested that, in the tropics, the termites play a part in improving and preserving soil fertility equal to that of the earthworms, as described by Darwin (1887), for temperate countries. Termites perform a valuable function in increasing the aeration and drainage of the soil. Robinson (1958) recorded that in coffee-growing areas of Kenya the feeding operations of the subterranean nesting *Odontotermes badius* result in a beneficial effect by increasing the number of soil burrows which increase the rate of aeration and of rainfall infiltration of both topsoil and subsoil. The larger burrows in the subsoil, after filling in with topsoil, provide favourable routes for axial root growth. In many parts of tropical Africa and Asia, the large mound surfaces of *Macrotermes* are utilized for cultivation of sisal, cotton and tobacco. Such crops grow better and have an intensified green colour and better yield indicating the high fertility of the soil of mound.

Feeding activities, symbiotic associations and their role

How do termite activities enrich the organic content of the soil? Termites feed on wood and other kinds of organic matter in the soil. In the non-fungus growing lower termites, the chewed wood particles ingested by these termites are helped to digest by the flagellate protozoan fauna (Hypermastigida and Polymastigida) inhabiting the rectal pouch of these termites.

Fungus-growing termites, cultivate fungi in special chambers of the nest on what are called "fungus combs" or "fungus gardens". According to Grasse (1957) these fungus combs are to be looked upon as stores of comminuted and chewed wood brought home from foraging areas by legions of termite workers and cemented together with faecal excrement to form coral-like combs. Sands (1960) has suggested that fungus combs were made entirely from faecal pellets. But whatever is the correct view on the composition of the fungus combs, they provide a medium on which the fungus (eg. *Termitomyces*) is cultivated. As a result of the fungal hyphae permeating the fungus comb, the substance of the fungus comb becomes soft and moist.

What roles do the fungus and the combs play in the nutrition of the termites? It has been observed (Grasse, 1937) that the conidia produced by the fungal hyphae form part of the food of workers and are mixed with the stomodeal food fed to nymphs. Grasse (1945) suggested that the ingested fungus may provide the termites with organic nitrogen and vitamins. But Luscher (1951) observed that the conidia of fungi are so rarely eaten by the termites that they play scarcely any significant role in the nutrition of these termites. Grasse (1959) was of the opinion that the fungus which grows on the fungus combs may produce certain enzymes which serve in the breakdown of lignin of the wood particles (constituting the fungus combs) freeing considerable quantities of cellulose which becomes readily available to the termites.

In these fungus-growing termites, flagellate protozoa are absent but in their place occur abundant numbers of bacteria which assist in the digestion of the cellulose obtained from the lignin of the wood (of the fungus combs) ingested by the termites. In view of this, Grasse (1959) considered that the members of the Macrotermitinae show a case of double symbiosis: with fungi on the one hand, and with bacteria on the other, a unique feature not met elsewhere in the animal kingdom.

Thus, by their ability to digest wood and other organic matter upon which they feed, the termites through their symbiotic relationships with fungus, bacteria and flagellates, play a significant ecological role as a major natural agency for the degradation and breakdown of vegetative matter and hasten the formation of humus, by incorporating their faecal matter into the nest material, the fungus combs and the various other structures they make. According to Edwards *et al.* (1970) perhaps the most important function of small soil animals in the dynamics of the ecoystem is the production of excreta and acceleration of decomposition of vegetative matter rather than that of providing biomass for the feeding of higher trophic levels.

Termites and soil formation, landscape and vegetation

Evidence is available to show that mound-building termites may be responsible for the re-establishment of new soils in some areas after erosion has taken place. Soil erosion during the quaternary period in some regions of the Congo (Zaire) and Uganda have exposed 'Stone lines' in the subsoil. In the process of formation of sand and soil clay above these 'stone lines,' there is reason to believe that the first stage was the colonization of the area by *Macrotermes* spp. which when building their nests brought up clay from near the water table. Such mounds tend to be rich in mineral salts. Further, because these termites make liberal use of faeces in building, these mounds are rich in organic-material. The existence of some of the sand and clay soils in east central Brazil has also been attributed to the activities of mound building termites.

In recent years, evidence has accumulated to show that termites play a significant role in shaping the major features of large areas of tropical savannahs of Africa and Australia. In Africa, the mounds of *Macrotermes bellicosus* may reach a diameter of 30 m and a height of 6 m and those of *M. natalensis* are somewhat smaller. In Australia, the gigantic termitaria of *Nasutitermes triodiae* and the compass nests of *Amitermes meridionalis* are striking features of the landscape. Such mounds are often so numerous in certain localities that, at a distance, they have often been mistaken for native settlement huts.

In the African savannahs the abandoned mounds of *M. bellicosus*, *M. natalensis* and *M. goliath* are rapidly colonised by vegetation (trees and shrubs) because these mounds have a higher mineral content than the surrounding soils, are better-drained and are less affected by grass fires because of their height. There is a definite succession in this process of colonisation by vegetation beginning with grasses, followed by shrubs and finally by trees, resulting in islands of woodland in grassland called 'termite savannah' by Troll (1936). These islands eventually spread and coalesce to form continuous forest. Eggeling (1947) has shown that the Budongo Forest in West Uganda is actively spreading over grasslands containing *Macrotermes* mounds.

Other aspects of Termite Soils

Various uses have been found for the mound soil of termites. The material of the mounds is often eaten by primitive tribes, presumably for the mineral salts it contains. As the mound soil is very fine and sets hard after watering, it has been used for making roads, tennis courts, pottery and bricks, some 450,000 bricks having been made from the soil of a single mound.

Termite mounds are not infrequently obstructions to mechanised agriculture, to the construction of railways, roads and other engineering projects and to the safety of aeroplanes on grass landing strips.

Need for more Research on Termites in India

Termites are generally better known for their destructive role as pests of agriculture, forestry, store, etc., although less than 10 per cent of termite species have actually been recorded as pests. The beneficial roles played by them has sometimes failed to get the serious attention and appreciation it deserves. Further, the life of the termites offer challenging problems in the study of social biology and animal behaviour.

Our knowledge of termites of the African continent is far more advanced than that of those from Asia including India. Our country has a very rich and varied termite fauna. Although much of the information on the taxonomy and bionomics of many of our termites is available in the excellent review by Roonwal (1970), it has to be emphasised that, on the whole, very little research

has been done in India on the biology of Indian termites. It is hoped that the proceedings of this Symposium will provide a stimulus to more of our young researchers to undertake serious studies on the biology of this fascinating group, the termites.

References

Drummond, H., 1886, On termite as tropical analogue of the earthworm. *Proc. R. Soc. Edinb.* **13**: 137–146.

Edwards, C. A.. Reichle, D. E. and Crossley, Jr. 1970, The role of soil invertebrates in turnover of organic matter and nutrients. In "Ecol. Stud. I, Analysis of temperate forest ecosystem",*Springer-Verlag*, New York, pp. 147–172.

Eggeling, W. J., 1947, Observations on the ecology of the Budongo Rain Forest, Ugandas *J. Ecol.*, **34**: 20–87.

Grasse, P. P., 1937, Recherche sur la systematique et la biologie des termites de l' Afrique occidentale Francaise. Premiere partie. Termitidae. *Ann. Soc. Entomol.* France, **106**: 1–100.

Grasse, P. P., 1945, Recherche sur la biologie des termites champignonnistes (Macrotermitinae). *Ann. Soc. Nat. Zool., Biol. Animale* 7 (11): 115–146

Grasse, P. P., 1959, Une nouveau type de Symbiose: La meules alimentaire des termite, champignonnistes. *Nature* **3293** : 385–389.

Grasse, P. P. and Noirot, C., 1957, La signification des meules a champignons des Macrotermitinae (Ins., Isopteres). *C. R. Acad. Sci. Paris*, 224 (14), 1845–1850.

Grasse, P. P. and Noirot, C., 1961, Nouvelles recherches sur la systematique et l' ethologie. des termites champignonnistes du genre *Bellicositermes* Emerson. *Insectes Sociaux* 8. 311–359:

Harris, W. V., 1964, Termites: Their Recognition and Control. *Longmans* pp. 71–84.

Howse, P. E., 1970, Termites: A Study in Social Behaviour *Hutchinson University Library*, pp. 25–26.

Joseph, K. J., 1962, Organization, Biology and Architecture of Termites. *J. Karnatak Univ.* 82–93.

Kendeigh, S. C., 974, Ecology with Special Reference to Animals and Man. Prentice-Hall, pp. 179.

Lee, K. E. and Wood, T. G., 1971, Termites and Soils. *Academic Press*, pp. 100–186.

Luscher, M., 1951, Significance of "Fungus gardens" in termite nests. *Nature* **167**, 34–35.

Robinson, J. B. D., 1958, Some chemical characteristics of "Termite Soils" in Kenya Coffee Fields. *J. Soil Sci.* **9**: 58–65.

Roonwal, M. L., 1970, Termites of the Oriental Region. In "Biology of Termites" Vol. II. Eds. Kumar Krishna and Frances M. Weesner, pp. 315–391.

Sands, W. A., 1960, The initiation of fungus comb construction in laboratory colonies of *Ancistrotermes guineensis* (Silvestri). *Insectes Sociaux*, **7**: 251–259).

Sands, W. A., 1969, The Association of Termites and Fungi. In "Biology of Termites" Eds. Kumar Krishna and Frances M. Weesner, **1**: 502–512.

Troll, C., 1936, Termiten Savannen. Festser. Norbert Krebs; Stuttgart, Englehorn, pp. 275–312.

Uttangi, J. C. and Joseph, K. J. 1960, Flagellate Symbionts (Protozoa) of termites from India. In "Termites in the Humid Tropics" Proceedings of the New Delhi Symposium UNESCO, Paris, pp. 155–161.

Wilson, E. O., 1972,The Insect Societies. *Belknap/Harvard*, pp. 103–119.

Seasonal Fluctuations of Proportions of different Castes as Found in the Fungus Combs of *Odontotermes obesus* (Rambur) and *Odontotermes microdentatus* Roonwal and Sen-Sarma

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Abstract

The study was conducted with a view to finding out if the fungus comb sampling of *O. microdentatus* and *O. obesus* gives an estimate of the proportion of workers and soldiers found in the colony. The study reveals that the fungus comb sampling gives an accurate estimate of the relative proportions of workers and soldiers. However, the population of fungus combs does not depicit the true proportion of workers, soldiers and nymphs. A higher worker soldier ratio in *O. microdentatus* than in *O. obesus* must be useful as a diagonostic character for the separation of the two species.

Introduction

The numerical estimation of animals is important from the ecological and

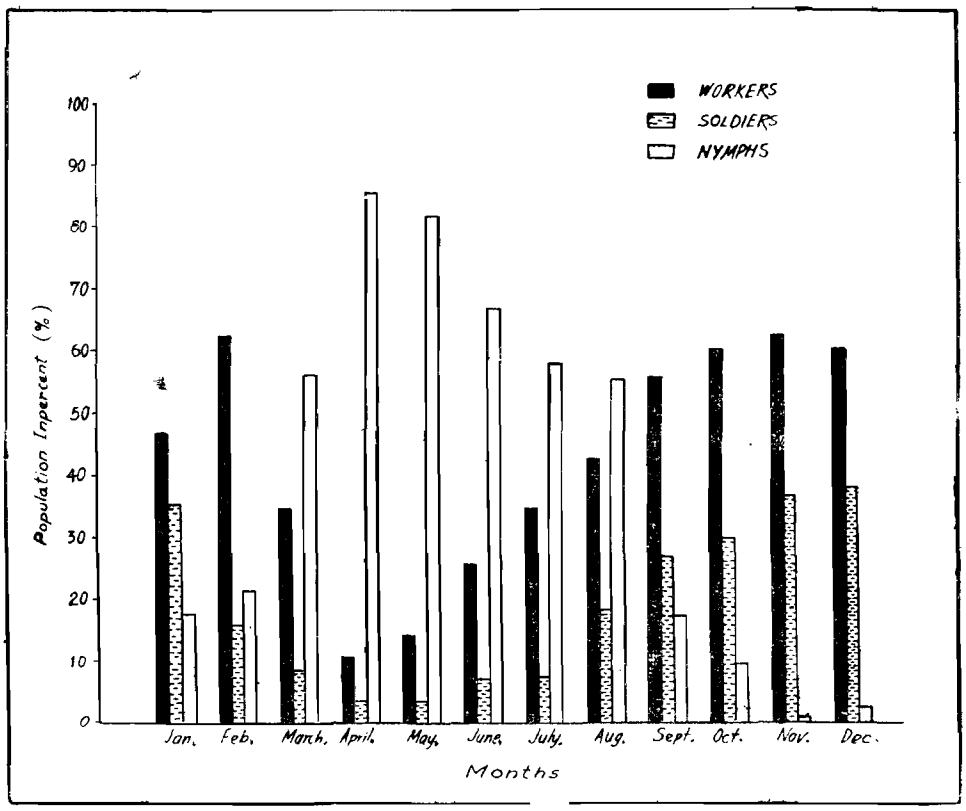

FIG. 1

Fig 1. The seasonal occurrence of different castes and immature stages in the fungus combs of *Odontotermes microdentatus*.

economic point of view. Population estimations for termites and other insects has been attempted by workers in India and other countries. With regard to population estimation of *Odontotermes* spp Gupta (1953) estimated mound

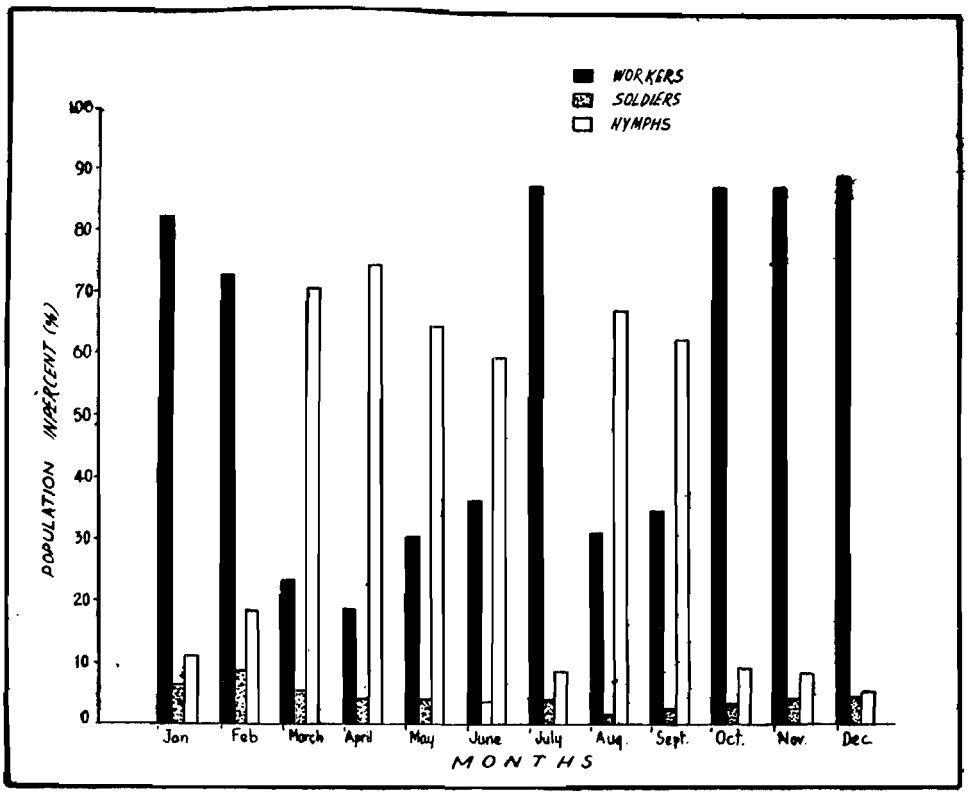

FIG. 2

Fig 2. The seasonal occurrence of different castes and immature stages in the fungus combs of *Odontotermes obesus*.

populations of *O. obesus* in Dehradun and reported seasonal fluctuations in colony composition for five months. Mukerji and Mitra (1949) made some observations on the proportion of soldiers, workers and nymphs in the fungus combs of *O. redemanni*, Roonwal (1954) reported the worker-soldier ratio in *O. parvidens*. But no estimates of population fluctuations and worker-soldier ratios are available for *O. microdentatus*. Further, seasonal fluctuations in the proportion of different castes in the fungus comb is not known for *O. obesus*. As the relative proportions of workers and soldiers is of considerable interest, it was thought desirable to test whether populations by fungus comb sampling, gives an accurate estimate of the proportion of workers to soldiers found in the colony.

Material and Methods

Four suitable termite mounds (two for *O. microdentatus* and two for

O. obesus) were selected in Chir Pine (Pinus roxburghic) at New Forest, Dehra-dun. For the purpose of sampling fungus combs, the mound soil to the ground level was removed very carefully (without disturbing the colony) using a hammer and chisel until the fungus comb was exposed. About 100 g of fungus comb from the *Beriecie* region of the mound was sampled every month from one mound of each species in the first year and from another mound of each species in the second year. All the termites were taken out from the sampled fungus comb and sorted out into castes and stages and development as counted.

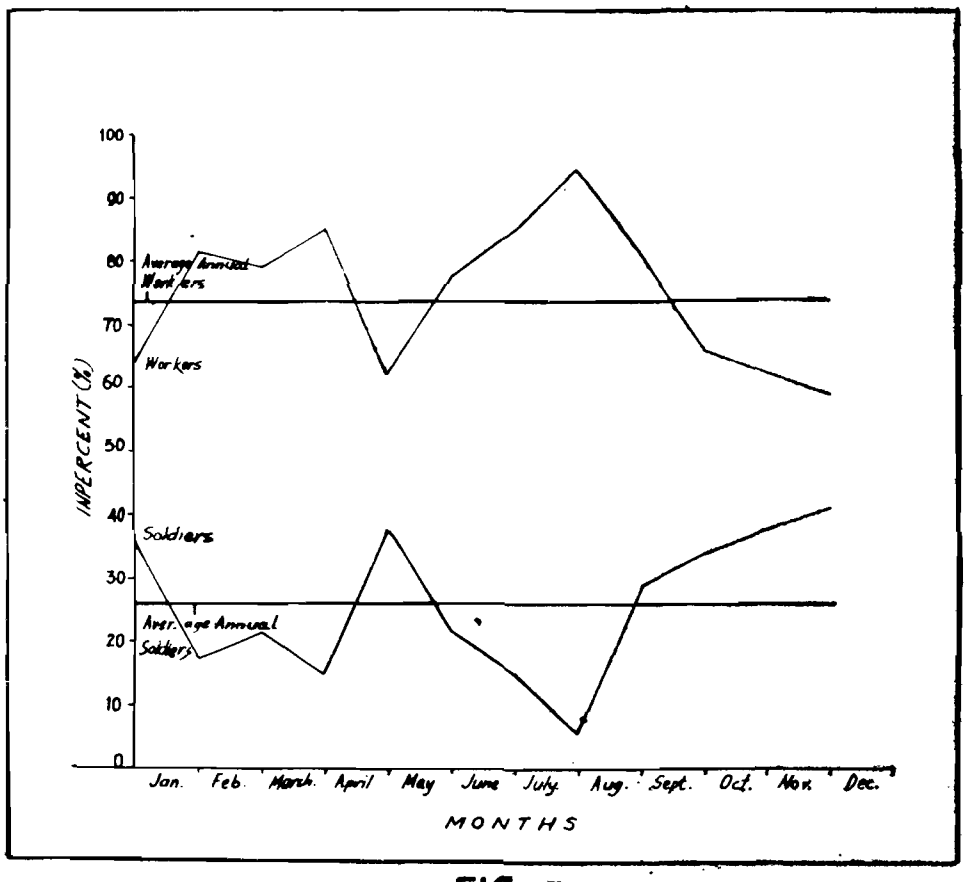

FIG. 3

The calculated proportion of workers to soldiers through the year and their annual average population in the fungus combs of *Odontotermes microdentatus*.

Results and Discussion

Figs. 1 and 2 depict the seasonal fluctuations of different castes and immature stages from the fungus combs of *O. microdentatus* and *O. obesus* respectively. The proportion of workers to soldiers of *O. microdentatus* and *O. obesus* are Figs. 3 and 4 respectively.

The annual average population of soldiers and workers in the colony of *O. obesus* was 9 per cent and 91 per cent respectively which agrees with the percentages given by Gupta (1953). The annual average population of soldiers and workers in the colony of *O. microdentatus* was 26 per cent and 74 per cent respectively. The relative proportion of soldiers to workers of these two species was interesting and may be used as a diagonostic character. The large population of immature stages in the fungus combs of both species suggests that most nymphs reside in the fungus combs. Mukerji and Mitra (1949) also reported a preponderance of immature forms in the fungus combs of *O. redemanni.*

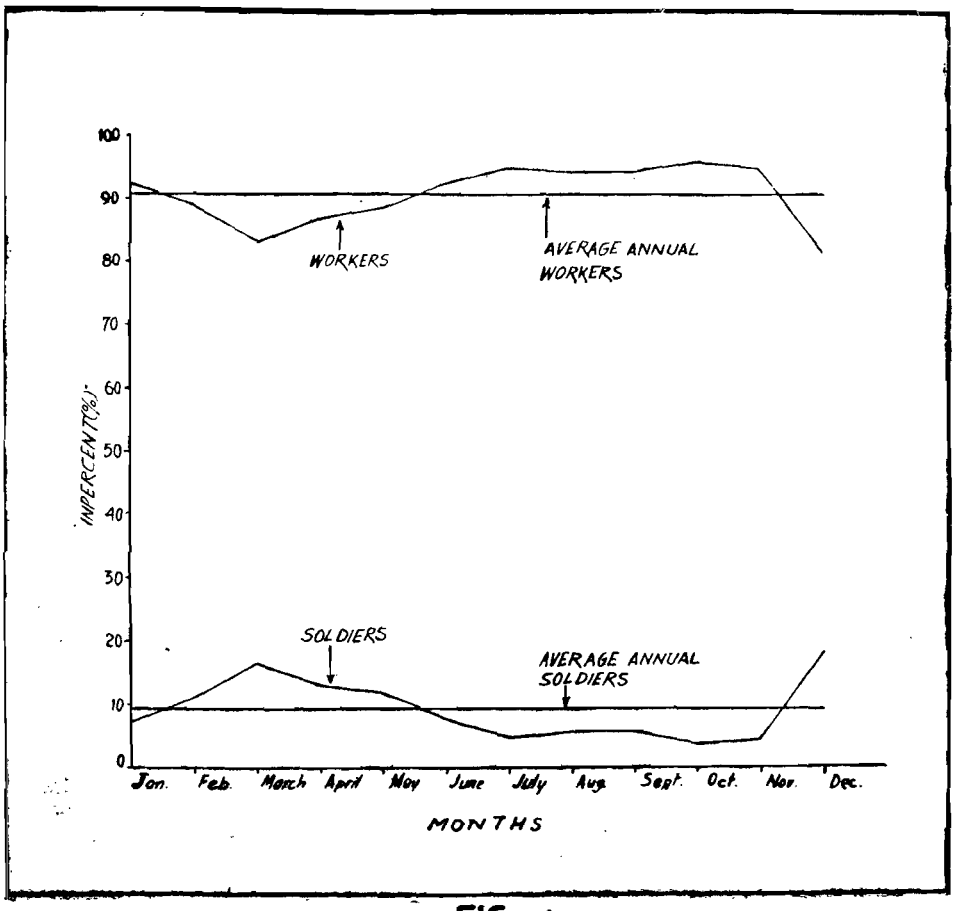

FIG. 4

The calculated proportion of workers to soldiers through the year and their annual average population in the fungus combs of *Odontotermes obesus.*

By comparing the figures given above with those obtained by Gupta (1953) on the basis of total counts of populations, it seems that fungus comb sampling can give a reasonably accurate estimation of the proportion of soldiers to

workers in the colony. However, because of fungus combs are depositories for eggs, the population of nymphs in the colony can not be predicted with reasonable accuracy.

The investigation was carried out under the guidance of Dr. P. K. Sen Sarma.

REFERENCES

GUPTA, S. D., 1953, Ecological studies of termites. Part I. Population of the mound building termite, *Odontotermes obesus* (Rambur) (Isoptera : Termitidae). *Proc. natn. Inst. Sci. India*, New Delhi (B) **19** : 697–704.

MUKHERJI, D. AND MITRA, P. K., 1949, Ecology of the mound building termites *Odontotermes redemanni* (Wasmann) in relation to necessary control. *Proc. Zool. Soc. Beng.* Calcutta, **2** : 9–27.

ROONWAL, M. L., 1954, Biology and ecology of Oriental termites (Isoptera) No. 1 *Odontotermes parvidens* Holdmg. Holmg. Severely damaging the bark and contributing to the death of standing feak trees in Uttar Pradesh in India. *J. Bombay nat. Hist Soc.*, Bombay, **52** : 459-462.

Food-Storing Habits of the Mound-Building Termite *Odontotermes wallonensis* (Wasmann) (Termitidae : Isoptera)

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ABSTRACT

During studies on the behaviour of *Odontotermes wallonensis* (Wasmann) it was observed that the important foraging periods of this species were from September to November and March to May. During these foraging periods, the termites were found storing chopped food material like grasses, graminaceous seeds and bark pieces of 1–2 mm size in separate cavities like modified chambers in the middle of the temite mound.

This is for the first time that obesrvations on food storing by *Odontotermes wallonensis* and storing in separate cavities in their nests has been reported from India. The cavity size, number of cavities, the type of food, and method of storing is explained.

TERMITES are highly-organised social insects living in well-established colonies usually in earthen mounds. The individuals of the colony can be grouped into different castes such as functional reproductives, workers and soldiers which they perform different functions for the development of the colony. Among the vast range of termite species, the mound-building termite *Odontotermes wallonensis* (Wasmann) is wide-spread in India and the most common species in

Karnataka State. This species builds solid earthen mounds of irregular shape with a number of large open-mouthed chimneys protrudings above the soil surface. Below the mound there are fungus chambers which are round and vary in size. The termites travel long distances in subterranean galleries and can damage many field crops, fruit trees, forest trees, avenue trees and plantation crops etc. During the course of study of the ecology and foraging behaviour of this species, the habit of storing food in separate cavities of the mound was discovered. This observation is being reported for the first time for this species.

Kalshoven (1956) made observations on the behaviour of *Macrotermes gilvus* Holmgr. in Java. He reported the accumulation of finely-cut vegetable matter in separate cavities of the nest with the size of the material varying from 0.5 to 2 mm. Some species of Hodotermitinae, Amitermitinae and Nasutitermitinae invariably store harvested material in their nests some times in exceedingly large quantities. The size of the fragments differs with the species concerned. Sands (1961), when studying the nests of grass harvesting species, *Trinervitermes* in Northern Nigeria reported that *T. geminatus* stored longer fragments (6.26 mm) than *T. togoensis* (3.97 mm) and *T. trinervius* (3.76 mm). Lee and Wood (1971) reported that the Australian species, *Nasutitermes triodae* and *Timulitermes hastilis* stored food pieces in the outer galleries of their nests, as loosely packed fragments of grass which would provide insulation as well as food storage.

Material and Methods

This investigation was carried out during the winter months (December, 1975–February, 1976) at the Main Research Station, Hebbal. Observations were made on the presence of food material inside the small chambers by digging-out the mounds in sections. The food chambers were collected individually, measured and the material stored in the chamber was examined.

Results and Discussion

The present study has shown clearly that the termite *Odontotermes wallonensis* stores chopped food material in separate cavites in the mound. This termite species was found foraging both during day and night time during the months of September-November and March to May.

The food chambers were very small compared to the fungus chambers, irregularly circular about 4–5 cm in diameter, situated at the middle and upper region of the mound. These food chambers were connected to the fungus chambers by a pathway through which only soldiers and workers could move and carry the food material. Normally, the food material was heaped at the bottom of the chamber. Three types of food material was found stored in the

mounds at the time of observations, but all of them were dried, finely-cut green grass 1–2 mm in length, small graminaceous seeds of 1–2.5 mm in size and sawdust-like white to dark, bark pieces, 0.5 to 2 mm in size.

The stored food materials were completely free from moisture and fungus attack. Normally, 4–6 such food chambers were noticed in big mounds. In some mounds, finely cut grass pieces were also noticed in the space outside the fungus combs inside the chamber.

From these observations, it appears that the accumulations of finely-cut plant materials are composed of mainly plant parts of various origins such as grass, grass seeds and bark pieces of trees. The storing of grass seeds and bark fragments was rare compared to storing of finely-cut grasses. Similar observations have been made by Kalshoven (1956) on *Macrotermes gilvus* from Java, except for the location of food chambers which were situated in the lowest part of the nest. Lee and Wood (1971) have reported that the stored food acts as insulating material in the nests of the Australian termites *Nasutitermes triodae* and *Timulitermes hastilis*. The habit of storing of finely-cut grass pieces in separate chambers as in the present study was found to differ from the findings of Sands (1961) and Lee and Wood (1971) for the species *Trinervitermes* from Northern Nigeria and *N. triodae*, *T. hastilis* from Australia, respectively. These two species stored longer fragments in the outer galleries of the mound in large quantities.

Since this is reported for the first time from this country, further work on the necessity of food storage, its function and the peak season of storing is under way.

References

Kalshoven, L. G. E., 1956, Observations of *Macrotermes gilvus* Holmgr. in Java–3 Accumulations of finely cut vegetable matter in the nests. *Insectes Sociaux*, Tome 3: 455–461.

Lee and Wood, T. G., 1971, *Termites and Soils*. Academic Press. London and New York, 251 pp.

Sands, W. A., 1961, Foraging behaviour and feeding habits in five species of *Trinervitermes* in West Africa. *Entomologia exp. appl.*, 4: 277–288.

Some characteristics of Termitaria Soil of *Odontotermes microdentatus* Roonwal and Sensarma, in relation to their Surroundings

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Abstract

A total of thirty two soil samples of inhabited and uninhabited mounds were analysed to determine the characteristics of termite soils in relation to the soils of the surroundings, with a view to find out whether the termite soils originate from the top soil or sub soil. The study reveals that the soil in both inhabited and uninhabited mounds has more finer fractions, better water-holding capacity, higher Fe_2O_3, Al_2O_3 as compared to surrounding sub-soil. Organic matter was almost similar in mound soil and in sub-soil. No considerable difference was noticed in CaO, MgO, P_2O_5, K_2O content and pH in mound soil and the surrounding soil.

From the stand point of forest vegetation, soil organisms are particulary important. They influence the types of humus layer, soil profile development and physico-chemical properties of soil. Thus, an intimate relationship exists between the life in soil and the forest stand which the land supports (Lutz and Chandler, 1966).

The physico-chemical characteristics of termite mound soil has been studied in Africa, India and Australia (Hesse, 1955; Nye, 1955; Harris, 1956; Maldague, 1959; Stoops, 1964) in *Macrotermes* sp. in Africa in *Cubitermes* in Africa (Kemp, 1955 and Stoops, 1964) in *Odontotermes* in India (Joachim and Kandiah, 1940; Pathak and Lehri, 1959) in various species of termites in Australia (Lee and Wood 1971). Termites in the tropics build mounds of various sizes. It is of interest to compare the mound soil with that of surrounding soil in order to find out if termites modifies the soil during the process of mound-building. With this end in view, the present study was taken up.

Material and Methods

A total of thirty two soil samples were collected sixteen from inhabited and sixteen from uninhabited mounds and surrounding soil at New Forest Estate, Dehradun. The sampling of soil was done from the east, north, west and south aspects of the mounds from the outer region (0–15 cm) and inner region (15–30 cm) at the median heights of the mounds. Samples from the adjacent area were collected in a similar manner from the top soil to a depth of 0–15 cm and the subsoil to a depth of 15–30 cm from the corresponding directions at a distance of a metre away from the basal periphery of the mound.

All the samples were air-dried, and passed through 2.0 mm round hole sieve and analysed. Mechanical composition was determined by the International Pipette method. Hydrogen ion concentration in a 1 : 2.5 soil water suspension and HCl extractable constituents by methods given by Piper (1950). Organic matter was determined by estimating organic carbon by the Walkley and Blacks wet digestion method (1934).

Results and Discussion

The differences in the values of the various factors studied were not significant either for the mounds *i.e.*, inhabited and uninhabited. Therefore, only the mean values of sets of four samples, each representing outer crust, inner crust, top soil and the subsoil are presented in Table I. A comparative assessment of some of the important soil properties was made.

Table I

Characteristics of the samples from termitaria and surroundings (Expressed on oven dry basis except stated otherwise)

Soil properties	Inhabited mound				Uninhabited			
	Termite soil		Surrounding soil		Termite soil		Surrounding soil	
	Outer crust	Inner crust	Top soil	Sub soil	Outer crust	Inner crust	Top soil	Sub soil
Coarse sand	7.83	3.13	11.72	12.20	12.47	11.79	26.84	17.88
Fine sand	31.71	25.10	43.51	43.40	37.09	34.53	37.84	41.98
Silt	27.43	36.71	26.56	21.92	25.78	33.01	19.31	25.01
Clay	31.13	32.87	15.81	15.20	18.39	19.04	14.56	13.62
W.H.C.	45.87	51.89	52.24	42.28	47.91	44.83	52.96	41.73
Organic matter	1.09	1.55	1.90	1.55	2.20	2.18	3.07	1.93
Fe_2O_3,Al_2O_3	11.77	11.68	8.95	9.01	9.65	8.75	6.75	7.05
CaO	0.29	0.44	0.41	0.38	0.52	0.45	0.48	0.41
MgO	0.68	0.79	0.68	0.68	1.25	1.27	1.03	0.94
P_2O_5	0.13	0.17	0.13	0.14	0.18	0.17	0.17	0.17
K_2O	0.29	0.26	0.43	0.58	0.21	0.35	0.41	0.38
pH	6.6	6.6	6.7	6.7	6.5	6.5	6.8	6.8

Mechanical composition and water-holding capacity: The coarser mechanical separates were the lowest and the silt and clay content were highest in the soils of the inner crust of the mound than in the other soil fractions in both inhabited and uninhabited mounds. Similarly, the coarser mechanical separates were lower and the silt and clay content higher in the soil of the outer crust than in the surrounding soil (top soil subsoil) in soil samples from both of the mounds. The proportions of clay fractions was higher in termitaria soil than in the top and subsoil. Coarse sand was strikingly lower, but fine sand was only slightly lower in both the mounds, indicating the preference of termites for the finer fractions for building termitaria. This is because coarse sand particles

size 0.2 mm and above are probably too larger for workers to carry easily with their mandibles. Proportions of clay fractions was also considerably higher in the inhabited mound soil than in the uninhabited mound soil, although the distribution of clay in the surrounding soils of both the mounds is almost identical. This can be accounted because the soil of the uninhabited mound was subjected to more rapid weathering than that of the inhabited mound where the activity of termites prevented any serious weathering. The preferential selection of fin particles (silt and clay) and the exclusion of coarse particles by the worke termites have also been observed by Joachim and Kandiah (1940) in the mounds of *O. redemanni* in Ceylon, Kemp (1955) in mounds of *Cubitermes umbratus*, Nye (1955) and Stoops (1964) in the mounds of *Macrotermes* in Africa. The water-holding capacity was higher in the outer and inner crust of both inhabited and uninhabited mounds compared to the surrounding subsoil. More fine fractions together with higher levels of organic matter might have resulted in better water-holding capacity of the termite soils.

Organic carbon: The highest organic matter content in both mounds was observed in the top soil which was obviously due to the contiunous fall of twigs etc. in forest area. The level of organic matter in the outer crust and inner crust of the mound did not however, differ much and values almost corresponded to that of the subsoil samples indicating a close similarity of termite soil to the subsoil. Similar conclusions have been made by Hesse (1955), Harris (1961) and Maldague (1959) for *Macrotermes*: Waston (1960) for *Cubitermes* in Africa; Lee and Wood (1971) for *Coptotermes, Amitermes, Drepanotermes. Nasutitermes* and *Tumulitermes* in Australia. Banerjee and Mohan (1976), however, concluded that mound soil was derived from the top soil, on the basis of similar levels of organic carbon in mound soil and top soil for *O. obesus*.

HCl-extractable-Fe_2O_3, Al_2O_3; CaO, MgO, P_2O_5 and K_2O: The Fe_2O_3 and Al_2O_3 content does not differ much in the outer crust and in the inner crust regions of mound and neither does the top soil and sub soil regions. A considerable increases was noticed in mound soil as compared to the surrounding soil. Not much difference was found in CaO, MgO, P_2O_5 and K_2O content between either the inner crust and outer crust, top soil or sub soil. It can, thus, be concluded that Fe_2O_3 and Al_2O_3 are two important cementing agents used by the termites.

Hydrogen-ion concentration: The pH level in the mound soil and in the surrounding soil did not differ much in either inhabited or uninhabited mounds Mukherji and Mitra (1949) did not find any difference in the pH of mound soil of *Odontotermes redemanni* and its adjacent soil in India.

Conclusion

The present study revealed that termites cause many changes in soil. Higher texture of mound soil is one of them. An almost similar level of organic con-

tent in mound soil and in the sub soil of the surrounding denotes the origin of mound soil from the sub-soil.

I am greatly indebted to Dr. P. K. Sen-Sarma, Forest Entomologist, Forest Research Institute and Colleges, Dehradun for suggesting the problem, invaluable guidance and constant encouragement.

References

Banerjee, S. P. and Mohan, S. C., 1976, Some characteristics of termitaria soils in relation to their surroundings in New Forest Estate, Dehradun. *Indian For.*, **100** (5) : 257–263.

Harris, W. V., 1956, Termite mound building. *Insects Soc.*, 3 : 265–265.

Harris, W. V., 1961, *Termites: Their recognition and control.* Longmans Green and Co. Ltd., London pp. 1–187.

Hesse, P. R., 1955, A chemical and physical study of the soils of termite mounds in East Africa. *J. Ecol.*, **43** : 449–461.

Joachim, A. W. R. and Kandiah, S., 1940, Studies on Ceylon soils. XIV A comparison of soil from termite mounds and adjacent land. *Trop. Agric.*, **95** : 333–338.

Kemp, B. P., 1955, The termites of north eastern Tanganyika. their distribution and biology. *Bull. Ent. Res.*, London, **46** : 113–135.

Lee, K. E. and Wood, T. G., 1917, *Termites and Soil.* Academic Press, London and New York. 1-251.

Maldague, M. E., 1959, Analysis de sols et materiaux de termitiers du congo Belg. *Insects Soc.*, **6** : 343–359.

Mukherji, D. and Mitra, P. K., 1949, Ecology of the mound building termites *Odontotermes rediemanni* (Wasm.) in relation to necessary control. *Proc. Zool. Soc. Beng.*, Calcutta, **6** : 9–27.

Nye, P. H., 1955, Some soil forming process in the humid tropics IV. The action of the soil fauna. *J. Soil Sci.*, **6** : 73–83.

Pathak, A. N. and Lehri, L. K., 1959, Studies on termite nests: Chemical, physical and biological characteristics of a termitarium in relation to its surroundings. *J. Indian Soc. Soil Sci.*, **7** : 87–90.

Piper, C. S., 1950, *Soil and plant analysis.* Adelaide.

Stoops, G., 1964, Application of some pedological methods to the analysis of termite mounds. In "*Etudes sur les termites Africains*" (A. Bouillon, ed.) Leopoldville Univ. Kinshasha : 379–398.

Walkley, A. and Blacks, I. A., 1934, An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.*, **37** : 29–38.

Watson, J. P., 1960, Some observations on soil horizons and insect activity in granite soils. *Proc. 1st Fed. Sci. Congr. Rhodesia and Myasaland* : 271–276.

Chemical Components of the Mound Soil and that of Royal Chamber of the Termite *Odontotermes assmuthi* Holmgren (Termitidae : Isoptera)

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Abstract

Analyses of mound soils of different termite spp., reviewed by Lee and Wood (1971) revealed the presence of mineral elements such as, calcium, magnesium and potassium in higher concentrations than the surrounding soil. Since the termite mounds of *Odontotermes assmuthi* Holmgren are common in the North Karnatak area, and the soil of the mounds is used by certain people for plastering walls, making ovens and other purposes, it is of interest was aroused to determine the nature of the binding elements from the mound soil of *O. assmuthi*. Silica, iron, aluminium, calcium and magnesium were present in the mound soils. The binding elements Al, Ca and Mg were found in even higher concentrations in the harder soil from the royal chamber.

Introduction

Analyses of the mineral elements of mound soils from different spp. of *Macrotermitids* and *non-macrotermitids* of Africa (Burtt, 1942 ; Milne, 1947 ; Wilde, 1952 ; Hesse, 1955 ; Sys, 1955 ; Boyer, 1956 ; Watson, 1962 and Goodland, 1965), of Australian termites (Lee and Wood, in press), of *Odontotermes* spp. from India and Ceylon (Sen, 1944 ; Pathak and Lehri, 1959) as reviewed by Lee and Wood (1971) revealed the presence of calcium, magnesium and potassium in higher concentrations than the surrounding soil. There was also a higher content of organic matter in the mound and other structures of various termite species from Africa, Australia, Ceylon and India. There appear to be no reports on the analysis for mineral elements of the soil from royal chamber which is of special construction for royal couple in the termite colony. It is of a interest to find out the nature of the binding inorganic elements from the mound soil and from the royal chamber of *Odontotermes assmuthi* Holmgren, because the mound soils of this termite are regularly used to plaster walls, making obesus and bricks and other purposes in the North Karnatak area. The classical methods of Vogel (1969) were used for the estimation of the various inorganic elements.

Results and Discussion

Silica (Si), iron (Fe), aluminium (Al), calcium and magnesium (Table I) are present in soils of the mound and the royal chamber. The percentages of the inorganic elements from the two different soil samples are given in the

Table I. Per cent organic matter was also analysed from these soils. It was found that organic matter was higher (9.62 per cent) in the soil from the royal chamber than that of the mound soil (8.85 per cent). Grasse and Joly (1941) and Stoops (1964) have also shown higher content of organic matter in the royal chamber than that of the outer casing of mound soil from African *Macrotermes* spp. Analyses for higher content of organic matter are also reported from the mounds of *Odontotermes redemanni* and *O. obscuriceps* from Ceylon by Joachim and Kandaiah (1940), *O. obscuriceps* from India by Pathak and Lehri (1959), from the galleries of Indian *Odontotermes* sp. by Shrikhande and Pathak (1948). It is only in *O. redemanni* the slight decrease in organic content has been reported. Organic matter (but occasionally a decrease) is also usually larger in the mounds of Australian termites (Lee and Wood, in press). The increased organic content in the royal chamber might come from :

TABLE I

Chemical components of the mound soil and that of royal chamber of the termite Odontotermes *assmuthi Holm.*

Soil sample/chemical components in per cent	Mound soil	Soil from Royal chamber
Silica	72.38	65.19
Iron	07.27	7.91
Aluminium	00.09	14.17
Calcium	00.29	00.58
Magnesium	00. 3	00.62
Organic matter	08.85	09.62

1) the saliva used by workers while reworking the soil for the construction of royal chamber (Grasse, 1939; Noirot 1970 and Lee and Wood, in press).
2) the incorporation of excretions of workers, soldiers and the royal couple.
3) the continuous expulsion of the liquid material by the queen while laying eggs.

Per cent of Si (65.19) in the soil of the royal chamber was found lower than that of the mound soil (72.38 per cent). Since the workers were using finely chewed up soil for the construction of the royal chamber, some Si might enter the guts of workers either advertently or inadvertently, thus causing the reduction in the Si content. It is a fact that gut content of workers of *O. assmuthi* shows the presence of Si along with other organic food materials.

The binding inorganic elements such as, Ca, Al and Mg were present in higher percentages - 0.58, 14.17 and 0.62 respectively in the soil from royal chamber, than in the mound soil (0.29, 0.09 and 0.3 respectively). The high

per cent of these inorganic elements in the soil of royal chamber might com from the organic plant food of the workers either through their saliva or excreta. The occurrence of a higher per cent of these binding elements and organic matter might explain why the royal chamber is stronger and harder than the mound soil. Another factor contributing to the hardness might be the finer clay particles that make up the royal chamber. The outer wall of the mound usually contained larger, comparatively less reworked particles than the royal chamber. The outer mound wall is comparatively not so hard and strong as that of the royal chamber. This may facilitate aeration of the colony.

Still the mound soil is relatively harder than the surrounding soil. Because of the hardness of the mounds, they will last for over 30 to 40 years exposure to sun and rain.

First author wishes to record his thanks to Professor C. J. George, Retired C. S. I. R. Scientist for suggesting this problem.

References

BURTT, B. D., 1942, Some east African vegetation communities. J. *Ecol.*, **30** : 65–146.

BOYER, P., 1956, Etude pedologique de la repartition et du dosage des bases totales dans les materiaux de la termitiere de la *Belicositermes natalenses* (Hav.) C. r. hebd. *Scanc. Acad. Sci.*. Paris. **242** : 801–803.

GOODLAND, R. J. A., 1965, On termitaria in a savanna ecosystem. *Can. J. Zool.*, **43** : 641–650.

GRASSE, P.·P., 1939, Le reconstruction du nid et le travail collectif chez les termites superieurs. *J, Psychol., norm. path.*, **36** : 370–396.

GRASSE, P. P. AND JOLY P., 1941, La teneur en matieres organiques de quelques tertes de termitiers. *Bull. Soc, Zool. Fr.*, **66** : 57–62.

HESSE, P. R., 1955, A chemical and physical study of the soils of termite mounds in East Africa. J. *Ecol.*, **43** : 449–461.

JOACHIM, A. W. R. AND KANDIAH, S., 1940, Studies on Ceylon soils. XIV A Comparison of soils from termite mounds and adjacent land. *Trop. Agric. Mag. Ceylon agric. Soc.*, **95** : 333–338.

LEE, K. E. AND WOOD, T. G., 1971, Termites and soils. *Academic press Inc.* London *Ltd.*

MILNE, G. 1947, A soil reconnaissance journey through parts of Tenganyika Territory. Dec. 1935 to Feb. 1936. *J. Ecol.*, **35** : 192–264.

NOIROT, C., 1970, The nests of termites. In "Biology of Termites" (K. Krishna and F. W. Weesner, eds). vol. 2, 73–125. *Academic Press*, New York.

PATHAK, A. N. AND LEHRI, L. K., 1959, Studies on termite nests. I chemical, physical and biological characteristics of a termitarium in relation to its surroundings. *J. Indian Soc. Soil Sci.*, **7** : 87–90.

SEN, A., 1944, The influence of feed upon the composition of termite soils. *Curr. Sci* **13** : 280–281.

SHRIKHANDE, J. G. AND PATHAK, A. N., 1948, Earthworms and insects in relation to soil fertility. *Curr. Sci.*, **17** : 327–328.

STOOPS, G., 1964, Application of some pedological methods to the analysis of termite mounds. In "Etude sur les Termites Africains" (A. Bouillon, ed.), pp. 379–398. *Leopoldville Univ.*, Leopoldville.

SYS, C., 1955, The importance of termites in the formation of latosols. *Sols. Afr.* 3 : 392–395.

VOGEL, A. I., 1969, Text Book of Quantitative Inorganic Analysis including elementary instrumental analysis. *Ed. 3, ELBS and Longman*, London.

White Grub Problems in Andhra Pradesh and their Control

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ABSTRACT

White grubs are among the most important polyphagous pests causing heavy damage to all crops and particularly to groundnut in an area of 10,000 hectare in the rain-scarce endemic belts of Kurnool and Anantapur districts of Andhra Pradesh. The predominent species found in this region is *Phylophaga consanguinea* B.

Since 1970, large-scale field trials were set up for evaluating the effectiveness of various granular insecticides and dusts for the control of white grub on groundnut and sorghum crops. The results showed that BHC 10 per cent dust at 125 kg/ha and phorate 10 per cent granules at 15.5 kg/ha at sowing gave 100 per cent control of white grub population. Phorate 10 per cent granules at 30 kg/ha and lindane 10 per cent granules at 70 kg/ha also gave 100 per cent control of grubs. The results obtained during 1971 indicated that phorate 10 per cent granules at 25 kg/ha is also quite effective. Phorate, when applied as broadcast treatment and mulched into the soil gave better control than furrow application.

During the 1975 *kharif* season, phorate was applied in contiguous blocks of 45 acres each, in areas endemic to this pest, in two villages of Kurnool and Anantapur districts. The treatment was very effective resulting in increased pod yields of 53.8 per cent and 30.2 per cent over untreated plots at the two locations. As a followup action the pest populations were assessed in the treated area during August 1976 and it was found that there was only a marginal advantage in having slightly lower populations of the pest than in the control plots.

Althouh the farmers have realised the efficacy of phorate for the control of white grubs, in view of its high cost, the recommendation did not gain much acceptance. To find a cheaper method of control, attempts were made by treating the groundnut seed prior to sowing during 1975. The results obtained have revealed that treatment with one kg carbaryl 50 per cent w.p. and 200 ml methyl parathion 50 per cent E.C. for 100 kg kernels has proved significantly superior in decreasing plant mortality.

WHITE grub is an important polyphagous pest causing heavy damage to all crops grown under rainfed conditions in *kharif* season, being particularly so in the endemic rain-scarce belt of dryland tract of Kurnool and Anantapur districts of Andhra Pradesh. It severely damages groundnut. jowar, maize, castor, tobacco, chillies, bajra, korra, upland rice, ginger etc. The problem is particularly localised in the light red alluvial soils of Dhone and Pathikonda taluks of Kurnool districts and Gooty and Kalyandurg taluks of Anantapur district. Estimates show that an area of about 10,000 hectares of groundnut was effected year after year since 1973 in the Kurnool and Anantapur districts resulting in a loss of 60–80 per cent of the crop annually. The predominent species is *Holotrichia serrata* F. Other species of white grubs in this endemic area were identified as *Anomola varians*, *Schizonycha ruficollis* and *Phyllognathus* sp.

Since more than one species is involved, it is contemplated to undertake a survey on the white grub complex in Andhra Pradesh and study the extent of damage caused by the species predominating in the various regions.

Studies on the biology of white grub reveals that the adults of these beetles remain in the soil and emerge out after the onset of monsoon. The first emergence of the beetles usually takes place in the first week of June. The beetles congregate in large numbers during night time on the trees of tamarind (*Tamarindus indica*), babul (*Acacia arabica*), neem (*Azadirecta indica*), drumstick (*Moringa olefera*) and feed on their leaves. The adult population starts declining in second week of August and disappears by the end of August. The grub population begin to decline from the third week of September when it goes into deeper soil layers for pupation.

Since 1970 large scale field trials were taken up for evaluating various granular insecticides and dusts for the control of the white grub in groundnut and sorghum crops in the endemic areas of Kurnool and Anantapur districts.

During 1970, aldrin 5 per cent dust at 125 kg/ha, BHC 10 per cent at 125 kg/ha applied in plough furrows before sowing accompanied by application of Phorate 10 G at 15.5 kg/ha at sowing were tried and compared with control (No treatment). The results reveal that BHC–cum–phorate application gave 100 per cent control of white grubs. There was no damage to the plants at 45 days after sowing. During the same year another observational trial was taken up with phorate 10 G at 30 kg/ha, lindane 10 G at 70 kg/ha, lindane 10 G at 50 kg/ha, DDT 10 per cent dust 100 kg/ha, BHC 10 per cent dust 160 kg/ha, heptachlor 5 per cent dust at 125 kg/ha and control (no treatment) on groundnut crop. Observations recorded at 60 days after sowing of the crop revealed that the treatments phorate at 30 kg/ha and lindane at 70 kg/ha eliminated the grubs and the damage to the crop in these plots was nil. The treatments with lindane 50 kg/ha. DDT and BHC were all similar and the damage to the crop was less

than one per cent. In the case of heptachlor damage was noticed. The damage in the control plots was as high as 90 per cent.

During 1971 phorate 10 G at 25 kg/ha, endosulfan 2 per cent dust at 104 kg/ha, lindane 6.5 per cent G 160 kg/ha, DDT 50 per cent dust at 25 kg/ha, disulfoton 5 per cent G 25 kg/ha, and untreated control were tried on groundnut crop. The results obtained revealed that phorate at 25 kg/ha is the best wherein the percentage of damaged plants and also the grub population was nil. Treatment with endosulfan 2 per cent dust is also promising and plant damage was negligible (5 per cent) with the lowest grub population. The damage to the crop in case of untreated plots was high (26.97 per cent).

The foregoing results show that phorate 10 G is the most effective in the control of white grub. In view of the earlier results, a large scale insecticidal trial was laid out during 1973 on sorghum and groundnut with the soil application of BHC 5 per cent dust at 50 kg/ha, area application of phorate 10 G 25 kg/ha, furrow application of phorate 10 G 12 kg/ha, soil application of DDT dust at 50 kg/ha, and control (No treatment).

The results revealed that phorate 10 G applied at the rate of 25 kg/ha is the most effective chemical for control of whitegrub when broad-cast and mulched into the soil. To demonstrate the efficacy of phorate 10 G in controlling white grub on groundnut, an operational research project was taken up in two villages namely Udumalapadu of Kurnool district and Bachupalli of Anantapur district, in a contiguous block of 45 acres in each of the two areas. The grub population and wilted plants were nil in most of the experimental area and pod yields increased 53.8 per cent and 352 per cent over control plots at Udumalpadu and Bachupalli respectively. As a followup action to assess whether treating a contiguous block of about 45 acres will have any additional advantage in suppressing white grub incidence in the succeeding year, data were collected during August 1976 on grub population in the same plots that were treated with phorate 10 G during 1975 under operational project at Anantapur. The results revealed that the average density of population of grubs from the treated plots were 3270 per hectare while in nearby untreated plots it was 7,050 grubs per hectare. Though there was an advantage in reducing the population, the results indicate that application of phorate 10 G in blocks of 45 acres do not yield the desired results in averting the pest completely ; perhaps treatment of still larger areas in a contiguous block will be more advantageous in suppressing the pest.

Though the efficacy of phorate 10 G at 25 kg/ha was realised by the farmers in controlling the pest, it is felt by the farmers that the treatment is too costly for adoption due to the fact that groundnut in these areas is raised in vast-almost contiguous-stretches and the crop depends on the vageries of monsoon rains. With a view to find out an alternative and cheap and effective method of control

for the root grub treating the groundnut seed the insecticides before sowing was attempted and an experiment was laidout during 1976 *kharif* on groundnut crop with the following treatments : (1) Seed treatment with one kg BHC 50 per cent WP and 200 ml methyl parathion 50 per cent E.C. for 100 kg groundnut kernels; (2) Seed treatment with one kg carbaryl 50 per cent w.p. and 200 ml methyl parathion for 100 kg groundnut kernels; (3) Phorate 10 G at 25 kg/ha; (4) manure heaps mixed with BHC 10 per cent dust: (5) manure heaps without insecticide, and (6) control (no treatment). The results obtained revealed that seed treatment with carbaryl 50 per cent w.p. one kg and 200 ml methyl parathion 50 per cent EC for 100 kg kernels proved significantly superior in minimising the plant mortality and enhancing the yield both of pods and haulms. The foregoing shows that seed treatment offers a possibility and means for overcoming the ravages of this pest in groundnut. Studies are in progress to determine whether this method is an effective, control of the pest or is only a determent to the grub.

Ecological Studies on White Grub *Holotrichia consanguinea* Blanch.

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Abstract

White grub *Holotrichia consanguinea* Blanch. is the most destructive pest of rainy season crops grown in semi arid region of Rajasthan. The damage is caused by the grubs which live underground. Efforts to control the grubs have not met with much success. In order to devise a suitable strategy, based on control of beetle, for managing the population of this pest, ecological studies were undertaken to find out : a. Correlation of beetle emergence with rainfall, b. host preference of beetles, c. population of beetles during active period and, d. movement of beetle in soil during inactive period.

Material and Methods

For recording the emergence of beetles light trap catches were made from May to July in 1974 and 1975. Light trap was placed on the College farm. The source of light used in the trap was 100 W incandescent bulb fitted between 4 baffles. The daily rainfall during this period was recorded. Weekly total (starting from 4th May) of number of beetles and rainfall was computed.

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For determining the host preference of the beetles all the trees and shrubs growing on and around the Collge farm were observed for the presence of beetles by shaking them with a pole between 9.00 p.m. and 11.00 p.m. regularly during June and July. On the basis of number of beetles collected from hosts their relative preference was decided.

For the estimation of beetle population during active period 'mark release and recapture' method was tried in 1974 but this method could not give clear picture as the number of beetles recaptured was very low in a trap fitted with incandescent bulb. Therefore, in 1975 another method based on the number of host trees was adopted for this experiment. For the estimation of beetles population, average number of beetles present on different categories of host was estimated by jerking and counting the beetles present on six trees in each category of host. These trees were selected without any bias from different parts of the entire farm. The beetle population per hectare was calculated by counting different categories of host trees present in four plots of one hectare each. The number of host trees were multiplied by respective average number of beetle per host tree. Grand total of these figures gave the expected number of beetles in one hectare plot.

Movement of beetles in soil during inactive period (*i. e.*, October to May) was studied by digging soil pits measuring $1m^3$ at monthly interval. The number of beetles and the depth at which they were found resting, were measured and recorded.

Results

It was observed in 1974 and 1975 that the first insurgence of beetles took place between 9th and 15th June. The cumulative rainfall during this period had reached to 30.4 mm in 1974 and 50.6 mm in 1975. The beetle emergence was in very small numbers when the cumulative rainfall was less than 30 mm in the preceding weeks (Table I).

After emergence the beetles were found to feed on a number of hosts. Perusal of Table II and III, clearly indicates that beetles preferred some hosts over others. The order of preference amongst hosts observed at Jobner was *Ber, Sainjana, Khejri, Guava, Gold mohar, Karonda* and *Neem* whereas at Lalsot it was *Ber, Gular, Sehta, Neem* and *Jhari Ber.*

Survey in the year 1975 indicated that the population of beetles in the month of July was about 1795 beetles per hectare (Table IV and V).

Soil sampling carried out from Oct., 1974 to May, 1974 indicated that during inactive period beetles remained in the soil at a depth of 40–70 cm in the months of October, November, December and January. In the month of

February and March they went deeper and stayed at a depth of 70–100 cm. From April onward they started slight upward movement (Table VI).

TABLE I

Emergence of whitegrub beetles in relation to rainfall

	1974			1975		
	No. of beetles trapped	Weekly rainfall in mm	Cumulative rainfall	No. of beetles trapped	Weekly rainfall in mm	Cumulative rainfall
1st June	15	–	–	7	4.2	4.2
8th June	6	27.2	27.2	17	4.0	8.2
15th June	670	3.2	30.4	117	42.4	50.6
22nd June	120	–	30.4	23	8.5	59.1
29th June	20	2.8	33.2	4	8.2	67.3
6th July	51	1.8	35.5	108	23.6	90.9
13th July	115	109.9	144.9	29	4.2	95.1
20th July	191	481.1	626.9	–	330.0	425.1
27th July	102	81.5	707.5	–	93.8	518.9
4th August	16	58.6	766.1	–	0.0	518.9

TABLE II

Observations on host preference of beetles in Jobner

Date of collection	* Number of beetles collected from						
	** Ber	Khejri	Sainjana	Karaunda	Guava	Gold Mohor	Neem
30.6.74	99	76	67	6	13	12	0
1.7.74	93	63	61	18	25	18	0
2.7.74	95	101	120	30	51	15	0
3.7.74	129	114	104	24	73	33	0
4.7.74	330	252	304	15	86	30	0
5.7.74	360	274	326	2	91	24	0
6.7.74	393	220	306	12	97	21	0
7.7.74	126	96	119	32	31	38	0
8.7.74	24	21	31	10	28	15	
Total	1649	1217	1430	149	495	216	0
Average/day	183.2	135.2	158.8	16.5	55.0	24.0	0.0
Average/day/ tree	61	45	53	6	18	8	0

* Total number of beetles trapped from three trees

** Technical name of host is given beneath Table III

DISCUSSION

The emergence of beetles of *H. consanguinea* has a marked correlation with the amount of rainfall. Though, the beetles were observed to emerge in small numbers in the last week of May, their first insurgence occurred only after the good premonsoon shower and the second insurgence occurred after the onset of

the monsoon (Table I). Kalra and Kulshrestha (1961) observed that though some beetles started emerging from the last week of April, the maximum emergence was with first shower of rain. Desai and Patel (1965) recorded beetle emergence from May to August. They observed maximum emergence in June–July after the first shower of rain. According to Rai *et al.* (1969) large number of beetles emerged after good pre-monsoon shower. In both the years (*i.e.*, 1974 and 1975) first insurgence of beetles occurred in the week ending on 15th June.

TABLE III

Observations on host preference of beetles in Lalsot

Date of collection	*No. of beetles collected					
	** Ber	Neem	Gular	Mango	Sehta	Jhari Ber
14.7.74	1039	28	79	0	47	0
15.7.74	484	18	207	1	92	0
18.7.74	117	23	121	0	0	1
29.7.74	50	6	0	0	0	89
30.7.74	195	1	0	0	1	36
31.7.74	159	6	0	0	0	51
1.8.74	20	0	0	0	0	18
2.8.74	10	0	0	0	0	0
Total	2074	82	407	1	140	195
Average/day	259.2	10.2	50.8	0.12	17.5	2.4

* Total number of beetles trapped from three trees.

** 1. Ber – *Zizyphus mauritiana*
2. Khejri – *Prosopis cineraria*
3. Sainjana – *Moringa oleifera*
4. Karaunda – *Carissa earandus*
5. Guava – *Psidium gujava*
6. Gold mohar – *Delonix regia*
7. Neem – *Azadirachta indica*
8. Gular – *Ficus glomerata*
9. Mango – *Mangifera indica*
10. Jhari ber – *Zizyphus rotundifolia*
11. Sehta – *Bauhinia* sp.

TABLE IV

Number of beetles collected from different host trees (July, 1975) for estimation of beetle population

Name of the host	No. of beetles collected per tree						Total	Average
	1	2	3	4	5	6		
Khejri *Prosopis cineraria* (Big)	146	199	83	297	51	244	1030	171.6
Khejri *Prosopis cineraria* (Small)	93	12	69	103	185	83	545	90.8
Ber *Zizyphus mauritiana*	226	114	36	201	91	190	858	142.5

By this time cumulative rainfall had crossed 30 mm. The small numbers of beetles emerged before 8th June in both the years might have been from fields irrigated for growing summer crops.

TABLE V

Per hectare population of beetles based on no. of host trees present (July, 1975)

Plot No.	Host	No. of host trees	Expected No. of beetles	Expected total No. of beetles/ha
A.	Khejri (Big)	9	9×172=1548	
	Khejri (Small)	5	5× 91= 445	2003
	Ber	0	—	
B.	Khejri (Big)	2	2×172= 344	
	Khejri (Small)	3	3× 91= 273	3620
	Ber	21	21×143=3003	
C.	Khejri (Big)	3	3×172= 516	
	Khejri (Small)	–	—	516
	Ber	–	—	
D.	Khejri (Big)	5	5×172= 860	
	Khejri (Small)	2	2× 91= 182	1042
	Ber	–	—	
			Total No. of beetles in four plots	7181
			Average No. of beetles per hectare	1795

TABLE VI

Seasonal movement of white grub beetles in soil

Locality – Johner Year 1974–75

Month * of sampling	No. of beetles observed in 5 pits at a depth of (in cm)											Range of depth at which adults were found in cm
	30	40	50	60	70	80	90	100	110	120	Total	
October	—	4	6	6	4	—	—	—	—	—	20	40–70
November	—	7	7	—	5	—	—	—	—	—	19	40–70
December	—	2	—	1	2	—	—	—	—	—	5	40–70
January	—	1	—	2	1	—	—	—	—	—	4	40–70
February	—	—	—	—	1	3	—	—	—	—	4	70–80
March	—	—	—	—	—	2	1	1	—	—	4	80–100
April	—	—	5	1	3	1	—	—	—	—	10	50–80
May	—	—	—	2	2	1	4	—	—	—	9	60–90

* Sampling was done between 10th and 15th of every month.

In Jobner there were different kinds of trees on which the beetles could feed but they showed a definite preference for Ber over others. The next preferred host was Khejri. Since the Khejri is quite large in number, this tree has a major

role in this locality in supporting the population of beetles. Neem tree which was observed to attract fairly large number of beetles in Lalsot, did not attract any beetle in Jobner.

In Lalsot too Ber was the most preferred host, followed by Gular and Neem. Since there were no Khejri trees in this locality, it was not possible to determine the preference between Gular and Khejri. It would be appropriate to mention here that in any locality, if one preferred host is not available in a patch, the beetles would congregate on the next available host no matter where it stands in order or preference. Secondly, if the population of beetles in a locality is large enough to saturate the most preferred hosts, the beetles can be found congregating simultaneously in large numbers on less preferred hosts, and in such situations it may appear difficult to determine the relative preference. However, if there is not so much of saturation of hosts with beetles the relative preference could be distinctly observed. It was also observed that in Ber the new leaves and sprouts appear by the end of May and prior to this the trees bear small number of old leaves. If there is premonsoon shower during this period the beetles would be found in very small number on Ber as the small number of old leaves present on Ber fails to attract large number of beetles. In such situation Khejri or Gular may appear to be the most preferred.

It was further observed that beetles could feed on a large numer of different kinds of host trees. Such observations were also made by Rai *et al.* (1969), and Bindra and Singh (1971). In many situations, beetles immediately after emergence from soil settle in large numbers of some non-host trees simply for mating and later on shift to their hosts. Such trees are often consufed as hosts. Mango tree is an example of this.

In another locality where, there were only two types of trees the Khejri and Roonjh *(Acacia leucophloea)*, the latter was found to be the most preferred and attracted the beetles many times in number than Khejri.

In the year 1974 capture and recapture method was tried for the estimation of beetle population but it did not give satisfactory results as the trap used with incandescent lamp failed to attract signficant number of beetles. Earlier Prasad and Thakur (1959) in Bihar set up light traps in field and collected nearly 1,600 beetles in one night. Such response towards light was not observed in the present investigations. If this method is to be used for population estimation, a trap with better attractancy will have to be devised. In the second year *i.e.*, 1975 population was estimated on the basis of average number of beetles feeding on host trees multiplied by absolute number of such host trees present in the area of observation. With this method population of beetles at Jobner in the month of July was worked out to be 1975 beetles per hectare (Tables, IV and V).

The beetles of *H. consanguinea* after completion of pupal period transform themselves into adults by the end of October and stay in the soil in this stage from October till their emergence in next monsoon. Similar observations were made by Patel and Desai (1965) and Rai *et al.* (1969). To overcome the adverse climatic conditions the beetles go deep into the soil where temperature and moisture are fairly constant. It was observed that from October to January beetles remained in soil depths ranging between 40–70 cm (Table VI, Fig. 1). In February and March they went deeper though the atmospheric and soil temperature during this period started rising. This behaviour of beetles may be attributed to reduction in soil moisture, which made them go into deeper soil layer having moisture conditions suitable to their requirement. These beetles stayed at this level with slight up and down movement during April and May and came out of soil after premonsoon showers by the end of May or June. Rai *et al.* (1969) also conducted survey in the month of June and observed most beetles in depth range of 30–75 cm.

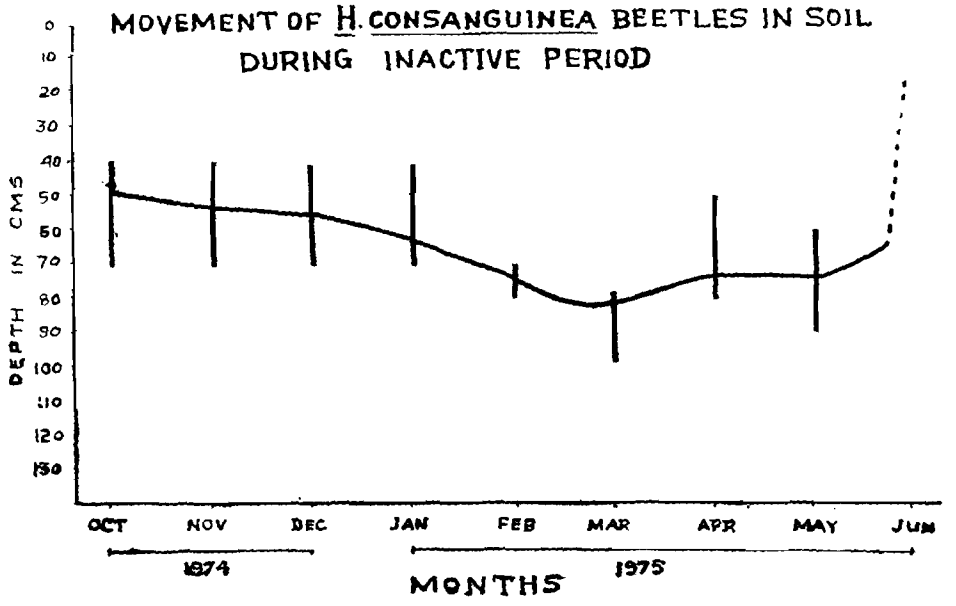

Fig. 1

Facilities provided by Associate Director Research, College of Agriculture, Jobner and the financial grant given by ICAR is gratefully acknowledged.

References

Bindra, O. S. and Singh, J., 1971, Biological observations on White Grub, *Lachnosterna* (Holotrichia) *consanguinea* Blanchard (Coleoptera : Scarabacidae) and the relative efficacy of different insecticides against adults. *Indian J. Ent.*, 33 : 235–227.

Desai, M. T. and Patel, R. M., 1965, Some observations on the biology and control of White grubs in soil (*Holoctricha consanguinea* Blanch.) affecting groundnut and cereals in Gujarat. *Indian J. Ent.*, 27 : 89–94.

KALRA, A. N. AND KULSHRESHTHA, J. P., 1961, Studies on the biology and control of *Lanchnosterna consanguinea* Blanch. a pest of sugarcane in Bihar (India). *Bull. Ent. Res.*, 52.

PRASAD, S. K. AND THAKUR, C., 1959, White-grub, *Lanchnonstera consanguinea* Blanch. a new menace to sugarcane. *Indian J. Ent.*, **21** : 184-89.

RAI, B. K., JOSHI, H. C., RATHORE, Y. K., DUTTA, S. M. AND SHINDE, V. K. R., 1969, Studies on the bionomics and contorol of White grub, *Holotrichia consanguinea* Blanch. in Lalsot, district Jaipur, Rajasthan. *Indian J. Ent.*, **31** : 132-142.

Some Aspects of Larval Taxonomy of White Grubs of Karnataka - India

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ABSTRACT

White grubs are the larvae of scarabaeid beetles. The adults are known as chafers or May-June beetles. Except for a short period of adult activity, during April-June, the rest of the life is spent underground. Many of the injurious species are found as larvae and the adults are seldom found. Therefore an attempt has been made to distinguish the species on the basis of larval characters. The nomenclature of principal larval characters follow Boving (1942) and Ritcher (1966). Keys to separate Scarabaeoid families, subfamilies and tribes of Melolonthinae are taken from Ritcher (1966) and keys for the species of Melolonthinae of Karnataka are provided.

INTRODUCTION

SINCE many species of white grubs are root feeders they are also called as root grubs, but not all white grubs are root grubs. Some of these white grubs are beneficial in litter breakdown and enriching the soil. Two of the three families (Passalidae and Lucanidae) of the superfamily Scarabaeoidea are harmless and help in incorporating organic matter to the soil by feeding on decaying wood. Among the twelve subfamilies of the family Scarabaeidae (Ritcher, 1966), melolonthids and rutelinids are root feeders by preference. Some species of Pleocominae (Genus *Pleocoma*), Glaphyrinae (Genus *Lichnanthe*) and Aphodinae (Genus *Aphodius*) are root feeders. Many adults of Melolonthinae, Rutelinae, Cetoniinae are defoliators. The genus *Oryctes* of Dynastinae are pests on palm. The remaining large majority of white grubs can be considered as helpful to man in enriching the soil by facilitating the disintegration of dung (Scarabaeinae Dynastinae), dead wood (Lucanidae, Passalidae Dynastinae, Acanthocerinae), leaf litter (Cetoniinae, Dynastinae, Aphodiinae, Geotrupinae) and carcasses (Troginae).

The superfamily Scarabaeoidea, contains over 35,000 known species that look very similar in shape and colour in their larval stages. Generally they are 'C' shaped, whitish in colour with 3 pairs of legs (grubs elongate with metathoracic legs reduced in Passalidae), head hypognathus. There are three thoracic and ten abdominal segments. All scarabaeids undergo 3 larval stages except the Pleocominae which has 8 to 13 larval instars, one per year.

Keys for identifying the commonly occurring Scarabaeid larvae are available for European and American species. Except for Gardner (1935) no such keys have been made for Indian species. A beginning has been made in the study the taxonomy of white grubs of India.

The earliest works available on the classification of Scarabaeid larvae are of European worker's (De Haan, 1836; Mulsant, 1842; Burmeister, 1848; Erichson, 1848). Recent comprehensive studies of scarabaeoid larval taxonomy includes Hayes (1929), Boving and Craighead (1931), Gardner (1935), Vanemden (1941), Boving (1942) and Ritcher (1966). Except for the works of Gardner (1935) and Ritcher (1961) on a few Indian species, no work on larval taxonomy of Scarabaeoids is available.

The aim of present paper is to give a basic key for the families of Scarabaeoidea and subfamilies of Scarabaeideae for the benefit of Indian workers. In doing so the authors have borrowed the entire key for families, subfamilies and tribes from Ritcher (1966).

Material and Methods

Third stage larvae of the species described here were reared to adults in rectangular glass jars of 10 × 15 × 25 cm. Sprouted bengalgram (*Cicer arietinum* L.) seeds were provided as food once in a week. The larvae meant for dissection were killed in just boiling water and preserved in 70 per cent alcohol. Permanent mounts of dissected parts like antennae, labrum, mandibles, maxilla, cranium, spiracles, legs and raster were prepared by digestion in 10 per cent sodium hydroxide for 24 to 48 hours. Specimens were washed and the dehydrated by passing through for five to ten minutes each in glacial acitic acid, acitic acid carbolic acid (1 : 1), carbolic acid xylene (1 : 1) and xylene, and mounted in Canada bolsom. Larvae were studied with a binocular dissecting microscope. Drawings were prepared using Bausch and Lamb microslide overhead projector. All characters were taken from 3rd stage larvae.

Results

Key to subfamilies of Scarabaeidae based on characters of the larvae

1. Maxilla with galea and lacinia distinctly separated 2
   Maxilla with galea and lacinia entirely fused, or fused proximally but distally free or (rarely) not fused but fitting tightly together 10

2. Distal segment of antenna little if any reduced in diameter compared to the other antennal segments 3

Distal segment of antenna much reduced in size, often appearing as an appendage of the penultimate segment 5

3. Anterior margin of labrum trilobed or broadly rounded; without serrations or truncate lobes ... a few *Aphodiinae*

Anterior margin of labrum serrate or with truncate lobes 4

4. Anterior margin of labrum with 3 truncate lobes. Prothoracic and mesothoracic legs with stridulatory organs *Hybosorinae*

Anterior margin of labrum strongly serrate. Stridulatory organs may be present on mesothoracic and metathoracic legs *Acanthocerinae*

5. Epipharynx with tormae united mesally, anterior phoba present. Anal opening usually surrounded by fleshy lobes 6

Tormae of epipharynx not united mesally, anterior phoba absent. Last abdominal segment without fleshy lobes 9

6. Antenna 3-segmented 7

Antenna 4 or apparently 5-segmented 8

7. Legs 2-or 3-segmented. Abdominal terga often divided into 2 distinct annulets. Body often hump-backed. Mesothoracic and metathoracic legs often with stridulatory organs. Metathoracic legs often reduced in size *Geotrupinae*

Legs 4-segmented. Abdominal terga divided into 3 distinct annulets. Body not hump-backed. Legs never with stridulatory organs *Troginae*

8. Legs 2-segmented. Claws very small or absent; if present each bearing one or two terminal setae. Antenna 4-segmented. Body strongly humb-backed... *Scarabaeinae*

Legs 4-segmented. Claws well-developed. Antenna 4-or apparently 5-segmented. Body not hump-backed...most *Aphodiinae*

9. Antenna 3-segmented. Anal slit angulate. Body without a uniform covering of soft hair like setae. Mesothoracic and matathoracic legs with stridulatory organs. Claws each bearing 2 setae *Pleocominae*

Antenna 4-segmented. Anal slit transverse. Body with a uniform dense covering of soft, hair-like setae. Mesothoracic and metathoracic legs without stridulatory organs. Claws each bearing 4 setae *Glaphyrinae*

10. Mandible with ventral stridulatory area absent, indistinct or consisting of a patch of minute granules. Anal opening usually angulate or Y-shaped. Galea and lacinia fused proximally but separated distally or tightly fitted together. Last antennal segment always with a single, large, oblong, dorsal, sensory spot *Melolonthinae*

Mandible with a ventral, oval, stridulatory area consisting of a few to many transverse, granular ridges. Anal opening a straight or slightly curved, transverse cleft. Galea and lacinia of maxilla fused forming a mala. Last antennal segment with one or more dorsal sensory spots 11

11. Lacinia of maxilla with 1 or 2 well-developed terminal unci or uncus almost absent. Maxillary stridulatory teeth always with anteriorly projecting points, never truncate 12

Lacinia of maxilla with 3 well-developed terminal unci. Maxillary stridulatory teeth truncate or with anteriorly projecting points 13

12. Labrum symmetrical, either entire, bilobed, or trilobed. Epizygum absent. Epipharynx always with a single nesium (sclerotized plate absent), plegmata absent. Haptomerum often with a conspicuous, transverse, curved row of stout setae which may or may not be interrupted by a median process. If the lacinia has 2 terminal unci, then the 2 unequal in size *Cetoniinae*

Labrum usually asymmetrical; epizygum usually present. Epipharynx usually with 2 nesia and usually with plegmata. Haptomerum never with a conspicuous, transverse, curved row of stout setae. If the lacinia has 2 terminal unci, then the 2 usually equal in size (*Tribes Anomalini and Rutelini*) *Rutelinae*

13. Plegmatia present. Haptomerum of epipharynx with a dense transverse row of 6 to 9 heli. Maxillary stridulatory teeth never truncate (*Tribe Adoretini*) *Rutelinae*

Plegmatia absent. Haptomerum of epipharynx with a raised, bi-lobed or tooth-like or ridge-like process. Maxillary stridulatory teeth usually truncate *Dynastinae*

Key to tribes of the subfamily Melolonthinae

1. Raster with a curved, transverse row of prominent setae anterior to the ventral anal lobes or with a prominent oblique row or rows of mustache-like setae, on each side 2

Raster with longitudinal palidia or with palidia absent 3

2. Cardo, maxillary articulating membrane, and many other parts of the body bearing numerous black dots. Dorsal anal lobe much smaller than the ventral anal lobes. Raster with a curved transverse, comb-like palidium.

...tribe *Sericini*

Black dots absent. Anal lobes similar in size. Raster with a prominent oblique row or rows of mustache-like setae, on each side, anterior to the ventral anal lobes.

....tribe *Diplotaxini*

3. Raster lyre-shaped and without palidia.
....tribe *Dichelonycini*

Raster with or without palidia, if lyre-shaped then with palidia. 4

4. Haptomerum of epipharynx with from 1 to 4 heli. 5
Haptomerum of epipharynx with 5 or more heli. 6

5. Haptomerum of epipharynx with 4 heli. All legs with well-developed claws. Raster with a pair of short, longitudinal palidia.
....tribe *Macrodactylini*

Haptomerum of epipharynx with a single helus. Claws of mesothoracic legs reduced in size. Raster without palidia.
...tribe *Hopliini*

6. Raster, on each side of the septula, with a pair of curved palidia, the outer palidium of each pair with pali directed laterad.
...tribe *Pachydemini*

Raster without palidia or with a single palidium on each side of the septula. Palidium, if polystichous, with all pali directed me sad. 7

7. Respiratory plates of spiracles constricted (surrounding bullae)
....most *Melolonthini*

8. Haptomerum of epipharynx with 5 or 6 heli. tribe Plectrini
Haptomerum of epipharynx with 8 or more heli. ...*a few Melolonthini*

Key to separate the species of Holotrichia *based on larval characters*

1. Maxillary articulating membrane (MAM) (Fig. 9) and coxa bearing sclerities of metathorax, with dark granules. Raster with palidia (PLA) (Fig. 2, 6 and 8) 2

Maxillary articulating membrane and coxa bearing sclerites of metathorax, without dark granules. Raster without palidia (Fig. 4)
...*Holotrichia sculpticoilis*

2. Raster with palidia parallel or converging at extremities, each set with less than 20 short stout pali (PA) (Fig. 6 and 9); proplegmatia (PPL) of epipharynx elliptical and broad or elongate and narrow (Fig. 5 and 7) 3
Raster with palidia slightly diverging posteriorly, each set with 20 or more short stout pali (Fig. 2): proplematia of epipharynx elongate and narrow (Fig. 1). ...*Holotrichia serrata*

3. Raster with palidia converging at both the extremities, set with 8 to 12 short stout pali (Fig. 8); proplegmatia of epipharynx narrow and short with 5 to 6 short proplegme (Fig. 7). ....*Holotrichia nelgiria*
Raster with palidia parallel set with 13 to 17 pali (Fig. 6); proplegmatia of epipharynx elliptical and broad, with 10 to 13 long proplegma (Fig. 5). ...*Holotrichia consanguinea*

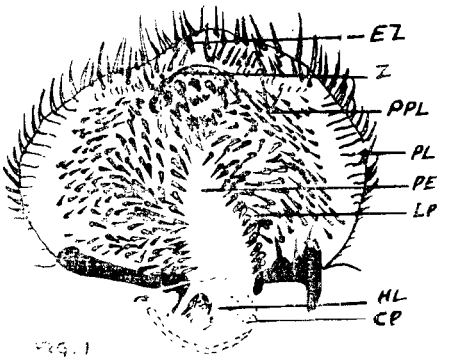

FIG. 1

FIG. 5

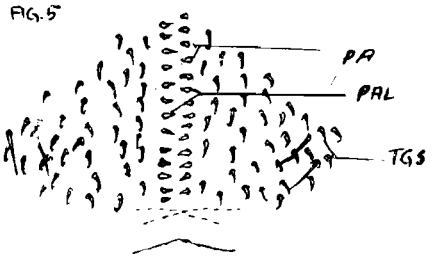

FIG. 6

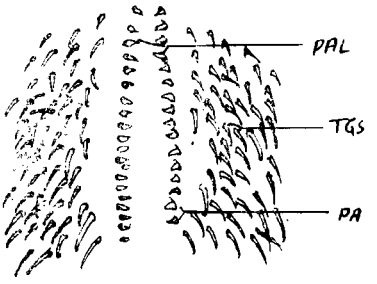

FIG. 2

FIG. 7

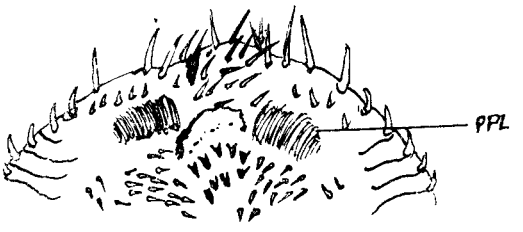

FIG. 3

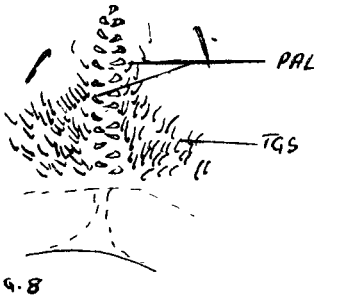

FIG. 8

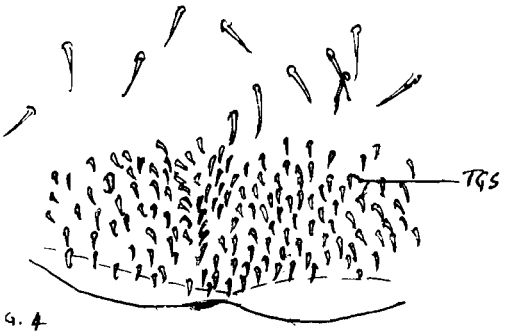

FIG. 4

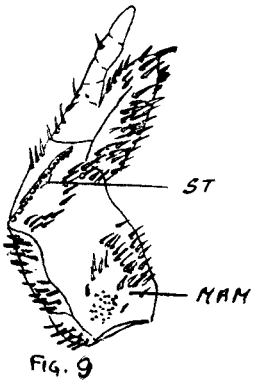

FIG. 9

Conclusion

The four species of *Holotrichia* that are commonly met with in Southern Karnataka have been classified on the basis of the third stage larval characters. Veeresh (1973) has listed 14 species of Melolonthine beetle from Karnataka, some of which are serious pests. Frey (1971) has listed more than 120 species of *Holotrichia* alone from India. Thus this is only a small begining in formulating keys for the scarabaeoid larvae. As and when full informations about the remaining species of this subfamily as well other subfamilies of family Scarabaei dae are available, a more comprehensive key needs to be formed. The authors hope that the present attempt will only help in stimulating workers in this line in India to initiate the much needed studies of larval taxonomy of this large group of beetles.

Thanks are due to Dr. G. P. ChannaBasavanna, Professor and Head, Department of Entomology for his kind help and encouragement.

References

Boving, A. G., 1942, A classification of larvae and audults of the genus *Phyllophaga*. *Mem. Ent. Soc.* Washington., 2: 97.

Boving, A. G. and Craighead, F. C., 1931, An illustrated synopsis of the principal larval forms of the order coleoptera. *Ent. Amer.*, 11: 351.

Burmeister, H., 1948, Die Entwichkelungeschichte der Gattung. *Deltochilum* Esch. Zeitung for Zoology, Zoolomic and Palaeozoologic., 1: 133–136 and 141–144.

DeHaan, W., 1836, Memoires sur les metamorphoses des Coleopteres. *Noulo. Ann. Mus. Nat. Hist.*. 4: 125.

Erichson, W. F., 1948, Naturgeschichte der insecten Dentschlands, Erste Abt., Colep., 3. Nicolai, Berlin., p. 968.

Frey, G., 1971, Keys to the Indian and Ceylonese species of the genus *Holotrichia* Hope (Coleoptera : Melolonthidae). *Entomol. Arb. Mus. G. Frey. Tutzing Muench.*, 22: 206–225.

Gardner, J. C. M., 1935, Immature stages of Indian Coleoptera (16) Scarabaeidae. *Ind. For' Rec. Ent. Ser.*, 1: 33.

Hayes, W. P., 1929, Morphology, taxonomy and biology of larval Scaraboidea. *Illinois Biol. Monograph.*, 12: 119.

Mulsant, E., 1942, Histoire naturelle des Coleopteres de France, part II, Lamellicornes. Lyon (et peris), Maison (Later paris Magnen and Blanchard Co.) p. 624.

Ritcher, P. O., 1961, Description of some North Indian Scarabaeid larvae (Coleoptera). *Indian J. Ent.*, 23: 13–19.

Ritcher, P. O., 1966, *White grubs and their allies.* Oregon State University Press, Oregon. p. 219.

Van Enden, F., 1941, Larvae of British beetles. **11**: A key to the British Lamellicornia larvae. *Ent. Monthly. Mag.*, 77: 117–127, 181–192.

Veeresh, G. K., 1973, Studies on the Melolonthine beetles (Coleoptera : Scarabaeidae) of Mysore State with special reference to the biology and control of *Holotrichia serrata* Fabricius. Ph.D. thesis, University of Agricultural Sciences, Bangalore-560024.

Soil-Inhabiting Beneficial Insects (Predators and Parasites of Insects) in India : A Brief Review

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ABSTRACT

Soil presents a congenial environment for several species of predatory and parasitic insects. Among the soil-inhabiting predatory insects, the members of the family Carabidae are distributed all over the world and practically all are carnivorous whether as larvae or imagines. In India., *Calosoma beesoni* Andr., *C. manderae* F. Var. *indicum* Hope., *C. olivieri* Dej., *Cicindela* species, several staphylinids and tenebrionids are important soil-dwelling predatory insects.

Members of the family Scelionidae and Tiphidae constitute the soil-inhabiting parasitic forms of insects.

The main object of this paper is to high-light some of the facts about the beneficial fauna of soil, hitherto neglected.

INTRODUCTION

Soil is an important habitat for several species of predatory carabids, cicindelids, staphylinids, meloids a few scarabaeids and tenebrionids and also scelionid and scoliid parasites of insects. No doubt these parasites and predators prey on injurious insects but their true value has not been fully assessed because of paucity of information. An attempt is here made to give an account of a little known beneficial groups neglected by soil biologists and ecologists in India.

REVIEW OF LITERATURE

I. *Soil dwelling pradators* :

i) *Carabidae :* The carabids are primitive amongst Coleoptera and are distributed all over the world. They are active at night and during the day they lie concealed under stones, logs of woods etc. The night carabids have considerable economic value as pest predators and all the species comprised in the family are carnivorous. In India several species have been reported and their importance has been discussed here in brief.

a) *Calosoma beesoni* Andr. which has been recorded from United province and Punjab preys on the larvae of the geometrid moth, *Ectropis deodarae* and nymphs of several species of grass hoppers (Beeson, 1923).

b) *Calosoma manderae* Fab. var. *Indicum* Hope. occurs in Kashmir, Punjab, Bengal and Bihar. The larvae and adults occur in oat and wheat

fields infested with caterpillars of *Cirphis unipuncta* and feed on them. They also prey on the caterpillars of *Plusia* sp., *Remigia* sp. and *Thermosa* sp., (Fletcher, 1919).

c) *Calosoma olivieri* Dej. is very common at Pusa and devours the nymphs of *Acridium peregrinum*, a species of grass hopper and larvae of *Cirphis unipuncta* (Andrews, 1929).

d) *Calosoma himalayanum* Gestro. is found abundantly in Kashmir and Punjab. The caterpillars of *Lymantria obfuscata* Wlk, a defoliator of *Salix alba* L. form the chief host of this species (Andrews, 1929).

e) *Chloenius bioculatus* Chaud. has larvae which live openly on Sunnhemp plants and prey on caterpillars of *Utethesia pulchella* L. which are much larger than themselves. Besides *U. pulchella,* various other caterpillars are eaten and, in confinement, these larvae and adult beetles feed freely on caterpillars of *Spodoptera litura* F., *Polytela gloriosae* F., *Diacrisia obliqua* Wlk. and *Antigastra catalunalis* Dup. (Andrews, 1929).

f) *Chloenius circumdatus* Brulle was the grubs which devour those of *Monolepta signata* and *Stictaspis ceratitina* Bezzi, by remaining close to the roots of sugarcane. It has been reported from Pusa (Andrews, 1929).

g) *Chloenius trinotatus* Laferte. Kushwaha and Sharma (1961) observed this species devouring the caterpillars of various species of Lepidoptera at Udaipur. It is readily attracted to light and during day it remains underneath farm refuge, weeds etc.

h) *Chloenius pictus* Chaud Andrews (1929) reported the larvae of *C. pictus* feeding on the larvae of sugarcane borer but no details were available as to the mode feeding.

i) *Broscus punctatus* Dej. adults have been taken from fields infested with *Agrotis ipsilon* Hufn. at Pusa. Under natural conditions, the beetles hunt for the caterpillars of *A. ipsilon* beneath the soil, chase them to the surface and they feed up on them. In the laboratory, they feed freely on caterpillars of *Spodoptera litura, Pieris brassicae* and *Chilo simplex* Butl. (Andrews, 1929).

j) *Pheropsophus sorbinus* (Dej) var. *deshordesi* (Mainder). has been reported from Assam and Karnataka. It feeds on the second instar white grubs particularly *Oryctes rhinoceros* both in its larval and adult stages. Another phenomenon observed is that the adults give a pungent smelling liquid when disturbed which wards off the enemies. This fluid causes prolonged irritation when comes in contact with human skin. The adults remain in manure pits 2–3″ below the surface and hunt for the grubs of *O. rhinoceros* (Rao and Manjunath, 1964).

Other carabid predators reported from India are (K) *Pheropsophus catoirei* Dej. (L), *P. hilaris* Fab. var. *Sobrinus* (M), *Rhopalpus janthinus* Red., (N) *Scarites*

spp., (Kushwaha and Sharma, 1961) and (O) *Anthia sexgutata* (Rai *et al.*, 1969). The latter species feeds on the adults of *Holotrichia consanguinea* and grass-hoppers during night time. The adults are long lived and two beetles were reared on grass hoppers for 18 month in the Entomology Laboratory, U.A.S.

(ii) *Cicindelidae* (a) *Cicindela sexpunctata L.* is distributed in *Tamil Nadu, Karnataka, Bengal, Calcutta, Udaipur* and *Kashmir*. It is beneficial because it feeds on the rice gundhi bug, *Leptocorisa acuta* (Fletcher, 1914). The other cicindelid predators reported from India are : (b) *C. spinolae* Gestro ; *C. leucoloma* Chand ; and *C. catena* (Kushwaha and Sharma, 1961).

(iii) *Staphyliniae quediosoma sericoilius* is widely distributed in India and feed on young *Odontotermes obesus* Holm. (Rahman, 1940).

(iv) *Meloidae* : The first instar grubs of *Gnathospastoides rouxi, Lytta termicollis* and *Zonabris pustulata* are predaceous on the eggs of various species of grass hoppers (Fletcher, 1917).

(v) *Scarabaeidae* Bhatia and Pritpal Singh (1962) reported that the larvae of *Trox procerus* fed on the eggs of desert locust, *Schistocerca gregaria.*

(vi) *Tenebrionidae* : *Pimelia inexpectata* adults feed on emerging vermiform larvae of desert locust (Bhatia and Pritpal Singh, 1962).

II Soil dwelling parasites :

(i) *Scelionidae* : The scelionids are usually *small*, dull-coloured and breed on eggs of Orthoptera. The species of scelionids encountered in India are : (a) *Scelio oryzae* which breeds on eggs of *Oxya velox* and has been reported from Coimbatore; (b) *Scelio hieroglyphi* Timb. which has been reared from egg pockets of different species of *Hieroglyphus* at Coimbatore and elsewhere (Pruthi and Mani, 1942); *Scelio ovophagus* is parasitic on the eggs of *H. nigrarepletus* (Mukerji, 1952) Ramachandra Rao (1952) observed phoresey in *Lepidoscelio viatrix* Brues. on *Orthacris simulans* and ChannaBasavanna (1954) recorded phoresey in *L. viatrix* on *Orthocris carli* at Bangalore and also made observations on the biology of this species.

(ii) *Scoliidae* : *Scolia 4-pustulata, S. auripennis, Scolia* species *Wagneni, Camposomeris collaris* and *Tiphia hirsutum* have been recorded from Bangalore as parasites of white grubs. However the percentage of parasitization was negligible (ChannaBasavanna, 1954). Avasthy (1967) recorded *S. auripennis* from Uttar Pradesh and Coimbatore on white grubs.

Conclusion and Future Lines of Work

There should be a catalogue of all the beneficial soil insect fauna of different agroclimatic regions of India to enable the role of these insects to be fully assessed as factors in controlling pest populations. This would also help in development of integrated control programmes.

References

Andrews, H. E., 1929, *The Fauna of British India including* Ceylon and Burma, *Coleoptera, Carabidae*. Vol. 1 : Carabinae, p. 1–431.

Avasthy, P. N., 1967, Sugarcane pests in India and their control (a review) *Pans.*, **13** : 111–117.

Beeson, C. F. C., 1923, The deodar defoliator. *Ind. For.*, **12** : 565–572.

Bhatia, D. R. and Pritpal Singh, 1962, Beetles as predators on desert locust in India. *Ind. J. Ent.*, **24** (2) : 103–108.

ChannaBasavanna, G. P., 1954, Scolidae parasites on Chaffer grubs. *Ann. Repp. Dept. Agri.* Mysore, 1953–54.

ChannaBasavanna, G. P., 1954, Phoresy exhibited by *Lepidoscelio viatrix* Brues (Scelionidae: Hymenoptera). *Ind. J. Ent.*, **15**: 264–266. 384–385.

Fletcher, T. B., 1914, *Some South Indian insects.* Government Press, Madras.

Fletcher, T. B., 1919, Second Hundred Notes on Indian Insects, *Agric. Res. Inst. Pusa, Bull.*, **89** : 31–35.

Kushwaha, K. S. and Sharma, L. S., 1961, Some common beetle predators (Insecta:Coleoptera) of Udaipur (Rajasthan) with brief notes on their seasonal occurrence and habit. *Proc. 48th Ind. Sci. Congr.*, **3** : 427.

Mukherji, S., 1952, On a new species of Scelionidae, *Scelio oviphagus* Sp. Nov. (Serphoidea= Proctotrupoidea : Hymenoptera) parasitic on eggs of *Hieroglyphus nigrorepletus* 1 Bol., In Ajmer (India). *Indian. J. Ent.*, **14** : 203–213.

Rahman, K. A., 1940, Important insect predators of India. *Proc. Ind. Acad. Sci.*, B(12) : 67–74.

Rai, B. K., Joshi, H. C., Rathore, Y. K., Dutta., S. M. and Shinde, V. K. R., 1969, Bionomics and control of *Holotrichia consanguinea.* *Ind. J. Ent.*, **31** (1) : 127–132.

Ramachandra Rao, Y., 1952, Scelionids as egg parasites of orthoptera-II. *Ind. J. Ent.*, **15** (2): 126.

Rao, V. P. and Manjunath, T. M., 1964, A new record of the carabid beetle *Pheropsophus sobrinus* (Desj.) var. *desbordesi* (Mainder) as a predator of the rhinoceros beetle, *Oryctes rhinoceros* (Linn.) in India. *Comm. Wealth Inst. of Biol. Cont. Tech. Bull.*, **4** : 40–41.

Soil Fauna Studies in India

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Abstract

The purpose of this paper is to introduce the soil fauna which is a neglected group of animals in India and to try to indicate some of the principal features concerning its study. The main objectives are to give an introduction to soil zoology and its history and to summarize information on ecology of different soil fauna like Acarina, Collembola

and other meso and macrofauna. The distribution and diversity of soil fauna will be discussed. The character of soil communities based on the work done in the Department Entomology, Banaras Hindu University and at other places in India will be discussed.

Introduction

The discipline which deals with the soil fauna is known as Soil Zoology and is a branch of Soil Biology. It is only recently that soil zoology has developed into a discipline in its own right. Some of the serious obstacles in the path of study are the hidden ways of life of soil anlmals, their small size and the difficulties in collecting them. Smith (1966) reported that the most difficult component of soil fauna to study are the soil arthropods. They are the most numerous, the most difficult to identify, possibly the most difficult to sample accurately. The determination of genus and species, and in many cases even the family of many groups of soil fauna is possible only by specialists. Willard (1974) pointed out that for the ecologist, one of the most difficult areas for soil invertebrates is taxonomy. This is very true, particularly in India due to paucity of taxonomy data.

Soil animal ecology has however, received considerable interest recently because these animals are considered to be important contributors to the soil fertility and humification processes. In India, soil animals are a most neglected group and remained virtually unexplored so far. In view of the fact that soil is readily available and valuable resource, it is surprising how little attention has been paid in our country to these animals. There are hardly any institutions in India where soil zoology finds a place in the curriculum of Zoology/Entomology Departments. Entomologists and zoologists have been preoccupied with studies on those soil arthropods which are known directly to affect the yield and quality of crops and the whole field of soil zoology is still in an infant stage, whereas European workers have contributed the major body of literature in this field.

The main purpose of this paper is to appraise the work done in the field of soil zoology in India and discuss those groups of animals which are the main concern of this symposium, based on all the published literatures. Singh and Pillai (1973) discussed general information on different groups of soil fauna in their article "The World beneath us". In India the soil zoology literature is difficult for a comprehensive survey, because publications are scattered in many obscure journals. In such circumstances, it is difficult to present a correct picture. However, I have tried to include as much as possible. I hope that this collection of papers will represent a useful source for the participants and other fellow workers.

The soil fauna community, abundance and distribution

The most abundant soil mesofauna are the mites (Arachnida : Acarina) and springtails (collembola). Certain small groups like Symphyla, Diplura, Protura

and Pauropoda etc. are also found in the soil and the litter. These are collectively known as soil arthropods. Singh and Mukharji (1971) and Choudhuri and Banerjee (1975) described the qualitative composition of soil arthropods in different fields. Singh and Mukharji (1973) observed that Acari and Collembola composed 72 to 97 per cent of the total arthropod fauna of the Indian soils. They further reported Acari, Collembola, Pauropoda and other soil arthropods in the ratio of 1/2 : 1/9 : 1/18 respectively. Singh and Pillai (1975) reported Acari and Collembola combined constituted 85.2 to 92.6 per cent of the total soil animals and that these ratios varied from field to field. They further reported that the ratio of Collembola and Acari in four habitats was roughly 1 : 1 in a banana field, 1 : 7 in a citrus orchard, 1 : 4 in fodder field and 1 : 3 in a cultivated area. Thus only in the banana field was the population ratio of Collembola and Acari almost equal and in other habitats Acari were more dominant. Singh and Pillai (personal communication) reported the frequency and dominance of different soil arthropods in different sites. Mukharji and Singh (1970) recorded maximum population densities of soil micro-arthropods in a rose garden during the month of August and the minimum during the months of May and July. Pillai (1974) estimated the Acarina population as up to 8808/m^2 and the Collembola as up to 8097/m^2 in a banana field at Varanasi (Fig 1).

Acari (Arachnida)

Mites are the commonest soil mesofauna in most soils and are particularly abundant in highly organic woodland and forest sites. In the main. Soil Acari belong to four orders *viz.*, the Mesostigmata, Prostigmata, Astigmata and Cryptostigmata.

Mesostigmata

Many of the predatory Mesostigmata are large active mites with mouthparts adopted for piercing, sucking, and tearing. These mites are present commonly in soils and are known to feed in culture on other mites, proturans, collembolance and pauropods. In Indian soils, this group contributes 5 to 10 per cent of total scarine fauna and 3.8 to 6.7 per cent of the total fauna (Sing and Pillai, 1975). The genera *Asca, Macrocheles, Dermanyssus, veigia* and *Pergamasus* are commonly present in cultivated and uncultivated soils in this region as reported by Singh and Pillai (1975). Choudhuri and Banerjee (1975) recorded *Asca* and *Macrocheles* from West Bengal. Singh and Pillai (1975) mentioned that the faunestic composition of Mesostigmata was not rich in most sites. The species such as *Asca* and *Dermanyssus* had a higher frequency and dominance in all habitate (Singh and Pillai, 1976). No other literature is availabie on ecology of this group of soil mites.

Prostigmata

These mites are found in extremely large numbers in some fields of Varanasi and are mainly herbivorous. Sometimes this group may contribute up to 75 per

cent of the total Acari. The dominance of Prostigmata is due to a higher frequency of occurrence of a single genus *Cocotydeus* in all the fields (Singh and Pillai, personal communication). But this group presented a poor faunistic composition in regard to species. The predatory activities of a number of common families, such as Trombidiidae and Rhagidiidae are well established. Singh and Mukharjee (1971) and Choudhuri and Banerjee (1975) listed the different species of Prostigmata. Among species occurring commonly in the soil, are the members of the Bdellidae, Rhagidiidae, Tydeidae and Cunaxidae. Very little is known about the soil prostigmatic mites of India.

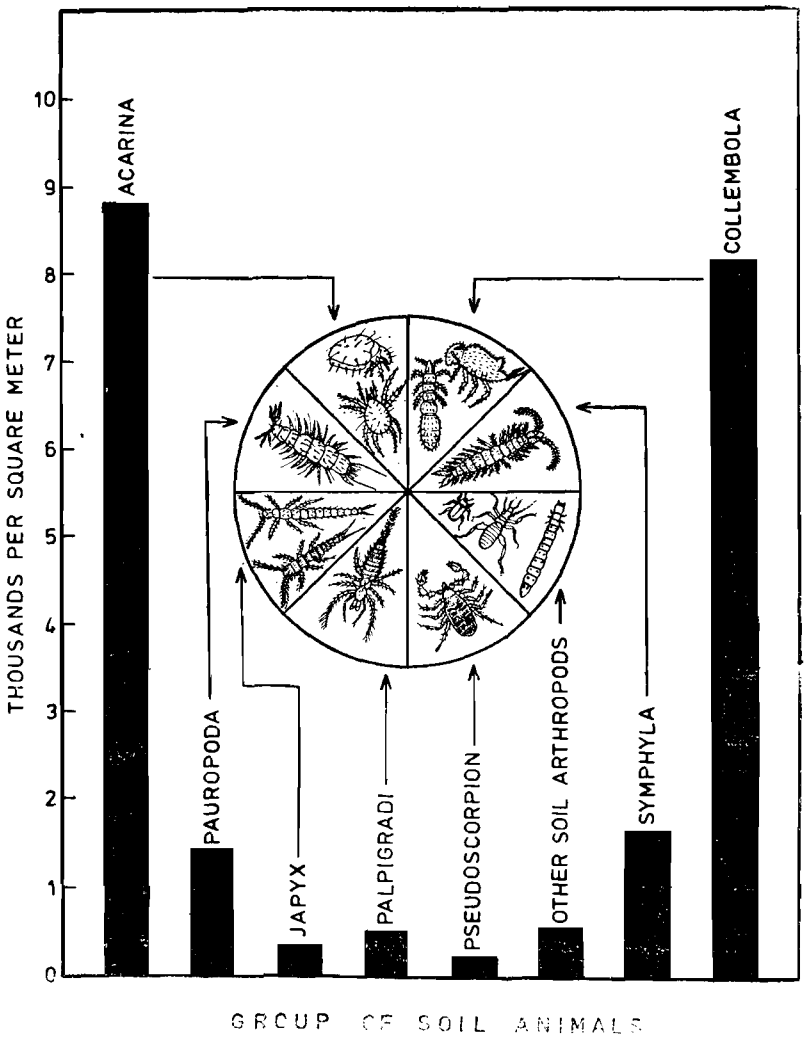

Fig. 4

Astigmata

The soil-dwelling members of this order belong to the family Acaridae. At Varanasi, this group is represented by only one genus, *Tyrophagus* (Singh and

Mukharji, 1971). These mites are not important elements in acarine fauna of many soils and their role in the soil community had been little studied. They constitute not more than 3 per cent of the total acarine fauna in the Varanasi soils (Singh and Pillai personal communication). The feeding habits of the soil-dwelling members of this groupt of mites are not well known, although it is probable that they feed on plan detritus, fungi and algae.

Cryptostigmata

The Oribatid mites are one of the richest soil arthropod groups both in numbers of species and individuals. Because of their numbers, they are most probably play an important role in the decomposition of organic substances. Balogh (1972) reported about 700 known genera of this group of mite but in India so far only 32 species and 21 genera are known to me (Bhattacharya *et al.*, 1974).

Singh and Mukharji (1971) and Choudhuri and Banerjee (1975) described the species composition of cryptostigmatid mites. Singh and Pillai (communicated) reported that Cryptostigmata accounted for 16.99 to 41.21 per cent of the total Acari in different fields at Varanasi. Singh and Pillai (1975) recorded *Oppia, Fosseremus. Galumna, Leptogalumna. Lohmannia, Epilohmannia, Protoribates, Scheloribates, Mycobates, Oribatula* and *Cryptacarus.* Among different species of Cryptostigmata, *Protoribates* was maximum in number per sample in all fields (Singh and Pillai, 1976). Species like *Posseremus, Galumna, Cryptacarus* and *Rhysotritia* were lower in frequency and numbers in different fields.

Collembola (Insecta)

The Collembola or 'springtails' represent one of the major groups of the soil mesofauna. A useful and comprehensive taxonomic treatment of Indian Collembola is given by Prabhoo (1971, 1791a) and Yosii (1966). Singh and Pillai (communicated) recorded relative abundances of Collembola in the total fauna ranging from 10.86 to 37.82 per cent in different fields. Collembola were the second largest group of micro or mesoarthropods The predominant genera in all habitats were *Onychiurus, Paratullbergia, Subisotoma, Isotomurus* and *Folsmides.* The other genera present in all habitats, but less frequently, were *Protdphorura, Hypogastrura, Xenylla, Friesea, Lobella, Pseudachoruptes, Cyphoderus, Lepidocyrtoides* and members of family Sminthuridae. Singh and Mukharji (1971) and Choudhuri and Banerjee (1975) listed the different species of Collembola. Choudhuri and Roy (1967, 1971, 1971a, 1972) carried out many ecological studies on Collembola in West Bengal. They reported 25 genera of the families Entomophryidae, Onychiuridae, Hypogasturidae, Neanuridae, Isotominidae and Sminthuridae. The population figures of Collembola of Choudhuri and Roy (1972) are not very clear.

Mukharji and Singh (1970) recorded that during the months of December

and February the Collembola population increases and reaches a peak during the months of March, August and January. Mahajan (personal communication) reported that Symphypleona group of Collembola is very common in the litter of decidous forest during rainy season in Varanasi. Singh and Pillai (1975) reported significant variations in the relative abundance and species composition of Collembola in the different habitats. The highest population density of *Folsomides* in fallow land and onychiurids in the banana field was unique. Qualitative composition of Collembola in different fields have showed that some species were more specific to particular habitats.

Diplura and Protura (Insecta)

Diplura and Protura share with Collembala the cryptozoic form of life. Diplurans and proturans are often neglected by soil zoologists because they are rarely collected in large numbers. Diplura may be subdivided into Campodeidae, Japygidae and Anajapygidae. The members of Japygidae are rather more robust and predatory in habit. Compodeids are also predators and the diet of both of these groups of Diplura consist of small soil arthropods such as Collembola as well enchytraeids etc. Singh and Mukharji (1971) listed the different species of Diplura. Singh and Pillai (personal communication) collected not more than 1 Protura per sample from banana field and not more than 3 Japyx per sample though they were present in all habitats· Very little information is available about Protura in this country and even in some entomological books (Kalyanam, 1967) it is stated that they are not recorded in India. Prabhoo (1972) reported different species of Protura from South India. Choudhuri and Roy (1970) reported the presence of Protura in some Districts of West Bengal. Singh and Pillai (communicated) reported the presence of Protura only in one field and it appears that Protura prefers humid soil rich in organic matter. Little is known about the feeding habits of proturans. Mahajan (personal communication) reported Protura from forest soil. This group requires further attention from soil zoologists.

Pauropoda (Myriapoda)

Pauropods are extremely small, rarely more than 1-2 mm in length and are seldom found in large numbers in the soil. They are easily recognised by their branched antennae. Very little information is available about Pauropoda. In sugarcane fields very high populations of this group of tiny animal have been recorded (Singh and Mukharji, 1971, 1973). Singh and Pillai (communicated) reported that Pauropoda contribute up to 6.6 per cent of the total fauna in some fields at Varanasi. They further recorded a maximum of 11 pauropods per sample from a banana field.

Symphyla (Myriapoda)

Symphylids are delicate myriapods, white in colour, rarely more than

10 mm in length with 11–12 pairs of legs in the adult. Symphylids feed voraciously, mainly on vegetable materials and soil microorganisms and some, such as *Scutigerella immaculata*, are the serious pests in glass house. They help in the breakdown of soil organic matter, particularly in glass houses, where they may be the dominant group of soil arthropods. These are considered to be very rare animals, but in several surveys of soil at Varanasi they were the most numerous myriapods present (Singh, 1970). He further reported that symphylids are very common particularly in rose, sugarcane and botanical gardens than in other fields. Singh and Pillai (communicated) reported symphylids up to 7.5 per cent of total fauna and a maximum of 13.0 per sample in a banana field. Singh and Mukharji (1971) reported *Scutigerella* and *Scolopendrella* as common genera.

Enchytraeidae (Oligochaeta)

The Enchytraeides is a family of small oligochetes, usually a few mm long. The largest species grow up to 5 cm long but the majority of species are 1 cm or less in length. These are commonly known as potworms, are white in colour and relatively uniform in size. They are widely distributed in terrestrial littoral and aquatic habitats especially where the conditions are somewhat acidic and rapid decomposition is occurring. They are particularly abundant, especially in acid soils with high organic matter content, in most temperate regions. Nielson (1955) estimated that population densities varied between 1000 and 100,000/m^2, compared with peak densities of over 200,000/m^2 in the more acid soils of heathland and conifer forest in Denmark.

With the exception of taxonomic studies by Prabhoo (1961, 1964) and Dash and Thambi (in press), the Enchytraeidae have not been studied in India and no ecological observations have been carried out. Thambi and Dash (1973) reported seasonal variation and biomass of enchytraeid populations in tropical grass-land at Berhampur (Orissa). They reported *Enchytraeus* and *Marioninia* as the most dominant species. The maximum density of the worms reached some 7000/m^2 in late August-September and the density remained around 5000/m^2 in autumn-winter. The minimum density reached some 500/m^2 in April-May.

Macrofauna

The macrofauna includes Lumbricidae (earthworms), Chilopoda (Centipedes), Diplopada (millipedes), wood-lice (Isopoda), pseudoscorpions (Chelonethi) and Palpigradi (Arachnida) and insects belonging to different orders such as Pascoptera, Embioptera, Dermaptera, Zoraptera, Hemiptera including litter-inhabiting bugs and root-feeding cicada nymphs, orthopteroid insects like crickets and grass hoppers, beetles and their grubs belonging to the families Elateridae (wireworms), Carabidae, Scarabaeidae, Melolonthinae;

lepidopterous larvae, fly maggots (Diptera), termites (Isoptera), ant-lions myrmilionidae, ants (formicidaes), root aphids and thrips. Of these, wire worms, chafer beetles, termites and crickets are capable of causing extensive damage to cultivated crops. Most of the higher insects are, however, temporary soi dwellers and spend only a part of their lives under subterranean conditions.

Palpigradi (Whipscorpions)

Palpigradi : Micro-whip-scorpions are tiny animals, 5 mm in length or less, with a long segmented tail. Singh and Mukharji(1971) collected *Koenenia* sp. from different fields. Singh and Pillai collected up to 5 Palpigradi per sample from a banana field. Most probably this is the first record of Palpigradi from India.

Chelonethi (Pseudoscorpion)

The pseudoscorpions are small arachnids, seldom over 5 mm in length. They feed chiefly on small insects. Choudhuri and Roy (1970) and Singh and Mukharji (1971) collected pseudoscorpions from different fields. Choudhuri and Roy (1970) mentioned that *Neobisium muscorum* (Pseudoscorpion) feeds on Collembola. Singh and Pillai (Personnel communication) also collected pseudoscorpions from different fields.

Lumbricidae (Oligochaeta)

They are commonly known as earthworms or night crawlers. Earthworm activity in the soil consists mainly of burrowing, ingestion and partial breakdown of organic matter and of subsequent egestion in the form of sub-surface or surface casts. The amount of soil worked over by earthworms is is tremendous ; much ecological work is needed on this important group of soil fauna in our country.

Chilopoda (Centipedes) and Diplopoda (Millipedes) (Myriapoda)

Centipedes are elongated flattened myriapods with alternate large and small segments, each bearing a pair of legs. They are widely distributed in moist habitats often found under leaf litter, in crevices, under rocks and bark of decaying fallen trees. They are carnivorous, feeding on aphids, flies, springtails mites, mematodes and other centipedes.

Millipedes are sparsely distributed. Their density ranges from a few to 80 individuals/m^2. They feed mainly on decaying plant materials. Some species can feed on fresh litter or even plant parts and as such cause occasional damage to germinating plants. No ecological data is available on this group of animals in India.

Woodlice (Isopods : Crustacea)

Woodlice live under logs and stones, mostly in dark and damp places in order to keep their delicate gill-like appendages moist. They have some ability

to conserve moisture due to the presence of their waterproof cuticle. Woodlice are largely omnivorous. Seasonal vertical migrations have been observed in many species. During the wet season they congregate on the top layer of soil profile and in the dry season migrate below it. The woodlice have not been studied in India ; therefore, no ecological information is available.

For the collection of soil we are using soil samplers of different sizes. For extraction purposes we are using floatation methods (Ladell apparatus, Ladell, 1936 and Singh and Pillai, 1976) and Tullgren funnels.

References

Balogh, J., 1972, The oribatid genera of the world. *Akademiai Kiado*, Budapest, 189 pp.

Bhattacharya, T., Bhaduri, A. K. and Raychaudhuri, D. N., 1974, Soil Oribatid mites of Santiniketan, Birbhum, West Bengal-I (Acarina : Lohmanniidae). *Oriental Insects*, **8** : 281-289.

Choudhuri, D. K. and Banerjee, S., 1975, Qualitative and quantitative composition of acari and Collembola in relation to soil organic matter-microbes complex. *Oriental Insects*, **9** : 313-316.

Choudhuri, D. K. and Roy, S., 1907, Qualitative composition of the collembolan fauna of some uncultivated fields in Nadia District (West Bengal) with a correlation between monthly population and individual soil factors. *Rev. Ecol. Biol. Sol.*, **4** : 507-515.

Choudhuri, D. K. and Roy, S., 1970, Interactions between soil Collembola and other subterranean arthropods. *Sci. Cult.*, **36** : 280-282.

Choudhuri, D. K. and Roy, S., 1971, Distribution of Collembola in relation to soil conditions in the district of Jalpaiguri, West Bengal (India). In *Organisms du Sol et Production Primaire, Proceedings of IV Colloquium Pedobiologiae*, 289-296, I.N.R.A., Paris.

Choudhuri, D. K. and Roy, S., 1971 a, The Collembola (Insects) of the uncultivated fields in Burdwan district (West Bengal), with remarks on correlation between monthly population and certain soil factors. *Proc. Zool. Soc.*, Calcutta **24** : 33-39.

Choudhuri, D. K. and Roy, S., 1972, An ecological study on Collembola of West Bengal (India). *Rec. Zool. Surv.*, India, **66** : 81-101.

Dash, M. C. and Thambi, A. V. (In Press). A taxonomic study of Enchytraeidae (Oligochaeta) from grassland soils of Southern Orissa, India. *Rev. Ecol. Biol. Sol.*

Kalyanam, N. P., 1967, *Common Insects of India.* Asia Publishing House, Bombay, 136 pp.

Ladell, W. R. S., 1936, A new apparatus for separating insects and other arthropods from the soil. *Ann. appl. Biol.*, **23** : 862-879.

Mukharji, S. P. and Singh, J., 1970, Seasonal variation in the densities of a soil arthropod population in a rose garden at Varanasi (India). *Pedobiologia*, **10** : 442-446.

Nielson, C. O., 1955, Survey of a year's results obtained by a recent method for the extraction of soil-inhabiting enchytraeid worms. In *Soil Zoology* (Kevan, D. K. McE., Ed.) pp. 202-214, Butterworths, London.

Pillai, K. S., 1974, *Ecological Studies* of *Soil Mesofauna in Some fields at Varanasi*. Ph.D. Thesis, Banaras Hindu University, 140 pp.

Prabhoo, N. R., 1961, Studies on Indian Enchytraeidae (Oligochacta:Annelida). I. Descriptions of three new species. *J. Zool. Soc.*, India **12** : 125-132.

PRABHOO, N. R., 1964, Studies on Indian Enchytraeidae (Oligochacta:Annelida) II. Determinations of two new species. *J. Zool. Soc.*, India, 16 : 82–86.

PRABHOO, N. R., 1971, Soil and litter Collembola of South India I-Arthropleona. *Oriental Insects*, 5 : 1–46.

PRABHOO, N. R., 1971a, Soil and litter Collembola of South India II–Symphypleona. *Orientae. Insects*, 5 : 243–262.

PRABHOO, N. R.: 1972, South India Protura. I–Two new species and three new records of Acerontomoidea. *Rev. Ecol. Biol. Sol.*, 9 : 711–718.

SINGH, J., 1970, *Studies of Soil Arthropods in Relation to Certain Ecological Factors*. Ph.D. Thesis Banaras Hindu University, 109 p.p.

SINGH, J. AND MUKHARJI, S. P., 1971, Qualitative composition of soil micro-arthropods in some fields at Varanasi (India). *Oriental Insects*, 5 : 487–494.

SINGH, J. AND MUKHARJI, S. P., 1973, Population size of soil arthropods in some fields at Varanasi (India). *Sci. Cult.*, 39 : 498–500.

SINGH, J. AND PILLAI, K. S., 1973, The world beneath us. *Science Reporter*, 318–321.

SINGH, J. AND PILLAI, K. S., 1975, A study of soil micro-arthropod communities in some fields. *Rev. Ecol. Biol. Sol.*, 12 : 579–590.

SINGH, J. AND PILLAI, K. S., 1976, The use of floatation method in the collection of microarthropod from arable soil in India. *Rev. Ecol. Biol. Sol.*, 13 : 331–335.

SINGH, J. AND PILLAI, K. S., 1976, Biocoenology of soil acari in some fields in Varanasi. *Acarology Newsletter*, 2 : 5–6.

SINGH, J. AND PILLAI, K. S. (communicated). Community structure and biocoenology of soil microarthropods in some fields at Varanasi (India). *Trans. R. Ent. Soc.*, London.

SMITH, LEO ROBERT, 1966, Life in Soil. In *Ecology and Field Biology* (Smith, Leo Robert). Harper and Row, Publishers, New York and London, pp. 261–274.

THAMBI, A. V. AND DASH, M. C., 1973, Seasonal variation in number and biomass of Enchytraeidae (Oligochaeta) populations in tropical grassland soils from India. *Tropical Ecology*, 14 : 228–237.

WILLARD, J. R., 1974, Soil invertebrates:VIII. A summary of populations and biomass. *Tech. Report* No. 56. Metador Project Canada.

YOSII, R., 1966, On some Collembola of Afghanistan, India and Ceylon, collected by the Kuphe Expedition, 1960. Reprinted from results of the Kyoto University Scientific expedition to the Karakoram and Hindukush, 1955, Vol. VIII.

Microarthropods Associated in the Decomposition Process of Pitter Litter of Meghalaya Pine (*Pinus khasya* Royle) Forests

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ABSTRACT

A study was made during the period May–August, 1976 of the microarthropods associated with the decomposition of the litter of pine forests of Meghalaya, North-East India. For this, five forest sites of different age group plantations of 1970 (young plantation), 1965, 1961 (High altitude *i.e.* 1190 metres) and 1961 (Low altitude *i.e.* 900 metres) and 1955 (Oldest plantation) were selected.

Observations were recorded on the differences in microarthropod abundance, their seasonal fluctuations in numbers and their role on litter decomposition in relation to different environmental conditions, such as the litter moisture, temperature, pH etc., at different sites. It was found that among microarthropods Collembola and Acarina play the most active role in the decomposition process of the pine litter under natural conditions.

Interesting correlations were obtained between the litter moisture, pH and the abundance of microarthropods (Collembola and Acarina) in litter bags. The significance of these data is discussed.

MANY species of soil microarthropods play a key role in the mineralization of litter. Information on their life habits, feeding behaviour, distribution and population changes is quite meagre and accumulated very slowly. This is mainly due to methodological problems. Litter bags have been employed to investigate whether the microarthropods of litter and soil layers are discrete populations with little intermingling and whether the composition of the litter fauna is a function of litter type. Litter bags are used to follow the succession of microarthropod species involved in the decomposition process of litter. Although the litter bag method has the advantages of permitting 1. complete separation of the litter and mineral soil components and 2. evaluation of the effect of mesh size of bag, the difficulties encountered are, the nylon bags which are commonly used are subject to damage and decay. Fibreglass bags are now being used in litter decomposition studies abroad but these are not available in India.

Microarthropods associated with the decomposition of pine litter in five different cultivated stands were studied in this investigation. The effect of

different environmental factors such as moisture and pH on the densities of these organisms was analysed.

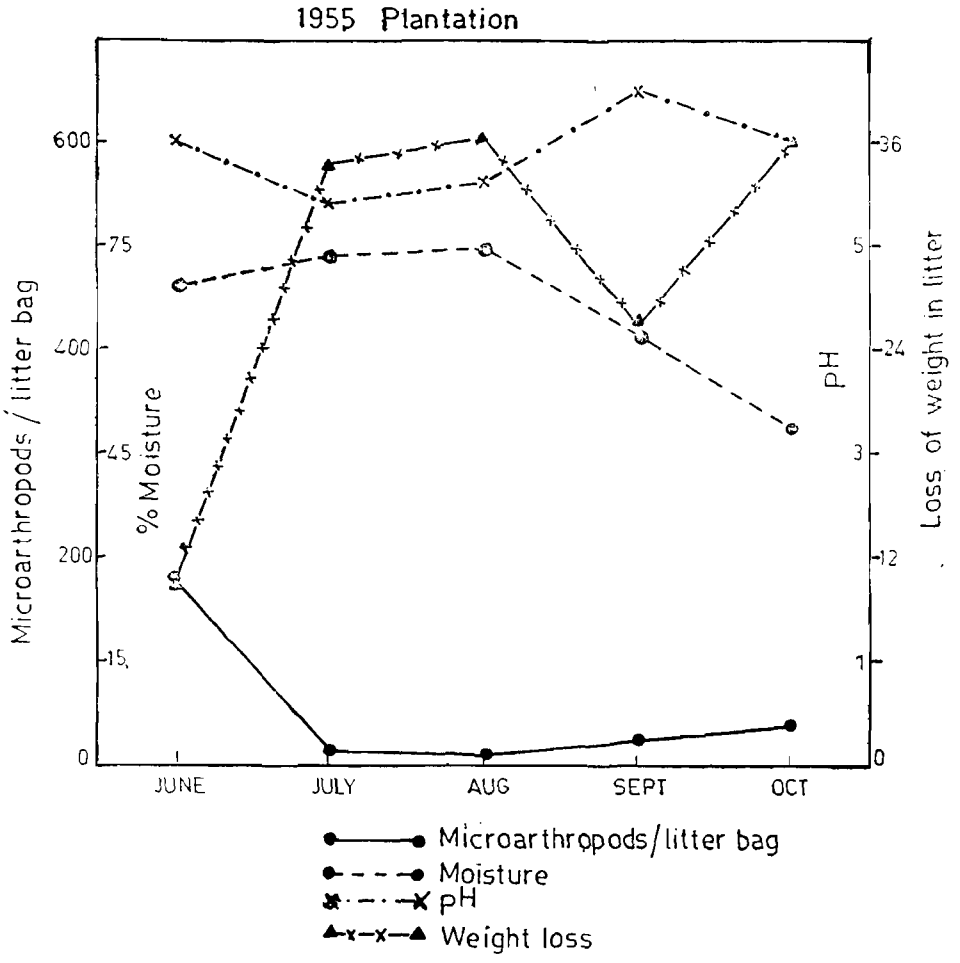

Fig. 1

Study areas

This study was conducted in five cultivated pine forests of different age groups in Shillong (25.34°N and 91.56°E), India. These five pine stands are at slightly different altitudes *viz.*, 1955 plantation at 1250 metres, 1970 plantation at 1225 metres, 1965 and one 1961 plantation at 1200 metres and another 1961 plantation at 950 metres. The common dominant undergrowths of all the experimental sites are *Artemisia* and *Eupatorium*.

Material and Methods

Nylon bags of 1 mm mesh size and 1 dm^2 were used for the present study. The choice of the mesh size and bag dimension is based on the report of

Crossley and Hogland (1962). Freshly-fallen pine needles were collected at the time of needle fall in April (1976). The needles were cut into uniform lengths of 5 cm and air dried. 10 g of air dried litter was then placed in each of the 1 dm^2 nylon bags. A total of 180 bags were prepared out of which 36 bags were placed in each of the five plantations (1955 plantation, 1965 plantation,

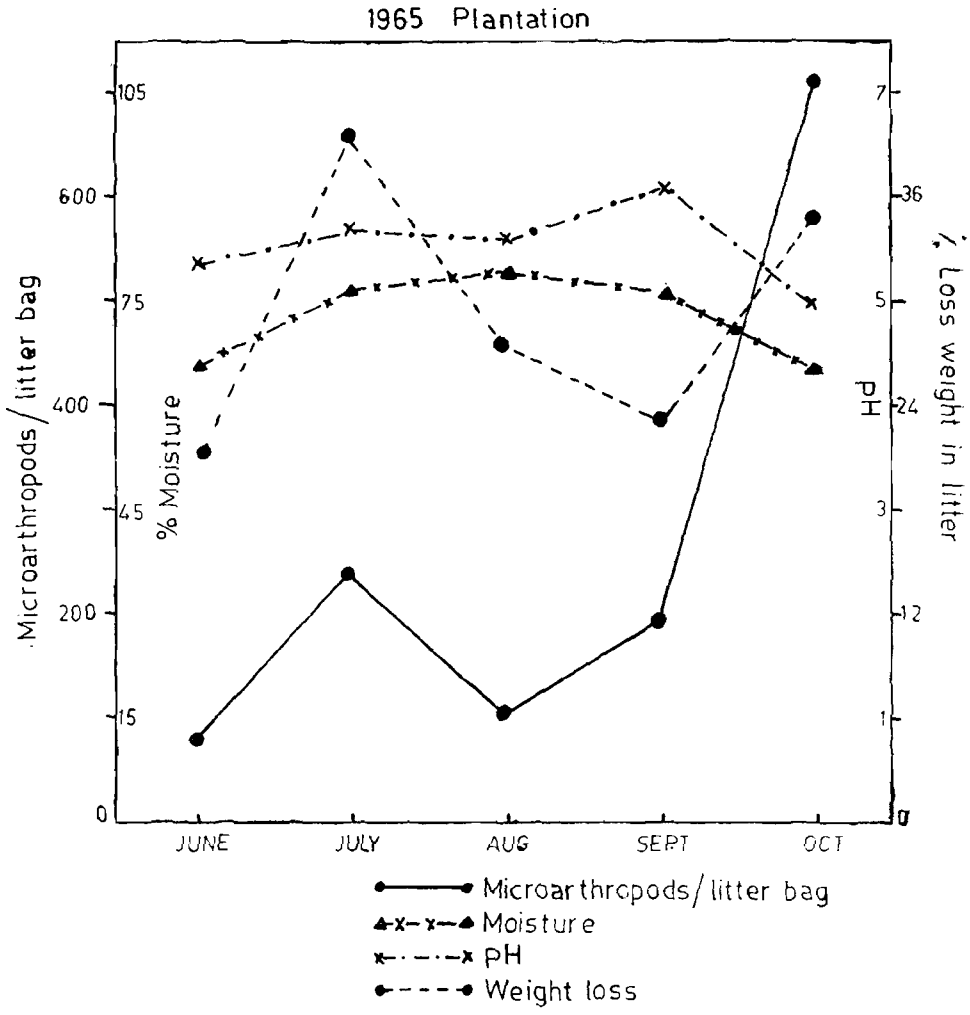

Fig. 2

1970 plantation, and 1961 plantations at two different elevations), under the litter of the forest floor. Thereafter, three bags were collected from each site every 30th day for a period of five months. Immediately on removal, the litter bags were sealed individually in polythene bags. The moisture content was determined by ovendrying to a constant weight at 105°C. The pH was recorded using a pH meter (Toshniwal type CL 43). Microarthropods were extracted by

a modified Tullgren funnel (Macfadyen 1955). The extracted microarthropods were categorised as Collembola, Acarina and miscellaneous group.

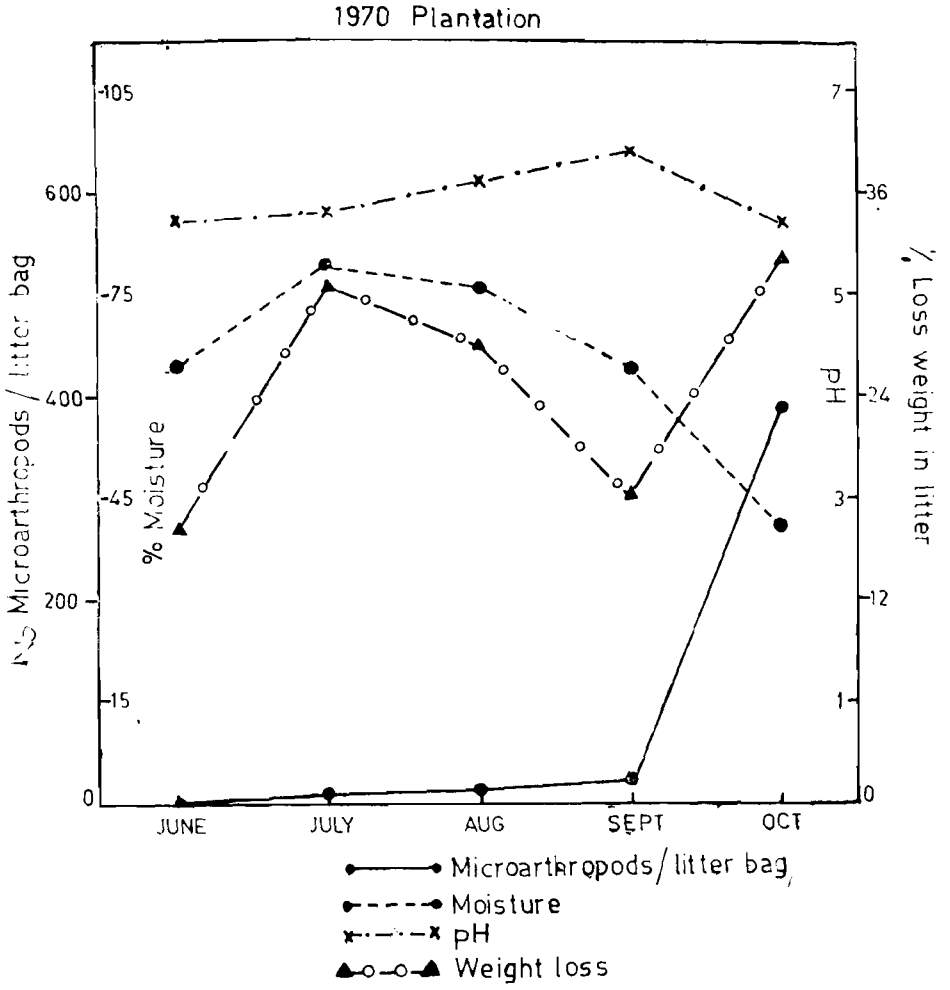

Fig. 3

Results and Discussion

A perusal of Table I in which the population densities of the three categories of microarthropods are summarised, reveals that the Acarina and Collembola are abundant with fluctuating densities, all through the five months (15th May to 15th Oct. 1976). Of the five plantations the greatest microarthropod abundance was observed in the 1965 plantation at 1200 m which has a thick tree density and rich litter layer. In contrast to this, very low densities of microarthropods were recorded in the 1961 (1200 m) plantation and 1955 (1250 m) plantation, which had been suffered from natural forest fire in March-April, 1976. The microarthropod density in the 1970 (1225 m) plantation and

1961 (950 m) plantation fall between these two extremes. This may be related to the comparatively moderate litter fall in these plantations. Quite a few of the litter bags used were found to be damaged. Other larger arthropods such as isopods, Symphyla and chironomid larvae (Diptera) were frequently found in such bags. These bags registered a marked weight loss as could be expected. The high densities of Collembola and Acarina recorded in October were due to addition of young ones and not by immigration, since gravid females and developing young ones were observed in the bags.

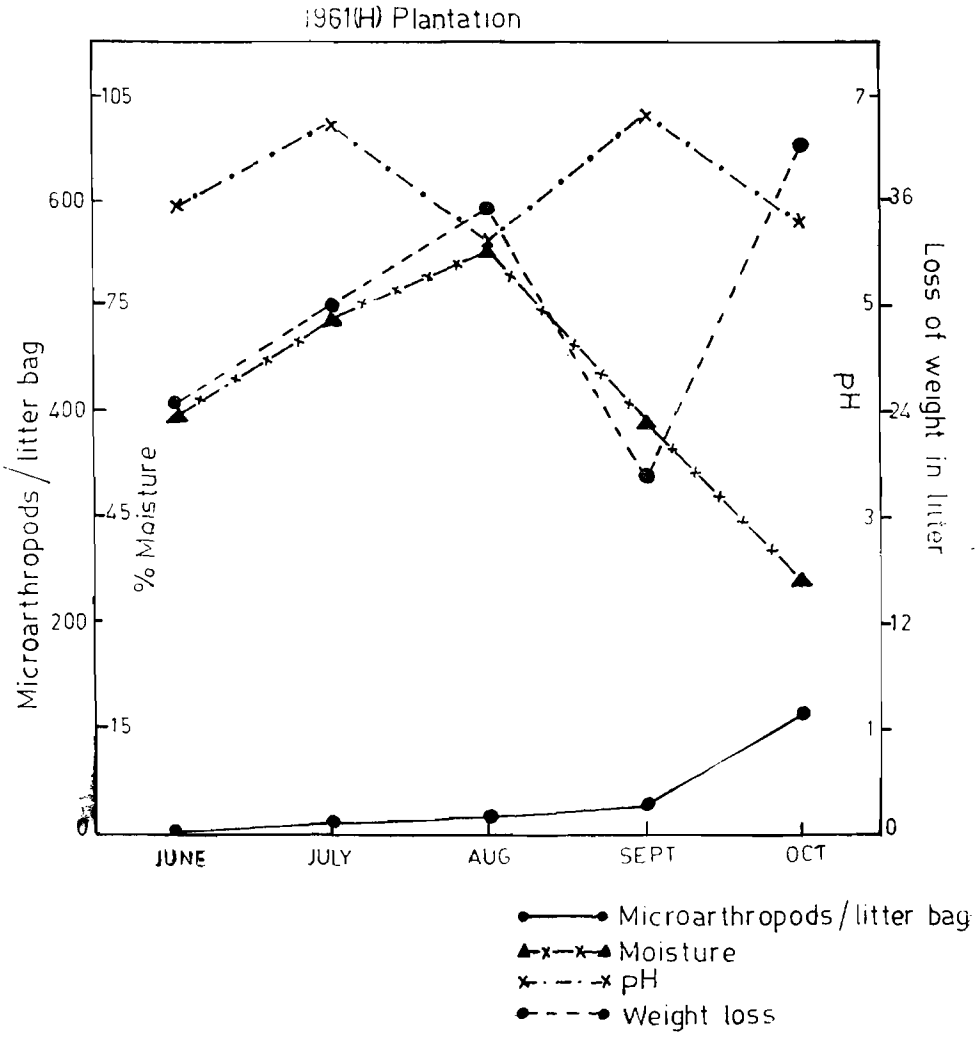

Fig. 4

Moisture contents of the bags ranged from 40 to 82 per cent (Table II). These low and high levels correspond to the dry (October) and rainy months (July and August) respectively. The pH was always on the acidic side (5.1 to

6.5 Table II) in all the plantations, without much variation in each. No correlation existed between microarthropod abundance and either moisture or pH.

TABLE I

Total mean number of different groups of microarthropods seen in the litter bags

Year of plantation	June				July				August				September				October			
	C.	A.	Misc.	Total	C.	A.	Misc.	Total	C.	A.	Misc.	Total	C.	A.	Misc.	Total	C.	A.	Misc.	Total
1970	0	0	0	0	2	6	2	10	4	7	3	14	3	18	2	24	186	204	3	393
1965	70	3	2	75	226	8	3	237	94	5	3	102	146	47	4	196	525	170	17	712
1955	2	173	1	176	4	7	2	13	2	4	2	8	4	16	2	24	22	15	3	40
1961 High altitude	0	3	0	3	2	7	1	10	5	8	3	16	7	17	3	27	34	81	2	117
1961 Low altitude	4	5	2	11	6	8	3	17	9	7	4	20	22	16	4	41	131	145	25	301

C=Collembola
A=Acarina

TABLE II

Microarthropod frequency in relation to pH, moisture and weight loss in litter

Year of plantation		June	July	August	September	October
1970	A	0	10	14	23	39.3
	B	16%	30.5%	27%	18%	32%
	C	5.75	5.85	6.15	6.45	5.75
	D	65%	79.3%	76.2%	63.9%	40.3%
1965	A	75	237	102	196	712
	B	21%	39.5%	27.5%	23%	35%
	C	5.4	5.7	5.6	6.1	4.9
	D	65	76%	78%	75.4%	64.1%
1955	A	176	13	8	24	40
	B	10.5%	35.3%	36.5%	25%	36%
	C	6	5.4	5.6	6.5	6
	D	69	73	74.3%	61.7	48%
1961 (High altitude)	A	3	10	16	27	117
	B	24.2 %	30%	35.4%	20%	39%
	C	5.9	6.7	5.6	6.8	5.8
	D	59	73.2%	82.8%	57%	34.7%
1961 (Low altitude)	A	11	17	20	41	301
	B	20.5 %	37%	33.8%	21.5%	33%
	C	5.3	5.5	6.8	5.8	5.1
	D	65%	74.5%	76.6%	62.8%	41.1%

A=Total microarthropods.
C=pH
B=Per cent of weight loss in the litter (in the bags)
D=Per cent of moisture content of the litter.

A strong positive correlation between moisture content and the densities of microarthropods per litter bag has been established by Weigert (1974) in his work in South Carolina old fields in U.S.A. Anderson (1975) in his work in Blean Woods National Nature Reserve, U.K., could not establish any correlation between weight loss in litter bags and microarthropod abundance and recorded a low correlation between moisture and microarthropod adundance. In the

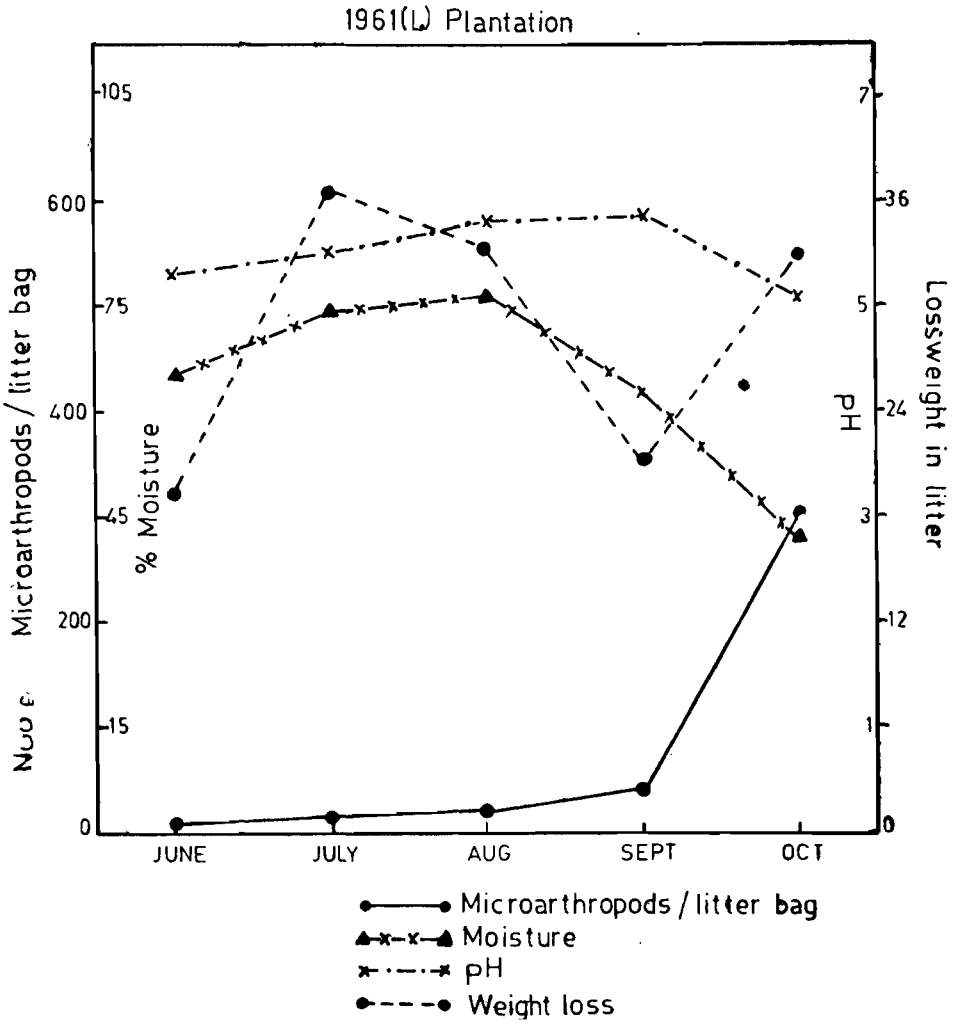

Fig. 5

present study, although the increased in weight loss observed in the litter bags corresponds to the increased abundance of microarthropods, no significant statistical correlation could be established between these two. This is explained by reports on oribatid mites Wallwork (1958) and Wooley (1960) who showed that not all mites are capable of feeding on fresh or coarse litter and that many

species require greatly decayed material. Litter decomposed by a sucession of arthropods species. (Anderson 1975).

The species invading the litter bags are determined by the mesh size of the bags used. The changeover in mites from fungal-feeding to litter-feeding occurs when polyphenols are reduced to low concentrations (Anderson 1973).

The slow rate of breakdown of litter confined in the litter bags can be attributed to the exclusion of earthworms and other larger meso-and macro fauna of the soil which fragment the litter make it palatable to most species of litter-inhabiting microarthropods. The microarthropods which occupy the various soil horizons act upon the decayed litter in succession as the litter becomes incorporated into the deeper layers of soil with progressing decay. Litter bags present such incorporation and this again slows down the rate of decomposition.

The authors wish to express their thanks to Prof. R. G. Michael and Prof. P. S. Rama krishnan, Head of the departments of Zoology and Botany respectively for providing necessary facilities. They are also grateful to Dr. J. M. Anderson, Hatherly Laboratories, UK, for his constant encouragement and helpful suggestions. Our thanks are due to North-Eastern Hile University and University Grants Commission for financial assistance.

References

Anderson, J. M., 1973, The breakdown and decomposition of sweet chesnut (*Castanea sativa* Mill) and beech (*Fagus sylvatica* L.) leaf litter in two decidous woodland soils : 1 Breakdown, leaching and decomposition. *Oecologia.*, **12**: 251-274.

Anderson, J. M., 1975, Succession, diversity and trophic relationships of some soil animals in decomposing leaf litter. *J. Anim. Ecol.*, **44**: 475-495.

Crossley, D. A. and Hogland, M. P., 1962, A litter bag method for the study of micro-arthropods inhabiting leaf litter. *Ecology*, **43**: 571-573.

Macfadyen, A., 1955, A comparison of methods for extracting soil arthropods. In: *Soil Zoology*, ed. Mc. E. Kevan, D. K., Butterworths, London pp. 315-332.

Wallwork, J. A., 1958, Notes on the feeding behaviour of some forest soil Acarina *Oikos*: **9**: 260-271.

Weigert, R. G., 1974, Litter-bag studies of microarthropod populations in three South Carolina old fields. *Ecology.*, **55**: 94-102.

Wooley, T. A., 1960, Some interesting aspects of oribatid ecology (Acarina). *Ann. Ent. Soc. Amer.*, **53**: 251-253.

Soil Arthropod Pests of Sugarcane in Tamil Nadu and their Control

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ABSTRACT

The sugarcane crop in Tamil Nadu is infested by a number of soil insects such as termites, white-grubs, aphids, ants, mealybugs, weevil etc., and non-insect arthropods such as isopods, myriapods and sympylids. These have for long been considered to be minor pests and so have not received much attention by economic entomologists.

These subterranean pests damage the sugarcane crop at different stages, beginning with germination and continuing till harvest. The germinating buds and setts are damaged, creating gaps in the crop. Subsequently, the roots underground stem portions are damaged, sometimes leading to total loss of fully-grown canes. The soil also harbours foliar pests like weevils, army-worms and grasshoppers. As well as direct injury, pests like root aphids transmit diseases. Because of their underground habitat, their activity becomes visible when the damge is in advanced state.

Soil application of insecticides like BHC has given good control of the pests and also increase in yield of cane, but has slightly harmful side effects such as persistence of the insecticide in the soil, phytotoxicity and adverse effects on beneficial organisms. These aspects are discussed in the paper.

SEVERAL species of soil arthropods are associated with sugarcane crops from planting to harvest, sometimes causing considerable damage to the crop (Avasthy, 1967; Long and Hensley, 1972). Termites have long been considered to be a major pest problem, particularly in sandy soils. White grubs have become a serious menace to sugarcane crops in several parts of the country during the last two decades. Other pests which are of some economic importance in recent years are soil isopods, root aphids, mealybugs, etc. (David, 1965; Jasmine and Ananthanarayana, 1975). Because of their subterranean habits and sporadic attacks, these pests have not received sufficient attention from economic entomologists. The work done in Tamil Nadu on these pests in sugarcane is discussed in this paper.

Species of soil arthropods in Tamil Nadu associated with sugarcane

The soil and the associated cane trash also shelters weevils, grasshoppers and armyworms, which damage the foliage.

Nature and extent damage

Termite damage to sugarcane is mainly by reducing the germination of setts, to the extent of 28 to 67 per cent, while the fully-grown canes are attacked only up to 1 per cent. *O. obesus* enters through the cut ends of setts and *T. biformis*

TABLE I

Important soil arthropods infesting sugarcane in Tamil Nadu

Name of arthropod pest	Part of cane damaged	Distribution
1. Termites		
Odontotermes obesus Rhomb.	Setts and fully-grown canes	All sandy soil areas in the State. Tanjore, Coimbatore.
O. bengalensis Holmgren	Setts	
Microtermes obesi Holmgren	Setts	
Trinervitermes biformis Wassmann	Sett buds	South Arcot, Tanjore.
2. White grubs		
Holotrichia serrata F.	Roots, rootlets and underground stalk	Coimbatore, Salem, North Arcot.
Anomala bengalensis Blanch	Roots rootlets and underground stalk	Coimbature.
3. Soil isopods		
Philoscia sacchari George	Sett buds	Tanjore and Coimbatore.
4. Root aphids		
Tetraneura javensis v.d. Goot	Roots and rootlets	Coimbatore.
Forda orientalis Green.	Roots and rootlets	Coimbatore.
5. Mealybugs		
Kirltschenenkella saccharalis	Roots and stems	Coimbatore and Tanjore.
6. Symphylids		
Identity unknown	Roots and root hairs	Coimbatore.

through the buds. A loss of 2.5 per cent in tonnage and 4.47 per cent in sugar production has been estimated. The damage is more severe during drought conditions. The soft parts of the planted setts are completely eaten away by the worker termites and in the fully-grown canes, these feed first on underground stalk region and then continue to feed on the standing cane from below upwards for a few feet rendering the cane a papery rind with soil and termite excreta inside. The outer leaves of the dameged shoots dry up first and subsequently the entire shoot dries up and the cane is dislodged.

White grubs: These feed on the roots and root-hairs extensively. The underground stalks are also gnawed and used as shelter. In severe infestations, the entire root system is completely eaten away and such canes fall down and dry up. The partially eaten roots turn black, the foliage changes to a yellow colour and the crop remains stunted under light infestation. Such canes may recover during September–October, when the grubs enter into the inactive pre-pupal stage. White-grub attack is generally in patches but in epidemic conditions, entire fields of 2–5 acres are totally damaged within a few days during July–August. Such canes are seldom useful for crushing or even for seed purpose.

Isopods: The nymphs of *P. sacchari* cut circular holes in the sett-buds and feed within the bud. The damaged buds fail to germinate. The nymphs also nibble through the root primordia in the germ band and prevent the formation of sett-roots. In the Tanjore district, bud damage has been to the extent of 2.3 to 12.7 per cent (David, 1965).

Aphids and mealy bugs: Colonies of root aphids, both adult and nymphs, are generally located 5–8 cm below soil surface, mostly on fresh roots (Nagarajan, 1957). There desap the sugarcane plants and consequently the leaves turn yellow and the infested plants become stunted in growth. Symptoms of mosaic are also noticeable among the infested plants (Jasmine and Ananthanarayana, 1975), indicating the possibility of the root aphid being associated as mosaic vectors. Young plants are more affected than fully-grown canes. In the Salem district, entire fields of more than 2 acres have been found to be affected by an unidentified species of aphid.

Mealy bug attacks have also been observed in ratoons, particularly when poorly-manured and neglected. These drain the sap leading to stunted growth of the crop.

Symphylids do damage to roots and rootlets of sugarcane seedlings by forming "pits", and can cause 30 to 40 per cent plant mortality at times (Rao, 1959).

Bionomics: Very little information is available on the bionomics of the soil arthropods associated with sugarcane. Termites thrive well in sandy soils, when the climate is warm, or during drought or water scarcity. The presence of organic matter in the soil such as cane trash is condusive to their multiplication. It is well-known that sugarcane fields applied with cane leaf trash as mulch are prone to heavy invasion by termites.

Whitegrubs are also more commonly in sandy soils rich in organic matter, although the pest also occurs in heavy and gravelly soils. The presence of trees like neem and *Ailanthus* around sugarcane fields helps in perpetuating the pest in the same area, because the adults feed on them and lay eggs in the bunds of channels or in the moist soil in the vicinity of or inside sugarcane fields. Under Coimbatore conditions, the activation of beetles from dormancy in the soil depends not on rains but on some showers during March-May which stimulate greater beetle activity (David and Ananthanarayana, 1974). As these whitegrubs are polyphagous, the presence of living roots in the soil, including those of many grasses are sufficient for their survival and growth, although pupation is retarded, larval size reduced and mortality high, as compared to those feeding on sugarcane roots. At Coimbatore, two natural enemies, *Bacillus popilliae* Dutky and *Scolio* sp. have been observed

to be active against the second and third instar grubs (David and Alexander, 1975).

The isopod, *P. sacchari* appears to be mainly saprophytic, because it thrives well when supplied with rich organic material in the soil. Its occurrence is also conditioned by the availability of sufficient moisture in the soil, and it is generally absent from dry soils.

Aphids and mealy bugs are always associated with ants, which appear to assist them to distribute among fresh roots in the sugarcane plants.

Control: Experiments conducted over the years have shown that soil applications of aldrin, chlordane, BHC dust at 1.0 kg a.i./ha and heptachlor at 3.0 kg a.i./ha gives adequate protection for sugarcane setts planted in the field (Kalyanaram *et al.*, 1960, Rao and Agarwal, 1957). Soil application of gamma BHC at 1.0 kg a.i. per ha promotes good germination of the crop, stimulates better vigour and protects the crop adequately from termite and shoot borer damage and enhances the yield up to about 18 tonnes per ha.

Whitegrubs were not successfully checked under Coimbatore conditions when BHC dust was applied, even at 10.0 kg a.i./ha, either at planting or during May-June. Insecticidal experiments (Table II) indicated that fensulfothion at 5.0 kg a.i.ha brought about significant reduction of the grub population (David and Ananthanarayana, 1976). As observed subsequently, control measures for whitegrubs in the farm, the quantity of the insecticide can be reduced further to 2 to 2.5 kg a.i./ha, when applied during June.

For the control of *P. sacchari*, soil application of gamma BHC in furrows proved helpful but confirmatory trials are necessary. Aphids and mealy bugs are generally in patches and so regular control measures have not been used. However, the large population of which occurred in association with an unidentified species of root aphid in the Salem District warranted the application of BHC 10 per cent dust at 25 kg per ha and this checked the pest very satisfactorily.

Influence of soil applications of insecticides on the yield of sugarcane

Soil applications of gamma BHC, fensulfothion etc. for the control of termites, shoot borer, and white-grubs respectively has consistently enhanced the yield of sugarcane, even in the absence of termite and grub infestation.

It has been found (Prasad, 1976) that gamma BHC enhances nitrogen uptake of sugarcane from the soil and also increases potassium concentration in the plant. There are also indications of an increase in root volume per plant and stimulation of microbial activity, leading to enrichment of soil organic matter. Thus, gamma BHC aids indirectly in sugarcane crop growth and yield, in addition to controlling termites and shoot borer.

TABLE II

Influence of insecticidal treatments on population of grubs, millable canes yield and sucrose (1972–73)

	Treatment	Population of				Yield of cane		
		Grubs		Millable canes		Mean per 1/250 ha	per hectare	Sucrose per cent
		Mean (square root) per 1/500 ha	per hectare	Mean per 1/250 ha	per hectare			
1.	BHC. dust 10 kg a.i./ ha - 1 appln.	7.43	27,600	236.25	59,062	318.70	79.68	17.74
2.	-do- 2 aplns.	7.12	25,350	224.50	56,125	298.50	74.63	17.47
3.	Fensulfothion G. 5. 5 kg a.i./ha - 1 appln.	5.09	12,950	243.00	60,750	323.60	80.90	17.45
4.	-do- 2 applns.	3.22	5,200	285.25	71,312	388.97	97.24	17.94
5.	Disulfoton G. S. 5 5 kg a.i./ha- 1 appln.	6.92	23,950	227.75	56,937	286.02	71.50	17.81
6.	-do- 2 applns.	6.43	20,650	226.50	56,625	290.02	72.50	17.93
7.	Phorate G. 10 5 kg a-i./ha - 1 appln.	7.12	25,350	228.75	57,187	316.55	79.13	17.33
8.	-Do- 2 applns.	6.86	23,550	228.25	57,062	309.30	77.30	18.16
9.	Dyfonate G. 10 5 kg a.i./ha - 1 appln.	5.48	15,000	231.25	57,812	310.10	77.50	16.57
10.	-Do- -2 applns.	6.29	19,800	248.75	62,187	332.75	83.20	17.49
11.	Quinalphos G. 5 5 kg a.i./ha - 1 appln.	6.86	23,550	213.50	53,375	249.15	62.30	17.49
12.	-Do- - 2 applns.	4.79	11,450	250.00	62,500	340.42	85.10	17.44
13.	Chlorfenvinphos E.C. 24 5 kg a.i./ha - 1 appln.	6.60	21,800	210.50	52.625	270.47	67.60	17.82
14.	-Do- - 2 applns.	6.45	21,300	220.50	55,125	289.10	72.30	16,77
		7.40	26,900	210.25	52,562	255.92	64.00	17.42
15.	Control S.E.	0.60		16.45		19.40		
	C.D.	1.18		32.24		38.00		

The factors contributing to the increase of sugarcane yield when treated with fensulfothion are yet to be studied.

Residual toxicity of insecticides in soil and sugarcane

Repeated applications of insecticides in the soil raise the problem of residues in the soil and the plant. BHC is known to remain as residues in the soil for a considerable time. Recently, its residual level in jaggery prepared from treated crop has been shown to be fairly high *viz.* 0.05 to 0.15 ppm, although still within tolerable limits. This cautions us to take proper precautions when advocating high doses or repeated applications of soil insecticides for the control of these pests. No studies have been made on the influence of these insecticides on beneficial organisms in the soil.

References

Agarwal, R. A. and Siddiqi, Z.A., 1957, Sugarcane pests. *Entomology in India*, 149–186.

Avasthy, P. N., 1967, The problem of whitegrubs of sugarcane in India. *Proc. ISSCT 12th Cong.*, 17: 1321–1333.

David, H., 1965, *Philoscia sacchari*. A new soil isopod damaging sugarcane buds in Tanjore district (Crustacea : Isopoda). *J. Zool. Soc. Ind* 17(1&2): 120–122.

David, H. and Ananthanarayana, K., 1974, Some aspects of the biology of whitegrubs in sugarcane in Tamil Nadu. *Whitegrub Newsletter*. 1(1): 11–15.

David, H. and Alexander, K. C., 1975, Natural occurrence of milky disease bacterium *Bacillus popilliae* Dutky on whitegrubs in India. *Curr. Sci.*, 44 (22): 819-820.

David, H. and Ananthanarayana, K., 1976, A preliminary study on chemical control of whitegrub, *Holotrichia serrata* F. damaging sugarcane. *Proc. S.T.A.I. Golden Jubilee* 25–30.

Kalyanaraman, V. M., Narayanaswamy, P. A. and Leela David, A., 1960, Insecticidal control of termites attacking sugarcane. *Madras Agric. J.*, 47(4): 165-169.

Long, W. H. and Hensley, S. D., 1972, Insect pests of Sugarcane. *Ann. Rev. Ent.*, 17 : 149-176.

Nagarajan, K. R., 1957, Rare occurrence of the root aphids on sugarcane in South India. *Curr. Sci.*, 44(21) : 780.

Nirmala Jasmine and Ananthanarayana, K., 1975, A new root aphid on sugarcane in South India. *Curr. Sci.*, 44(21) : 780.

Prasad, C. R., 1976, To improve the efficiency of nitrogen utilisation under sub-optimal levels of nitrogen application through use of gamma BHC. Paper presented at Sugarcane Workshop, Coimbatore.

Rao, G. N and Agarwal, R. A., 1957, Control of sugarcane termite by the use of modern insecticides at Coimbatore. Proc. 3rd All India Conf. *Sug. Res.* and *Dev. Workers*, 2 : 303–306.

Rao, G. N., 1959, The occurrence of a symphylid (Class Myriapoda) as a pest of sugarcane at Coimbatore. *Curr. Sci.*, 28(4): 170.

Myllocerus Weevils as Soil Dwellers

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Abstract

The weevil genus *Myllocerus* (Otiorrhynchinae) includes important soil inhabiting insect pests of crops. The distribution of this genus is confined to the old-world. In India, seventy seven species of *Myllocerus* have been reported. Thirty eight species have been reported from South India including the recent report from Karnataka.

The insects are basically soil-dwellers because a major part of their life is spent within soil (egg, larva, pupa and teneral adult). The larvae feed on roots of crops while the adults are defoliators during the main cropping season.

In Karnataka, *Myllocerus undecimpustulatus* var. *Maculosus* Desb., *M. subfasciatus* Guerin, *M. discolor* Boh., *M. dentifer* Fab., *M. dorsatus* Fab. and *M. viridanus* Fab. are economically important. The biology of former three species have been worked out by Trehan (1929), Subramaniam (1958) and Siddappaji (1976) and that of *M. laetivirens* Mshl. from north India by Bose (1941). Except *M. discolor*, where both the larvae as well as adults undergo diapause in the cold season from November till March, the rest are known to hibernate in the larval stage. The results of the study on the distribution (faunistic) of *Myllocerus* species in Karnataka are provided in this paper.

Introduction

The curculionid genus *Myllocerus* (Otiorrhynchinae : Phyllobiides) is repesented by over 125 species all over the old world. Both adults and larvae are plant feeders and thus potentially injurious to crops. The insects are typical soil-dwellers during the egg, larva, pupa and teneral adult stages. These stages are less known because of their concealed way of life. The larvae are exclusively root feeders of grasses and crop plants (Marshall, 1916). Marshall (1916) reported over 76 species of *Myllocerus* from the then British India including Sri Lanka and Burma and he further stated that India is apparently the centre of origin for *Myllocerus*. Of these. 38 species are known from South India (Ayyar, 1922) and 14 species from Karnataka (Marshall, 1916 ; Usman and Puttarudraiah, 1958 ; Siddappaji and Katagihallimath, 1962 ; Siddappaji, 1976). Anstead (1910) reported that they are important defoliating weevils of economic plants.

Fletcher (1917, 1920) observed the grubs of *Myllocerus* feeding on roots of sugarcane, maize, semicultivated and wild *Saccharum* spp, and also found pupae in soil in indigo fields. Ghosh (1921) reported the larval damage to cotton roots and recognised it as a pest in early stages of the crop. Trehan (1929) stated that the larvae caused more damage to cotton roots than the adults to foliage. Stebbing (1914) collected the adults in 1902 on forest plants.

Though different species of *Myllocerus* have been reported by several workers as pest of a variety of hosts in different regions within and outside India, the biology of only four species, namely, *Myllocerus undecimpustulatus* var *maculosus* Desb. from the Punjab, *M. subfasciatus* Guerin from Coimbatore, *M. laetivirens* Marshall from Delhi and *M. discolor* Boh. from Karnataka, by Trehan (1929), Subramaniam (1958), Bose (1941) and Siddappaji (1976), respectively has been studied. Since our knowledge of the fauna of this economically important genus in Karnataka was limited, a study was made to fill in this gap in relation to different agroclimatic conditions and hosts.

Material and Methods

Agro-climatically the State can be divided into four regions (Naik *et al.*, 1971): 1. Coastal region–a narrow coastal plain between edge of western ghats and the Arabian Sea, with a rainfall of over 250 cm, 2. Hilly region–along the western coast with a rainfall range of 130–250 cm with certain points having a rainfall as high as 875 cm. 3. Transition region–a narrow strip along eastern slope of hilly region with reasonably assured rainfall. 4. Dry region–the north central and south–eastern parts of the State, with low rainfall.

Collections of different species of *Myllocerus* weevils occurring in cultivated as well as among wild plants were made periodically and the identity of the species confirmed by specialists.

Results and Discussion

The species of *Myllocerus* encountered in Karnataka during the present investigation were: 1. *Myllocerus andrewesi* Marshall, *M. blandus* Faust, 3. *M. cardoni* Marshall, 4. *M. dentifer* (Fabricius), 5. *M. discolor* Boheman, 6. *M. dorsatus* (Fabricius), 7. *M. fabricii* Guerin, 8. *M. pauper* Faust, 9. *M. pretiosus* Faust, 10. *M. setulifer* Desb., 11. *M. subjasciatus* Guerin, 12. *M. transmarinus* Herbst, 13. *M. undecimpustulatus* Faust and 14. *M. viridanus* Fabricius. The species at serial numbers, 1, 4, 8 and 10 are new records for the State. Three species occurred as well in their varietal forms, namely 1. *M. discolor* var. *variegata* and *uniformis*, 2. *M. subfasciatus* var. *mutabilis* and *spurcatus* and 3. *M. undecimpustulatus* var. *maculosus*, *marmoratus* and *pistor*.

Of the 14 species, a few were found on crops under several different agro-climatic conditions in the State. Most species that infested crops of economic importance were seasonal pests on *khariff* crops. Only a few were found active throughout the year. None of the species was host specific though there were preferences for certain hosts.

Adults of *M. discolor* and *M. subfasciatus* were found throughout the year. They were on crops in the main season and on tree hosts in the cold season. Adults of the former species were observed to undergo reproductive diapause and larvae hibernated, from November till March, while the latter species was found to confine itself to the non-seasonal vegetable crops like brinjal in the plains and to tree hosts in hilly (Malnad) and coastal areas. *M. discolor*, *M. dentifer* and *M. pauper* were not in the latter areas. *M. discolor* bred in crop lands from April to October/November and thereafter both the larvae and adults were found diapausing. Adults of *M. undecimpustulatus* were not found in south plains, and were represented by the verietal forms only. *M. pretiosus* was found to occur in the hilly region–(Plantation zone) on tree hosts and not found in plains of the State. Even the species that were found on tree hosts (forest) in the hilly

tract were distributed mostly very close to cultivated ground in the vicinity. In all these cases loose soil, optimum soil moisture and soil temperature and the availability of plant roots favoured the development of the immature stages of the weevil.

The information obtained on faunistic distribution during the present study is discussed in relation to the findings of the previous workers under each species briefly.

Myllocerus andrewesi: Although the species occurs in the hilly areas of Karnataka as recorded by Marshall (1916) in the hill areas of Tamil Nadu-Niligiris and Anamalai (2500–4000 ft.) it was also found in the wet plains of Hassan district

Myllocerus blandus: It occurred throughout the State and the results are in agreement with the findings of the early workers (Marshall, 1956; Fletcher, 1920; Hussain, 1923; Beeson, 1941; Sohi, 1964) from different places in India on orchard and field crops.

Myllocerus cardoni: The species was noticed on quite a few forest trees as reported by previous workers (Beeson, 1941; Bhasin *et al.*, 1956: Mathur and Singh, 1959; 1960) and is widely distributed.

Myllocerus dentifer: A species widely distributed throughout South India (Ayyar, 1922) and also in Nagpur (Marshall, 1916). It was found only in the plains of Karnataka, associated with millets and conspicuously absent in hilly and coastal regions of the State.

Myllocerus discolor: The current investigation showed the species to be confined to cultivated fields in plains. It was not found in hilly or coastal regions which receive heavy and frequent rains during the breeding season of the species (April–October). It was interesting to note a sharp break in the distribution of the species even in the same taluk (Chikmagalur), the weevil being very commonly found in one locality and completely absent in a place only a few metres away. This was related to the difference in the rainfall in the two places. Earlier records (Anstead, 1910; Marshall, 1916) of *M. discolor* in high elevated places could not be corroborated so far as its distribution in Karnataka was concerned since it was not found on the Nandhi hills (4500 ft.) near Bangalore.

Myllocerus fabricii and *M. dorsatus:* There are widely distributed from forest trees in the State as reported (Stebbing, 1914; Beeson, 1941) from different parts of the country.

Myllocerus pauper: This species is confined to the dry plains of the State in and around cultivated land on crops and trees.

Myllocerus pretiosus: A species reported from several places in South India including some places now included in Karnataka-(Lefroy, 1906; Marshall,

1916). Our records are confined to tree hosts in the hilly-heavy rainfall areas infesting.

Myllocerus setulifer : It is widely distributed on forest trees and flowering plants which may be defoliated by swarm of the beetles. The present findings agree with the findings of Beeson (1941). The adults were also observed migrating to field crops in the plains of the State.

Myllocerus subfasciatus: The species is very widely distributed and its distribution in the varietal forms *mutabilis* and *spurcatus*, is in agreement with the findings of Marshall (1916), Subramaniam (1958), and Mathur and Singh (1960). It is interesting to note that the species was found to occur mostly on trees in the hilly regions whereas it was mostly on Solanaceous plants in the plains and transition regions.

Myllocerus transmarinus: A species recorded from various hilly areas of India. The present observations on the species is in agreement with the reports of Marshall (1916).

Myllocerus undecimpustulatus: The typical form of the species as described by Marshall (1916) was confined to the northern parts of the State and the hilly regions of Karnataka. The differences in the abudance of two of the varietal forms was interesting, the variety *pistor* was more abundant in the hilly areas whereas the variety *maculosus* was abundant throughout the southern plains.

Myllocerus viridanus: The species occurs throughout South India Ayyar (1922), and the prerent studies found the species to be very widely distributed in Karnataka and highly polyphagous.

Since the members of the genus *Myllocerus* are largely dependent on cultivated fields for their breeding, the local population are confined to the areas around crops. Thus number of species in extensive forest area is very much limited.

References

Ansted, D. R., 1910, Notes and comments by the Scientific Officer, Weevils on fruit trees. *Planter's Chronicle.*, 5 (23) : 273.

Ayyar, T. V. R., 1917, List of crops and pests. *Rept. Proc. 2nd Ent. Mtg.*, Pusa, pp. 340.

Ayyar, T. V. R., 1920, Some insects recently noted as injurious in South India. *Rept. Proc. 3rd Ent. Mtg.*, 1 : 315-417.

Ayyar, T. V. R., 1922, The weevil fauna of South India with special reference to species of economic importance. *Bull. Agr. Res. Inst.*, Pusa. 125:21.

Beeson, C. F. C., 1941, *The ecology and control of the forest insects of India and the neighbouring countries. Imp. For. Res. Inst.*, Dehra-Dun, pp. 1007.

Bhasin, G. D., Roonwal, M. L. and Singh, B., 1956, A list of insect pests of forest plants in India and the adjacent countries. *Ind. For. Bull.*, No. 171.

Bose, M., 1941, Short notes and exhibits. *Ind. J. Ent.*, 3 (2) : 337-338.

Fletcher, T. B., 1917, Lists of crops and pests. *Rept. Proc. 2nd Ent. Mtg.*, Pusa, pp. 340.

FLETCHER, T. B., 1920, Annotated list of Indian crop pests. *Rept. Proc. 3rd Ent. Mtg.*, Pusa pp, 1136.

GHOSH, C. C., 1921, Supplementary observationson borers in sugarcane, Rice etc. *Report Proc. 4th Ent. Mtg.*, Pusa, p. 401.

HUSSAIN, M. A., 1923, Annual report of the Entomologist. *Rept. Dept. Agr. Punjab*, Lahore pp. 173–184.

LEFROY, H.M., 1906, *Indian insect pests, Curculionidae*. Taylor and Francis Co., London, part I, pp. 367.

MATHUR, R. M. AND SINGH, B., 1959, *A list of insect pests of forest plants in India and adjacent countries. Ind. For. Bull. (Ent.)*, No. 171 (New series).

NAIK, K. C., HAVANAGI, G. V., VENKATA RAO, B. V. AND KRISHNAMURTHY, K., 1971, *More water resources for agriculture in Mysore. Symp. on Water Resources. Univ. Agri. Sci.*, Bangalore, pp. 22.

SIDDAPPAJI, C. AND KATAGHALLIMATH, S. S., 1962, A note on the survey of *Myllocerus* weevils in Mysore State and preliminary insecticidal trials to control them. *2nd All India Congr. Zool.*, Varanasi. Abst. of papers.

SIDDAPPAJI, C., 1976, Studies on the fauna of *Myllocerus* in Karnataka and Biology of *Myllocerus discolor* Boh. (Coleoptera : Curculionidae). M.Sc. (Agri) thesis Dept. of Entomology, UAS, Bangalore.

SOHI, G. S., 1964, Pests of cotton. *In Entomology in India. The Entomological Society of India*, pp. 529.

STEBBING, E. P., 1914, *Indian forest insects of economic importance. Coleoptera*, p. 648. Govt. of India Publ.

SUBRAMANIAM, T. R., 1958, Life history of the ash weevil (*Myllocerus subfasicatus* Guer.) on brinjal (*Salanum melongona* L.) *J. Madras Univ.*, B-28 : 69–71.

TREHAN, K. N., 1929, Life history, bionomics and control of *Myllocerus maculosus* desp. (Coleoptera : Curculionidae). *Bull. Agr. Res. Inst.*, Pusa, 181:28.

USMAN, S. AND PUTTARUDRAIAH, M., 1955, A list of insects of Mysore including mites. *Ent. Ser. Bull.*, 16:114.

Moisture an Essential Factor for the Survival of *Polytus mellerborgii* (Boheman) (Coleoptera : Curculionidae)

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ABSTRACT

The small banana weevil, *Polytus mellerborgii* (Boheman), was found infesting banana rhizomes and also pseudostems in certain parts of Karnataka *viz.*, Bangalore, Mysore, Shimoga and Chithradurga. They were found always coated with a thin film of water. Whenever the specimens were taken out from the parts of the plants or from

damp places they died. The experiment conducted in the laboratory showed that this thin film of water around the body of the weevil was essential for the survival of the weevil.

THE small banana weevil, *Polytus mellerborgii* (Boheman) was found infesting banana rhizomes and also the pseudostems in certain parts of Karnataka viz., Bangalore, Mysore, Shimoga and Chitradurga. They were found always coated with a thin film of water. Whenever the adults were taken out from the parts of the plants or from damp places and placed on dry surface, they died.

An experiment was conducted to determine the survival of the weevils with and without food material and in dry and wet soil conditions. Petri dish cages were used for the experiment, two sets having moist soil with and without food and another two sets having dry soil with and without food were maintained under observation for a period of 30 days. For each set 10 adult weevils were released.

The results showed that the weevils lived for a maximum period of more than 30 days, a minimum period of 27 days and an average period of 29.5 days with food and for a maximum period of 12 days, a minimum period of 9 days and an average period of 10 days without food under wet soil conditions. The weevils lived for 2 to 5 days with an average of 3.5 days with food and for 0.125 to 1.0 day with an average of 0.2 day without food under dry soil conditions (Table I).

TABLE I

Survival capacity of the adults of Polytus mellerborgii *(Boheman) with and without food under wet and dry soil conditions* (in days)

	with food			without food		
	Maximum	Minimum	Average	Maximum	Minimum	Average
Wet soil	> 30.00	27.00	29.50	12.00	9.00	10.00
Dry soil	5.00	2.00	3.50	1.00	0.125	0.20

The authors are thankful to Dr. S. V. Patil, Director of Instruction (Agri) and Dr. T. S. Thontadarya, Professor of Entomology, College of Agriculture. Dharwad, for this constant encouragement.

Bionomics of *Myllocerus undecimpustulatus* Fst. Infesting Cotton in Marathwada

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ABSTRACT

Cotton grey weevil is a polyphagous pest and although it has been reported as a minor pest of cotton, it is causing appreciable damage to the cotton and jowar crops in Marathwada. *Myllocerus undecimpustulatus* Fst. and *Heteroprochus pruinosus* Fst. are the predominant species so far observed in this region. The first one is a polyphagous and mainly feeds on cotton, jowar, arhar and bhindi. The second species feeds only on brinjal.

Life history studies were conducted on these species on cotton in the laboratory. Male and female beetles were confined in rearing cages in a petri dish with moist soil for egg laying. Simultaneously, single cotton seeds were allowed to grow in small glass-tubes. After hatching a single larva was released in each glass tube containing a seedling. In later stages, the grubs were reared on small potted plants.

Females lay 100-250 eggs singly in the soil. The incubation period ranges from 3 to 7 (average 5.1) days. On hatching, the young larva feeds on the tender roots. The larval period varies from 28 to 33 (average 30.2) days. The larval and pupal stages are passed in the soil. The pupal period is completed in 5 to 9 (average 7.0) days. The adults live for about 25 days. The damage is caused both by adults as well as larvae. The adults feed on leaves and larvae on roots. The maximum damage is caused during July-September when the crops is at a younger stage.

An egg pathogen, *Aspergillus* sp. has also been recorded. This fungus has been tentatively identified. Parasitised eggs do not hatch. Further studies on its pathogenicity and multiplication are necessary.

INTRODUCTION

COTTON grey weevil, *Myllocerus undecimpustulatus* Fst. is a polyphagous pest widely distributed throughout India. It was first reported at Kanpur in 1895, on cotton. Although, it has been reported as only a minor pest of cotton brinjal, maize, sorghum, bajra, ragi, lady's finger, sugarcane, apple, mango, pomegranate, strawberry, ber, pear, peach, arhar, deccanhemp and groundnut (Nagpal, 1948 and Gupta, 1966), it is causing appreciable damage to cotton and jowar crops in Marathwada region. Because of the occurrence of the pest on cotton, the present studies have been initiated at Marathwada Agricultural University, Parbhani beginning this year. The observations of two overlapping generations are presented in this paper, which were completed in July to end of October, 1976. Further studies are in progress.

Trehan (1929), Gupta (1966) and Pande (1971) studied the bionomics of *Myllocerus maculosus* Desb. The former author reported it on nineteen different host plants. *Myllocerus undecimpustulatus* Fst. and *Heteroptochus pruinosus* Fst. are the two predominant species so far observed in this region. The second species feeds only on brinjal.

Material and Methods

Life history studies were conducted in laboratory conditions. Male and female beetles were confined in rearing cages in petridishes with moist soil for egg-laying. Simultaneously, single cotton seeds were allowed to grow in small glass tubes. After hatching, a single larva was released in each glass tube containing a seedling, In the later stages, the grubs were reared on small potted plants.

Results and Discussion

Life history : The preoviposition period ranged from 6 to 8 days and the ovipositional period from 9 to 18 days. Females laid 100 to 250 eggs singly in the soil. These results contradict those of Trehan (1929), Gupta (1966) and Pande (1971) who reported egg-laying in batches. Eggs are dirty-white, oval and smooth, measuring on average 0.62×0.35 mm. Towards hatching, the embryo can be seen clearly through the cutiticle and has light brown mandibles. The larva work out of the egg shell from the anterior end with a wriggling movement and takes about three hours to emerge. The incubation period ranged from 3 to 7 (average 5.1) days. The larvae feed on roots. The larval period varied from 28 to 33 (average 30.2) days. The larva is creamy white with prognathous mouthparts and its mandibles are very strong. The larva is blind, legless and with short antennae. The larval and pupal stages are passed in soil and the freshly-formed exarate pupa is glabrous, creamy-white and is lodged in an earthen cell. The pupal period is completed in 5 to 9 (average 7.0) days and the adults live for about 25 to 40 days. The male beetles are smaller than the females with small pointed abdomens.

The damage is caused both by adults and larvae. The adults feed on foliage, starting from the leaf margin towards the ribs and generally in 'U' shaped patches. The larvae feed from the tips to the base of the roots, keeping a thin lower layer intact. The maximum damage is caused during July-September when the crops are at a young stage. These results are more or less similar to the findings of above workers.

An egg pathogen, *Aspergillus* sp. has also been reported. But this fungus has been only tentatively identified. Parasitised eggs do not hatch. Further studies on its pathogenicity and multiplication will be made.

The authors are thankful to Dr. V. S. Kuspe, Vice-Chancellor, Marathwada, Agricultural University, Parbhani (M. S.) for initiation encouragement and providing facilities. Thanks are due to Sri Samuel for typing the manuscript.

References

Gupta, B. P., 1966, *Labdev. J. Sci. Technol.* 4(2): 124–127.

Nagpal, H. C., 1948, Indian Central Cotton Committee, Publication, pp. 51.

Pande, Y. D., 1971. *Zeitachrift. fur. Ang. Entomologie.*, 69(2): 204–209.

Treha n,1929, *Bull. Agri. Res. Ins. Pusa*, No. 181, pp. 28.

Persistence of Aldrin Residues in Two Types of Soil

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Abstract

Aldrin at 3, 9 and 15 kg *a. i.*/ha was applied to field plots of both clay loam soil of Udaipur and sandy loam soil of Jobner before sowing crops. The crop rotation followed was maize-root crop-fallow at Udaipur and bajra-rootcrop-fallow at Jobner. These dosages resulted in initial deposits of approx. 1.8, 3.7 and 8.8 ppm in soils respectively.

The residues dissipated to the extent of 100, 90 and 88 per cent in about 7 months for the three dosages used in clay loam soil, whereas the corresponding dissipation was 95, 91 and 89 per cent in sandy loam soil. Similarly, about 14 months of application the dissipation of aldrin from the three dosages was to the extent of 100, 97 and 91 per cent for clay loam soil and 100, 100 and 98 per cent for sandy loam soil and indicated that there was a slightly higher dissipation of aldrin residues from sandy loam soil compared to clay loam soil.

The conversion of aldrin into dieldrin occurred in both types of soils and continued for 6–7 months, but declined thereafter. The amounts of dieldrin found after 14 months was a base detectable level 0.4 and 0.6 ppm in clay loam soil, and 0.9, 1.8 and 1.9 ppm in sandy loam soil. The data also showed that there was more coversion of aldrin into dieldrin in sandy loam soil than clay loam soil.

Introduction

Aldrin is widely recommended in India and abroad for the control of soil-inhabiting insects such as termites, cutworms, wireworms, etc. In view of the spectacular success achieved with the soil incorporation of aldrin elsewhere, a large number of India workers have tested its effectiveness against soil insects under different agro-climatic conditions. Srivastava and Khan (1963) and Butani (1967) recommended its pre-sowing application at the rate of 1-3 kg a.i./ha for the control of termites and cutworms. However, doses as high as 10 kg a.i./ha resulted in only about 60 per cent motality of third instar larvae of white

grubs (Joshi *et al.*, 1969). Being a highly persistent insecticide it has been reported to provide sufficient protection to the crops from a few months to many years (Lichtenstein *et al.*, 1962, 1971 ; Nash and Woolson, 1967 and Onsager *et al.*, 1970). The conversion of aldrin into dieldrin causes further toxicity to the insects and persistence in the soil (George *et al.*, 1965; Powell *et al.*, 1970). Since practically no work has been carried out in India on the persistence of aldrin in soil, the present investigation was carried out to study the fate of aldrin in two different types of soils.

Material and Methods

Field experiments were laid out in *kharif* 1972 in a randomized block design in two widely-different soil and agroclimatic conditions of Rajasthan *viz.*, Udaipur representing humid climate and clay loam soil (coarse sand–12.38 per cent, fine sand–24.12 per cent, silt–28.80 per cent, clay–34.70 per cent) and Jobner representing semi–arid climate and sandy loam soil (coarse–sand-17 per cent, fine sand–58 per cent, silt–15.50 per cent, clay-9.20 per cent). The application of aldrin at 3, 9 and 15 kg a.i./ha in the form of 50 per cent dust was applied to both types of soil to a depth of about 10 cm. The crops raised were maize in clay loam soil and bajra in sandy loam soil followed by root crops (best root, carrot and radish). The treated plots were thereafter, left fallow in subsequent seasons.

Soil samples (up to 10 cm deep) were collected using an auger at five random spots in each plot. Soil was air–dried and ground to pass through 2 mm sieve. The insecticides were extracted from soil by tumbling using n-hexane at a rate of 2 ml/g of sample. The residues of aldrin were determined by the phenylazide spectrophotometric technique of O'Donnell *et al.* (1954). Another aliquot from the same sample extractives was taken for dieldrin estimation. The residues of dieldrin were determined by the phenylazide spectrophotometric technique of O'Donnell *et al.* (1955).

The fortification of untreated soil samples with insecticides gave a residue recovery as high as 97 per cent for aldrin and 95 per cent for dieldrin from both ypes of soils.

Results and Discussion

Application of aldrin at 3 kg a.i./ha resulted in deposits of 1.744 ppm in clay loam soil and 1.801 ppm in sandy loam soil (Table I). The amounts of aldrin residues found, 1, 2, 4 and 7 months after, were 1.097, 0.752, 0.292 ppm and traces respectively in clay loam soil corresponding to 37.1, 56.9, 83.3 and 100.0 per cent dissipation. On the other hand, the residues in sandy loam soil fell to 1.232, 0.631, 0.129, 0.091 ppm and traces after 1, 2, 4, 7 and 10 months of application resulting in the dissipation of 31.6, 65.0, 92.8, 94.9 and

100 per cent respectively. These results thus indicate that there was similiar rates of dissipation of aldrin residues from both soils. The trend of dissipation of aldrin was also the same in the case of 9 kg a.i. aldrin/ha dose (Table II). However, with 15 kg a.i./ha dose, the dissipation of aldrin was little faster in sandy loam soil than in clay loam soil (Table III). The residues of aldrin remaining 14 months after 15 kg aldrin/ha treatment were 0.778 ppm in clay loam soil and 0.118 ppm in sandy loam soil. Thus, the following two facts emerge :

TABLE I

Residues of aldrin applied at 3 kg a.i./*ha in clay and sandy loam soil*

Months after application	*Clay loam soil*		*Sandy loam soil*	
	Aldrin (ppm)	Dieldrin (ppm)	Aldrin (ppm)	Dieldrin (ppm)
0	1.744	—	1.801	—
1	1.097 (37.1)	—	1.232 (31.6)	—
2	0.752 (56.9)	—	0.631 (65.0)	—
4	0.292 (83.3)	—	0.129 (92.8)	—
7	BDL (100.0)	0.355	0.091 (94.9)	0.762
10	BDL (100.0)	0.263	BDL (100.0)	1.136
14	BDL (100.0)	0.123	BDL (100.0)	1.179

Note : Figures in parenthesis represent the percentage reduction of aldrin residues.
BDL – Below detectable level.

(i) The dissipation of aldrin up to 4 months of application was fast but slowed down thereafter. These results agree with those of Elgar (1966) who also found that the residues of aldrin were lost rapidly from all types of soil immediately following application dropping to about 15 per cent of the initial amount after a year and thereafter at a much slower rate.

(ii) In general, the persistence of aldrin in clay loam soil was slightly higher than in sandy loam soil. These results corroborate the findings of Lichtenstein and Schulz (1959) who found in their field experiments that aldrin persisted longer in muck soil (0.M-40 per cent) than in silt loam soil (0.M-3.8 per cent). They further reported that the amount of aldrin recovered 2 months after treatment from a muck soil in lab was 1.27 times higher than from a loam soil. In the field they recovered 1.94 times more aldrin from a much soil than from a silt loam soil 6 months after application.

TABLE II

Residues of aldrin applied at 9 kg a.i./*ha in clay and sandy loam soil*

Months after application	Clay loam soil		Sandy loam soil	
	Aldrin (ppm)	Dieldrin (ppm)	Aldrin (ppm)	Dieldrin (ppm)
0	3.215	—	3.665	—
1	2.554	—	2.876	—
	(20.56)		(21.52)	
2	1.838	—	1.931	—
	(42.83)		(47.31)	
4	0.776	—	0.405	—
	(75.86)		(88.95)	
7	0.320	0.706	0.328	1.256
	(90.04)		(91.05)	
10	0.138	0.468	0.086	1.988
	(95.71)		(97.65)	
14	0.081	0.379	BDL	1.775
	(97.48)		(100.00)	

Note : Figures in parenthesis represent the percentage reduction of aldrin residues.
BDL – Below detectable level.

TABLE III

Residues of aldrin applied at 15 kg a.i./*ha in clay and sandy loam soil*

Months after application	Clay loam soil		Sandy loam soil	
	Aldrin (ppm)	Dieldrin (ppm)	Aldrin (ppm)	Dieldrin (ppm)
0	8.505	—	8.798	—
1	7.072	—	6.315	—
	(16.85)		(28.22)	
2	5.689	—	4.216	—
	(33.11)		(52.08)	
4	1.309	—	0.998	—
	(84.61)		(88.65)	
7	1.040	1.748	0.985	1.892
	(87.77)		(88.80)	
10	0.944	0.451	0.398	2.590
	(88.89)		(95.55)	
14	0.778	0.522	0.118	1.693
	(90.85)		(97.86)	

Note : Figures in parenthesis represent the percentage reduction of aldrin residues.
BDL – Below detectable level.

In the present investigation, the conversion of aldrin into dieldrin was observed in both types of soil. It was also reported that aldrin was converted to dieldrin within soils (Edwards *et al.*, 1957, Bollen *et al.*, 1958, Gannon and

Bigger, 1958), such conversion of aldrin into dieldrin in soil may be due to prevailing weather conditions and the activity of microorganisms. The amount of dieldrin recorded from the 3, 9 and 15 kg aldrin applications was a maximum of 0.355, 0.706 and 1.748 ppm in clay loam soil, and 1.179, 1.988 and 2.590 ppm in sandy loam soil (Table I, II and III) respectively, showing a higher rate of conversion of aldrin into dieldrin in sandy loam soil than in clay loam soil. This may be due to the higher temperature that prevailed for a longer period in sandy loam soil than that of clay loam soil. These results corroborate the findings of Lichtenstein and Schulz (1959) who also found relatively more dieldrin in sandy loam soil and in the soil which had been treated at lower concentration.

The authors are thankful to the Head, Department of Entomology and Dean/Director (Research), University of Udaipur for providing necessary facilities during the course of the investigations. This research was supported by a P. L. 480 Research Grant, FG-IN-431 (47, CR-294).

References

Bollen, W. B., Roberts, J. E. and Morrison, H. E., 1958, Soil properties and factors influencing aldrin-dieldrin recovery and transformation. *J. econ. Ent.*, **51**: 214-219.

Butani, D. K., 1967, Sugarcane Termites-A resume. *Indian Sug.*, **17**: 543-549.

Edwards, C. A., 1972, *Insecticides* - In Organic Chemicals in the soil environment. Edited by Goring and Hamaker. **8**: 513-568 pp. Marcel Dekker, INC., New York.

Edwards, C. A., Beck, S. D. and Lichtenstein, E. P., 1957, Bioassay of aldrin and lindane in soil. *J. econ. Ent.*, **50**: 622-626.

Elgar, K. E., 1966, Analysis of crops and soils for residues of the soil insecticides aldrin and telodrin. *J. Sci. Fd. agric.*, **17**: 541-545.

Gannon, N. and Bigger, J. H., 1958, The conversion of aldrin and heptachlor to their epoxide in soil. *J. econ. Ent.*, **51**: 1-2.

George, C., Decker, G. C., Bruce, W. N. and Bigger, J. H., 1965, The accumulation and dissipation of residues resulting from the use of aldrin in soils. *J. econ. Ent.*, **58**: 266-271.

Joshi, R. K., Kaul, C. L. and Srivastava, B. P., 1969, Studies on chemical control of white gurbs, *Holotrichlia ionsanguinea* Blanch (Melolonthidae : Coleoptera). *Indian J. Ent.*, **31**: 143-146.

Lichtenstein, E. P. and Schulz, K. R., 1959, Breakdown of lindane and aldrin in soils. *J. econ. Ent.*, **52**: 118-124.

Lichtenstein, E. P. and Schulz, K. R., 1959, Persistence of some chlorinated hydrocarbon insecticides as influenced by soil types, rate of application and temperature. *J. econ. Ent.*, **52**: 124-131.

Lichtenstein, E. P., Mueller, C. H., Myrdal, G. R. and Schulz, K. R., 1962, Vertical distribution and persistence of insecticidal residues in soils as influenced by mode of application and a cover crop. *J. econ. Ent*, **55**: 215-219.

Lichtenstein, E. P., Fuhremann, T. W. and Schulz, K. R., 1971, Persistence and vertical distribution of DDT, lindane and aldrin residues 10 and 15 years after a single soil application. *J. agric. Fd. Chem.*, **19**: 718-721.

Nash, R. G. and Woolson, E. A., 1967, Persistence of chlorinated hydrocarbon insecticides in soils. *Science, N.Y.* **157**: 924-927.

O'DONNEL, A. E.. NEAL, M. M., WEISS, F. T., BANN, J. M., DECINO, T. J. AND LAU, S. C., 1954, Chemical determination of aldrin in crop materials. *J. agric. Fd. Chem.*, **2** : 573.

O'DONNEL, A. E., JOHNSON, H. W. AND WEISS, F. T., 1955, Chemical determination of dieldrin in crop materials. *J. agric. Fd. Chem.*, **3** : 757–762.

ONSAGER, J. A., RUSK, H. W. AND BUTLER, L. I., 1970, Residues of aldrin, dieldrin, chlorane and DDT in soil and sugarbeets. *J. econ. Ent.*, **63** : 1143–1148.

POWELL, A. J. B., TREVER, S. AND MCCULLY, K. A., 1970, Effect of commercial processing on residues of aldrin and dieldrin in tomatoes and residues in subsequent crops grown on treated plots. *J. agric. Fd. Chem.* **18** : 224–227.

SRIVASTAVA, B. K. AND KHAN, R. M., 1963, Bionomics and control of *Holotrochia insularis* Brenske (Melolonthidae : Coleoptera). *Indian J. Ent.*, **25** : 347–354.

Behaviour of Five Systemic Insecticides in Coffee Soil

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ABSTRACT

Five systemic insecticides were applied to a soil of pH 6.2. Quick degradation of phorate and disulfoton was noticed even after 24 hours. The maximum number of degraded metabolites were noticed after 10 days in the case of disulfoton, after 20 days in the case of fensulfothion and phorate and at 30 days in the case of carbofuran. Maximum activity was noticed up to 20 days for fensulfothion, up to 30 days for disulfoton and phorate. Carbofuran formed the maximum number of metabolites after one month and was persistent up to 185 days. Thus, fensulfothion is the least persistent, and carbofuran being very persistent have advantages and disadvantages in pest control programmes in relation to toxicity and residues.

INTRODUCTION

COFFEE plants are prone to attack by many pests such as green bugs, mealybugs cockchafers, cutworms, wireworms, leaf miners etc. in the nursery and new clearings and to a number of other pests like white stem borer, red borer, thrips, aphids, snails etc., as well as those mentioned above in established plantations. Many types of insecticides are used in coffee plantations for the control of these soil as well as foliar pests.

Of possible control measures, insecticide granules persist longer than emulsions which persist longer than miscible liquids, while wettable powders and dusts disappear most repidly of all (Edwards, 1966). Thus, granular insecticides have more residual activity over the other types of formulations. Recent thinking on integrated pest control programme also favours the use of systemic

granular formulations for the control of foliar pests to keep the aerial portion of the plants free from contamination and residues of the insecticides, thus allowing the parasites and predators to remain active.

In addition to this the application of systemic granules to the soil provides the benefit of controlling soil pests as well as foliar pests with a single application. Other advantages conferred by the use of systemic granules are, in maintaining the toxicant in the plant system to control both chewing as well as sucking types of insects and there is no loss of the toxicant due to wash off by rains etc. The use of granules minimises environmental contamination due to spray drifts and reduces cost in heavy investment on spray machinery and savings in labour cost.

Thus, most interest is centered around granular insecticides in recent times, so investigations were undertaken to study the field performance of some of the newer granular insecticides.

Material and Methods

The following granular insecticides were used in the trials :

1. Fensulfothion 5 per cent granules, 2. Disulfoton 5 per cent granules, 3. Solvirex 5 per cent granules, 4. Carbofuran 3 per cent granules and 5. Phorate 10 per cent granules. Except for carbofuran the rest were all organophosphates. All had systemic properties and were used at 40 g of 5 per cent granules 20 g of 10 per cent granules and 66 g of 3 per cent granules per plant on equal concentration basis.

Granules were applied to coffee plants aged about 32 years old as follows depending on the probable pest incidence that might occur during the year.

1. One application during June and October.
2. Two applications during June + August and September + October.
3. Three applications during June + August + September and August + September + October.
4. Four applications during June + August + September + October.

The soil round the feeder root zone was stirred to a depth of 15 cm after removing the mulch. The granules were distributed uniformly round the feeder root zone into the stirred soil and the soil was again made uniform and the mulch was covered again. Treatments were replicated 10 times and were randomly distributed.

For studies on persistence and degradation, soil samples were collected in August from the plots to which where treatments were applied and all data pertains to this month. Fifty grams of soil was taken from 4 places representing all the four

sides of each plant at 15, 25 and 35 cm depths separately. The samples were stored immediately in the deepfreeze at–23°C until used for analysis. Samples were collected 24 hours after the application and at 10 days intervals until 60 days. Each individual depth sample for each replicate was analysed separately and the data of 10 replicates were pooled and presented.

The soil samples were extracted with suitable solvents 5 times for half an hour each time. The ratio of material to solvent employed was 1 : 2. After thorough extraction all the 5 extracts were combined and concentrated in a rotary evaporator. The concentrated extract was dried in petri dishes. The residue was dissolved in acetonitrile and subjected to charcoal cleanup. The final volume of acetonitrile was concentrated to 1 ml and 100 microlitres aliquot of this was spotted on to standard silica gel G. TLC plates. The plates were developed in hexane : acetone (90 : 10) for organophosphates and in hexane : ether (1 : 5) for canbofuran. After development, plates were dried under room temperature and sprayed with 0.5 per cent palladus chloride for or organophosphates and 1.5 per cent KOH solution followed by 0.1 per cent fluoroborate chromogenic reagents for canbofuran and the Rf of the different spots were recorded. In the absence of suitable reference standard metabolites, only the Rf values are given in the Table.

Results

It is seen that although Disyston and Solvirex contain the same active ingredient, disulfoton Disyston converts to a single metabolite at the surface and no further leaching to lower layers was noticed after 24 hours whereas solvirex was readily converted to 3 metabolites and leached to the 25 cm depth during 24 hours indicating the change brought about by the nature of formulation. The maximum number of metabolites noted in both cases were 5. All the metabolites appear within 10 days and all of them persist until 20 days. In the case of Disyston all the metabolites except one seem to persist up to 30 days whereas with Solvirex 2 metabolites disappear by 30 days. By 40 days, almost all the metabolites and the parent compound degraded for both formulations. Of all the metabolites, the compounds with Rf 0.5 and 0 13 seem to be more persistent. The parent compound began to dwindle in quantity by 20 days and became reduced to traces by 30 days. Thus, the effective life of the compound may be between 20 and 30 days. Disyston has a slower rate of degradation and Solvirex a faster rate of degradation and easy leaching. No carbofuran was degraded by 24 hours after application but it leached to the 25 cm depth as the parent compound It degraded more slowly and maximum number of metabolites were noticed between 10 and 20 days. By 30 days, the metabolites and the parent compound were only traces and nothing was detectable by 40 days. In comparison to Disyston and Solvirex, effectiveness remained the same between 10 and 20

Persistence and degredation of granular insecticides in soil

RF. VALUES

Observed on	Disyston 5 g			Solvirex 5 g			Dasanit 5 g			Thimet 10			Furadon 3 g		
	15 cm	25 cm	35 cm	15 cm	25 cm	35 cm	15 cm	25 cm	35 cm	15 cm	25 cm	35 cm	15 cm	25 cm	35 cm
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
26-8-1975	0			0.0						0	0	—			
(24 hours after				0.39	0.39		0.39*	0.39	Nil	0.007	0.007	—	0.54	0.54	0.54
application)	0.5			0.5	0.5					0.48	0.48	—			
	0.9	Nil	Nil	0.9*	0.9	Nil				0.59*	0.59	0.59			
5-9-1975	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.03	0.0	0.03
(10 days after)	0.13	—	—	—	0.13	—	—	—	—	0.007	0.007	0.007			
	0.29	0.29	0.29	0.29	0.29	0.29	0.39	0.39	0.39	0.37	0.37	0.37			
	0.39	0.39	0.39	0.39	0.39	0.39	0.42	0.42	0.42	0.48	0.48	0.48	0.55	0.55	0 55
	0.5	0.5	0.5	0.5	0.5	0.5	0.49	0.49	0.49	0.59	0.59	0.59			
	0.9	0.9	0.9	0.9	0.9	0.9	0.83	0.83	—	0.8	0.8	0.8			
15-9-1975	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(20 days after)	—	0.13	0.13	—	0.13	0.13	0.22	—	0.22	0.007	0.007	0.007			
	0.29	0.29	0.29	0.29	0.29	0.29	0.39	0.39	0.39	0.24	0.24	0.24	0.03	0.03	0.03
	0.39	0.39	0.39	0.39	0.39	0.39	0.42	0.42	0.42	0.31	0.31	0.31	0.15	0.15	0.15
	0.5	0.5	0.5	0.5	0.5	0.5	0.49	0.49	0.42	0.37	0.37	0.37	0.54	0.55	0.54
	0.9	0.9	0.9	0.9	0.9	0.9	0.83	0.83	0.83	0.59	0.59	0.59	0.71	0.71	0.7
										0.72	0.72	0.72			
										0.8	0.8	0.8			

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
25-9-1975	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(30 days after)	0.13	0.13	0.13	0.13	0.13	0.13	—	—	—	0.0037	0.007	0.007	0.03	0.03	0.03
	0.29	0.29	0.29	—	—	0.29	0.39	0.39	0.39	0·24	0.24	0.24	0.15	0.15	0.15
	0.39	—	—	—	—	—	0.42	—	—	0.31	0.31	0.31	0.54	0.55	0.55
	0.5	0.5	0.5	0.5	0.5	0.5	0.49	—	—	0.37	0.37	0.37	0.71	0.71	0.71
	0.9	0.9	0.9	0.9	0.9	0.9	0.83	0.83	0.83	0.6	0.6	0.59	0.82	0.82	0.82
										0.72	0.72	0.72			
											0.8	0.8			
6-10-1975	0.0	—	—	—	—	—				0.0	0.0	0.0	0.0	0.0	0.0
(10 days after)	—	—	—	0.13	—	0.13				0.007	0.007	0.007	0.03	0.03	0.03
	—	—	—	—	—	—				—	—	—	0.15	0.15	0.15
	—	—	—	—	—	—	Nil	Nil	Nil	0.37	0.37	0.37	0.54	0.54	0.54
	0.5	0.5	0.5	0.5		0.5				0.72	0.72	0.72	0.71	0.71	0.71
	0.9	0.9	0.9	0.9		0.9					0.8	0.8	0.81		
10-10-1975	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	**	**	**

* Corresponds to parent compound.

** All compounds noticed beyond 155 days.

days, dasanit and its metabolites degraded at a faster rate. Phorate leached and broke down quicker. It had leached up to 35 cm depth as the parent compound and had already formed 3 metabolites at the 15 and 25 cm depths within 24 hours of application. Further degradation and leaching was seen uniformly at all the depths and a maximum of 7 metabolites was seen by 20 days and persisted up to the end of 30 days. The parent compound occurred up to the end of 30 days and the 5 metabolites persisted up to the end of 40 days. Nothing was detectable at the end of 50 days. Compounds with Rf 0.0, 0.007, 0.037 and 0.8 seemed to be more persistent. In comparison to Disyston, Solvirex and carbofuron, phorate persisted larger and was and effective up to 30 to 40 days, in spite of its easy leachability and quicker metabolism. Carbofuran had not degraded after 24 hours but had leached up to 35 cm depth as the parent compound. At the end of 10 days, it had formed only one metabolite uniformly at all the 3 depths. At the end of 20 days it had formed four metabolites and the maximum number of 5 metabolites was recorded between 20–30 days. This condition persisted for about 155 days. The metabolites were persistent until the following April and complete degradation occurred by May, *i.e.*, about 8 months from the time of application.

Discussion

Disyston and Solvirex can be considered together. Singh *et al.* (1972), reported the residues of disulfoton remained for about 63–85 days and Rajakannu *et al.*, (1973) reported slow disippation up to 30 days, a rapid decline later, and persistence of residues beyond 60 days. Takase *et al.*, (1971) recorded a higher rate of degradation in rice fields than in acid soils. Menzer *et al*, (1970), Suett (1975), reported that residues of disulfoton persisted slightly longer than those of phorate whereas we found both Disyston and Solvirex to persist for only 40 days and less than phorate. Read (1969), reported the persistence of fensulfothion for at least 3 months by bioassay and Chishol (1974), also reported that it is moderately persistent and the residue persisted for 4 years in frozen carrots. In the present study fensulfothion persisted for only about 30 days in coffee soils. Benjamini *et al.* (1959), reported 5 metabolites of fensulfothion whereas Katague and Anderson (1967) and Bowman and Hill, (1971), recorded only 3 metabolites and the absence of the sulfoxide and its oxygen analogue.

In the present study, 5 distinct metabolites were recorded. Getzin and Chapman (1960) reported, that phorate is partially hydrolysed as well as oxidised and the parent compound was found up to 7, 14 and 28 days in different soils with little sulfoxide and sulfone. Granular treatments appeared to persist better than emulsions which agreed with the findings of Schulz *et al.*, (1973). Lichtenstein *et al.*, (1974), reported that phorate persisted better in incorporated soil than after surface application. Phorate disappeared rapidly and a concen-

tration of less than 0.1 ppm were measured after 14 and 30 days. Its sulfone and sulfoxide was reported 20–30 minutes after application to soil. Getzin and Shanks (1970), reported that phorate sulfoxide and sulphone persisted beyond 16 weeks and the thiolate analogues degraded to low levels within 2–8 days. They also recorded that the toxicity of phorate sulfoxide was greater several weeks after application than immediately following treatment, because small quantities of the sulfoxide were converted to phorate.

In the present study, about 7 metabolites of phorate were recorded ; this needs further confirmation. Movement of the parent compound was seen from the top layer to lower layers which differs from the study of Lichtenstein *et al.* (1974), and might be an error during field sampling so needs further confirmation. The persistence was recorded up to 50 days unlike in other studies where it persisted longer.

Caro *et al.*, (1973) investigated the dissipation of soil - incorporated carbofuran, applied either as broadcast or as furrow application, in two small water sheds and concluded that it disappears from soil by first order kinetics, the 'half-life' ranging from 46–117 days and persistence was better after furrow application than broadcast. Degradation was accelerated by high soil water content, high pH, and heavy soil texture. From 0.5 to 2 per cent of applied insecticidewas lost in runoff water. Getzin (1973), reported that the time required for 50 per cent breakdown of carbofuran varied from 3 weeks to over 50 weeks and the degradation was 7–10 times faster in alkaline soil (pH 7.9) than in acid and neutral soils (pH 4.3–6.8). Williams *et al.* (1976), also reported that degradation of carbofuran was particularly slow in soils of poorly-drained clay muck, well-drained clay muck and poorly-drained clay. Carbofuran persisted for about 6 months in coffee soils. Gupta and Rawlins (1966), also recorded that the two systemic insecticides Isolan and Baygon persist for more than 100 days and 6 months respectively. All the above reports indicate that carbamate insecticides persist longer than organophosphates.

One of the reasons for the quicker degradation of the organophosphates in coffee soils in comparison to other agricultural soils is the presence of high amounts of copper-phosphate complex in coffee soils. Since coffee plantations have been routinely sprayed with Bordeaux mixture and other fixed copper formulations for more than 30–40 years a high accumulation of copper was found in the plantation areas amounting to about 170 kg of acid-extractable total copper per hectare in the top 15 cm layer. This large amount of copper interacts with the phosphatic fertilizers routinely-applied and forms a copper-phosphate complex which is insoluble in water, and thus the nutritive value of the phosphatic fertilizers applied is entirely lost. It is also reported that cupric ions and a few other cations catalyse the hydrolysis of organophosphate esters

(Wagner-Jauregg *et al.*, 1955) and this effect is more pronounced when the copper exists in chelated form, as it undoubtedly does in most soils (Mitchell, 1964). In an *in vitro* comparison, the half life of a phosphate ester was decreased by a factor of 100 in the presence of millimolar amounts of a number of amino acid chelates and by a factor of more than 300 by the histidine chelate (Wagner-Jauregg *et al.*, 1955). Thus, the effectivity of the organophosphate esters is very much reduced in coffee soils leading to quicker detoxification.

Disulfoton is reported to have no significant effect on earthworms whereas phorate is highly toxic (Edwards *et al.*, 1967). Kring (1969) found that fensulfothion had no marked effect on earthworms. Edwards (1969) and Kring (1969), indicated that carbaryl, carbofuran and Bux (R) when used as soil insecticides resulted in marked decrease in earthworm populations, as well as those of Collembola. Since in coffee plantations, there is no tillage, soil animals become increasingly important in the maintenance of soil fertility and the effects of pesticides would be of more significance (Edwards, 1969).

In so far as other soil arthopods are concerned, Edwards *et al.*, (1967), have pointed out that the less residual organophosphates like phorate, disulfoton and fensulfothion did not affect either the number of animals or biomass to the same extent as in aldrin or dieldrin. However, the moderately persistent carbamate soil insecticides like carbofuran are very broad-spectrum poisons and need more research.

Conclusions: It was found that the organophosphatic esters such as disulfoton, phorate and fensulfothion were very short-lived in coffee soils. Fensulfothion being the least persistent (30 days) disulfoton about 40 days, phorate about 50 days and carbofuran, about 6 months. This faster rate of degradation of all these pesticides in coffee soils is attributed to the higher amounts of cupric ion complexes in coffee soils due to continuous use of copper fungicides. The short-lived organophosphates can be used in pest control 15 days prior to the harvest and no residues can be detected in the harvested beans, but in the routine pest control operations the application has to be repeated at frequent intervals due to faster rate of detoxification, leading to increases in cost of treatment. The moderately persistent, carbofuran, is useful in long range pest control programmes because a single application during August persists for nearly 6 months and is more economical. Since residues of carbofuran is noticed in the harvested coffee bean even after single application during August and the tolerance limit carbofuran residues in coffee beans is fixed at 0.1 ppm, the use of carbofuran in coffee estates must be withheld till such time the amount and timings of application is worked out to limit the residues in the final harvested bean to well below tolerance limits. More metabolites in case of fensulfothion and phorate were recorded than normally and this needs further confirmation.

Persistence of the parent compounds, their leachability to lower depths needs further confirmation. No adverse effect of disulfoton, phorate and fensulfothion was recorded on earthworms and other soil organisms whereas the carbamate insecticide, carbofuran, adversely effects earthworms and other soil animals.

The authors are grateful te Dr. D'Souza, Directar of Researeh, for the interest in these studies, to B. S. Aswathkumar, F. A. (Sr.) for the help rendered in the field and Laboratory studies and to Bayer India, Rallis India, and Sandoz India, Ltd., for the co-operation extended by supplying the technical and commercial formulations used in the studies.

References

Benjamini, E., Metcalf, R. L. and Fukuto, T. R., 1959, The chemistry and mode of action of the insecticide O, O- Diethyl o-p-methylsulphinylphenyl phosphorothionate and its analogues. *J. Econ. Ent.*, **52** : 94–98.

Caro, J. H., Freeman, H. P., Glotfelty, D. E., Turner, B. C. and Edwards, W. M., 1973, Dissipation of soil incorporated carbofuran in the field. *J. agric. Food Chem.*, **21** : 1010–1015.

Chisol, D.. 1974, Persistence of fensulfothion in soil and uptake by rutabagas and carrots. *Can. J. Plant Sci.*, **54** : 667–671.

Edwards, C. A., 1966, Insecticide residues in Soil. *Residue Reviews*, **13** : 83–132.

Edwards, C. A., 1969, Soil pollutants and soil animals. *Scientific American* (*April*) p. 88–99.

Edwards, C. A., Thompson, A. R. and Lofty, J. R., 1967, Changes in soil invertebrate populations caused by some organophosphorus insecticides. *Proc. 4th Brit. Insecticide and Fungicide Conference*, p. 48–55.

Getzin, L. W., 1973, Persistence and degradation of carbofuran in soil. *Environ. Entomol.*, **2** : 461–467.

Getzin, L. W. and Chapman, R. K. 1960, The fate of phorate in soils. *J. econ. Ent.*, **53** : 47–51.

Getzin, L. W. and Shanks, C. H. Jr., 1970, Persistence, degradation and bioactivity of phorate and its oxidative analogues in soil. *J. econ. Ent.*, **63** : 52–58.

Gupta, D. S. and Rawlins, W. R., 1966, Persistence of two carbamate insecticides in three types of soils. *Ind. J. Ent.*, **28** : 482–493.

Katagu, D. B. and Anderson, C. A., 1967, Metabolism of ^{32}P labelled Dasanit in cotton plants *Bull. Environ. Contam. Toxicol* **2** : 228–235.

Kring, J. B., 1969, Mortality of the earthworm *Lumbricus terrestris* L. following soil applications of insecticides to a tobacco field. *J. econ. Ent.*, **62** : 963.

Litchtenstein, E. P., Tom Fuhrenmann, W. and Schulz, K. R., 1974, Translocation and metabolism of 14C phorate as affected by percolating water in a model soil, plant ecosystem. *J. agri. Food. Chem.*, **22** : 991–996.

Menzer, R. E., Fontanilla, E. D. and Ditman, L. D., 1970, Degradation of disulfoton and phorate in soil influenced by environmental factors and soil type. *Bull. Environ. Cont. Toxical.*, **5** : 1–5.

Mitchell, R. L., 1964, Trace elements in soil. Chap. 8. P. 320–368, in F. F. Bear, Ed., Chemistry of the soil, *2nd Ed., Reinhold Publ. Corp.*, New York. 515 pp.

Rajakannu, Asaf Ali, K. K., Raghu Raj, R., Thirumurthy, S., Subramanian, T. R. and Krishnamurthy, K. K., 1973, Estimation of disulfoton residues in bhendi fruit by chemical and biossay methods and dissipation of disulfoton in soil. *Madras Agri. J.*, **60** : 534–536.

READ, D. C., 1969, Persistence of some newer insecticides in mineral soils measured by bioassay *J. econ. Ent.*, **62** : 1338–1342.

SCHULZ, K. R., LITECHTENSTEIN, E. P., FUHRAMANN, T. W. AND LIANG, T. T., 1973, Movement and metabolism of phorate under field conditions after granular band application. J. *econ. Ent.*, **66** : 873–875.

SINGH, K., GULATI, K. C. AND DEWAN, R. S., 1972, Persistence of Disyston residues in soils and plants. *Indian j. Agri. Sci.*, **42** : 1135–1138.

SUETT, D. L., 1975, Persistance and degradation of chlorfenvinfos, chlormephos, disulfoton, phorate and pirimiphos ethyl following spraying and late summer soil application. *Pesticide. Science*, **6** : 385-393.

TAKASE, TSUDA, I. H., TSUDA AND YOSHIMOTO, 1971, The fate of disulfoton in soil. *J. Jap. Appl. Entomol-Zoology*, **15** : 63–69.

WAGNER-JAUREGG, T., HACKLEY, B. E. JR., LIES, T. R., OWENS, O. O. AND PROPER, R., 1955, Model reactions of phosphorus containing enzyme inactivators. IV. The catalytic activity of certain metal salts and chelates in the hydrolysis of diisoprophyl fluorophosphate. *j. Amer Chem. Soc.* 77 : 922–929.

WILLIAMS, I. H., 1976, Persistence of carbofuran residues in some British Columbia soils. *Bull-Environ. Cont. Toxical*, **15** : 242-243.

Persistence of Aldicarb in Different Soil Types Relative to Weather Elements

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ABSTRACT

The persistence of aldicarb was studied in three different soil types, *viz*, alluvial clay, black clay and red soilty loam in pot cultures. The persistence of the aldicarb was assessed using a bioassay technique with aphids, (*Aphis gossypii*) G. on cotton. The aldicarb was found to persist longer during the months of December to April. Among different soil types, aldicarb persisted longer in black clay soil (91–102 days) than alluvial clay 81-94 days) and red silty loam (75-98 days) at 1.0 kg a.i/ha. Increase in the dose, resulted in prolonged persistence of the toxicant up to 109 days at 1.5 kg a.i/ha. The relationship existing between persistence of aldicarb and weather elements indicated that rainfall, rainy days and soil temperature were negatively associated with persistence of the toxicant in all soil types. The partial regression coefficient indicated that the distribution of rain had more influence in hastening the loss of the toxicant than amount of rainfall. However, at higher dose soil temperasure was found to have more influence than rainfall in causing the loss of the toxicant in black clay and red silty loam soil at 1.0 kg.

THE toxicity of systemic insecticide, aldicarb (Temik(R)-2-methyl-2-(methylthio) propionaldehyde o - (methyl carbamyl) oxime against aphid, *Aphis gossypii* G. leafhopper, *Amrasca devastans* (Dist.) and *Thrips tabaci* Lind. on cotton, bhendi and brinjal in field has been well-established in recent years (Swamiappan, 1969 ; Palanisamy, 1971 ; Rao, 1973 ; Uthamasamy *et al.*, 1973). It has been reported that the toxicity of soil-applied systemic insecticides is influenced by edaphic and environmental factors. As not much is known on the toxicity of aldicarb under various types of soil in tropical countries, the present investigation was carried out with well-defined soil types and results are correlated with weather factors.

MATERIAL AND METHODS

Three types of soils, *viz.*, alluvial clay, black clay and red silty loam were used and their properties are furnished in Table I. Pots were filled with 10 kg

TABLE I

Physico-chemical properties of the soils

	Alluvial clay	Black clay	Red silty loam
1. Mechanical composition (%)			
a) Clay	46.4	41.2	21.4
b) Silt	12.0	4.7	23.3
c) Fine sand	15.5	11.9	18.6
d) Coarse sand	15.6	37.9	30.9
2. Water holding capacity (%)	41.2	53.1	52.1
3. pH	8.2	8.0	8.2
4. EC (m mhos/cm)	0.3	0.2	0.3
5. Cation exchange capacity (m.e/100 g)	26.0	22.0	19.0
6. Organic carbon (%)	1.0	0.4	0.9
7. Total Nitrogen (mg/g)	1.6	1.6	0.7

of the different soils. Calculated quantities of aldicarb (Temik 10 G supplied by M/s Union Carbide India Ltd.) based on the population of cotton plants/ha (calculated taking the recommended spacing cotton) were applied in a form of circular band 2.5 cm away from the point of seed placement and at 10 cm depth. Aldicarb was applied at the rate of 0.5, 1.0 and 1.5 kg a.i/ha to black clay and at 1.0 kg to alluvial clay and red silty loam. The pots were buried into the soil up to the level in the pot in a meteorological observatory and were removed after a specified time. Cotton seeds (MCU 5) were sown at the rate of 4 per pot and watered to 80 per cent water-holding capacity. The pots were kept under glass house conditions for further observations. The seedlings were thinned to two per pot after fifteen days. Periodic tests were made at 7.5 cm depth of the soil to assess the water requirements to maintain the moisture level keeping additional untreated pots. The persistence of toxicant was assessed by

bioassay with cotton aphids, *Aphis gossypii* G. Ten young adult apterous aphids were confined on the underside of the third leaf from the top using a microcage. The mortality of aphids was assessed 48 hr. after inoculation. This was repeated at weekly intervals, and sometimes more frequently, until there was less than 50 per cent mortality.

In one set of experiments, the pots treated with aldicarb were exposed for one month. This was carried out for a period of eleven months from September, 1974 to July, 1975. The treatments were replicated four times including a check where the pots were not exposed to weather elements at all.

In another experiment, five sets of pots as detailed above were buried on 1st September, 1974 and a set of pots was removed after 1, 2, 3, 4 and 5 months. Soil temperatures in three different soils was recorded at a depth of 10 cm using a thermometer.

Results and Discussion

In black clay soil, aldicarb persisted longer (91-102 days) than alluvial clay (81-94 days) and red silty loam (75-98 days) at 1.0 kg/ha (Table II). An increase in the dose of aldicarb (1.5 kg) resulted in prolonged persistence of the toxicant up to 109 days in black clay soil as against the maximum of 86 days observed at 0.5 kg.

Table II

Persistence of aldicarb in three types of soil (Days up to which 50 per cent mortality of aphids observed within 48 hours – means of 3 observations)

Period	Black clay			Alluvial clay	Red silty loam	S. E.	C. D. (P=0.05)
	0.5 kg	1.0 kg	1.5 kg	1.0 kg	1.0 kg		
Check	77.8	106.8	105.3	84.3	89.3	7.7**	23.1
Sept., 1974	71.0	67.3	69.5	68.0	72.5	N. S.	–
Oct., 1974	74.5	68.5	88.3	77.3	62.5	N. S.	–
Nov., 1974	71.3	75.5	92.3	73.8	77.0	1.6**	4.9
Dec., 1974	74.0	96.8	109.3	81.0	84.5	3.9**	11.7
Jan., 1975	75.0	101.0	106.8	81.0	84.3	4.2**	12.7
Feb., 1975	86.5	102.0	108.5	94.0	98.5	1.2**	3.5
March, 1975	83.3	91.5	95.3	87.0	75.3	2.5**	7.5
April, 1975	77.5	95.5	108.3	88.5	97.8	3.0**	9.0
May, 1975	55.8	69.5	78.5	60.8	59.5	3.5**	10.6
June, 1975	52.8	92.5	100.5	58.0	34.0	3.1**	9.2
July, 1975	47.5	64.8	73.3	57.0	56.0	2.7**	8.0
Sept.-Oct., 1974	27.3	30.3	38.8	35.0	31.5	1.5**	4.5
Sept.-Nov., 1974	16.4	27.5	35.3	20.3	15.0	4.9**	14.7

N. S. – Not significant

* – Significant at 5 per cent

** – Significant at 1 per cent

When aldicarb was applied at 1.0 or 1.5 kg to the soil, toxicant was found in detectable quantities by aphid bioassay even three months after application. At 0.5 kg the toxicant completely disappeared within three months. Increases in dose beyond 1.0 kg did not produce any significant difference in persistence.

Aldicarb persisted longer during the months of December to April in all soils. This might be due to low rainfall and soil temperature during this period (Table III). The environmental factors, rainfall (both quantity and distribution)

TABLE III

Details of weather elements recorded during experimental months

	Soil temperature °C at 10 cm depth									Total rainfall (mm)	Rainy days (No.)
	Alluvial clay			Black clay			Red silty loam				
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean		
Sept. 1974	34.4	25.3	29.9	35.5	24.0	29.7	33.6	26.2	29.8	90.2	13
Oct. 1974	35.0	25.6	30.3	36.3	24.1	30.2	34.1	26.2	30.1	18.3	5
Nov. 1974	34.1	26.0	30.1	36.5	23.8	29.5	32.7	26.2	29.5	46.0	3
Dec. 1974	31.3	24.0	27.8	34.8	21.0	27.4	30.2	24.6	27.4	3.5	2
Jan. 1975	32.3	23.9	28.1	36.9	20.0	28.5	30.3	24.4	27.4	—	0
Feb. 1975	33.2	24.4	28.8	38.5	21.5	30.0	31.7	23.7	27.7	0.6	2
March 1975	37.5	21.4	29.4	41.9	20.5	31.2	33.4	21.8	27.6	84.9	4
April 1975	40.9	21.7	31.3	44.9	22.5	33.7	33.9	22.6	28.2	6.3	3
May 1975	41.1	23.1	32.1	43.3	23.7	33.5	41.6	24.1	32.9	134.7	7
June 1975	43.0	24.1	32.6	43.4	22.6	33.0	44.2	17.9	31.1	85.6	13
July 1975	40.4	23.7	32.1	42.6	25.2	34.0	43.9	18.3	31.1	69.2	12
Sept.-Oct. 1974	34.7	25.5	30.1	35.9	24.0	30.0	33.8	26.2	30.0	108.5	18
Sept.-Nov. 1974	34.5	25.7	30.1	36.1	23.9	30.0	33.5	26.2	29.8	154.5	21
Sept.-Dec. 1974	33.7	25.3	29.5	35.8	23.2	29.5	32.6	25.8	29.2	158.0	23

and soil temperature were negatively correlated with the persistence of the chemical in all soils (Table IV). In alluvial clay, the distribution of rain rather than the total rain had a more profound effect in hastening the loss of the toxicant (Table V). In black clay at 0.5 kg, the same trend was observed. However, at 1.5 kg the soil temperature had more influence than rainfall in hastening the loss of the toxicant in black clay and at 1.0 kg in red silty loam soil. Graham-Bryce *et al.* (1972) reported that the persistence of toxicants was less when the frequency of rainfall was more. The toxicants released from the soil must be lost either by leaching or volatilization or by decomposition. It had been reported that 50 per cent soil moisture was optimum for oxidation of aldicarb to its metabolites (Bull *et al.*, 1970). A faster rate of decomposition and conversion to non-toxic products occurred at 100 per cent soil moisture. Much of the aldicarb applied existed as sulfoxide (Hough *et al.*, 1975). Hence,

it is expected that if soil moisture is above 80 per cent, the oxidative products of aldicarb are easily leached out from the soil, because they have very low 'Q' values range from 1 to 2 ; the parent material having a 'Q' value of (Bromilow, 1973).

TABLE IV

Relationship between weather elements and persistence of aldicarb in different types of soil ('r' value)

Weather factors	Persistence of aldicarb in days				
	Black clay soil			Alluvival clay soil	Red silty loam soil
	0.5 kg	1.0 kg	1.5 kg	1.0 kg	1.04 kg
Soil temperature (maximum)	−0.404	0.033	−0.029	−0.537	−0.822** $\hat{Y}=179.29-3.00X$
Soil temperature (minimum)	−0.616* $\hat{Y}=173.34\ 4.57X$	−0.892** $-\hat{Y}=261.51\ 7.84X$	−0.779** $-\hat{Y}=245.92\ 6.77X$	−0.249	0.503
Soil temperature (Mean)	−0.580	−0.265	−0.335	−0.701* $\hat{Y}=237.89-5.39X$	−0.771** $\hat{Y}=306.48-7.96\times$
Rainfall (mm)	−0.594	−0.580	−0.720* $\hat{Y}=104.82-0.23\times$	−0.705* $\hat{Y}=84.58-0.19X$	−0.666* $\hat{Y}=86.28\ 0.27X$
Rainy days (No.)	−0.725* $\hat{Y}=81.03-1.91X$	−0.595	−0.711* $\hat{Y}=106.47-2.20X$	−0.806** $\hat{Y}=87.69-2.16X$	−0.758** $\hat{Y}=90.60-3.05X$

* — Significant at P=0.05

** — Significant at P=0.01

The sake of loss of toxicant from the soil was found to increase with increase in temperature. Temperature affects most of the processes that influence the disappearance of insecticides from soil *i.e.*, chemical degradation, bacterial decomposition, volatilisation, solubility and desorption (Edwards, 1974). The solubility of aldicarb increased with increase in temperature (Anon., 1975). The increased soil temperature might have increased the solubility of aldicarb in soil moisture. The 'half-life' of the oxidised products in aqueous solution would be reduced due to increase in temperature. Rate of leaching (Furmidge *et al.*, 1966) and volatilization (Spencer and Cliath, 1973), are governed by temperature and rainfall. Volatilization of pesticides was more rapid from wet than dry soils (Bowman *et al.*, 1965 ; Guenzi and Beard, 1970 ; Willis *et al.*, 1971). Bull *et al.* (1970) reported volatilization of aldicarb increased with increased water evaporation. Water loss accelerates pesticide volatilization by 'wick effect'

where by pesticides move to the soil by mass flow in water moving to the surface to replace that evaporated (Spencer and Cliath, 1973).

TABLE V

Partial and multiple regression coefficients for weather elements and persistence of aldicarb in different soil types

		'b'	Standardised partial regression coefficient	Order of importance
A. *Black clay (0.5 kg)*				
Rainy days	(X_1)	—1.4828	—0.5620	I
Soil Minimum temperature	(X_2)	—1.8520	—0.2500	II
$\hat{Y}=120.427-1.483\ X_1-1.852\ X_2$				
B. *Block clay (1.5 kg)*				
Rainfall	(X_1)	—0.4586	—0.4586	II
Rainy days	(X_2)	—0.0296	—0.0300	III
Soil minimum temperature	(X_3)	—0.5632	—0.5632	I
$\hat{Y}=212.096-0.486\ X_1-0.030\ X_2-0.563\ X_3$				
C. *Alluvial clay*				
Rainfall	(X_1)	—0.0631	—0.2302	II
Rainy days	(X_2)	—1.3551	—0.5047	I
Soil mean temperature	(X_3)	—1.5882	—0.2065	III
$\hat{Y}=134.066-0.063\ X_1-1.355\ X_2-1.588\ X_3$				
D. *Red silty loam*				
Rainfall	(X_1)	—0.0701	—0.0540	IV
Rainy days	(X_2)	—3.3832	—0.2657	II
Soil maximum temperature	(X_3)	—4.8972	—0.4229	I
Soil Mean temperature	(X_4)	—6.1783	—0.1888	III
$\hat{Y}=450.674-0.070\ X_1-3.383X_2-4.897X_3-6.178X_4$				

REFERENCES

ANONYMOUS, 1974, *Temik Pesticide.* Union Carbide Technical Information. Union Carbide Corporation, Salinas, California.

BOWMAN, M. C., SCHECHTER, M. S. AND CARTER, R. L., 1965, Behaviour of chlorinated insecticides in a broad spectrum of soil type. *J. Agric. Food Chem.*, **13** : 360–365.

BROMILOW, R.H., 1973, Breakdown and fate of oximecarbamate nematicides in crops and soils. *Ann. Appl. Biol.*, **75** : 473–479.

BULL, D. L., STOKES, R. A., COPPEDGE, J. R. AND RIDGWAY, R. L., 1970, Further studies of the fate of aldicarb in soil. *J. econ. Ent.*, **63** : 283–289.

EDWARDS, C. A., 1974, Factors affecting persistence of pesticides in the soil. *Chemistry and Industry*, pp. 190–193.

FURMIDGE, C. G. L., HILL, A. C. AND OSGERBY, J. M., 1966, Physicochemical aspects of the availability of pesticides in the soil. I. Leaching of pesticides from granular formulations. *J. Sci. Food Agric.*, **17** : 518–525.

GRAHAM-BRYCE, I. J., STEVENSON, J.H. AND ETHERIDGE, P., 1972, Factors affecting the performance of granular insecticides applied to field beans. *Pestic. Sci.*, **3**: 781-797.

GUENZI, W. D. AND BEARD, W. E., 1970, Volatilisation of lindane and DDT from soil. *Soil Sci. Soc. Amer. Proc.*, **34**: 443-447.

HOUGH, A., THOMASON, I. J. AND FAMER, W. J., 1975, Behaviour of aldicarb in soil relative to control of *Heterodera schachtii*. *J. Nematol.*, **7**: 214-220.

PALANISWAMY, P., 1971, *Studies on the relative efficiency of certain systemic granular insecticides in the control of major pests of okra* (Abelmoschus esculentus (L) *Moench*). M.Sc. (Ag.) Dissert. Univ. Madras, Madras.

RAO, N.H.P., 1973, *Persistence of granular soil insecticides in cotton.* Unpub. M.Sc. Dissert, I.A.R.I., New Delhi

SPENCER, W. F. AND CLIATH, M. M , 1973, Pesticide volatilization as related to water loss from soil. *J. Environ. Qual.*, **2**: 284-289.

SWAMIAPPAN, M., 1969, *Further studies on the use of systemic granular insecticides as soi application in the control of major pests of cotton.* M.Sc. (Ag.) Dissert., Univ. Madras, Madras.

UTHAMASAMY, S., GOPALAN, M. AND VENKATANARAYANAN, D , 1973, Control of major sucking pests of egg-plant (*Solanum melongena*) with systemic granular insecticides. *Pesticides*, 7(2): 14-17.

WILLIS, G. J., PARR, J. F. AND SMITH, S., 1971, Volatilization of soil-applied DDT and DDD from flooded and non-flooded plots. *Pestic. Monit. J.*, **4**: 204-208.

Vertical and Horizontal Movement of Insecticides in Soils

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ABSTRACT

Horizontal and vertical movements of aldrin and BHC in clay-loam soil were studied. Aldrin at 9 and 15 kg *a.i.*/ha and BHC at 15 and 30 kg *a.i.*/ha were applied to the top 0-5 cm soil layer.

The vertical migration of aldrin in the soil from an initial deposit of 7.35 ppm (9 kg *a.i.*/ha dose) after 142 days of application was to the extent of 21.6 per cent and 11.4 per cent in 5-7 cm and 7-9 cm layers respectively. In case of 12.26 ppm deposit from 15 kg *a. i.*/ha dose, the vertical migration of aldrin residues was 12.6 per cent, 10.4 per cent and 1.2 per cent in 5-7 cm, 7-9 cm and 9-11 cm deep soil layers respectively. However no horizontal movement of the aldrin doses was observed.

The application of BHC to 0-5 cm deep soil resulted in deposits of 18.52 and 40.00 ppm from the application of 15 and 30 kg *a.i* /ha respectively. The movement of BHC was observed in both directions even after 240 days of application. The horizontal

movement was up to 2 cm distance from the treatment of BHC resulting in 0.11 to 0.43 per cent migration of the deposit. However, the vertical movement at this interval was to the extent of 9.40 per cent, 2.21 per cent and 0.43 per cent from 15 kg dose and 7.20 per cent, 2.15 per cent and 1.45 per cent from 30 kg dose in 5-7, 7-9 and 9-11 cm deep soil respectively.

Introduction

Both aldrin and BHC are used extensively in India for the protection of crops from soil insects. Their persistence and effectiveness, however, are governed by a number of factors. Leaching and cultivation are important factors which not only displace the insecticides from the place of application but also help in their degradation (Edwards, 1966). Displacement of insecticides may also be due to their absorption on the soil particles. Lichtenstein (1958) reported that insecticides worked into the soil by rototilling to a depth of 5 cm were located after 17 months primarily within the upper 3 cm layer. Because of possible contamination of water by leached soil insecticides, it is desirable to study their movement through the soil. An attempt was made to investigate both horizontal and vertical movement of insecticides in clay loam soil and the results obtained are described below.

Material and Methods

Small plots of 3m × 1m were used to study the vertical and horizontal movement of insecticides. In the centre of each plot a strip 0.0 m wide, 0.9 m long and 0.5 m deep was dug across the length (Fig. 1) and filled with well pulverised

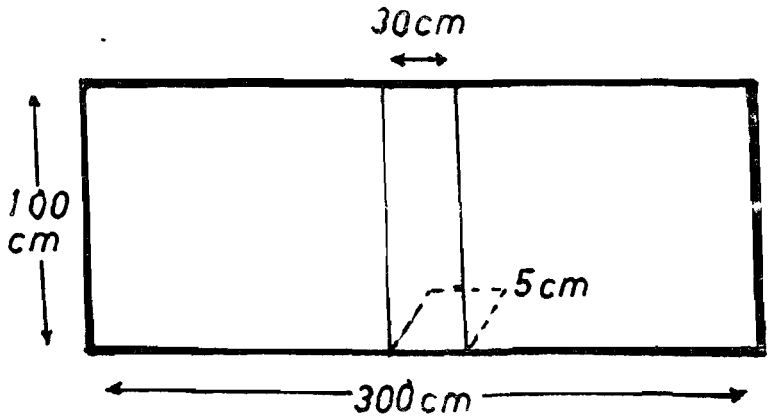

Fig. 1

soil. The insecticide, in dust formulation, were applied as a uniform thin layer to a depth of about 5 cm from the top at the rate of 9 and 15 kg *a.i.*/ha for aldrin, and 15 and 30 kg *a.i.*/ha for BHC. The insecticide layer was covered from above with soil to bring it level with the rest of the plot. Thus, there were five treatments including a control and each was replicated three times. Each plot was irrigated individually immediately after treatment with 20.1 of water and the irrigations were repeated every 15 days.

The soil samples were taken at a distance of 2 cm in the horizontal direction as against a 2 cm in the vertical direction from the placement of insecticide, using of a cylindrical vertically marked augur. Care was taken to avoid contamination while taking the sample. Samples were air dried. And aldrin and BHC residues were extracted from soil samples using distilled n-hexane and acetane at 2 ml/g as solvents respectively and tumbling on a motorised shaker for half an hour.

The residues of aldrin were determined using phenylazide spectrophotometric technique of 0-Donnel *et al.* (1954) while the BHC residue were estimated by the recommended procedure of BHC Panel (1962) with the slight modifications given in A.O.A.C. (1965).

Result and Discussion

Vertical movement of insecticide appears to be a significant factor in the loss of insecticide from soil. The data in Table I indicates that 12–20 per cent, 75 per cent and 92 per cent of the aldrin applied was lost from the two application dosages in 30, 60 and 142 days respectively at the placement layer. In 30 days, about 3 per cent the insecticide reached the next 2 cm depth. However, in 142 days it reached the 4–6 cm depth (9–11 cm from the top) from the placement layer, in amounts corresponding to the base dictation level and 1.2 per cent of the deposit. In the case of BHC (Table II) the rate of dissipation from the point of application of two application dosages was also similar *i.e.*, 30–32 per cent in 30 days, 76–81 per cent in 120 days and 88–92 per cent in 240 days. Quite large amounts of insecticide were recovered in the next 2 cm deep layer after 30 days. After 120 days' BHC was detected in the 4–6 cm depth (9–11 cm from the top) in traces, but in 240 days the amounts recovered were 0.08 ppm from the 15 kg application and 0.58 ppm from the 30 kg application dose.

Table I

Vertical movement of aldrin (ppm) in clay loam soil

Days after treatment	Depth (cm)			
	0–5	5–7	7–9	9–11
		9 kg a.i./ha		
0	7.35			
30	5.86(79.7)	0.28(3.8)	—	—
60	1.89(25.7)	1 62(22.0)	BDL	—
142	0.60(8.1)	1.60(21.7)	0.84(11.4)	BDL
		15 kg a.i./ha		
0	12.26			
30	10.73(87.5)	0.41(3.3)		
60	3.12(25.4)	0.33(2.6)	0.33(2 6)	—
142	1.02(8.3)	1.55(12.6)	1.28(10.4)	0.15(1.2)

Note : B.D.L.—Below detectable level ; figures in parantheses represent percentage.

TABLE II

Vertical movement of BHC (ppm) in clay loam soil

Days after treatment	Depth (cm)			
	0–5	5–7	7–9	9–11
		15 kg a. i./ha		
0	18.52			
30	13.00(70.19)	4.74(25.59)	—	—
60	9.17(49.51)	4.05(21.87)	0.27(1.46)	—
120	4.52(24.41)	3.10(16.74)	0.33(1.78)	BDL
240	2.24(12.10)	1.74(9.40)	0.41(2.21)	0.08(0.43)
		30 kg a. i. / ha		
0	40.0			
30	27.09(67.72)	9.64(24.10)	—	—
60	22.26(55.65)	5.51(18.73)	0.51(1.25)	—
120	7.38(18.45)	4.40(11.00)	0.62(1.55)	BDL
240	3.21(8.03)	2.88(7.20)	0.86(2.15)	0.58(1.45)

Note : BDL—Below detectable level ; figures in parentheses represent percentage.

These results indicate clearly that both aldrin and BHC moved downwards. The amount of insecticide which moved vertically, increased with time particularly for aldrin and was greater in the close 2 cm depth than the further depths. The low amounts of residues found at subsequent depths was probably. due to the reduced amounts of insecticide available in the immediate upper 2 cm layer.

The horizontal movement of aldrin and BHC residues was also investigated. In the case of aldrin, the residues in 0–2 cm distance from the treatment place were below detectable level (Table III). In the case of BHC the recoveries

TABLE III

Horizontal movement of aldrin (ppm) in clay loam soil

Days after treatment	Distance (cm)			
	0	0–2	2–4	4–6
		9 kg a. i./ha		
0	7.35			
30	5.86(79.7)	BDL	BDL	—
60	1.89(25.7)	BDL	BDL	—
142	0.60(8.1)	BDL	BDL	—
		15 kg a. i./ha		
0	12.26			—
30	10.73(87.5)	BDL	BDL	—
60	3.12(25.4)	BDL	BDL	—
142	1.02(8.3)	BDL	BDL	—

Note : BLD–Below detectable level ; Figures in parentheses represent percentage.

from 0–2 cm horizontal soil samples were to the extent of 1.2–1.7 per cent, 2.3–3.6 per cent, 0.8–1.0 per cent and 0.1–0.4 per cent at 30, 60, 120 and 240 days of treatment respectively. Moreover, traces of BHC were also detected at further distances (2-4 cm) but were below the dectable level (Table IV).

TABLE IV

Horizontal movement of BHC (ppm) in clay loam soil

Days after treatment	Distance (cm)			
	0	0–2	2–4	4–6
		15 kg a. i./ha		
0	18.52	—	—	—
30	13.00(70.19)	0.31(1.67)	—	—
60	9.17(49.51)	0.67(3.62)	BDL	—
120	4.52(24.41)	0.19(1.03)	BDL	—
240	2.24(12.10)	0.02(0.11)	BDL	—
		30 kg a. i./ha		
0	40.0	—	—	—
30	27.09(67.72)	0.48(1.20)	—	—
60	22.26(55.65)	0.93(2.33)	BDL	—
120	7.38(18.45)	0.31(0.78)	BDL	—
240	3.21(8.03	0.17(0.43)	BDL	—

Note : Below detectable level ; Figures in parentheses represent percentage.

Therefore this suggested that there was greater movement of insecticide in the vertical than in the horizontal direction. Since, the treated soils were not disturbed by cultivation, the movement of insecticides in clay loam soil may be attributed to either leaching with water or absorption on the soil particles. The assumption justifies the small horizontal movement as compared to the vertical movement in which irrigation water tends to move downward taking insecticide with it. Whatever little horizontal movement was seen that may be due to absorption on to soil particles. Therefore, it indicates that the soil type has a great bearing on the movement of insecticide because their properties differ considerably.

The findings corroborate following observations. Lichtenstein and Schulz (1961) reported that the persistence of aldrin was affected by soil moisture. Water apparently, causes a displacement of the aldrin from the soil particles. Lichtenstein *et al.* (1962) determined the influence of mode of application and a cover crop on the persistence and vertical distribution of insecticides in soils. Aldrin and heptachlor were applied either to the soil surface only or incorporated into the soil by rototilling to approximately 5 inches. Recoveries of insecticidal residues ranged from 2.7 per cent to 5.3 per cent of the applied dosages, 4 months after a soil surface application. One year after treatment of the upper soil layers, 90 per cent of the recovered residues were located within the upper 3

inches of the soil. The highest concentration of the insecticides was found within the second inch of the soil layer. A deeper penetration and a more equal distribution of the insecticidal residues was noticed 3 years after soil treatment.

The authors are thankful to the Head, Department of Entomology and Dean/Director (Research), University of Udaipur for providing necessary facilities during the course of the investigations. This research was supported by a P. L. 480 Research Grant, FG-IN-431 (A7, CR-294).

References

AOAC, 1965, Official methods of analysis of the Association of Agricultural Chemists. *Association of Agricultural Chemists*, Washington A.D.C.

BHC-Panel, 1962, The determination of small amounts of BHC in flour and edible oils. *Analyst*, **87** : 220-227.

Edwards, C.A., 1966, Insecticide residues in soils. *Res. Rev.*, **13** : 83-132.

Lichtenstein, E. P. and Schulz, K. R., 1961, Effect of soil cultivation, soil surface and water on the persistence of insecticidal residues in soils. *J. econ. Ent.*, **54**: 517-522.

Lichtenstein, E. P., 1958, Movement of insecticides in soils under leaching and non-leaching conditions. *J. econ. Ent.*, **51** : 380-383.

Lichtenstein, E. P., Mueller, C. H., Myrdal, G. R. and Schulz, K. R., 1962, Vertical distribution and persistence of insecticidal residues in soils as influenced by mode of application and a cover crop. *J. econ. Ent.*, **55** : 215-219.

O'Donnell, A.E., Neal, M.M., Weiss, F.T., Bann, J. M., DeCino, J.D. and Lau, S.C., 1954, Chemical determination of aldrin in crop materials. *Agric. and Food Chem.*, 2 573-583.

Preliminary Observations on the Persistence of Lindane and Heptachlor in Soil

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Abstract

Organochlorine insecticides are used for the control of soil-borne insects. They are known to persist for long periods. However, authors differ in their estimates of the persistence of different insecticides in soil (Edwards, 1966). The persistence is governed by the type of the insecticides, nature of the soil and the climatic conditions. Some work has also been carried out to find out whether the presence or absence of a cover crop would have any effect on the persistence. A preliminary trial has been carried out at the Central Plant Protection Training Institute to find out the persistence of lindane and heptachlor in soil with and wiihout a cover crop.

Material and Methods

The trials were laid out in a randomised block design at the Institute's farm where the soil is a sandy loam. Four blocks each containing 8 plots measuring 4×4.5 m were prepared. Four of the plots in each block were treated at random as follows :

1. 0.65 per cent lindane dust at 2.5 kg active ingredient per hectare.
2. 0.65 per cent lindane dust at 2.5 kg active ingredient per hectare with a cover crop of jowar.
3. Cover crop of jowar without any insecticide.
4. Control without crop and insecticide.

The required quantity of the dust was mixed with some more soil and distributed as uniformly as possible in the plot and then raked in.

The remaining four plots in the block were treated similarly at random substituting 5 per cent heptachlor dust for lindane dust. Jowar seed (CSH1) was planted in the plots which were to have the cover crop. The plots were irrigated once a week. Soil samples were taken to a depth of 10 cm at monthly intervals at 5 places in each plot selected at random and bulked. The samples were analysed by thin-layer chromatography as described below :

1. Extraction

Twentyfive grams of the soil was weighed into a paper extraction thimble, plugged with cotton and extracted in a Soxhlet extractor with hexane for 3 hrs. The solvent was then removed, leaving a residue of 2 ml in the flask. The residue was transferred to a 10 ml stoppered measuring flask and made up to the mark with hexane. Thus 1 ml of the extract was equivalent to 2.5 g of the soil sample.

2. Quantitative measurement of the insecticide

An aliquot of the extract was spotted on a 250 micron thick silica gel-silver nitrate thin-layer plate along with standard solution of lindane and heptachlor. The spots were visualised by exposure to ultra-violet light and quantitated by comparison with standards.

Preparation of silica gel–silver nitrate plates

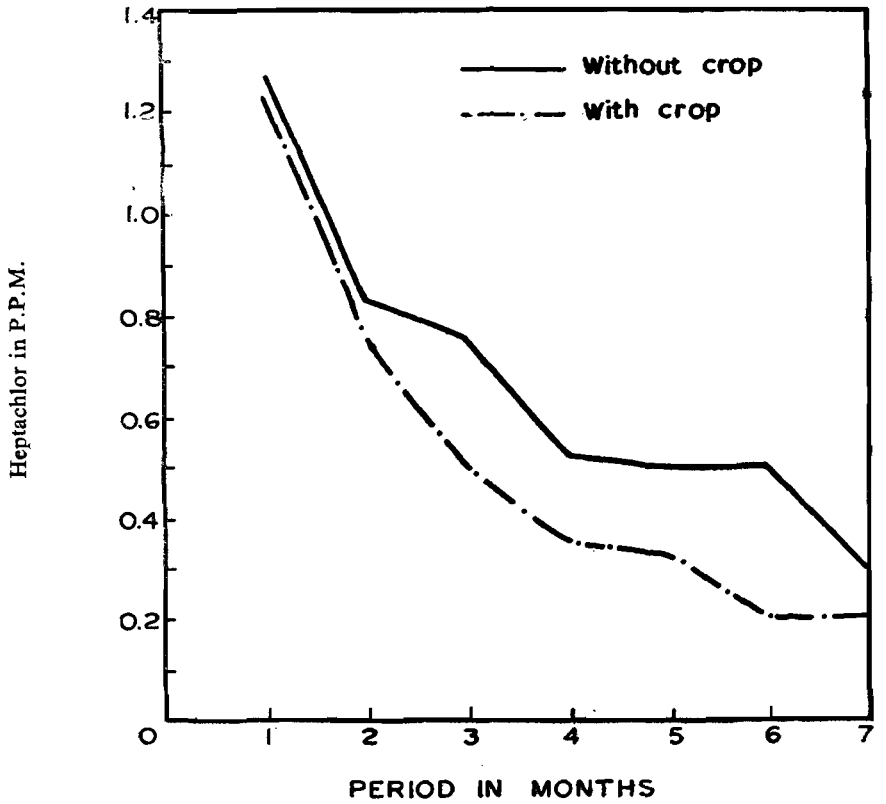
The plates were prepared according to the method of Moats (1966). In this method the silica gel 'G' was washed with water to remove traces of soluble chlorides. This increased the sensitivity of the plate, by keeping the background white when it was exposed to ultra-violet light after development.

Plates measuring 10 × 20 cm were arranged on the mounting board after being thoroughly cleaned with water and detergent. The plates were then wiped

carefully with a piece of cotton dipped in acetone. The applicator was placed on the first plate and was so arranged that it gave a 250 micron thick layer. 8 g of silica gel 'G' was weighed out into a 250 ml beaker and slurried with 75 ml of distilled water. The slurry was stirred well and filtered through a Buchner funnel. The filter cake was washed with 250–300 ml of distilled water. Then as much of the water as possible was removed under suction. The moist filter cake was transferred into a 25 ml ground glass stoppered test tube containing 20 mg of silver nitrate dissolved in 2 ml of water. 4–5 ml of distilled water was added and the test tube stoppered and shaken vigorously for about 30 seconds, and poured into the applicator which was then drawn smoothly over the plates. With 8 g of silica gel it was possible to coat 4 plates of 10×20 cm. The plates were used on the day they were made.

Spotting and development

Standard solutions containing 1, 2 and 3μ g of lindane/heptachlor were spotted along with 2.5 g of the soil sample. The plate was developed in cyclo-



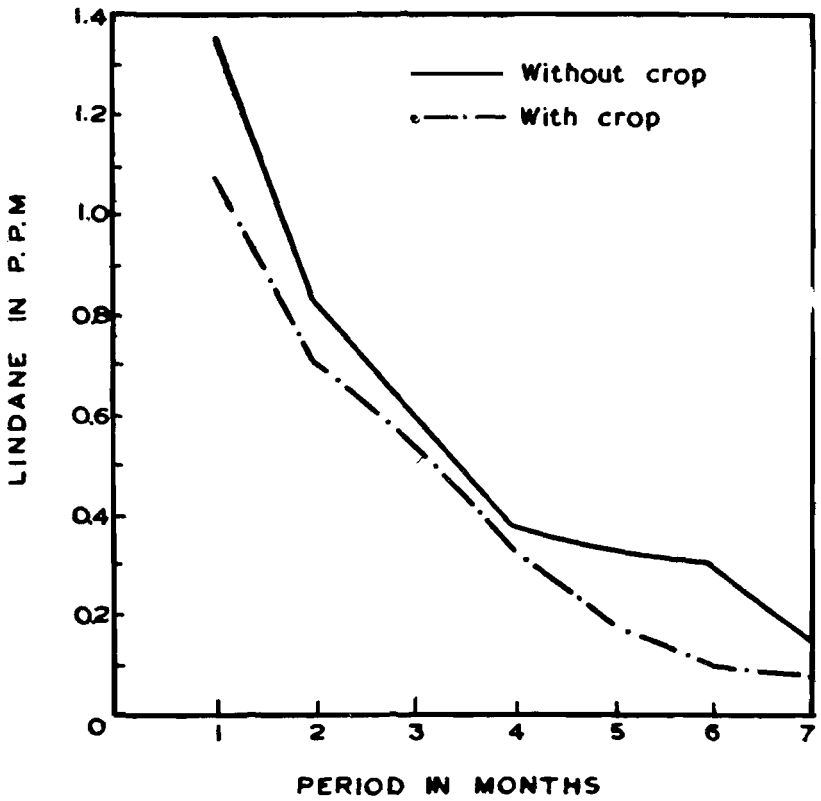
PERSISTENCE OF HEPTACHLOR IN SOIL

Fig. 1

hexane. The plate was then removed, solvent evaporated and it was exposed to ultra-violet (250 μ) light for 3 minutes. It was then exposed to steam for about 20 seconds and again put under the ultra-violet lamp for another five minutes. The insecticides appeared as dark brown spots against a white background. Under the experimental conditions it was possible to detect 0.1 μg of lin dane and heptachlor.

Results and Conclusion

The experimental results are given Table I and Fig. 1. They show that the concentration of the insecticides decreases rapidly during the first four months and then slows down considerably. It appears from the figure that 50 per cent loss of both lindane and heptachlor occurs at the end of about 3 and 4 months respectively.



PERSISTENCE OF LINDANE IN SOIL

Fig. 2

The persistence curves with or without the cover crop shows a similar trend. It is evident that in the presence of a cover crop the persistence is less for both the insecticides, although the difference is not very significant.

TABLE I

Average quantity of lindane and heptachlor present after 1 to 9 months of treatment

Particulars of sample	Quantity of pesticide present in ppm at the end of months								
	1	2	3	4	5	6	7	8	9
LSO	1.3	0.8	0.6	0.3	0.4	0.3	0.2	—	—
LSJ	1.1	0.7	0.7	0.2	0.2	0.2	0.1	—	—
HSO	1.3	0.8	0.7	0.5	0.7	0.5	0.3	0.06	—
SHJ	1.2	0.8	0.5	0.4	0.3	0.2	0.2	—	—

An examination of the results shows that the persistence as well as the effect of the cover crop are at variance with the results obtained by workers in other countries. However, the shorter persistence in the covered plots may be because these plots were cultivated in relation to planting the crop. It may be mentioned here that the trial was carried out during the months of November to July. The day-time temperature during period ranged between 27°–42°C and heavy winds prevail from November to March. It is wellknown that climatic factors influence the persistence of insecticides in soil (Edwards, 1970). The formulations used in the trial namely lindane and heptachlor dusts may also have contributed to the more rapid loss of the insecticides. The soil in the experimental plots was a sandy loam. It may be concluded from the preliminary trial that the persistence of organochlorine insecticides in soils in India may be somewhat different to those reported from temperate regions because of the different agroclimatic conditions.

REFERENCES

EDWARDS C.A., 1968, Insecticides residues in soil. in Residue Reviews, 13 : 83–132. *Publ. Springer-Verlag*, Berlin.

MOATS, W. A., 1966, Analysis of dairy products for chlorinated insecticide residues by thin-layer chromatography. J. *Ass. Off. Ag. Ch.*, 49 : 795.

EDWARDS, C. A., 1970, Peristent Pesticides in the environment. *Butterworths*, London.

A Note on the Degradation of Carboxin (Vitavax) and Oxycarboxin (Plantvax) by a Species of *Pseudomonas* Isolated from Soil

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Abstract

An unidentified species of *Pseudomonas* capable of utilising Carboxin and Oxycarboxin as sole source of carbon and nitrogen was isolated from red sandy loam soil perfused with the solutions of these fungicides. The bacterium hydrolyzed Oxycarboxin to aniline and oxidized Carboxin to corresponding sulphoxide and then to sulphone. Sulphone derivative was further hydrolyzed liberating aniline. Further, hydrolysis of aniline by the organism resulted in the accumulation of ammonium which was partly oxidised to nitrite. Nitrite accumulated in the medium without further oxidation to nitrate. The step-wise degradation of the two fungicides is discussed.

Key words: Degradation–Carboxin–Oxycarboxin–Aniline–Nitrite.

Carboxin (Vitavax ; 5, 6–dihydro–2 methyl–1, 4–Oxathiin – 3 carboxanilide) and Oxycarboxin (Plantvax ; 5, 6–dihydro–2–methyl–1, 4–oxathiin–3–carboxanilide, 4, 4–dioxide) are commonly used fungicides for the control of loose smut of wheat and barley (von Schmeling and Kulka, 1966). Allam and Sinclair (1969) reported that carboxin was metabolized to sulphone and other aniline derivatives in cotton seedlings. In incubation studies with soil, Chin *et al.* (1970b) were able to obtain sulphoxide from carboxin, but no further oxidation of sulphoxide. Wallnofer (1969) and Wallnofer and Koniger (1972b) studied the metabolism of the fungicides with *Rhizopus japonicus*. The fungus was able to convert carboxin to sulphoxide and then to sulphone with accumulation of butyranilide and some other unidentified end-products. A *Nocardia*–like soil–bacterium utilised carboxin as sole source of carbon and nitrogen (Bachofer *et al.*, 1973). Major metabolite of Carboxin in barley seedlings and mature plants was p-hydroxyphenyl derivative as reported by Briggs *et al.* (1974). So far there are no reports on the degradation of the fungicides by microorganisms with liberation of aniline and accumulation of ammonium and nitrite.

Red sandy loam soil (pH-6.5, organic matter–0.54) passed through 2 mm sieve was continuously perfused with the fungicides Vitavax (170 ppm) and Plantvax (1000 ppm) using persistaltic pump with a flow rate, 0.1 ml/min for six months. From the enriched soil, a bacterium was isolated by serial dilution and plating method (Sethunathan, 1972). The organism was identified as species of *Pseudomonas* on the basis of morphological and physiological characteristics.

Twenty four hour old broth culture of the bacterium, grown in shake culture, was centrifuged at 10,000 rpm for 10 min and washed three to four times with physiological saline (0.85 per cent) and resuspended in saline. One ml of this was inoculated into a mineral medium. The medium contained K_2HPO_4, 7.0 g ; KH_2PO_4, 3.0 g and $MgSO_4$, $7H_2O$, 0.1 g to a litre of distilled water. pH was adjusted to 7.0. It was dispensed in 250 ml capacity Erlenmeyer flask at the rate of 100 ml per flask. Aqueous solutions of the respective fungicides were passed through sterilized Seitz filter and added aseptically to the media to get a final concentration of 20 ppm. No carbon or nitrogen source, other than the fungicide, was added to the media in the flasks. The inoculated flasks were incubated under shake culture conditions. Uninoculated media, containing only fungicides, served as controls. At periodical intervals one ml aliquots of the culture were withdrawn and assayed for the products of degradation of the fungicides. Aniline was detected by thin-layer chromatography and also by colorimetric method (Lane, 1970). For thin-layer chromatography the samples were extracted with chloroform, spotted on 0.5 mm thick silica gel plates and developed in chloroform. The plates were sprayed with 0.01 per cent fluorescein (in methanol) and the spots were detected by observing under ultraviolet light. The culture was also tested for pH and the presence of parent compound. Ammonium was estimated by Nesslerization, nitrite by sulphanilic acid and N(1-naphthyl) ethylenediamine hydrochloride diazotization and nitrate by 2.4-phenol disulphonic acid method (Bremner, 1965).

For soil incubation studies, the same red sandy loam soil, from which the bacterium was isolated, was used. The respective fungicides were added to the soil at three levels, namely, 100, 1000 and 10,000 ppm, mixed well and placed in small plastic cups with perprated caps. The moisture content of the soil in each case was adjusted to 60 per cent of the maximum water holding capacity with sterile distilled water. The soil without the fungicide served as a control. The cups were incubated at $28^{\circ} \pm 2^{\circ}C$. Moisture content was maintained constant by periodical additions of sterile water. The samples were withdrawn at monthly intervals and assayed for the products of degradation of the fungicide as in broth-culture studies.

In a synthetic liquid medium containing mineral salts and Oxycarboxin as sole source of carbon and nitrogen, the bacterium was able to hydrolyze the fungicide to aniline and carboxylic acid derivative in twenty days and with further incubation for five days both ammonia and nitrite accumulated in the medium. However no oxidation of nitrite to nitrate was noticed.

With carboxin as sole source of carbon and nitrogen, the bacterium oxidized carboxin to sulphoxide in three days and then to sulphone in seven days. Aniline was liberated as before. Further, degradation of aniline led to

the formation of ammonium and its partial conversion to nitrite. However, ammonium and nitrite did not accumulate until after forty two days of incubation with this fungicide.

The parent compound completely disappeared from the medium with a drastic reduction of pH to 3.5 from an initial value of 7.0 at the end of the incubation period. Formation of 5,6-dihydro 2-methyl 1,4-oxathin 3-carboxlic acid, 4,4-dioxide in the case of both Vitavax and Plantvax with separation of aniline moiety were detected on thin-layer chromatograms alongside aniline. The liberation of aniline was also confirmed by colorimetric estimation.

The degradation of the two fungicides was also studied in unamended red sandy loam soil. In soil incubation studies, Oxycarboxin was degraded with accumulation of ammonium and nitrite after eight months whereas, with carboxin, it took eleven months before ammonium and nitrite accumulation in the soil could be detected. With further incubation for little over twelve months, oxidation of nitrite to nitrate could not be observed. In the control flasks the parent compound of the fungicides remained unaffected.

Such an extensive microbial degradation of the two fungicides with the liberation of aniline, hydrolysis of aniline to ammonium and the conversion of ammonium to nitrite have not been demonstrated so far either in liquid culture or in soil-incubation studies. The detailed report on these studies will be published later.

References

Allam, A. I. and Sinclair, J. B., 1969. Degradation of DMOC (Vitavax) in cotton seedlings. *Phytopathology*, **59**: 1548-1549.

Bchofer, R., Oltmanns, O. and Lingens, F., 1973. Isolation and characterization of a *Nocardia*-like soil-bacterium growing on carboxanilide fungicides. *Arch. Mikrobiol.*, **90**: 141-149

Bremner, J. M., 1965. Inorganic forms of nitrogen. in: *Methods of soil analysis*, (Ed.) C.A. Black Agronomy series No. 9, Part 2, American Society of Agronomy, Madison, Wisconsin, pp. 1179-1237.

Briggs, E. D., Waring, R. H., Hackett, A. M., 1974. The metabolism of carboxin in growing barley. *Pestic. Sci.*, **5**: 599-607.

Chin, W. T., Stone, G. M. and Smith, A. E., 1970b. Degradation of carboxin (Vitavax) in water and soil. *J. Agri. Food. Chem.*, **18**: 731-732.

Lane, J. R., 1970. Colorimetric microdetermination of Vitavax (5, 6-dihydro-2 methyl - 1, 4-oxathiin-3-carboxanilide) residues in crops. *J. Agri. Food Chem.* **18**: 409-412.

Sethunathan, N., 1972. Diazinon degradation in submerged soil and rice-paddy water. *Advan. Chem. Ser.*, **111**: 244-255.

von-Schmeling, E. and Kulka, M., 1966. Systemic fungicidal activity of 1, 4-oxathiin derivatives. *Science*, **152**: 659-660.

Wallnofer, P., 1969. Der mikroboielle Abbauder 1, 4-Oxathiin derivatives, 2, 3, dihydro-5-carboxanilide-6-methyl-1, 4-Oxathiin (DCMO). *Arch. Mikrobiol.*, **64**: 319-326.

Wallnofer, P. R. and Koniger, M., 1972b. The metabolism of the systemic fungicide carboxin (Vitavax) by *Rhizopus Japonicus*. *Intnl. J. Environ. Anal. chem.*, 2: 37-43.

Metabolism of Fensulfothion by a Soil Bacterium, *Pseudomonas alcaligenes* C_1

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ABSTRACT

Fensulfothion (0, 0-diethyl, 0—(4-methyl sulfinyl phenyl) phosphorothioate is extensively used to control nematodes and other insect pests. The pesticide has been found to be fairly persistent, and also contaminate lakes and untreated fields through run-off water.

Enrichment cultures with fensulfothion yielded a number of microorganisms, both bacteria and fungi capable of utilising fensulfothion as a source of corbon, phosphorous and sulfur. Among the bacterial isolates, one isolate, *Pseudomonas alcaligenes* C_1 was found to grow better on fensulfothion than other isolates and this organism was selected for our further studies on fensulfothion. Metabolism studies revealed that the organism utilises this pesticide by clearing the P-O-aryl bond, resulting in the formation of para methyl sulfinyl phenol and a phosphoric acid ester. The characterisation of metabolites were done using thin layer chromatography, UV, IR and NMR spectra. The probable role these organisms may play in the removal of the pesticide in the environment is discussed.

INTRODUCTION

THE natural ecological balance may be upset by sudden changes in the environment. Since most pesticides are synthetic chemicals, they cause several changes even among the non-target organisms (both fanna and flora) in soil. It has been generally felt that the damage caused to the ecosystem is related to the relative resistance, or susceptibility of the compound to biodegradation. It is understandable that a fast-acting, highly-specific and easily-degradable pesticide is least likely to cause any permanent damage to the ecosystem. Since it is also known that some of the degraded products of pesticides can be potential hazards it is imparative that the microbial metablism of pesticides is understood.

Fensulfothion (FEN) (0,0-diethyl, 0-(4-methyl sulfinyl phenyl) phosphorothioate), an organophosphorous pesticide has been extensively used for the control of golden nematode of potato *(Heterodera rostochiensis)* for several years in the Nilgiris district of Tamil Nadu in India. The repeated use of this pesticide at very high doses (60 kg/ha) and also at high elevations (above 2000 meters MSL) greatly magnifies the chances of run-off pollution and other environmental hazards. It is of importance because of our earlier finding that fensulfothion is very persistent in soil (Sheela and Vasantharajan, 1976). A

number of microorgnisms, obtained by enrichment culture methods from the Institute campus soil and also from the fensulfothion-treated soils from the Nilgiris, were found to utilise fensulfothion as sources of nutrition. Fensulfothion is metabolised in animals and plants to its oxygen analogues (W.H.O., 1973). But nothing is known about its microbial metabolism except that applied fensulfothion disappears from soil within a few days to months, with a suggestion that the probably due to microbial degradation (Duffy, 1969; Harris, 1969; Read, 1971; Williams, *et al.* 1972).

This study was undertaken with a view to understand the detoxification of this pesticide by microorganisms isolated from fensulfothion-treated soils.

Material and Methods

Chemicals

Fensulfothion (0,0-diethyl, 0-(4-methyl sulfinyl phenyl phosphorothioate), 98 per cent technical grade, was a gift from Bayer (India) Limited, Bombay. The technical grade fensulfothion was purified by extracting it into chloroform : ethanol (5 : 1) layer from an aqueous alkaline (pH 11.0) solution of fensulfothion which was contaminated with traces of thiomethyl phenol. The solvent layer was separated and dried over anhydrous sodium sulfate. The solvent then removed under vacuum and fensulfothion thus obtained was further purified on TLC and used. Acetylcholine chloride (99 per cent pure), cholinesterase type IV (Horse serum) and Dowex-1 were obtained from Sigma Chemical Company, St. Louis, Mo., USA. Authentic thiomethyl phenol was kindly supplied by Prof. D. L. Bull, US Department of Agriculture, Texas, USA.

The authentic p-methyl sulfiny penol was prepared by the method of Zincke and Ebel (Zincke and Ebel, 1914). The crystallised p-methyl sulfinyl phenol was found to be pure when checked on silica gel thin layer plates showing a single spot with diazotised p-nitroaniline as the spray reagent. The crystals were shining needles and had a melting point of 90-91C. All other chemicals used were of analytical grade availablable commercially.

Isolation of fensulfothion utilising microorganisms

500 g of virgin soil collected from the Institute campus were treated with 20 g of 5 per cent granules of fensulfothion to give a 1 per cent final concentration of the active ingredient and was incubated at 30°C keeping the moisture at 40-50 per cent of water holding capacity. After about two weeks, 1 g samples from the above were used as inocula for the isolation of FEN utilising microorganisms. Filter-sterilised pesticide was added to suitable mineral salts basal medium to serve as a source of carbon, phosphorus, sulphur or a combination of these elements. To 50 ml medium to 250 Erlenmeyer flasks the above sample of soil was added and incubated at 30°C. Serial transfers were made at weekly intervals into corresponding media for several weeks, after which the cultures

were streaked on to plates containing respective media solidified with 1.5 per cent agar. The organisms were purified in the usual way and maintained on FEN containing agar slants.

Soil samples collected from FEN treated areas in Nilgiris were also used as inocula to obtain pesticide-utilising organisms.

Analytical methods

Paper and silica gel thin layer chromatography (250 μ) were used to detect FEN metabolities. A number of solvent systems were used for developing the chromatogram and the phosphorus-containing compounds were detected by the method of Hanes and Isherwood (Hanes and Isherwood, 1949) and with $PtCl_2$ (McRae and McKenley, 1963). The phenol was detected with diazotised p-nitro-aniline.

Disappearance of fensulfothion in culture

Pseudomonas alcaligenes C_1 and *Alcaligenes* NC_3 which utilise fensulfothion as a source of carbon were used for studying the disappearance of fensulfothion in culture. 50 ml of mineral salts basal medium containing 0.1 per cent fensulfothion was inoculated with 1 ml of 18–24 hr old culture of the required organism, incubated at 30°C on a rotary shaker. Two replicates were kept for each organism and the disappearance of fensulfothion was followed until 120 hr, using cholinesterase inhibition assay. The fensulfothion concentration was determined by drawing 1 ml of each of the sample, centrifuging and making up the volume of the supernatant to 10 ml. Suitable aliquots were taken and used for the estimation of residual fensulfothion. Uninoculated controls were also kept for determining the loss of fensulfothion due to autodegradation or volatilisation. The amount of residual fensulfothion at each interval was calculated from the standard graph for fensulfothion.

Metabolism of fensulfothion by Pseudomonas alcaligenes C_1

Pseudomonas alcaligenes C_1 was very potent in utilising fensulfothion as a carbon source and used in this study for following the metabolism of fensulfothion.

The organism was grown in the mineral salts basal medium containing 0.05 per cent fensulfothion on a rotary shaker at 30°C for 24 hr. The culture was then centrifuged at 7,000X g for 15 min. The culture filtrate was adjusted to pH 11.0 with IN NaOH and extracted three times with an equal volume of chloroform ethanol (5:1) to remove the residual fensulfothion. The pH was then brought to 6.0 and extracted three times with equal volumes of chloroform. The residual aqueous fraction was adjusted to pH 2.0 and extracted with ethyl acetate. The extracts at each pH were pooled and dried with anhydrous sodium sulfate and evaporated under vacuum. The residues were taken in 5 ml of

chloroform and used for chromatographic separation and estimation of metabolities. Suitable aliquots were spotted on Whatman No. 1 filter paper or silica gel thin layer plates (250μ) and subjected to ascending chromatography using benzene : acetic acid : water (4:4:1, v/v/v) as developing solvent. The air-dried chromatograms were sprayed with diazotised p-nitro-aniline for detecting phenols and $PtCl_2$ reagent for phosphoric acid esters.

In order to obtain more metabolites within a short time, a replacement culture technique was employed for the isolation of metabolites. *P. alcaligenes* C_1 was grown in nutrient broth containing 0.05 per cent fensulfothion and harvested after 24 hr. The cells were washed twice with 0.02 m sodium phophate buffer (pH 7.0). The cells (4g) were suspended in 100 ml of the same buffer in a 500 ml Erlenmeyer flask and 6.5 m moles of fensulfothion was added. For control, buffer containing fensulfothion without cells was used. The flasks were incubated at 30°C on a rotary shaker for 8 hr. After incubation, the culture was centrifuged at 7,000 X g in a RC2B Sorvall centrifuge for 15 min and the supernatant was collected. The extraction procedures were same as described earlier except that the pH 6.0 step was omitted.

Purification of metabolites

The purification of phenol and phosphoric acid ester was done by anion-exchange chromatography using Dowex-1 column (1×17 cm) Clapp and Casida' 1958). The ethylacetate extract was freed of moisture by adding anhydrous sodium sulfate and evaporating to dryness. The residue was retaken in 2 ml of distilled water and loaded on to the column. The phenol was eluted with 100 ml of glass distilled water and collected in 5 ml fractions. The phenol starts eluting between the 8th and 20th fractions. The fractions 8–20 were pooled and the pH was adjusted to 6.0. The compound was extracted out using chloroform, evaporated to dryness and taken back in 5 ml of chloroform. Further purification was done on preparative TLC and the chromatograms were sprayed with p-nitro-aniline.

After the elution of the phenol, the column was washed with 100 ml of glass distilled water. The phosphoric acid ester was eluted with 100 ml of 0.05N HCl and the elute was extracted with ethyl acetate, the extract was evaporated to dryness and taken back in chloroform and further purified by preparative TLC using Benzene ; acetic acid; water (4:4:1, v/v/v) as the developing agent. The matabolite was located by spraying with $PtCl_2$ reagent.

The metabolites were characterised by their chromatographic mobilities, melting point studies and spectroscopic characteristics. The melting points of both authentic and the metabolite phenol were noted in a Leitz Wetzlar melting point apparatus. The UV spectra were taken in ethyl alcohol using Unicam

SP-700 A recording spectrophotometer. The IR spectra were recorded in a Carl Zeiss Jena UR 10 spectrophotometer, the material being taken as a film. The NMR spectra of the compounds in $CDCl_3$ were taken in a Verian HA-100D spectrometer using tetramethyl silane as the internal standard.

Growth of P. alcaligenes ***C_1 on ethanol***

In order to check whether the metabolism of FEN by C_1 is through the utilisation of the phosphoric acid ester, the organism was grown in mineral salts basal medium containing 0.05 per cent ethanol as the sole source of carbon following the same methods as detailed earlier. The OD was recorded periodically at 620 mm in a Bausch and Lomb Colorimeter.

Results

A number of microorganisms, both bacteria and fungi were obtained from fensulfothion treated soils. Interestingly, only bacteria were able to utilise the pesticide as a carbon source and belonged to the genera *Pseudomonas*, *Alcaligenes* and *Citrobacter* whereas the fungi mainly belonged to the genera, *Aspergillus*, *Penicillium* and *Fusarium*. One isolate, each of *Talaromyces flavus* and *Rhizopus oryzae* were also obtained. The fungal isolates used FEN as phosphorus and/or sulphur source and not as a carbon source.

Two strains *Alcaligenes* NC_3 and *P. alcaligenes* C_1 were studied in detail and were found to utilise 70 and 82 per cent of FEN added to the culture medium within 120 hrs. Since *P. alcaligenes* C_1 was found to grow better on FEN, this was used to study the metabolism of FEN.

The culture filtrate showed two products, one a phosphoric acid ester and another a phenol. When authentic paramethyl sulfinyl phenol and the metabolite was run side by side on a silica gel thin layer (250μ), both showed the same chromatographic mobilities. The phenol showed a sharpy melting point at 91°C (7) similar to that of the authentic sample. The ultra violet spectrum of the product phenol showed an absorption maximum at 226 mm in erhyl alcohol and was undistinguishable from that of the authentic phenol. Infrared and nuclear magnetic resonance spectra of both authentic and the microbial metabolite phenol showed similar spectral characteristics and therefore the metabolite was identified as p-methyl sulfinyl phenol. The other metabolic product answered for phosphorus with $PtCl_2$ and Hanes and Isherwood reagents. From IR and NMR spectra the structure of the ester could not be conclusively arrived at. The spectrum suggested the presence of a long chain aliphatic compound which has not yet been identified. However the utilisation of ethanol by *P. alcaligenes* C_1 gave an indication that the organism metabolites FEN via the dealkylation of alkyl phosphoric acid.

Discussion

The consumption of pesticides in modern agriculture has steadily increased, and at the same time, the necessity to remove their residues from the environment after their application has become most urgent. The major means by which these are decomposed in nature is by microbial metabolism.

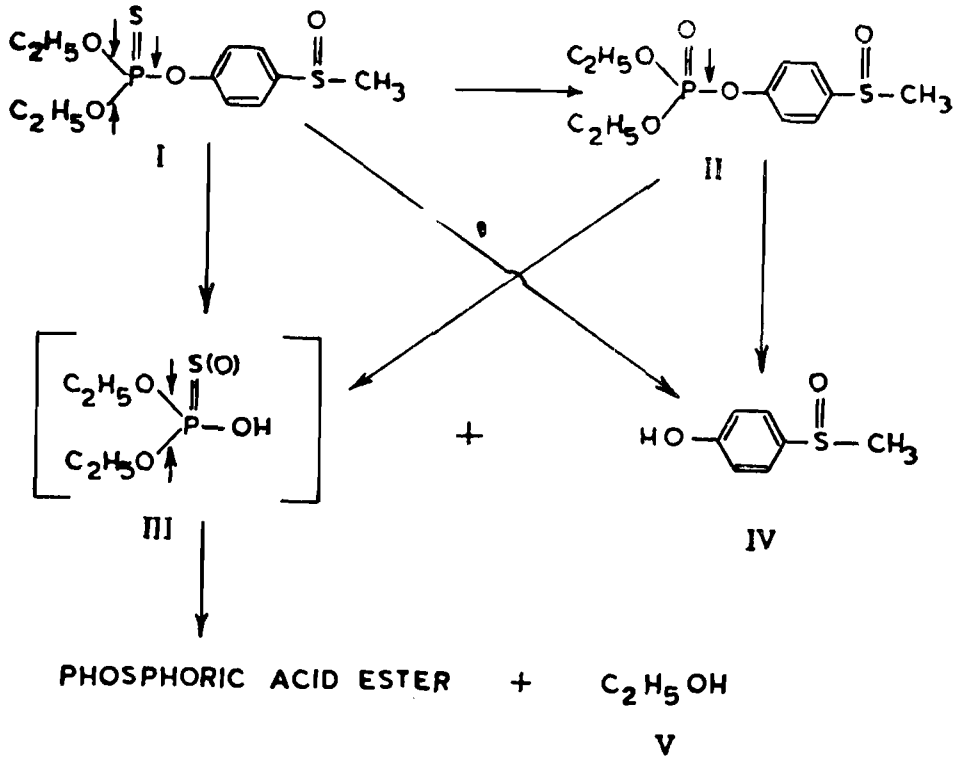

Fig.1 Metabolism of fensulfothion by *Pseudomenas alcaligenes* C_1

The most frequently encountered metabolic reaction where a microorganism utilises a pesticide is by the hydrolysis of the compound. The enzymes involved in hydrolysis are mainly phosphatases which cleave any phosphorus ester or anhydride bond. The initial step in the decomposition of diazinon, thionazin, and indeed, most O, O-dialkyl phosphorothioates in soil either before or after conversion to the P=O analogues is usually a hydrolytic cleavage of the variable moiety from the phosphorus group followed by further degradation of the fragments (Getzin, 1967 ; 1968). A diazinondegrading *Flavobacterium* was found to actively metabolise parathion by the hydrolytic route resulting in the formation of diethyl phosphoric acid and p-nitro phenol (Sethunathan and Yoshida, 1972).

The metabolism of fensulfothion in plants and animals is mainly through the oxidative pathway resulting in the formation of the oxygen analogues. Our

observations with the microbial metabolism of fensulfothion revealed that *P. alcaligenes* C_1 utilises it as a carbon source mainly by the hydrolysis of the P–O–C ester bond which may or may not be preceded by an oxidation of the parent compound (II). The hydrolysis of fensulfothion yielded p-methyl sulfinyl phenol (IV) and a phosphorus compound (III) which did not correspond to DEPA or DEPTA. While the p-methyl sulfinyl phenol accumulates in the medium, we could not detect DEPA, DEPTA, MEPA or MEPTA in the same. This observation coupled with the fact that the organism can effectively grow on ethanol shows that either DEPA or DEPTA or the parent compound itself may be desethylated and the released ethanol (V) metabolised further as an energy source. But the accumulation of a phosphorus-containing compound is intriguing and it will be worth investigating the significance of the same, the IR and NMR spectra indicate that the compound might be a long chain substituted fatty acid. It will be interesting to watch whether any polymer like poly-β-hydroxy butyric acid is formed, which will be all the more interesting because the organism itself does not grow on β-hydroxy butyric acid nor does it accumulate poly-β-hydroxy butyric acid.

In the case of Parathion, the p-nitrophenol formed is further converted to nitrocatechol or hydroquinone with the release of nitrite (Munnecke and Hsieh, 1974). But the further fate of phenol metabolite is yet unknown. The metabolic pathway by *P alcaligenes* C_1 is illustrated in Fig. 1.

The financial assistance from Department of Atomic Energy, India, is gratefully acknowledged.

References

Duffy, J. R., Cited after D.C. Read, 1969, Persistence of some newer insecticides in mineral soils measured by bioassay. J. *Econ. Entomol.*, **62**: 1338–1342.

Getzin, L. W., 1967, Metabolism of Diazinon and Zinophos in soils. J. *Econ. Entomol.*, **60**: 505–508.

Getzin, L. W., 1968, Persistence of Diazinon and Zinophos in soil effects of autoclaving, temperature, moisture and acidity. J. *Econ. Entomol.*, **61**: 1560–1565.

Hanes, C. S. and Isherwood, F. A., 1949, Separation of the phosphoric acid esters on the filter paper chromatogram. *Nature*, **164**: 1107.

Harris, C. R., 1969, Laboratory studies on the persistence and biological activity of some insecticides in soil. J. *Econ. Entomol.*, **62**: 1437.

MacRae, H. F. and McKinley, W. P., 1963, Chromatographic identification of some organophosphorus insecticides in the presence of plant extracts. J. *agric. Fd. Chem.*, **11**: 174–178.

Matsmara, F. and Boush, G. M., 1971, In: *Soil Biochemistry* (Editors A.D. McLaren and J. Skujins). **2**: 320-336.

Munnecke, D. M. and Hsieh, D. P. H., 1974, Microblal decontamination of parathion and p-nitrophenol in aqueous media. *Appl. Microbiol.*, **28**: 212–217.

PLAPP, F. W. AND CASIDA, J. E., 1958, Ion exchange chromatography for hydrolysis products of organophosphate insecticides. *Anal. Chem.*, **30**: 1622.

READ, D. C., 1971, Bioactivity and persistence of some new insecticides in a mineral soil. *J. Econ. Entomol.*, **64**: 800-804.

SHEELA, S. AND VASANTHARAJAN, V.N., 1977, Persistence of Fensulfothion in soil. *J. Environ Sci. Health, B* **12**: 15-35.

SETHUNATHAN, N. AND YOSHIDA, T., 1972, Conversion of parathion to paranitrophenol by Diazinon-degrading bacterium *Flavobacterium* sp. *Proceedings of the Annual Meeting of the Institute of Environmental Sciences*, New York, 0.255.

VARLEY, H., 1967, Determination of serum cholinesterase, In *Practical Clinical Biochemistry*, William Heinemann Medical Books Ltd., London and Interscience Books Inc., New York, IV edition, p. 300.

W.H.O. PESTICIDE RESIDUE SERIES, 1973, In: *1972 Evaluations of Some Pesticide Residues in Food.* **2**: 295-320.

WILLIAMS, I. H., BROWN, M. J. AND FINLAYSON, G., 1972, Determination of residues of Fensulfothion and its sulfone in muck soil. *J. agric. Fd. Chem.*, **20**: 1219.

ZINCKE, TH. AND EBEL, C., 1914, uber 1-phenol-4-mercaptan. *Berichte der Deutschen Chemischen Gesselschaft.*, **47**: 1100-1108.

Effects of Aldicarb and its Metabolites on CO_2 Evolution and Nitrogen Transformation

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ABSTRACT

The soils were treated with aldicarb, sulfoxide or sulfone, incubated and estimated for their ammoniacal, nitrate and nitrate nitrogen contents at weekly intervals. The CO_2 evolved at weekly intervals was also recorded. In alluvial clay soil, aldicarb and sulfoxide increased the CO_2 evolution initailly and diminished it later. The total CO_2 evolution was high at 10 μg level. The increase was higher in metabolite-treated soil than in aldicarb treated soil. In black clay soil, there was not much difference. In red silty loam, the reduction in CO_2 evolution occurred throughout the period of incubation. The toxicants did not apparently have any effect on the ammoniacal nitrogen in all soils. However, aldicarb increased the ammoniacal nitrogen when incubated for three or four weeks. The toxicants reduced nitrification in red silty loam and enhanced it in alluvial clay during first week only.

INTRODUCTION

It is known that any chemical agents, which have harmful effects on organisms in soil result in the alteration of various soil biological processes such as nitrogen

mineralisation. Singh and Prasad (1973) ; Balasubramanian and Gita Nilakantan (1976) and Regupathy and Subramaniam (1976) reported the inhibitory effect of aldicarb on populations of soil microbes. Hence, the present study was made to find out whether aldicarb affected the mineralisation of nitrogen so as to impair the availability of nitrogen.

Material and Methods

The soils, method of treatment and chemicals were same as reported elsewhere (Regupathy and Subramaniam, 1976). To study the effects of aldicarb and its metabolites on nitrogen transformations. samples drawn at weekly intervals from incubated soils were analysed for ammoniacal, nitrite and nitrate nitrogen. The ammoniacal nitrogen was estimated by Kjeldahl's method (Piper,

Table I

Effects of aldicarb and its metabolites on the evolution of CO_2 in different soils (mg/100 g soil - Means of 2 observations)

Soil	Incubation time in days	Aldicarb (μg)		Sulfoxide (μg)		Sulfone (μg)		Untreated control
		1	10	1	10	1	10	
	7	17.6	22.4	20.4	26.5	9.5	28.6	11.1
Alluvial clay	14	12.8	23.7	11.4	25.8	3.4	23.7	5.0
	21	8.9	12.3	9.8	17.3	3.0	15.0	18.8
	28	6.7	8.2	11.6	12.0	3.0	12.5	15.6
	Mean	11.5	16.7	13.3	20.4	4.7	19.9	13.1
						S.E.	C.D. (P=0.05)	
Toxicant						1.5**	4.5	
Toxicant × incubation time						3.1*	8.9	
	7	8.8	13.1	9.9	13.9	11.0	14.9	16.9
Black clay	14	11.7	12.8	11.3	13.1	12.4	12.8	13.1
	21	10.4	10.5	9.8	11.4	12.1	13.6	10.8
	28	9.2	8.5	8.7	10.3	11.5	9.5	10.8
	Mean	10.0	11.2	9.9	12.2	11.8	12.7	12.6
						S.E.	C.D. (P=0.05)	
Toxicant						0.7*	2.0	
Toxicant × incubation time						N. S.		
	7	7.4	20.4	9.6	18.1	11.6	25.7	25.1
Red silty loam	14	19.6	27.8	22.9	19.0	7.8	29.2	23.3
	21	3.3	20.7	22.8	22.6	2.1	21.6	18.7
	28	3.2	16.2	15.6	16.7	2.9	14.6	18.2
	Mean	8.4	22.5	17.7	19.1	6.1	22.8	25.3
						S.E.	C.D. (P=0.05)	
Toxicant						1.6**	4.5	
Toxicant × incubation time						N. S.		

1966) and the nitrate and nitrite nitrogen were quantified by spectrophotometry using phenol-disulfonic acid and alpha naphthalamine reagents respectively (Jackson, 1973).

One hundred grams of soil were mixed with aldicarb and its metabolites at 1 and 10 μg/g of soil, moistened to 50 per cent of water-holding capacity and incubated for 4 weeks. The CO_2 evolved was absorbed in 0.1 N NaOH and estimated by back-titrating with 0.1 N HCl after adding 50 per cent barium chloride solution using phenolphthalein as indicator. Analyses were done at weekly intervals.

TABLE II

Effects of aldicarb and its metabolites on ammoniacal nitrogen in different soils (μg/g of soil)

Soil	Incubation time in days	Aldicarb (μg)		Sulfoxide (μg)		Sulfone (μg)		Untreated check
		1	10	1	10	1	10	
Alluvial clay	7	17.2	16.6	6.4	8.6	1.8	9.0	5.3
	14	12.6	10.2	13.7	13.6	10.4	12.4	13.5
	21	69.6	34.6	13.4	10.0	8.2	16.8	23.6
	28	42.5	19.0	9.6	24.7	9.4	14.8	12.3
	Mean	35.5	20.1	10.8	14.2	9.2	13.3	13.7
						S.E.	C.D. (P=0.05)	
	Toxicant					5.1	15.0	
Black clay	7	17.5	5.3	7.1	7.3	5.4	7.6	5.4
	14	11.1	10.8	12.4	5.4	41.4	5.3	12.5
	21	32.1	28.4	15.6	16.7	15.6	17.4	13.2
	28	19.7	21.1	9.1	5.4	14.2	8.9	14.5
	Mean	20.1	16.4	11.1	8.7	19.2	9.8	11.4
		Not significant						
Red silty loam	7	22.5	12.3	10.9	10.7	12.6	34.5	9.0
	14	6.7	8.2	7.1	7.2	12.4	8.8	12.2
	21	28.3	31.8	16.4	15.8	29.1	15.6	17.2
	28	17.3	22.6	8.9	7.1	7.1	7.1	13.5
	Mean	18.7	18.7	10.8	10.2	15.3	16.5	13.0
		Not significant						

RESULTS AND DISCUSSION

In alluvail clay soil, the evolution of CO_2 was increased by aldicarb and sulfoxide initially but later the CO_2 evolution diminished (Table I). An increase in the concentrations of the toxicants increased the CO_2 evolution further. In sulfone-treated soil at the higher concentration the same trend was observed and the amount evolved was even greater compared to that evolved from aldicarb

and sulfoxide-treated soil. Comparisons based on overall means indicate that sulfoxide and sulfone at 10μg enhanced CO_2 evolution. In black clay soil, the interaction between toxican and incubation was not significant. The mean values indicated only slight reduction at the 1μg level of aldicarb and sulfoxide. In red silty loam, the reduction was recorded throughout the period of observation due to aldicarb and sulfone at lower concerntration.

Application of sulfoxide and sulfone apparently did not have any effect on the ammonification of native nitrogen of soils (Table II). However, aldicarb increased the rate of ammonification when incubated with soil for three to four weeks.

TABLE III

Effects of aldicarb and its metabolites on nitrite nitrogen in different soils (μg/g of soil - Means of 2 observations)

Soil	Incubation time in days	Aldicarb (μg)		Sulfoxide (μg)		Sulfone (μg)		Untreated control
		1	10	1	10	1	10	
	7	10.3	6.1	5.0	7.3	2.7	6.2	5.1
Alluvial clay	14	8.1	8.2	3.8	7.3	7.5	7.0	8.3
	21	11.3	11.5	10.2	11.6	10.2	10.2	10.0
	28	6.8	8.9	7.9	5.0	8.7	8.1	7.7
	Mean	9.1	8.7	6.7	7.8	7.3	7.9	7.7
						S.E.	C.D.(P=0.05)	
Toxicant						0.5*	1.6	
Toxicant × incubation time						1.1*	3.2	
	7	5.3	6.4	6.8	7.7	9.8	4.1	7.7
Black clay	14	7.0	9.5	6.5	8.3	6.5	7.3	6.5
	21	16.7	16.2	9.3	9.7	12.6	2.8	11.9
	28	10.4	9.3	10.7	3.9	11.3	9.2	10.6
	Mean	9.9	10.4	8.3	7.4	10.0	5.8	9.2
						S.E.	C.D.(P=0.05)	
Toxicant						0.7*	2.0	
Toxicant × incubation time						1.4	4.0	
	7	5.2	11.9	13.0	7.2	9.4	8.5	16.0
Red silty	14	7.6	8.6	7.4	5.2	6.3	7.6	8.4
loam	21	11.8	11.6	11.7	10.3	13.9	12.4	11.2
	28	10.4	9.0	9.1	9.0	9.5	0.7	6.1
	Mean	8.8	10.3	10.3	7.9	9.8	7.3	10.4
						S.E.	C.D.(P=0.05)	
Toxicant						0.6**	1.9	
Toxicant × incubation time						1.3**	3.7	

The nitrite nitrogen content of soils showed an initial decrease and later it increased or remained on a par with the untreated soil except for alluvial clay

(Table III). No influence of sulfoxide and sulfone was observed. However, in red silty loam soil there was a reduction up to the second week in soils treated with metabolites over the untreated control and this increased later. A similar trend was observed in the case of nitrate nitrogen also (Table IV). In alluvial clay, the rate of nitrification increased initially due to the aldicarb application, but later this remained on a par with that in untreated soil.

TABLE IV

Effects of aldicarb and its metabolites on nitrate nitrogen in different soils (μg/g soil – Means of 2 observations)

Soil	Incubation time in days	Aldicarb (μg)		Sulfoxide (μg)		Sulfone (μg)		Untreated control
		1	10	1	10	1	10	
	7	25.2	17.8	27.2	23.0	21.8	25.8	4.4
Alluvial clay	14	41.7	36.1	26.6	38.3	37.9	41.6	34.0
	21	34.5	32.5	26.3	31.4	38.7	39.4	36.2
	28	44.2	30.8	26.3	41.6	39.1	42.4	38.1
	Mean	36.4	29.3	26.6	33.6	34.3	37.2	28.2
						S.E.	C.D.(P=0.05)	
Toxicants						0.8**	2.4	
Toxicants × incubation time						1.6**	4.8	
	7	2.8	7.9	13.3	6.4	9.8	26.7	9.8
Black clay	14	15.0	15.6	14.0	19.3	14.1	18.1	16.4
	21	18.6	8.1	8.0	16.3	7.1	12.9	14.1
	28	8.7	16.2	9.6	18.7	9.3	17.7	25.0
	Mean	11.3	12.0	11.2	15.1	10.1	18.8	16.3
						S.E.	C.D.(P=0.05)	
Toxicants						0.9**	2.5	
Toxicants × incubation time						1.7**	4.9	
	7	12.2	8.1	15.6	22.9	15.5	18.8	23.8
Red silty	14	15.5	11.4	22.6	38.5	12.7	14.6	22.1
loam	21	24.1	15.3	23.2	12.8	7.2	13.9	7.4
	28	24.5	7.9	29.0	28.0	11.2	17.8	8.0
	Mean	19.1	10.6	22.6	25.5	11.6	16.2	15.3
						S.E.	C.D. (P=0.05)	
Toxicants						1.0**	2.8	
Toxicants × incubation time						1.9**	5.6	

N. S.—Not significant

*—Significant at P=0.05

**—Significant at P=0.01

In alluvial clay and red silty loam soil, application of aldicarb and sulfoxide increased the CO_2 evolution and nitrification initially. Later, the amount of CO_2 evolved decreased. This might be due to increased activity of actinomycetes and bacterial populations (Regupathy and Subramanian, 1976). Metabolic

degradation of aldicarb leading to a cessation of stimulatory action might be the reason for the reduction of CO_2 evolution. In soil, aldicarb was oxidised immediately to sulfoxide (Bull *et al.*, 1970) which was degraded to its corresponding oxime and nitrile metabolites and by concurrent oxidation to aldicarb sulfone. Though the insecticides might be toxic to particular groups the resistant isolates were found to utilise the insecticides as their sole source of carbon (Bhaskaran *et al.*, 1973 ; Purushothaman *et al.*, 1974). Though aldicarb was toxic, it could be utilised rapidly by microorganisms as reported by Spurr and Sousa (1974). There were indications that aldicarb was metabolised within 16 to 30 days. Aldicarb residues decreased by 50 per cent during the 30 days test period (Kuseske *et al.*, 1974) and much of the aldicarb applied, existed as sulfoxide (Hough *et al.*, 1975). Microorganisms can metabolise the pesticides through their cellular or extracellular enzymes, essentially by hydrolysis (Martens, 1972). The CO_2 evolution was very high in metabolite-treated soil, especially that treated with sulfone (Table I). The metabolites, sulfoxide and sulfone arising from the metabolic degradation of aldicarb were transient in nature for the most part (Bartley *et al.*, 1970). These were further converted into water-soluble residues consisting of alcohols, aldehydes and their conjugates. Low molecular weight alcohols and aldehydes cause a rapid activation of microbial respiration and growth in soil, though the populations remained unaltered (Griebel and Owens, 1972).

The increase in ammoniacal nitrogen in soil treated with aldicarb might be due to suppression of microbes which utilise ammonia. Populations of autotrophic nitrifying bacteria were found to be depressed by aldicarb (Kuseske *et al.*, 1974). Once aldicarb was degraded, the effect on nitrification or nitrifiers could be reversed, since the metabolites has no substantial effect on the level of ammonia.

The initial increase in nitrification in alluvial clay compared to an initial decrease in other soils might be due to differential reaction of the nitrifiers present in various soils.

In black clay soil, aldicarb did not have much influence on microbial activity as evidenced by CO_2 evolution. This might be due to low organic matter content (0.37 per cent when compared to 0.88 to 1.03 per cent in red silty loam and alluvial clay respectively) which consequently leads to a low population of microflora (Regupathy and Subramaniam, 1976).

References

Balasubramanian, A. and Gita Nilakantan., 1976, Effect of Temik on the microflora and indole acetic acid production of a red sandy loam soil. *Curr. Res.*, **5** : 15–17.

Bartley, W. J., Andrewes, N. R., Chancey, E. L., Bagley, W. P. and Spurr, H. W., 1970, The metabolism of Temik aldicarb pesticide (2-methyl-2 methylthio-propionaldehyde (methyl-carbamoyl oxime) in the cotton plant. *J. Agril. Food. Chem.*, **18** : 446–453.

BHASKARAN, R., KANDASWAMY, D., OBLISAMI, G. AND SUBRAMANIAM, T.R., 1973, Utilization of disyston as carbon and phosphorus sources by soil microflora. *Curr. Sci.*, 42: 835-836.

BULL, D. L., STOKES, R. A., COPPEDGE, J. R. AND RIDGWAY, R., 1970, Further studies of the fate of aldicarb in soil. *J. econ. Ent.*, 63: 1283-1289.

GRIEBEL, G. E. AND OWENS, L. D.. 1972, Nature of the transient activation of soil micro-organisms by ethanol or acetaldehyde. *Soil Biol. Biochem.*, 4: 1-8.

HOUGH, A., THOMASON, I. J. AND FARMER, W. J., 1975, Behaviour of aldicarb in soil relative to control of *Heterodera schachtii*. *J. Nematol.*, 7: 214-220.

JACKSON, M. L., 1973, *Soil Chemical Analysis*. Prentice Hall of India Private Ltd., New Delhi. p. 498.

KUSESKE, D. W., FUNKE, B. R. AND SCHULZ, J. T., 1974, Effects and persistence of Baygon (Propoxur) and Temik (Aldicarb) insecticides in soil. *Plant Soil*, 41: 255-269.

MARTENS, R., 1972, Types of reaction during microbial degradation of pesticides. *Landban, forsch. Volkenrode.*, 14: 93-98.

PIPER, C. S., 1966, *Soil and Plant Analysis*. Hans Publishers, Bombay, p. 368.

PURUSHOTHAMAN, D., KESAVAN, R., OBLISAMI, G., JANAKI, I. P. AND VELUSAMY, R., 1974, Microbial factor in the degradation of cytrolane in wetland soil. *Assoc. Microbiol. India 15th Annu. Confr.* Bangalore *Suppl.*, p. 79-80.

REGUPATHY, A. AND SUBRAMANIAM, T. R., 1976, Effect of aldicarb and its metabolites on the populations of soil bacteria, fungi and actinomycetes. Symp. Soil. Biol. Ecol. Bangalore.

SINGH, I. AND PRASAD, S. K., 1973, Effect of some nematicides on namatodes and soil micro-organisms. *Indian J. Nematol.*, 3: 109-133.

SPURR, H. W. AND SOUSA, A. A., 1974, Potential interactions of aldicarb and its metabolites on nontarget organisms in the environment. *J. Environ. Qual.*, 3: 130-133.

Effects of Aldicarb on A Non-target Soil Dwelling Phytopathogen

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ABSTRACT

The effects of aldicarb, (2 methyl-2 methylthio propionaldehyde O-methyl carbamyl oxime), a soil-applied pesticide, on the soil dwelling phytopathogen *Pseudomonas solanacearum* Smith which causes tomato wilt, was studied. Application of 10 per cent aldicarb granules to Hebbal red sandy loam soil at the normal recommended level (5 ppm a. i) enhanced the bacterial population whereas at 10 ppm concentration, although an initial reduction in population was noticed, no significant difference was observed later. The fungal and actinomycetes populations were not affected to any great extent at either concentration of the chemical. The 5 ppm aldicarb treatment stimulated the *P. solanacearum* proliferation initially in the Hebbal soil whereas at 10 ppm concentration,

although inhibitory to the phytopathogen for the first two weeks, their numbers were enhanced considerably thereafter. The morphology of the bacterial colonies was also altered significantly with aldicarb treatment. Even though *P. solanacearum* was able to tolerate aldicarb up to 1000 ppm *in vitro*, the growth was better at 100 ppm concentration, indicating that the bacterium has developed some adaptive mechanism for the insecticide.

PESTICIDES applied to soil may remain in the soil for a considerable period either in their unaltered forms or as degradation products. Such pesticide residues have been known to affect the microbial activities of the soil (Robson and Gunner, 1970; Tu, 1970; Balasubramanian and Siddaramappa, 1974). It is also likely that the pesticide residues come into contact with beneficial as well as harmful phytopathogens present in soil. The effect of aldicarb, a commonly used carbamate soil pesticide, on the survival of the tomato wilt pathogen, *Pseudomonas solanacearum* Smith is reported in this paper.

MATERIAL AND METHODS

Effect of 10 per cent aldicarb granules on soil microflora: Five hundred g of Hebbal red sandy loam soil was passed through 2 mm sieve and thoroughly mixed with 5 ppm and 10 ppm (*a.i*) concentrations of 10 per cent aldicarb granules. These were placed in uniform-sized glass bottles, adjusted to 50 per cent of maximum water-holding capacity (MWHC) and incubated at 28°C±2°C. Three replications of each treatment and a control, were maintained.

The g soil samples from these replications were taken and transferred to 90 ml sterile water blanks in 250 ml Erlenmeyer flask. After a thorough shaking, serial dilutions were made and from 1 ml of the appropriate dilution, the populations of bacteria, actinomycetes and fungi were enumerated following the procedure described by Allen (1957). For enumeration of bacteria and actinomycetes 'soil extract agar' was used and for fungi, Martin's Rose Bengal agar was used. The microbial population per g of soil was calculated on moisture-free basis.

Influence of aldicarb on the survival of P solanacearum: Five hundred g of sieved Hebbal red sandy loam soil taken from each pot was autoclaved three times at 15 psi on three consecutive days. The sterilized soil was mixed with 0, 5 and 10 ppm (*a.i*) of aldicarb and inoculated with 10 ml quantity of *P. solanacearum* cell suspension, containing approximately 1 million cells per ml. The soil moisture was adjusted to 50 per cent MWHC and incubated at 28°C±2°C. Soil samples were taken to weekly intervals and the population of *P. solanacearum* enumerated by the serial dilution technique on a selective medium, *viz.*, casein hydrolysate 5 g, pepton 5 g, glucose 5 g, agar 20 g and triphenyl tetrazolium chloride (TTC) 5 ml (1 per cent solution) per litre, water (1 litre; pH 7.2).

Tolerance of P. solanacearum *to higher concentrations of aldicarb*: One ml of a 36 hours old *P. solanacearum* culture was inoculated into 99 ml of nutrient broth containing 0, 100, 1000 and 5000 ppm of aldicarb in 250 ml side-arm flasks. After incubation at 28°C±2°C on a gyratory shaker, the transmittance was measured daily in a Klett Summerson colorimeter at 430 nm and the optical density (O.D.) was computed.

Results and Discussion

The bacterial populations were, in general, enhanced in the aldicarb-treated Hebbal red sandy loam soil more than the fungal and actinomycetes populations and the effect was more pronounced in case of the soil treated with 5 ppm (recommended dose) of the insecticide (Table I). Kuseske *et al.* (1974) have reported that aldicarb at 5 ppm concentration did not greatly influence the microbial populations in a sandy loam soil. Although significant reductions in soil microbial populations have been reported by treatments with other insecticides such as heptachlor (Shamiyem and Johnson, 1973), phorate, disulfoton, fensulfothion (Sreenivasulu and Rangaswami, 1973), belonging to various other groups of insecticides, it appears that aldicarb enhanced the bacterial populations of Hebbal at 5 ppm concentration. It is possible that the growth of bacteria in this soil was stimulated in the presence of aldicarb so the numbers of those becteria that degraded this chemical were enhanced. It is also likely, in the absence of any information on the degradation of this chemical by any specific group of soil microorganisms, that the other groups of soil microflora, *viz.*, fungi and actinomycetes might degrade the insecticide and help in releasing products useful for the proliferation of the bacterial population.

Table I

Effect of 10 per cent aldicarb granules on the soil microflora

Microorganism	Incubation period (days)	0 ppm (control)	5 ppm	10 ppm	Statistical significance (CD at 5% level)
	7	1.39	0.84*	0.76*	0.19
Bacteria (10^6/g)	20	6.80	11.31*	5.58	2.44
	30	2.69	5.30*	3.34	1.46
	7	0.74	0.52	0.80	NS
Fungi (10^4/g)	20	2.23	1.77	2.21	NS
	30	4.22	3.77*	6.04	0.61
	7	0.19	0.32*	0.12	0.12
Actinomycetes (10^6/g)	20	0.53	0.61	0.17	NS
	30	0.09	0.42*	9.42*	0.07

NS: Not significant

*: Significant at 5 per cent level

The results of the effect of aldicarb on the survival of *P. solanacearum* in Hebbal soil indicated that the application of 5 ppm concentration of the chemical caused an initial increase in the number of *P. solanacearum* cells up to 7 days, whereas a drastic reduction in their population was observed with the 10 ppm treatment compared with the untreated control soil (Table II). However,

TABLE II

Effect of 10 per cent aldicarb granules on the survival of Pseudomonas solanacearum *in soil*

(Population expressed on moisture-free soil)

Incubation period (days)	0 ppm (control) (X 10^6)	5 ppm (X 10^6)	10 ppm (X 10^6)	Statistical significance (CD at 5% level)
7	3.59	5.90*	0.16*	1.86
14	9.09	2.80*	0.54*	3.71
21	15.12	9.00*	22.10*	2.97
28	5.60	8.19	28.79*	3.96

* Significantly different at 5 per cent level.

the population of *P. solanacearum* reduced considerably thereafter both in the untreated as well as 5 ppm aldicarb-treated soil, whereas in the 10 ppm treated soil there was a significant increase, nearly 5 times more, compared to the untreated soil. This was a clear indication that aldicarb affected the growth of *P. solanacearum* in Hebbal soil. The effect was also apparent from the variations in the morphological chararters of the colonies from different treatments (Fig. 1). The colony size of the organisms was bigger in case of aldicarb

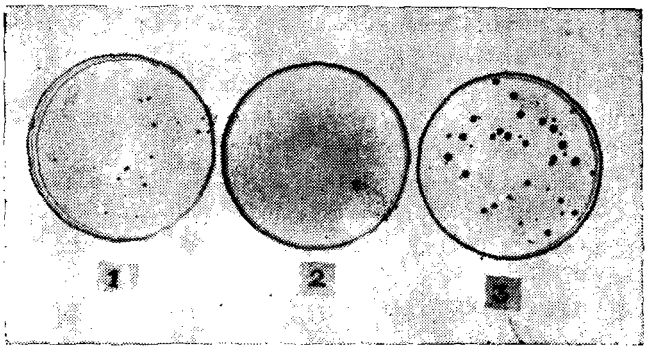

Fig. 1

treatment compared with the untreated cells, and it was more so with 10 ppm-treated cells which indicated that the effect of the pesticide on this organism in this soil varied with the concentration of the chemical. Considering the earlier reports (Bull *et al.*, 1970 ; Kearby *et al.*, 1970 ; Woodham *et al.*, 1973) that

aldicarb applied to soil is degraded within 15 days depending on the soil conditions, it is possible that the degradation products altered the normal metabolism of *P. solanacearum* favourably which had resulted in the enhancement of their numbers and colony size in the plates.

P. solanacearum cells were able to tolerate aldicarb in the growth medium up to 1000 ppm ; but the growth of the organism was better at 100 ppm concentration, compared with the other treatments (Table III). The results indicate

TABLE III

Tolerance of Pseudomonas solanacearum *to higher concentrations of aldicarb*

Treatment	Optical density				
	1st day	2nd day	3rd day	4th day	5th day
0 ppm (control)	0.301	0.538	0.638	0.678	0.658
100 ppm	0.268	0.678	0.798	0.959	1.000
1000 ppm	0.226	0.238	0.238	0.252	0.252
5000 ppm	0.181	0.181	0.181	0.181	0.181

Blank OD=0.181

that the phytopathogen has probably developed some adaptive mechanism for the pesticide at this concentration.

The authours are grateful to the authorities of University of Agricultural Sciences, Bangalore for providing facilities for the studies.

REFERENCES

ALLEN, O. N., 1957, *Experiments in Soil Bacteriology*. 3rd Ed., Burgess Publ. Co., Minneapolis, Minn.

BALASUBRAMANIAN, A. AND SIDDARAMAPPA, R., 1974, Effect of Maneb on certain microbiological and chemical properties of Hebbal red soil. *Curr. Res.* (UAS), **3**: 44-45.

BULL, D. L., STOKES, R. A., COPPEDGE, J. R. AND RIDGWAY, R. L., 1970, Further studies on the fate of aldicarb in soil. *J. Econ. Entomol.*, **63**: 1283-1289.

KERBY, W. H., ERAEGOVICH, C. D. AND BLISS, M. Jr., 1970, Residue studies on aldicarb in soil and scotch Pine, *J. Ecan. Entomol.*, **63**: 1317-1319.

KUSESKE, D. W., FUNKE, B. R. AND SCHULZ, J. T., 1974, Effect and persistence of Baygon (Propoxur) and Temik (Aldicarb) insecticides in soil. *Pl. Soil*, **41**: 255-269.

ROBSON, H. AND GUNNER, H. B., 1970, Differential response of soil microflora to diazinon. *Pl. Soil*, **33**: 613-621.

SHAMIYEM, N. B. AND JOHNSON, L.F., 1973, Effect of heptachlor on number of bacteria, actinomycetes, and fungi in soil. *Soil Biol. Biochem.*, **5**: 309-314.

SREENIVASULU, S. AND RANGASWAMI, G., 1973, Studies on the effect of three granular organophosphorus insecticides on soil microflora. *Indian J. Microbiol.*, **13**: 89-95.

TU, C. M., 1970, Effect of four organophosphorus insecticides on microbial activities in soil. *Appl. Microbiol.*, **19**: 479-484.

WOODHAM, D. W., EDWARDS, R. R., REEVES, R. G. AND SCHUTZMANN, R. L., 1973, Total toxic aldicarb residues in soil, cotton seed and cotton lint following soil treatment with the insecticide on the Texas High Plains. *J. Agr. Food Chem.*, **21**: 303-307.

Effects of Aldicarb and its Metabolites on Populations of Soil Bacteria, Fungi and Actinomycetes

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ABSTRACT

The interaction of aldicarb and its metabolites, sulfoxide and sulfone with soil bacteria, fungi and actinomycetes was studied by incubating the soils treated with the toxicants at 1 and 10μg/g of soil for four weeks. The bacterial population was increased by aldicarb and its metabolites at 1 μg level in alluvial clay. The enhancement of the population was high in the case of aldicarb followed by sulfoxide and sulfone. However, at 10 μg level the population was less. In black clay soil a reduction in the population occurred due to aldicarb. In general, the toxicants enhanced the actinomycetes population. The effect of aldicarb was more pronounced than that of its metabolites. Treatment with aldicarb or sulfoxide or sulfone had invariably reduced the fungal population in all the soil types studied.

INTRODUCTION

THE systemic insecticide aldicarb (Temik(R)) has been proved to be effective tool for suppressing the population of injurious sucking insects attacking crops like cotton, bhendi and brinjal. The constant use of pesticides in soil has aroused the interest of biologists to obrain information on the impact of these insecticides on the soil microorganisms which helps in maintaining soil fertility. A negative influence of pesticides on the microbes has been reporteed when optimum amounts of insecticide were applied (Bollen, 1961). However, it is useful to investigate the effect of current chemicals which are agriculturally important under different agroclimatic regions.

MATERIAL AND METHODS

The soils used in the present studies were alluvial clay, black clay and red silty, loam the properties of which are furnished elsewhere (Regupathy and Subramaniam, 1976). Stock solutions of aldicarb and its metabolites, sulfoxide and sulfone (Technical grade supplied by M/s Union Carbide India Limited) were prepared by dissolving in acetone and then adding water. The insecticidal solutions were mixed with 200 g portions of soil at the rate of 1 and 10 μg per g of soil. The soil was incubated for four weeks the beakers being covered with polythene sheets after bringing the moisture level to 50 per cent water-holding capacity of the soils at 28$\pm$2°C. Soil samples were taken at weekly intervals and the microbial populations estimated by a serial dilution technique. The

bacterial, actinomycete and fungal populations were estimated using soil-extract agar, Kuster's agar and Martin's rose bengal agar respectively (Pramer and Schmidt, 1964).

Results and Discussion

The bacterial population was enhanced by application of aldicarb and sulfone at 1 μg level, up to two weeks and thereafter it decreased. Although at 10 μg level, the population was reduced, the difference was not statistically significant (Table I). However, the population increased after the second week when treated with sulfoxide at 1 μg in alluvial clay soil. In black clay soil, the reduction was noticed at later stage due to aldicarb, whereas in sulfoxide and sulfone-treated soils the variation was not great. The enhancement in bacterial population was observed in red silty loam due to aldicarb up to three weeks compared with untreated soil. The population increased in sulfoxide and sulfone-treated soils during fourth week compared with those in treated with aldicarb.

Table I

Effects of aldicarb and its metabolites on the populations of bacteria in different soils (Population in millions/g of soil—Means of 3 observations)

Soil	Incubation time in days	Aldicarb (μg)		Sulfoxide (μg)		Sulfone (μg)		Untreated control
		1	10	1	10	1	10	
	7	16.30	10.43	16.46	14.79	15.03	16.51	7.77
	14	33.70	7.53	9.59	25.96	20.56	18.58	12.00
Alluvial clay	21	14.21	17.87	40.79	8.74	21.37	17.55	28.48
	28	25.03	16.97	16.84	12.06	15.30	10.74	17.39
	Mean	22.31	13.20	20.92	15.39	18.07	15.85	16.41
						S.E.	*C.D.* (P=0.05)	
Toxicant						1.81**	5.12	
Toxicant × incubation time						3.62**	10.24	
	7	7.08	9.81	7.77	23.66	10.91	11.92	12.29
	14	12.75	11.73	13.96	13.95	20.46	13.25	9.49
Black clay	21	4.16	2.94	7.09	19.51	14.97	11.54	20.06
	28	4.73	7.33	17.12	8.75	9.39	6.69	10.37
	Mean	7.18	7.95	11.48	16.47	13.93	10.85	13.50
						S.E.	*C.D.* (P=0.05)	
Toxicant						1.24**	3.50	
Toxicant × incubation time						2.47**	6.99	
	7	27.39	15.51	14.77	11.90	16.86	10.72	16.88
	14	22.42	28.37	9.88	28.47	16.39	17.04	24.67
Red silty loam	21	22.22	16.77	14.01	16.30	23.11	30.82	13.56
	28	16.23	21.54	26.57	16.49	23.97	10.70	25.50
	Mean	22.07	20.55	19.64	18.29	20.08	17.32	20.15
						S.E.	*C.D.* (P=0.05)	
Toxicant						0.89**	2.52	
Toxicant × incubation time						1.79**	5.06	

Actinomycete populations significantly increased in aldicarb and sulfoxide-treated alluvial soil at 1 μg (Table II). In red silty loam, the significant increase was observed at both concentrations of aldicarb and at 10 μg of sulfoxide and sulfone. However, in black clay soil, only an initial increase was observed at the 10 μg level of sulfoxide and sulfone.

TABLE II

Effects of aldicarb and its metabolites on the populations of actinomycetes in different soils (population in ten thousands/g of soil — Means of 3 observations)

Soil	Incubation time in days	Aldicarb (μ/g)		Sulfoxide (μ/g)		Sulfone (μ/g)		Untreated control
		1	10	1	10	1	10	
	7	17.81	29.53	12.24	13.28	12.58	21.03	10.08
Alluvial clay	14	97.64	17.76	46.04	25.92	12.61	11.35	8.15
	21	1.10	18.22	22.69	5.95	10.78	12.66	13.75
	28	25.85	14.91	24.17	19.96	13.26	10.11	25.51
	Mean	35.59	20.10	26.28	16.52	12.30	13.78	14.37
						S.E.	C.D. (P=0.05)	
Toxicant						2.25**	6.35	
Toxicant × incubation time						4.49**	12.70	
	7	21.41	41.22	21.03	55.37	18.08	26.35	28.10
Black clay	14	21.73	19.77	19.56	14.81	18.28	24.43	15.49
	21	17.82	24.47	16.25	18.46	11.87	21.24	9.20
	28	5.92	15.48	27.17	10.43	17.11	5.86	30.97
	Mean	16.72	25.23	21.00	24.60	16.33	19.47	20.94
						S.E.	C.D. (P=0.05)	
Toxicant						2.06**	5.81	
Toxicant × incubation time						4.11**	11.62	
	7	68.65	39.95	38.95	45.70	27.01	35.06	30.34
Red silty	14	39.05	44.32	19.17	39.87	58.90	15.89	16.58
loam	21	20.20	35.33	31.92	26.10	20.12	53.33	19.78
	28	17.97	24.06	15.28	27.82	21.82	26.03	23.95
	Mean	35.63	35.91	26.33	34.87	18.71	32.58	22.66
						S.E	C.D. (P=0.05)	
Toxicant						2.18**	6.15	
Toxicant × incubation time						4.35**	12.30	

N. S. — Not significant
* — Significant at P=0.05
** — Significant at P=0.01.

Application of aldicarb and its metabolites inhibited the fungal population throughout the period of incubation, the reduction increasing with an increase in the level of toxicants applied to alluvial clay (Table III). The reduction caused by aldicarb at 1 μg was higher than by its metabolites. However, in black clay, the reduction was observed during later stages only. In red silty

loam, the influence of aldicarb and its metabolites on fungal populations was intermediate between that in alluvial clay and black clay.

TABLE III

Effects of aldicarb and its metabolites on the populations of fungi in different soils (population in thousands/g of soil – Means of 3 observations)

Soil	Incubation time in days	Aldicarb (μg)		Sulfoxide (μg)		Sulfone (μg)		Untreated control
		1	10	1	10	1	10	
Alluvial clay	7	102.9	31.3	76.5	25.5	56.6	76.9	100.8
	14	170.1	44.3	49.7	46.6	31.2	53.9	19.3
	21	230.7	108.5	328.7	52.4	323.5	47.1	458.1
	28	122.4	132.5	216.7	76.5	212.1	88.8	266.7
	Mean	156.5	79.1	167.8	50.2	155.9	69.2	211.2
						S.E.	*C.D.*	(P=0.05)
Toxicant						27.5	77.9	
Toxicant × incubation time						N.S.		
Black clay	7	24.2	47.0	27.1	38.6	38.2	33.4	41.0
	14	24.3	26.2	23.2	24.9	30.1	26.0	21.3
	21	8.9	17.7	58.3	52.7	59.3	39.2	275.6
	28	46.7	47.4	84.0	37.9	92.1	41.8	80.3
	Mean	26.9	34.6	48.2	38.5	54.9	35.1	105.4
						S.E.	*C.D.*	(P=0.05)
Toxicant						12.1**	34.1	
Toxicant × incubation time						28.1**	79.5	
Red silty loam	7	158.4	104.0	85.3	101.3	81.9	75.7	130.6
	14	469.1	59.1	36.2	75.4	55.6	56.7	74.1
	21	208.8	140.0	209.0	158.7	197.2	148.7	290.3
	28	168.1	234.8	134.3	156.3	151.5	142.9	155.7
	Mean	149.4	137.0	116.2	122.9	121.6	106.0	163.5
						S.E.	*C.D.*	(P=0.05)
Toxicant						8.7**	24.5	
Toxicant × incubation time						17.3**	49.0	

The populations of bacteria and actinomycetes increased in soil with application of aldicarb and this stimulatory effect was more pronounced for actinomycetes than for bacteria. The results of the present investigations conform with the earlier work carried out by Kuseske *et al.* (1974) and Balasubramanian and Gita Nilakantan (1976). However, Singh and Prasad (1973) reported deleterious effect of aldicarb at all dosages tested. This might be due to the differential reaction of various species of bacterium present in soils (Kuseske *et al.*, 1974; Spurr and Sousa, 1974; Balasubramanian and Gita Nilakantan, 1975). The metabolites, sulfoxide and sulfone were less effective in enhancing the population than aldicarb. This suggests that stimulatory effect decreased with increased metabolic breakdown of aldicarb. Bull *et al.* (1970) reported

that, in soil, aldicarb was immediately oxidised to sulfoxide to the extent of 12.7 per cent within 30 minutes after application and 48 per cent after a week. When the concentration of aldicarb and its metabolites was increased, bacterial population decreased. It seemed that bacteria can adapt to low levels of aldicarb and can utilise the degraded products. Spurr and Sousa (1974) observed the non-toxic nature of aldicarb and its metabolic products, except nitrite, to a number of bacteria.

The inhibitory effect of aldicarb on fungal populations is in conformity with the earlier findings of Singh and Prasad (1973). Spurr and Sousa (1974) also reported the inhibition of the growth of the fungi by aldicarb.

The influence of the toxicants was not observed in black clay as compared with the other soils. This might be due to low organic carbon content of 0.37 per cent as against 1.03 and 0.88 in alluvial clay and red silty loam.

References

Balasubramanian, A. and Gita Nilakantan, 1975, Effect of an insecticide on growth and metabolism of some non-target soil microorganisms. *J. Nuclear agric. biol.*, **4** : 38–40.

Balasubramanian, A. and Gita Nilakantan, 1975, Effect of Temik on the microflora and indole acetic acid production of a red sandy loam soil. *Curr. Res.*, **5** : 15–17.

Bollen, W. B. 1961, Interactions between pesticides and soil microorganisms. *Ann. Rev Microbiol.*, **15** : 69–92.

Bull, D. L., Stokes, R. A., Coppedge, J. R. and Ridgway, R. L., 1970, Further studies of the fate of aldicarb in soil. *J. econ. Ent.*, **63** : 1283–1289.

Kuseske, D. W., Funke, B. R. and Schulz, J. T., 1974, Effects and persistence of Baygon (Propoxur) and Temik (Aldicarb) insecticides in soil. *Plant Soil*, 41 : 255–269.

Pramer, D. and Schmidt, E. L., 1964, *Experimental Soil Microbiology*. Burgess Publishing Co., Minneopolis, Minnesota. p. 107.

Regupathy, A. and Subramanian, A. M., 1976, Persistence of aldicarb in different soil types relative to weather elements. *Symp. Soil Biol. Ecol.*, Bangalore.

Singh, I. and Prasad, S. K., 1973, Effect of some nematicides on nematodes and soil micro-organisms. *Indian J. Nematol.*, **3** : 109–133.

Spurr, H. W. and Sousa, A. A., 1974, Potential interactions of aldicarb and its metabolites on non-target orgasnisms in the environment. *J. environ. Qual.*, **3** : 130–133.

Observations on Leaf Litter Decomposition after Treatment with Different Pesticides

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Abstract

Impacts of pesticides on litter decomposition rates were studied for four different plant species. While parathion and carbamate accelerated the rate of decomposition, BHC, DDT and endrin to a certain extent, arrested this activity.

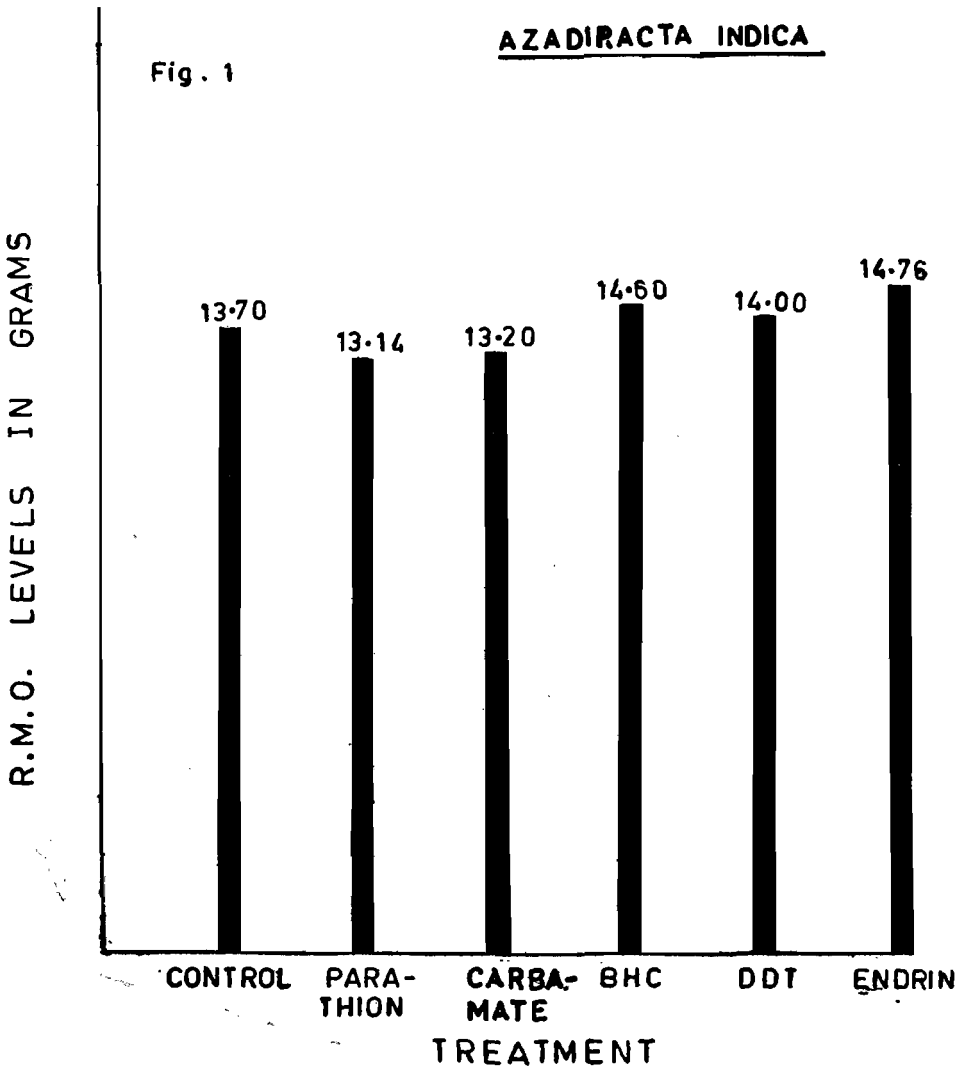
Introduction

In biogeochemical cycles, the leaf litter serves as an important link between plant and soil components of the ecosystem. The litter decomposition is the main process by which plants return their nutrients to soil. Recently, in the wake of modern agricultural practices, often as insurance against pest damage, vast quantities of pesticides are applied, with little regard for what happens to the natural processes which are going on in the soil. Since BHC, DDT, endrin, parathion and carbamate are amongth the most widely-used pesticides in the environment of Gujarat State, it was thought desirable to study the impacts of these pesticides on decomposition of litter of some of common plants of this region In the present paper we have reported the results of a fifth-day leaf litter decomposition experiment conducted in our laboratories. Trees litter belonging to *Azadirachta indica, Cassia fistula, Polyalthia longifolia* and *Albizzia lebbek* species were chosen for the study.

Material and Methods

Leaf litter from the above-mentioned trees was collected from the Gujarat University Campus, Ahmedabad and stored separately in litter bags. From this 25 g of litter each plant species were transferred to six sets earthen pot crucibles. To each crucible 10 g of soil collected from the vicinity of the respective trees was added. After marking the crucibles, 10 c. c. of 2 per cent solution of 5 different kinds of formulated pesticides were added so that 5 sets of pesticide-treated and one set of control replicates for each litter type were prepared. The pesticides used were obtained in following formulations Parathion 50 per cent E. C., carbaryl (Sevimol[R]) 40 per cent E. C., endrin 20 per cent E. C., DDT 25 per cent E. C. and BHC 50 per cent W. P. from the local suppliers. Initially, and at a regular interval of 10 days, 50 c c of tap water

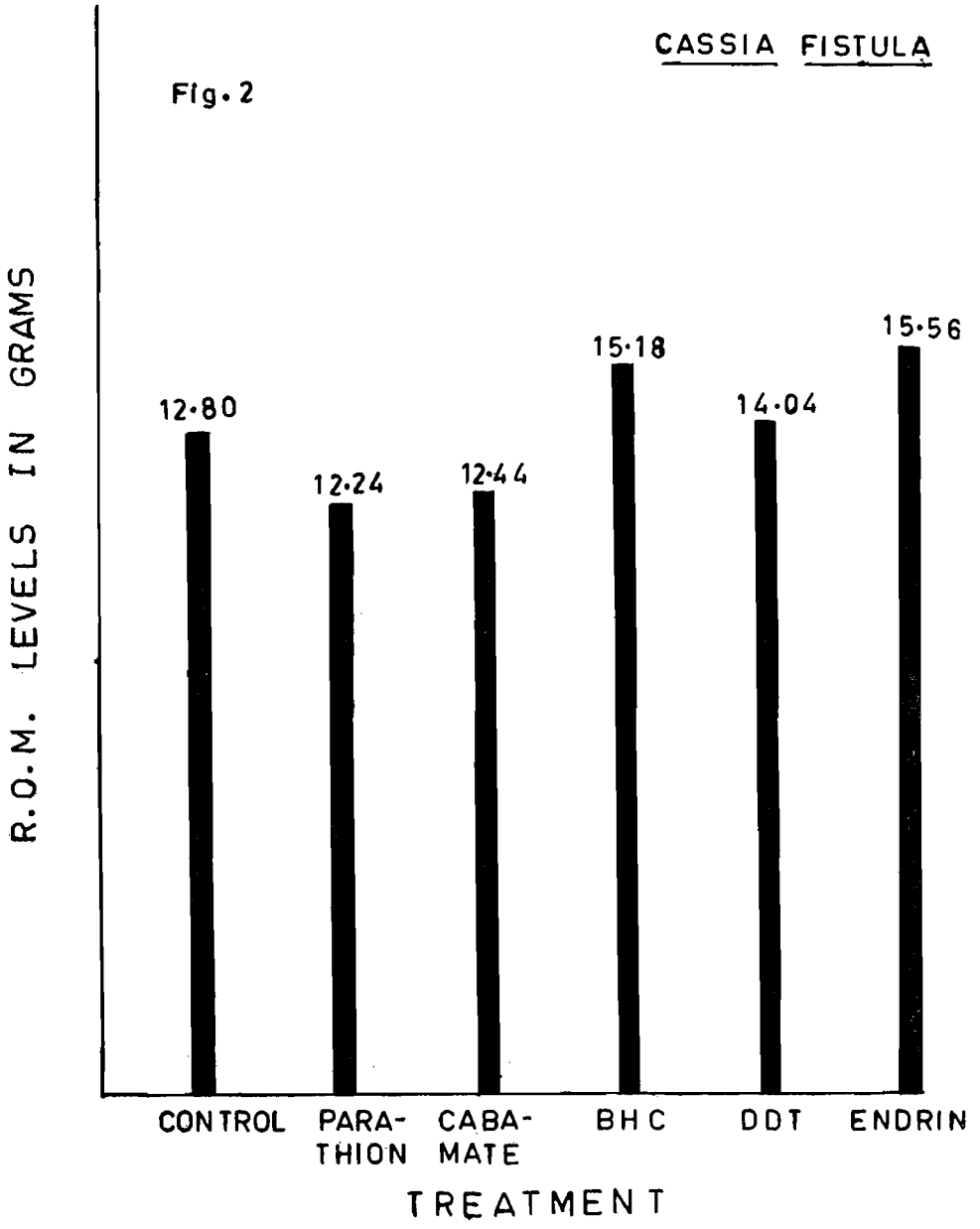
was sprinkled on to the litter to maintain moisture and facilitate the decomposition process. After 50 days the litter decomposition were studied by determination of residual organic matter Robinson (1930). Dry combustion of the residual matter was carried out in an electrically-operated furnace maintained at 700°C, until a constant weight was reached. The environmental conditions were similar throughout.



In calculating the results, since the inactive ingradient in the BCH does not combust, an equal amount of weight was substracted from the later to correct for this. Following standard statistical procedures the F values for each litter group were derived.

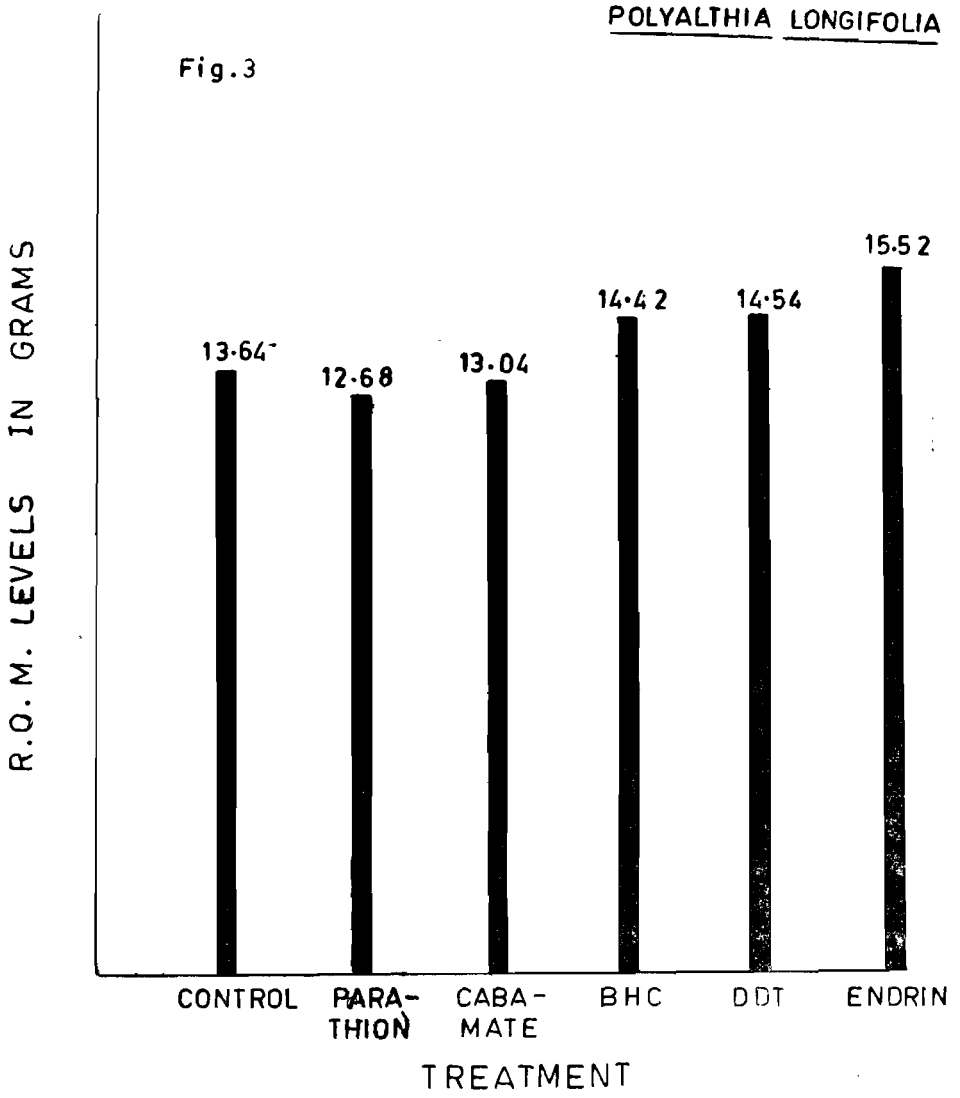
Results and Discussion

The data tabulated in Table I indicate the residual organic matter for each type of litter replicates after 50 days.



Comparison of the mean values of the residual organic matter in the litter treated with the various pesticides and the control. indicates that the values for

BHC, DDT and endrin are higher than those obtained for the control, whereas for parathion and carbaxyl these values are lower than the control. This reveals that the decomposition rate in the litter treated with BHC, DDT and endrin is



slowed down whereas in the litter treated with parathion and carbamate it seems to be accelerated. The interaction between pesticides and rate of decomposition of leaf litter was significant for *Polyalthia longifolia* and *Albizzia lebbeck*.

Although the interaction between the pesticides and the decomposition of *Azadirachta indica* and *Cassia fistula* leaf litter was not significant trends in the decomposition of the organic matter were found to be similar to those observed for *Polyalthia longifolia* and *Albizzia lebbeck* (fig. 1-4).

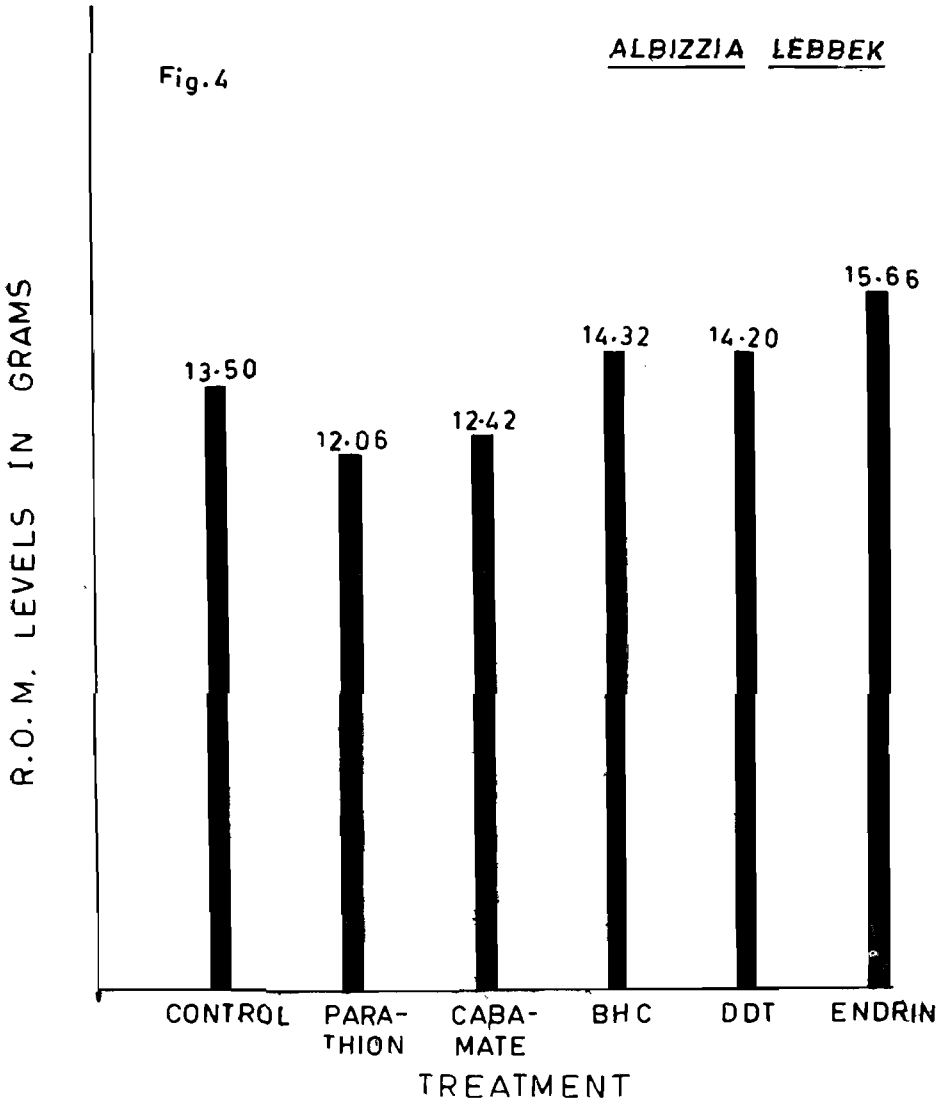
In most natural situations the microorganisms of the soil are essential for its fertility. The microorganisms are responsible for converting nitrogen, phosphorus and sulphur (that are present in litter) to forms available to plants. increases or decreases in decomposition rate could be related to the presence or absence of particular types of microbes in the soil system.

TABLE I

Residual organic matter in grams

Plants/species treatment		Parathion	Carbamate	Control	BHC	DDT	Endrin
Azadirachta indica		12.7	12.0	14.5	13.7	12.5	15.3
		12.0	14.0	12.5	14.7	14.0	15.5
		12.8	14.0	13.8	17.2	14.8	16.5
		14.7	12.0	12.7	15.1	14.7	15.3
		13.5	14.0	15.0	12.4	14.0	11.2
	Total	65.7	66.0	68.5	73.1	70.00	73.8
	Mean	13.14	13.20	13.7	14.6	14.00	14.76
Cassia fistula		12.2	11.5	14.6	15.7	13.0	15.5
		10.8	10.2	11.1	13.7	12.0	12.2
		14.7	16.4	17.8	16.7	17.1	19.0
		11.0	11.3	12.1	14.8	14.1	15.0
		12.5	12.8	14.0	15.0	14.0	16.1
	Total	61.2	62.2	69.0	75.9	70.2	77.8
	Mean	12.24	12.44	13.8	15.18	14.04	15.56
Polyalthia longifolia		11.4	11.9	12.4	15.5	14.6	14.8
		12.8	12.6	13.1	15.2	14.5	16.9
		13.7	13.5	14.2	13.2	14.8	15.5
		13.8	14.7	14.3	15.0	14.8	15.4
		11.7	12.5	14.2	13.2	14.0	15.0
	Total	63.4	65.2	68.2	72.1	72.7	77.6
	Mean	12.68	13.04	13.64	14.42	14.54	15.52
Albizzia lebbeck		12.2	12.8	14.6	14.0	15.0	16.0
		10 0	12.0	13.5	13.5	14.5	14.9
		13.5	12.3	14.5	15.4	16.0	17.8
		12.6	12.9	11.8	13.7	12.0	14.8
		12.0	12.1	13.1	15.0	13.5	14.8
	Total	60 3	62.1	67.5	71.6	71.0	78.3
	Mean	12.06	12.42	13.50	14.32	14.2	15.66

Considerable evidence exists that the use of insecticides may affect soil fertility. Populations of earthworms, soil mites and insects are dramatically changed by some insecticides (Davey, 1963; Polivka, 1953) and these in turn affect the soil fungi which are their principal food. Interactions between microbial populations and pesticides in soil system have been studied by several



workers. It is known that some microorganisms can degrade DDT to DDD under the proper conditions ; a few can degrade dieldrin to aldrin and several other breakdown products of unknown toxicity (Siddaramappa *et al.*, 1973; Florezana, 1973). Our ignorance of the interaction of insecticides, herbicides and other environmental poisons with soil microorganisms is great. A lack of

attention to the possible long-range effects of these and similar problems in our environment might ultimately prove to be fatal to mankind (Ehrlich *et al.*, 1973). The problems of persistent pesticides raised by Nash and Woolson (1967) should be given due consideration while developing our agriculture.

We are thankful to Dr. V. C. Shah, Professor and Head, Department of Zoology, Gujarat University for providing necessary facilities. Our thanks are also due to the Gujarat University for the grants for Pesticide Research.

References

Davey, S. P., 1963, Effects of chemicals on earthworms : a review of the literature. *U. S. Fisb. Widl. Serv. Spec. Sci. Rep. Wildl.*, **74**: 20.

Ehrlich, P. R., Ehrilich, A. H. and Holdren, P. J. P., 1973, Human ecology. *W. H. Freeman and Company*, San Francisco, p. 304.

Florenzano, G., 1973, Ecological crisis in agriculture and soil fertility. *Italia Agricola* **110**: (1) : 77–98 (It).

Gawaad, A. A. A., Hammad, M. and Elgar, F. H., 1973, Effect of some insecticides on soil microorganism. *Agrokemia es Talajtan.*, 22(1–2): 161–168 (Ku, en fr, ru).

Jones, A. S. and Hodges, C. S., 1974, Persistence of mirex and its effects on soil micro-organisms. *Journal of agricultural and food chemistry*, 22(3): 435–439 (En).

Nash, R. G. and Woolson, E. H., 1967, Persistence of chlorinated hydrocarbon pesticides in soils. *Science*, **157**: 924–927.

Polivka, J. B., 1953, More about the effect of insecticides on earthworm population. Presented at 62nd Annual meeting. *Ohio Acad. Sci. Columbus* (Unpublished), 10 p.

Siddaramappa, R., Rajaram, K. P. and Sethunathan, N., 1973, Degradation of parathion by bacteria isolated from flooded soil. *Applied Microbiology*, 26 (6): 846–849 (En).

Studies of the Impact of Aldicarb on White Grubs and some Non-target Soil Organisms

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Abstract

Aldicarb is used in the control of white grubs. In laboratory experimental studies, effects of aldicarb on target and the non-target organisms such as earthworms and millipedes were observed. At 0.1 per cent soil concentration treatment the first mortality of white grubs was recorded after 48 hours, after 13 hours for earthworms and after 24 hours for millipedes. The 50 per cent martality level was reached after 96, 15 and 48 hours respectively by these soil organisms. The experiments were repeated after changing the concentration of aldicarb. In all cases, the non-target organisms were affected in a lesser period than white grubs. When the concentration was raised it was also indicated that non-target organisms required a shorter time for 50 per cent or 100 per cent mortality.

Introduction

The pesticide aldicarb was first registered in U.S.A. for use on cotton in 1967. In india, its use is relatively recent. Vyas and Purani (1976) have reported its use for the control of white grubs in Sabarkantha. Although the yields of crop may be increased by such chemicals by controlling the pests, one must recognize that such chemicals may adversely affect the whole spectrum of non-target organisms, not only where applied, but even thousands of miles from the site of application (Niering, 1968). To an ecologist concerned with the total enviornment, such pesticides pose some serious threats to natural ecosystems. Information on the effects of aldicarb in the Indian environment is very sparse. This paper summarizes some of the effects of aldicarb on target pests like white grubs and also its effects on non-target organisms such as earthworms, millipedes and garden slugs.

Material and Methods

The study was conducted in the environmental biology laboratory of the department. A large number of samples of white grubs, earthworms, millipedes and garden slugs were collected for the study from various regions of the Gujarat University Campus, Ahmedabad. These were kept alive under conditions similar to those in their natural habitat. The pesticide experiments were done in earthen pots of 250 to 300 cc capacity. Initially, 100 g of soil collected from the natural habitat of these organisms was placed in each pot. To this, powdered commercial aldicarb was mixed in 12 different concentrations. The concentrations ranged from 0.01 per cent to 2.0 per cent with some pots as controls. White grubs, earthworms, millipedes and slugs were introduced into pots containing treated and non-treated soils. Morphometric behaviour and mortality rates was studied by direct observations. A minimum of 10 samples of organisms were tested in each batch. The environmental conditions were maintained uniformly for all batches through out the period of study.

Observations

All organisms introduced in aldicarb-treated soils, did not behave normally, whereas, in the non-treated pots, the behaviour of organisms remained normal through out the period of study. Attempts to escape from treated soil by white grubs and earthworms was observed which respectively attempted to emerge towards the surface or burrow deeper in soil. Slugs reversed their normal position and laid on their backs, and millipedes coiled up. The subsequent changes in the morphometric behaviour of the organisms in aldicarb treated pots leading to mortality are reported in Tables I to IV.

Discussion

Aldicarb has the property of being systemic as well as a contact poison. It acts as one of the carbamoyloxime cholinesterase inhibitor. It controls white

TABLE I

Morphometric behavioral changes and mortality rates in white grubs

Concentration of aldicarb (%)	Time (hours) e	s	i	M_1	M_{50}	M_{100}
0.1	15	18	21	72	125	130
0.15	15	18	20	48	110	120
0.20	10	11	13	48	105	110
0.50	8	9	9	12	96	100
0.70	6	8	.8	12	22	96
1.00	2	3	3	10	20	48
0.0 Control	—	—	—	—	—	—

e = Emergence from soil
s = Sluggishness
i = Immobility
M_1 = First mortality

M_{50} = 50 per cent mortality
M_{100} = 100 per cent mortality
Normal behaviour

TABLE II

Morphometric behavioral changes and mortality rates in earthworms

Concentration of aldicarb (%)	Time (hours) n	c	b	M_1	M_{50}	M_{100}
0.01	6	8	13	15	28	32
0.02	4	7	10	14	20	29
0.05	2	4	11	12	16	26
0.08	0	4	8	10	14	25
0.10	0	3	8	8	10	20
0.15	0	3	4	6	11	16
0.20	0	2	3	4	11	15
0.50	0	2	2.5	3	7	14
0.70	0	2	2.5	3	10	13
1.0	0	0.5	0.5	1	3	5.5
1.5	0	0.25	0.5	0.75	1	4
2.0	0	0.25	0.5	0.5	1	2.3
Control	—	—	—	—	—	—

n = No burrowing tendency
c = Colour change
b = Bleeding
M_1 = First mortality

M_{50} = 50 per cent mortality
M_{100} = 100 per cent mortality
Normal behaviour

grubs and other sucking pests mainly by systemic action. For such action, the chemical has to be released in soil which facilitates its translocation to plant systems throuh roots. Since aldicarbs is released in soil, the contamination of soil takes place prior to that of the plant sap. Thus, contact poisoning can precede its systemic action. Earlier reports by Davey (1963), Polivka (1953), Mellnby (1967) and others on effects of insecticides and fungicides on the soil

TABLE III

Morphometric behavioral changes and mortality rates in millipedes

Concentration of aldicarb (%)	Time (hours) c	u	v	M_1	M_{50}	M_{100}
0.01	5	35	37	40	46	56
0.02	5	33	34	38	44	52
0.05	3	25	26	28	38	49
0.08	3	24	25	26	38	48
0.1	3	22	24	26	32	48
0.15	3.5	20	23	25	27	44
0.20	3	21	23	25	27	42
0.50	3	20	21	24	29	38
0.70	3	20	22	24	28	31
1.00	2.5	19	20	22	26	29
1.5	2	16	18	19	23	26
2.0	2	6	7	10	22	24
Control	—	—	—	—	—	—

c = Coiling the body
u = Inability to coil and dorsally lying
v = Vigorous leg movements
M_1 = First mortality
M_{50} = 50 per cent mortality
M_{100} = 100 per cent mortality
Normal behaviour

TABLE IV

Morphometric behavioral changes and mortality rates in slugs

Concentration of aldicarb (%)	Time (hours) c	s	M_{50}	M_{100}
0.01	15	17	25	32
0.02	15	18	25	31
0.05	10	12	18	30
0.08	8	12	24	27
0.10	8	13	23	26
0.15	7	11.5	21	26
0.20	7	12	21	26
0.50	6	8	14	22
0.70	6	8	19	21
1.0	5	7	14	16
1.5	2	3	5	6
2.0	1	3	5	6
Control	—	—	—	—

c = Coiling of body
s = Secretion increase
M_{50} = 50 per cent mortality
M_{100} = 100 per cent mortality
Normal behaviour

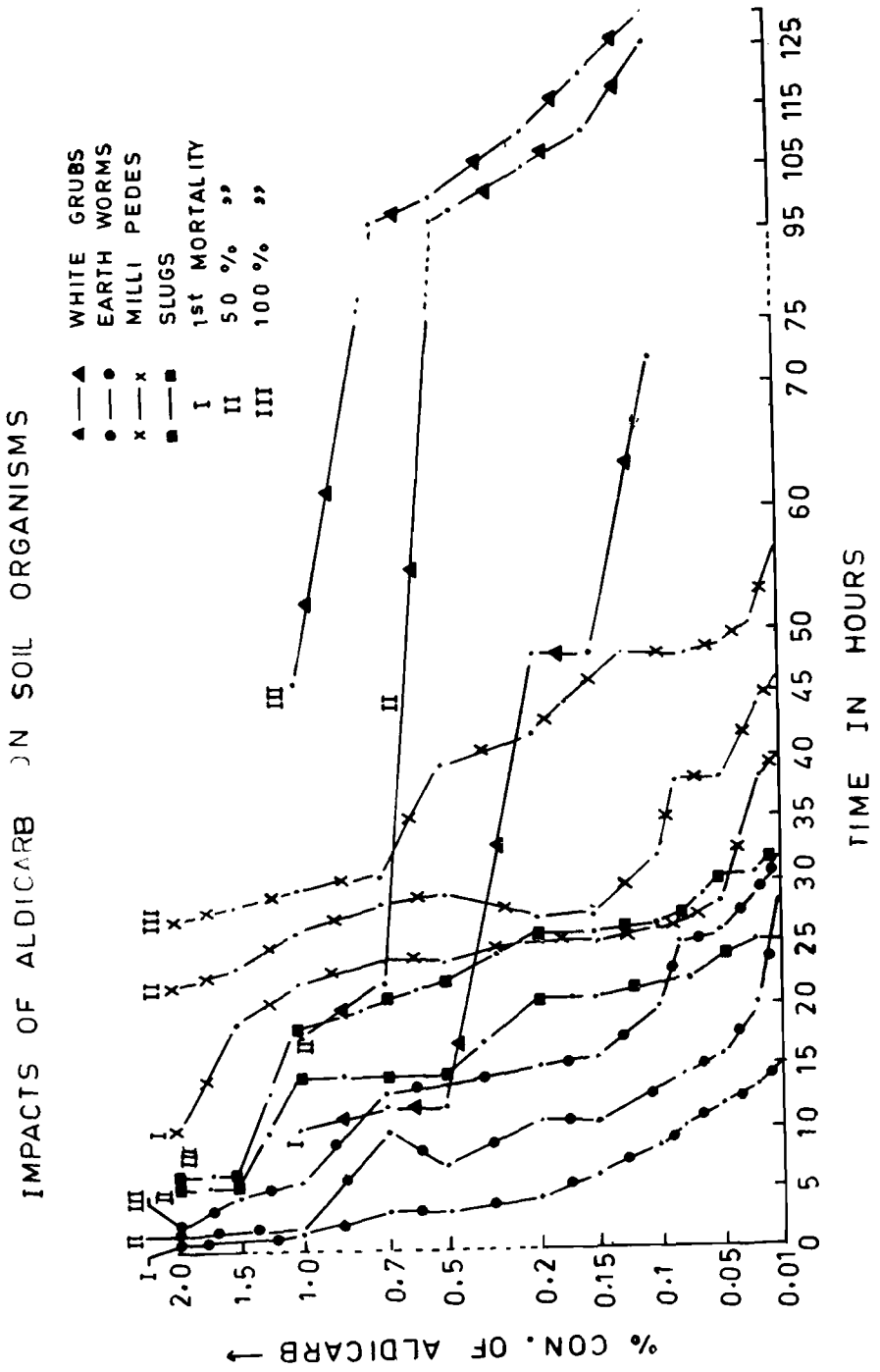
IMPACTS OF ALDICARB ON SOIL ORGANISMS
WHITE GRUBS
EARTH WORMS
MILLI PEDES
SLUGS
I 1st MORTALITY
II 50 % "
III 100 % "
% CON. OF ALDICARB
2.0
1.5
1.0
0.7
0.5
0.2
0.15
0.1
0.05
0.01
0 5 10 15 20 25 30 35 40 45 50 60 70 75 95 105 115 125
TIME IN HOURS

Fig. 1

fauna show that these chemicals can effect the soil life adversely. Earthworms, millipedes and slugs represent the soil megafauna, and although the use of temik is aimed to kill white grubs, it is possible that it can also kill the such non-target organisms. A comparison of 100 per cent mortality at different cencentration of aldicarbs indicates that earthworms and slugs are the first affected. Even at 0.1 per cent concentration earthworms and slugs reached 100 per cent mortality within 20 and 26 hrs respectively. For white grubs, at this concentration, 100 per cent mortality was reached after 130 hrs. Thus white grubs proved to be more resistant than other members of the soil fauna. The symptoms of morphometric and behavioral changes in the various organisms observed also indicated that the earthworms and slugs are susceptilble. Earthworms lose their ability to burrow within 2 hours of treatment with a 0.05 per cent concentration of aldicarbs. Their muscles become ineffective at increased concentrations. The mucus on the body of slugs appeared more rapidly increases in the concentration of aldicarbs. Thus, their ability to resist higher concentrations of the chemical decreases. White grubs and millipedes, on the other hand, are able to maintain their mobility for as long as 15 and 3 hrs respectively after treatment with 0.1 per cent concentration and vigourous movements of the appendages of millipedes were observed as long as 24 hrs after treatment.

Differences in morphometric changes and the mortality period between the organisms studied may be explained in terms of their anatomy and mode of life Earthworms and slugs do not have thick body coverings and their body surface is specially adapted for respiration, so it is natural that the thin permeable skin is the fiirst site of pesticide action. Moreover, these organisms are detritivorous and therefore while eating receive contaminated food in their alimentary canal. Thus, the mode of action of aldicarbs is dual *i.e.*, it works as contact as well as a stomach poisons. The contract poison effect is relatively less for millipedes and white grubs because they are provided with a better protective covering.

The degradation of a pesticide is most important from soil pollution point of view. The two major metabolites of aldicarb are aldicarb sulfoxide and aldicarb sulfone. Both of these are highly toxic to some organisms. The acute LD 50 of aldicarb for rats is 0.9 mg/kg. Comparative figues for aldicarb sulfoxide and aldicarb sulfone are 0.9 mg/kg and 25 mg/kg respectively. Thus up to the first two metabolites, the danger of persistence to toxicity can not be ruled out. Although, aldicarb is biodegradable and unlike DDT, lindane or dieldrin which can kill earthworm populations due to their persistent nature (Polivka, 1951 ; Van der Drift, 1963 ; Raw, 1963), do not pose any problem of a persistent nature. However, its repeated use can have the similar effects on soil fauna. Ultimately the soil quality which depends upon its various inhabitants (Kubiena, 1953 ; Edwards and Heath, 1963, Franz and Leitenberge (1948) and it is likely to deteriorate with the depletion of soil fauna.

Conclusions

Since aldicarb is not a presistent pesticide, its long-lasting impacts may be few. Although, it might be relatively harmless, its two important metabolites *viz.*, aldicarb sulfoxide and aldicarb sulfone are reported to produce toxic effects. This may cause depletion of non-target fauna if repeatedly used.

We are indebted to professor Vinod C. Shah, Head, Zology Department for providing the facilities.

References

Davey, S. P., 1963, Effects on chemicals on earthworms: a review of the literature. *A. S. Fisb. wildl. Serv., Spec. Sci. Rep. Wildl.* 74. 20 p.

Edwards, C. A. and Heath, G. W., 1953, In "Soil organisms." (J. Docken and J. Van dar Drift, eds.), pp. 76-84, North-Holland Publ. Co., Amsterdam.

Franz, H. and Leitenberger, L., 1948. *Ost. Zool. Z.*, 1, 491-518.

Kubiena, W. L., 1953, The Soil of Europe. *Murby*, London.

Mellanby, K. 1967. Pesticides and Pollution. *Collins*, London. 221 p.

Niering, W. A., 1968, The effects of Pesticides. *Bioscience*, 18: 869-875.

Polivka, J. B., 1951, Effect of insecticides upon earthworm populations. *Ohio J. Sci.*, 51: 195-196.

Polivka, J. B., 1953, More about the effect of insecticides on earthworm populations. Presented at 62nd Annual Meeting, *Ohi Acad. Sci.*, Columbus. (unpublished) 10 p.

Raw, F., 1963, The accumulation of residues of chlorinated hydrocarbon insecticides in soil invertebrates. *Rep. Rothamst. Exp. Sta.* 1: 149.

Technical Information, 1975, Temik Aldicarb Pesticide: Union Carbide Corporation. p. 63.

Drift J. Vander, 1963, The influence of biocides on the soil fauna. *Tijdschr. Planterziekteu* 69: [188-199.

Vyas, A. B. and Purani. K. H. 1976, An analysis of farmers reports on pest control by pesticides in Idar tatuka of Gujarat State. Int. Symp. ISNA: 'Effective use of pesticides.'

Efficacy of certain Soil Insecticides against Root Grub (*Holotrichia serrata* F.) under different conditions of Cultivation

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Abstract

The insecticides tried at recommended levels against the root grub *Holotrichia serrata* F. include, heptachlor (dust 6 per cent and 20 EC), chlordane 20 EC, disulphoton 5 G, phorate 10 G, carbofuran 3 G, chlorpyrifos 20 EC (Dursban), turbophos 5 G,

(Counter) ; aldicarb 10 G. (Temik) ; Carbaryl 5 per cent bait (Savin bait) and quinolphos 5 G. (Ekalux). In the experiment conducted on white grubs in coconut, the effect of the insecticides were more pronounced under irrigated conditions compared to no irrigation after treatment. The per cent control in unirrigated was, 31.0, 24.1, 27.5, 37.9 and 31.0 in chlordane, chlorpyrifos, aldicarb, turbophos and phorate respectively compared to irrigated condition, 53.1, 93.7, 0.0, 90.6 and 84.3 per cent control respectively. Similar trend was observed in grapevine yard also.

In sugarcane and ratoon sorghum field, the granular insecticides gave good control of grubs when applied to rows, in the beginning of the season but the grub population revived after 3 months suggesting that there was no residual effect of the granular phosphatic and carbomate insecticides. Similar trend was observed in the vegetable field where phorate, carbofuran and chlorpyrifos gave significant control compared to chlordane and heptchlor, which were par with no chemical, but after 3 weeks of treatment there was revival of grubs, evidently due to migration from untreated areas. In coffee plantation where there was enough moisture, before and after treatment, the per cent control was 45, 86, 86, 39, 89 and 77 from heptachlor, phorate, chlorpyrifos, disulphoton, carbofuran and chlordane respectively compared to no insecticide.

Introduction

There have been some of doubts among the cultivators as to the effect of several recommended soil insecticides against root grubs. To determine the optimum dosage, method of application and time of application to get the maximum benefit of the pesticides, several experiments were conducted for 3 seasons on white grubs occurring on different crops under different agroclimatic conditions in Karnataka. The insecticides tried in these experiments were mostly the newer soil insecticides that were either already in use against this pest or intended to be introduced as soil insecticides and compared with chlordane 20 EC and heptaclor 6 per cent dust or 20 EC which were in long use against this pest in this State. BHC 10 per cent dust, one of the commonly used insecticides against this pest in this country, is not included in these trials, as this insecticide has been widely tested on white grubs here and abroad and is being recommended at 125 kg per hectare.

Although several alternate methods are available for the management of this pest (Veeresh, 1977) still application of insecticides become inevitable in many cases and unavoidable under some cropping pattern. In India more than a dozen species of white grubs cause great damage to cultivated crops, but two species *Holotrichia serrata* F. and *H. consanguinea* Bl. are very widely distributed, the former is found all over the country and the later is wide spread in the Northern part of this country.

Organochlorine insecticides have been found quite effective against white grubs if applied at the first instar stage (Tashiro and Fiori, 1969). Among the phosphatic and carbomate insecticides, phorate 10 G, quinalphos 5 G, disulphoton 5 G, turbophos 5 G, all at 1 kg a.i/acre ; chlorpyrifos 20 EC, at 0.5 kg

a.i/acre and carbofuron 3 G, at 0.30 kg a.i/acre have all given good control (Veeresh, 1973 and 1976), provided the time of application synchronised with the emergence of adults which always occurred after the first rains during April–June. The same chemicals did not give satisfactory control in the standing crops when the grubs were fully grown, even with double the recommended dosage.

In the present study the efficacy of various insecticides in the control of root grub (*Holotrichia serrata* F) in coconuts, grape, vegetables, sugarcane, sorghum and coffee were investigated and discussed.

Material and Methods

All the experiments were carried out under natural conditions. The grubs were in the first instar in vegetable field and in sugarcane at Thondevadi (Tables–III and II). In all other places the grubs were in 3rd instar. Samples were taken before laying out experiments to ascertain the minimum population required for the experiment. The experiments were randomised and replicated. The plot size varied from 3 × 3 m to 5 × 3 m. Ths granular insecticides were mixed with about a litre of moist sand before applying to facilitate even distribution. E. C. formulations were mixed with water and spread evenly with the help of rose can. The soil was worked in and irrigated wherever desired.

Table I

Comparative efficacy of some soil insecticides against root grub (Holotrichia serrata) *in coconut plant*

Treatments	Qnty/ plot (m^2)	No irrigation after treatment		Irrigated after treatment	
		*Live grubs/ plot	% control	*Live grubs/ plot	% control
		Observations recorded after 7 days of treatment			
Chlordane 20 per cent EC	20 ml	5.00	31.00	3.75 (2.14)	53.1
Chlorpyrifos 20 per cent EC	10 ml	5.50	24.10	0.50 (1.18)	93.7
Aldicarb 10 per cent G	20 g	5.25	27.50	8.00 (2.93)	00.0
Turbophos 5 per cent G	20 g	4.30	37.90	0.85 (1.25)	90.6
Phorate 10 per cent G	20 g	5.00	31.00	1.25 (1.41)	84.3
Untreated	—	7.25	—	8.00 (2.88)†	—

N.S. G.M. = 1.97 C.D. at 5 per cent level 0.917
S.E. of mean difference 0.357 C.D. at 1 per cent level 1.439
* Average of 4 replication † Transformed mean values.

In coconut and grapevine (Tables I and V) the insecticides were applied, one meter around the base and the water was made to stand for some time in the irrigated plots.

In sugarcane (6 months old) and sorghum ratoon crop the insecticides were applied on either side of the rows by making 6-9 cm furrows and drenchin, irrigation was given (Table II).

TABLE II

Comparative efficacy of soil insecticides against root grubs (Holotrichia serrata *F*) *in sugarcane and ratoon sorghum*

No. of live grubs (average of replication)

Treatments	Qnty/ AC (kg)	Thondavati Mysore District		Chikkaballapur Kolar District		Hospet Bellary District
		Sugarcane (Standing crop)		Ratoon sorghum		Sugarcane (Standing crop)
		3 weeks after treat. live grubs/ plot	3 months after treat. live grubs/ plot	3 weeks after treat. live grubs/ plot	3 months after treat. live grubs/ plot	3 weeks after treatment live grubs/plot
Phorate 10 per cent G	10	1.33 (0.501)*	42.33	4.33 (0.206)	8.67	0.67 (0 401)
Disulpoton 5 per cent G	12	5.67 (0.813)	49.67	4.00 (0.138)	13.00	1.00 (0.460)
Carbofuran 3 per cent G	10	6.00 (0.787)	43.00	5.00 (0.259)	21.00	0.00 (0.301)
Quinolphos 5 per cent G	10	4.00 (0.702)	41.67	3.00 (0.301)	6.33	0.33 (0.326)
Carbaryl 5% bait (Sevin)	10	1.33 (0.501)	45.67	4.33 (0.233)	8.33	2.00 (0.541)
Turbophos 5 per cent G	10	3.33 (0.693)	41.33	2.67 (0.159)	11.67	0.67 (0.401)
Aldicarb 10 per cent G	10	12.33 (1.086)	46.00	3.33 (0.259)	11.00	2.67 (0.651)
Control	—	13.00 (1.170)	45.00	7 33 (0.333)	9.67	5.67 (0.761)
		Significant	N.S.	N.S.	N.S.	N.S.

* Transformed value

C.D. at 1% 0.4042.

In the vegetable plots (French been) the insecticides were applied before sowing and water was sprinkled after sowing (Table III).

In coffee plantation (12 year old plants) the plots (5 × 3 m) were dug to a depth of 15 cm after applying insecticides (Table IV). No irrigation was given as there was enough moisture with intermitent drizzling.

Osbervations were taken by digging the entire plots and counted the live grubs except in case of French bean plots (Table III) where surviving plants were counted. The results were compared between treatments and with the check.

TABLE III

Comparative efficacy of soil insecticides against root grubs (H. serrata) *in vegetables (French bean)*

Treatments	No. of surviving bean plants/plot (out of 250 plants)	
	15 days after treatment	30 days after treatment
Heptachlor 20% EC 1.81 kg a.i./acre	17.0 (93.2%)*	0.0 (100.0%)
Heptochlor 6% dust 1.81 kg a.i./acre	61.0 (76.0%)	0.0 (100.0%)
Chlordane 20% EC 2.72 kg a i./acre	37.0 (85.0%)	20.0 (92.0%)
Chlorpyrifos 20% EC 0.46 kg/acre	161.0 (36.0%)	156.0 (38.0%)
Carbofuran 3% G 0.3 kg a.i./acre	211.0 (16.0%)	209.0 (16.0%)
Phorate 10% G 0.91 kg a.i./acre	185.0 (26.0%)	182.0 (27.0%)
Control	58.0 (77.0%)	2.6 (99.0°/₀)

Values are average of 3 replications

Figures in parentheses are per cent mortality of bean plants.

RESULTS AND DISCUSSION

From the perusal of values in Table I it is evident that with irrigation, the efficiency of the insecticides is increased in the control of white grubs. It was observed that the per cent control under unirrigated condition, after 7 days, was 31.0, 24.10, 27.50, 37.90 and 31.00 compared to 53.10, 93.7, 00.0, 90.6 and 84.3 under irrigated condition in chlordane, chlorpyrifos, aldicarb, turbophos and phorate respectively. There was no significant difference among the treatments

under unirrigated condition but under irrigated condition aldicarb has no effect on grubs. Perhaps what little effect it had by its vapour action on grubs under unirrigated condition was nullified under irrrigation. Chlorpyrifos, turbophos and phorate were highly effective under irrigation. Low mortality under unirrigated conditions may be due to the fact that the insecticides did not move deep into the soil as the moisture was a limiting factor. Further under low moisture content these insecticides held tightly by the soil colloids (Clay) and organic matter (Baily and White, 1964). Van Der Schof and Tashiro (1975) found that efficacy of soil insecticides against white grubs depended upon the pre and post treatment irrigation.

TABLE IV

Effect of insecticide on root grubs (H. serrata) *in coffee plantation*

Treatments	Live grubs (15 days after treatment)	% control
Heptachlor 6 per cent dust 1.81 kg a.i./acre.	49.75	45
Phorate 10 per cent G, 0.91 kg a.i./acre.	13.50	86
Chlorpyrifos 20 per cent EC 0.46 kg a.i./acre.	13.50	86
Disulphoton 5 per cent G, 0.91 kg a.i./acre.	5.00	39
Carbofuran 3 per cent G, 0.30 kg a.i./acre.	11.25	89
Chlordane 75 per cent EC, 2.72 kg a.i./acre.	21.75	77
Control (untreated)	71.50	

C. D. at 5 per cent = 23.12

Under standing sugarcane and ratoon sorghum crops (Table II) the efficacy of insecticides was noticed only in the first place (Thondavadi) where the grubs were in first instar and in other two places where the grubs were in 3rd instar no effect was noticed. It is known that to get satisfactory control under standing crop, the insecticides must be applied when the pest is still in the first instar (Veeresh, 1977). At Thondevadi (Mysore District) the soil was sandy loam, and there was better movement of air. In other two places the soils were heavy. Under planted conditions there was no scope for proper mixing of the insecticides, thus prevented the insecticides to come in contact with grubs which were inbetween the roots. However, even in the plots where significant control was registered at 3 weeks after treatment (Thondevadi - Table II) there was resurgence of the pest 3 monte after treatment, evidently due to no residual effect of these insecticides. Phorate residues were not observed in soil beyond 60 days (Shetty, 1975). Organophosphorus insecticides persisted for a shorter period in soils (Corden and Young, 1965). Carbomates like carbofuron and carbaryl does not persist more than 3 months under irrigated condition because the degradation is accelerated by the presence of higher soil moisture (Caro *et al.*, 1973).

The ineffectiveness of heplachlor (both dust and E.C.) against grub was very pronounced in the beginning of the treatment as shown in Table III. Chlordane also failed to give good protection to French bean in the beginning, although it was better compared to heptachlor. Chlorpyrifos, carbofuron and phorate gave good protection by killing all the grubs before the French beans sprouted. There were some mortality of plants at 30 days after treatment in these treatment, due to migration from the boarder. Although chlordane and heptachlor might have acted slowly on the grubs later but the fact that they failed to protect the plants in the beginning is an indication that these insecticides are not good where quick control of grubs is desired. These findings are in agreement with the results of Harris and Lichtenstein (1961). Similar trend is seen in coffee plantation also (Table IV) where heptachlor and disulphoton did not give even 50 per cent mortality and once again phorate, chlorpyrifos and carbofuron have proved their superiority in acting quickly on grubs where enough moisture was available. Chlordane at higher doses also prove to be an effective insecticide against grubs as indicated in this experiment (Table IV). The same trend is seen in the grape

TABLE V

Effect of insecticides on root grubs (H. serrata) *in grapevine*

Treatment	Qnty/pit	Live grubs after	
		1 week	6 weeks
Chlordane 20 per cent EC	20 ml	15 (54%)	81 (48%)
Chlordane 20 per cent EC	10 ml	25 (24%)	28 (20%)
Chlorpyrifos 20 per cent EC	10 ml	2 (94%)	6 (88.6%)
Chlorpyrifos 20 per cent EC	50 ml	12 (64%)	17 (50%)
Aldicarb 10 per cent G	20 g	32 (0.0)	35 (0.0%)
Aldicarb 10 per cent G	10 g	32 (0.0%)	35 (0.0%)
Phorate 10 per cent G	20 g	5 (81%)	9 (74%)
Phorate 10 per cent G	10 g	5 (84%)	10 (71%)
Turbophos 5 per cent G	20 g	3 (90%)	8 (77%)
Turbophos 5 per cent G	10 g	24 (27%)	27 (30%)
Check	—	32.0 (0.0%)	32 (0.0%)

Figures in parentheses are per cent mortality of root grubs.

vine (Table V) also in respect of chlordane. Aldicarb is par with no insecticide in grape vine (Table V) similar to in coconut (Table I).

From the above observations it can be concluded that the efficacy of soil insecticides against white grubs depends on several factors. These experiments have indicated that the method of application, the time of application and type of crops, decide the quality and the efficacy of the insecticides against the grubs. To get satisfactory control the insecticides must be applied before sowing, after the first summer rains, when the grubs will be in the first instar and will be confined to upper 6–8 cm soil. Irrigation after treatment increases the efficiency of several soil insecticides. In standing crops insecticides will not give desired results because of the difficulty in incorporating insecticides which may not reach the grubs. However, if the insecticides are applied synchronising with the first summer rain, satisfactory control can be obtained in the standing crop also. Wherever phosphatic and carbomate insectscides are intended to be used, they must be applied all over the infested area to avoid migration of grubs from untreated area to treated area at later stages.

Reeerences

Bailey, G. W. and White, J. L., 1964, Review of adsorption and desorption of organic pesticides by soil colloids with implications concerning pesticide bioactivity. *J. agric. Fd. Chem.*, **12** : 324–332.

Caro, J. H., Freeman, H. P., Glot felty, D. E., Turner, B. C. and Edwards, W. M., 1973, Dissipation of soil incorporated carbofuran in the field. *J. agric. Fd. Chem.*, **21** (6) : 1010.

Corden, M. E. and Young, R. A., 1965, Changes in soil microflora following fungicides treatments. *Soil Sci.*, **97** : 262–275.

Harris, C. R. and Lichtenstein. E. P., 1961, Factors affecting volatilization of insecticidal residues from soils. *J. Econ. Ent.*, **54** : 1038–1045.

Shetty, S. V. R., 1970, Effect of some insecticidal residues in soil and plant on cholinesterase inhibition activity. M.Sc. (Ag) thesis submitted to University of Agricultural Sciences, Hebbal, Bangalore.

Tashiro, H. and Fiori, B. J., 1969, Susceptibilities of European chafer and Japanese beetle grubs to chlordane and dieldrin, suggesting reduction in application rate. *J. Econ. Entmol.*, **62** : 1179–83.

VanDerSchaf, P. and Tashiro, H., 1975, Control of Japanese beetle and European chafer grub with Dursban insectides. *Down to Earth*, **31** : 9-13.

Veeresh, G. K., 1973, Preliminary evaluation of insecticides for the control of the root grub (*Holotrichia serrata* F.) (Melolonthinae : Coleoptera). *Pesticide*, **7** : 27–28.

Veeresh, G. K., 1976, Coconut root grubs and their control in Karnataka. Proceedings, International Symposium on Coconut Research and Development. CPCRI, Kasargod, Dec. 28-31, 1976.

Veeresh, G. K., 1977, Studies on the root grubs of Karnataka with special reference to bionomics and control of *Holotrichia serrata* F. (Coleoptera : Melolonthinae) UAS, Monograph series. No. 2.

Comparative Efficacy of different Insecticides on the Mound-building Termite, *Odontotermes wallonensis* (Wasmann), (Termitidae : Isoptera)

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ABSTRACT

An effective, simple method of controlling termites has been worked out. Experiments conducted at M.R.S., Hebbal, with six insecticides for the control of termites in mounds of 3 to $3\frac{1}{2}$ feet diameter, showed that aluminium phosphide at 9 g (3 tab), phorate 10 per cent granules at 50 g, chlordane 20 per cent at EC 50 ml and pyridyl phosphate 20 per cent EC, at 20 ml per mound completely controlled the termites including some associated animals. The entire termite population including the royal pairs of the colony was killed. The other two treatments namely, ethylene dibromide at 3 ml and BHC 50 per cent W.P. at 50 g/mound were less effective in reducing the mound population. EDB and BHC gave only 50 per cent and 25 per cent control, respectively.

TERMITES are major pests of fields crops, fruit trees and forests in India. The more ecomically important crops subjected to the attack of termites are sugarcane, wheat, maize, groundnut, soybean, coconut, mango, citrus, tamarind, casuarina, eucalyptus etc. In addition they also damage woodwork of the buildings. Fletcher (1912) reported the annual loss caused by termites to grain crops in India to be at about 280 million Rupees. According to Mehta and Varma (1968) the average annual loss due to termites to agricultural crops is 230 million Rupees.

The mound-building termite, *Odontotermes wallonensis* (Wasmann) is a common species, widely occurring in Karnataka and a serious pest of the above-mentioned hosts. Attempts were made to control this pest by treating the mounds chemically and the results are discussed here.

Most of the chemicals tested by earlier workers were chlorinated hydrocarbons and gave only partial or complete success. Singh and Sharma (1957) reported partial success with DDT and BHC 50 per cent W.P. when applied at 2 oz per nest of *Odontotermes obesus* (Rambur). Bindra (1960) obtained complete control by applying 2 oz of each of the following insecticides per nest, DDT, BHC 50 per cent W.P., chlordane 75 per cent EC, toxaphene 25 per cent EC, dieldrin 18 per cent EC and aldrin 40 per cent EC at 1 oz per nest. These insecticides were dissolved in 10 gallons of water and poured into the termitaria.

MATERIAL AND METHODS

This experiment was conducted at the Main Research Station, Hebbal, during August-September, 1976. Twenty eight live mounds were selected at random. The size of the mounds varied from 1-1½ m in diameter and 25-100 cm in height. Six chemicals were tested with a control replicated four times. The chemicals tested include two chlorinated hydrocarbons, BHC 50 per cent W. P. at 50 g/mound and chlordane 20 per cent EC at 50 ml/mound; two organophosphorus compounds, phorate 10 per cent granules at 50 g/mound and chlorpyrifos (Dursban[R]) 20 per cent EC at 20 ml/mound and two fumigants, aluminium phosphide (Phosfume[R]-3 tablets) at 9 g/mound and ethylene dibromide (Edbampoule[R]) at 3 ml/mound.

The wettable powder and liquid formulations were dissolved in 10 litres of water and poured into the open holes. The granular formulations and tablets were directly applied through holes in the termitaria. Ethylene dibromide ampoules were opened at the tip and inserted into the holes. After the treatment mounds were immediately sealed with wet earth.

The results were obtained two weeks after treatment by opening the entire mound and counting the dead and live queens, as well noting the condition of other castes including fungus combs.

RESULTS AND DISCUSSION

Except BHC 50 per cent W.P. and ethylene dibromide, all treatments gave complete control of termites including queen, workers, soldiers and other fauna. After BHC treatment, queens in all the replication were healthy, and only partial kill of soldiers, workers, nymphs and fungus was obtained. In mounds treated with ethylene dibromide there was complete control in one replication but in the remaning three, queens were healthy and there was only slight damage to fungus combs. This partial success is perhaps due to the placement of ethylene dibromide ampoules in the upper part of the mound. In the mounds where the queens were dead, fungus growth was completely prevented, and fungus turned black with white wilting hyphal filaments, the combs were reduced to half size and completely rotten. The rotten fungus had high humidity and smelled like manure. In addition two cobras were killed in chlordane and phorate-treated mounds. However, other associated animals like sow-bugs, beetles, cockroaches and centipedes were not affected by the chlordane treatment. Rats were also found dead in aluminium phosphide and phorate-treated mounds.

The present findings agrees with those of Singh and Sharma (1957), but differ to those of Bindra (1960) in respect of the effectiveness of BHC in the control of termites. For the first time organophosphorus chemicals such as phorate and chlorphyrifos has been used with success against *O. wallonensis*.

With further evaluation for the optimal dosage and method of application, these chemicals can be effectively used against mound-building termite without much labour and cost.

The authors are very grateful to Dr. G. P. ChannaBasavanna, Professor and Head of the Department of Entomology, Agricultural College, Hebbal for facilities and encouragement

References

BINDRA, O. S., 1961, Termite damage in North Western Mahya Pradesh with results of experiments on their chemical control. *Indlan J. Ent.*, **22**: 277–282.

FLETCHER, T. B., 1912, Termites or white ants. *Agric. J. India*, 7 (3): 219–239.

MEHTA, P. R. AND VARMA, B. K., 1968, *Plant Protection.* Farm Information Unit, Directorate of Extension, Agriculture, Community Development and Cooperation, New Delhi, 587 pp.

SINGH SARDAR AND SHARMA, P. L., 1957, Destruction of nests of mound forming termites. *Indian J. Ent*, **19** (2): 91–95.

Control of Sugarcane Nematodes with Granular Nematicides

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Abstract

Preliminary field trials were undertaken at the Sugarcane Breeding Institute, Coimbatore to study the effect of granular nematicides on the sugarcane crop and control of nematodes associated with it. Results indicate a general increase in the yield of sugar cane crop associated with reduction of the plant parasite nematodes in the soil. The utility of the promising nematicide carbofuran, can be further investigated for use on large scale.

THE economic importance of nematode damage causing yield declines in sugarcane crops is now well known. Soil fumigation with DD, EDB, DBCP given good control of the nematode populations in soil and greatly stimulated the growth of the cane crops (Anon, 1956; Anon, 1960, 1961, 1962; Innes *et al.*, 1960; Parsons, 1970; Chu, 1970; Singh and Misra, 1973; Varadarajan *et al.*, 1974 and Bachchhav *et al.*, 1976). However, non-availability of chemicals to farmers, the cost and specialised methods of application have prevented use of the chemicals on large-scale. Now-a-days, granular nematicides that are readily available, easy to apply and give good control of nematodes are gradually replacing fumigants. Birchfield (1971) showed that aldicarb, fensulfothion and Macap (R) increased yields of sugarcane by controlling nematode populations

Dick (1972) proved that aldicarb was the best nematicide for nematode control in this region. However, not much work has been done with granular nematicides in India against sugarcane nematodes. So, field trials were done to study the effect of granular chemicals on sugarcane nematodes and crop yield both at field level and also in seedling flats of sugarcane nursery.

EXPERIMENT I

MATERIAL AND METHODS

Field trials were conducted at the Sugarcane Breeding Institute, Coimbatore during the year 1974-75. A field that showed a high degree of chlorosis in previous stand was selected for this purpose.

The field was prepared, the sugarcane variety Co. 419 planted and maintained by recommended practices. The experiment was laid out in a simple randomised block design replicated 6 times, size of the plot being 4 rows of 6 m. The following chemicals were applied at a dosage of 1.0 kg a.i./ha.

1. Fensulfothion
2. Dichlophethion
3. Carbofuran
4. Phenamiphos and
5. Control

The required quantities of the chemical was weighed and distributed in furrows around the root zone of one month old settlings and the plots were immediately irrigated. Between each plot, two rows were maintained, as buffer and care was taken to regulate the irrigation water to prevent contamination between treatments. Soil samples were taken before treatment, 7 weeks after

TABLE I

*Effects of nematicide applicaiions on nematode populations and sugarcane yield**

Treatment	Nematode population[a]			Total millable canes thousnds/ha	Yield in MT/ha	C. C. S.%
	I	II	III			
Carbofuran	1637	129	3206	62	96	10.17
Phenamiphos	2065	146	3080	60	77	7.89
Fensulfothion	1544	137	2902	57	75	7.70
Dichlophenthion	2103	883	3416	60	72	7.10
Control	2226	1502	3274	54	68	6.52

a : Nematode count (numbers in 250 cc)

I = Pretreatment samples

II = 45 days after treatment

III = at harvest

* Average of 6 replicates

treatment and at harvest. Each sample consist of composite of 5 probes to 20 cm depth per plot. Of this bulked sample a sub-sample of 250 cc of soil was taken and nematodes extracted by a combination of Cobb's sieving technique and sugar flotation method. The number of nematodes present in each sample were estimated (Table I). Data on cane yield, total number of millable canes and C.C.S. per cent are also presented in this table.

Results And Discussion

Nematodes in the samples were mainly of the genera *Pratylenchus*, *Rotylenchulus*, *Helicotylenchus* and *Hoplolaimus*; although a few specimens of other genera occurred their numbers were too small to consider.

It is evident from the data in Table I, that the nematode population decreased substantially, after treatment up to 45 days. Subsequently, there was an increase in population even in the treated plots and at harvest, there was no discernable difference, between the treated and control plots. This result is confirms earlier reports (Singh and Misra, 1973 ; Bachchhav *et al.*, 1976 ; Dick, 1970). The explanation put forward for such a rapid increase is that the new healthy root system in the treated plots provides ideal multiplication zone for the few nematodes that escape and result in a fast build up of the population. However, an increase in the yield was observed in the treated plots. Sugarcane is a long duration crop and the early growth phase is of critical importance. in the treated plots, the reduction in the nematode populations coincided with the early stage of growth of the young settlings which were able to thrive better. Later, however, the increased nematode populations did not impair the development of the cane much because the plant is then able to cope up with the conditions and put out fresh roots. Such a tolerance in cane as they advance in growth has also been reported by Innes and Chinloy (1960).

The experiment outlined above although preliminary, indicated clearly that carbofuran at the dosage applied increased the yield of sugarcane and also controlled the nematode population initially. The same was true for other treatments but their efficacy was relatively less. Though the results were not statistically significant the higher yield in the treated plots suggests the feasibility of using granular nematicidess especially carbofuran, in nematode infested areas to control nematodes. Allowing for the cost of the chemical and application, a profit of Rs. 2,800 per ha, can be incurred by the above treatment.

Soil fumigation has not been practicable in India due to the difficulty in applying to large areas and cost. At present, a number of granular nematodes are available that can be applied easily to sugarcane crops without special equipment, with economic returns.

Experiment II

Material and Mathods

Trials were also made to study the effect of granular nematicides on seedling growth and germination in seedling flats. Nematicides selected for this purpose were fensulfothion, carbofuran, DBCP and phenamiphos at the rate of 1kg a.i/ha, tried in two sets, one with and other without a wet Ceresan (R)(0.5 per cent) drench, as described below :

1. fensulfothion
2. DBCP (Dibromo-chloropropene)
3. carbofuran
4. phenamiphos
5. fensulfothion + wet ceresan
6. DBCP + wet ceresan
7. carbofuran + wet ceresan
8. phenamiphos + wet ceresan
9. wet ceresan(R) alone
10. Control - no treatment

Seedling flats were prepared by methods followed at the Sugarcane Breeding Institute, Coimbatore Fluff of variety Co. 453 G. C. was sown in three replications. The required quantities of nematicides were weighed out and fine furrows were made in the seedling beds in which the chemical were distributed evenly. The surface soil was then levelled and about 2.5 g. of fluff was sown in each flat. Those flats that require the wet ceresan (R) treatments were drenched with 0.25 per cent solution. This treatment was repeated at weekly intervals for 10 weeks.

Table II

Effect of nematicides on nematode populations germination counts and height of sugarcane seedlings, 10 weeks after sowing(a)

Treatment	Total seedlings at 10 weeks**	Height in mm.**	Nematode in 100 g soil (b) I	Nematode in 100 g soil (b) II
Fensulfothion	324	58.7	11.00	12.00
DBCP	280	59.33	20.00	0.00
Carbofuran	335	62.00	6.50	0.00
Phenamiphos	287	69.00	15.00	9.00
Fensulfothion+Wet Ceresan	271	69.67	10.00	4.00
DBCP+Wet Ceresan (R)	262	59.00	13.5	7.00
Carbofuran+Wet Ceresan (R)	261	63.67	0.00	0.00
Phenomiphos+Wet Ceresan (R)	270	65.00	10.00	11.00
Wet Ceresan (R)	252	65.00	188.00	185.00
Control	291	57.00	159.00	159.00

a : Average of 3 replications.

b : Nematode population at

I=45 days after treatment.

II=Time of removal of seedlings.

** Significant at 5 per cent level CD=77.7.

Germination counts were takes 4 times at 10 day intervals after sowing of the fluff. Seedlings were removed 10 weeks after sowing of fluff and their final height measured and total seedling counts taken. Data are presented in Table II.

Results and Discussion

It can be noted from Table II that application of nematicides brought about a substantial decrease in populations of the nematode 45 days after treatment. The reduction was still more distinct at the time of removal of seedlings *i.e.*, 10 weeks. Further, more seedlings survived in the treated flats and their height was also greater than in non-treated. However, by adding of the wet ceresan(R) treatment, there was no improvement in either the number or the vigor of the seedlings. Carbofuran produced the highest number of seedlings whereas treating with phenamiphos resulted in maximum height. The vigor of seedlings after carbofuran treatment, although of a lower order, was better than that of control.

It is interesting to note that there was near complete kill of the nematodes after application of the nematodes, which is in sharp contrast to the results obtained on a field scale, where the suppression of the population was achieved in early stages but subsequently the populations built up in all treatments (Experiment I). Thus, effective and adequate control of nematodes in sugarcane nursery buds is possible with the application of carbofuran, which, incidentally seems the most effective chemical in controlling nematodes of field crops of sugarcane (Experiment I).

The author wishes to express her sincere thanks to Shri H. David, Entomologist, Sugarcane Breeding Institute, Coimbatore for his help rendered during this investigation and also for the critical review of the paper. Thanks are due to Shri P. K. Jayatilakei of Sri Lanka, Sugar Corporation, Kantalai, Sri Lanka for his kind assistance in the observation of nursery flat trial. To Drs. J. Thuljaram Rao, Director, and S. S. Shah, former Director, Sugarcane Breeding Institute, Coimbatore, I wish to express my deep sense of gratitude for all the facilities provided for this study. The Council of Scientific and Industrial Research, New Delhi, 49' I wish to extend my thanks for providing the funds necessary for this research, which was carried out as Scientists Pool Officer at this Institute.

References

Anonymous, 1956, Soil fumigation interest rises. *Hawaiian* Sug. *Plrs' Ass. Exp. Stat. Ann Rept.*, 27.

Anonymous, 1960, Identification and determination of pathogenicity of nematodes on sugarcane. *Ibid*, pp. 18–20.

Anonymous, 1961, Nematode studies continue. *Ibid*, pp. 22–23.

Anonymous, 1962, Effect of Nematodes shown. *Ibid.*

Bachchhav, M. B. and Patil, A.O., 1976, Control of nematodes with chemicals in sugarcane plant crop. *Ind. Sug.*, XXVI(2): 69–71.

BIRCHFIELD, W., 1971, Effect of some nematicides on plant nematodes and sugarcane yield. ISSCT 14 Congress, 1022-1030.

CHU, H. T., 1970, The economics of fumigating sugarcane soils in Taiwan. *Sug. Path. Newsletter*, 1 : 56-57.

DICK, J., 1970, Sugarcane nematology in South Africa. *Sugarcane Path Newsletter*, (4) : 10-13.

INNES, R. F. AND CHINLOY, T., 1960, Sugarcane responses obtained in Jamaica from the use of fuamigants. *Proc. Br. W. Indes Sug. Tech.*, pp. 28-33.

PARSONS, H. N., 1970, Preliminary investigation on incidence and control of plant nematodes in a new sugarcane estate in Nigeria. *Trop. Agric* (Trinidad), 47 : 103-113.

SINGH, KISAN AND MISRA, S. R., 1973, Chemical control of parasite nematodes in sugarcane. Part I. *Inst. Sug. Jour.* LXXV(899) : 335-336.

SINGH, KISAN AND MISRA, S. R., 1073, Chemical control of parasitic nematodes in Sugarcane Part II. *Ibid*, LXXV (900): 369-370.

Sugarcane Nematodes and Chlorosis

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ABSTRACT

Association of nematodes with the sugarcane crop, resulting in yield decline due to subnormal growth of cane and various degrees of stunting, loss of chlorophyll from leaves, drying of leaf tips and margins and poor root system has been reported.

INTRODUCTION

DURING the last decade, increased attention has been paid to the presence of nematodes in all agricultural crops. The earliest records of nematodes attacking sugarcane are from Java where Treub (1885) and Soltwedel (1888) found the root-knot nematode (*Meloidogyne*) species and lesion nematodes (*Pratylenchus*) species in the roots of sugarcane. Cobb (1906, 1915) conducted a survey of sugarcane soils in Hawaii and described the injury of cane roots by two species of nematodes, namely, *Meloidogyne incognita* (Kofoid and White, 1919), Chitwood 1947 and *Radopholus similis*(Cobb, 1883) Thorne. In India, reference to sugarcane nematodes and their possible involvement in general malnutrition, excessive tillering and other abnormalities has been made as early as in 1919 by Barber. Subsequently, a series of papers reporting the presence of various nematode genera in and around sugarcane roots have been published (Siddiqi, 1960; David, 1960, 1961; Nagaraja Rao *et al.*, 1961; Siddiqi *et al.*, 1961; Chandy *et al.*, 1963; Taradarajan *et al.*, 1974).

Recent surveys undertaken to ascertain the type and population of plant parasite nematodes found in and around Coimbatore and South Arcot Districts of Tamil Nadu revealed the presence of the following genera and species :

Lesion nematode : *Pratylenchus delathrei* Luc, 1958 and *Pratylenchus pratensis* (deMan 1880) Filipjev 1936 were found in high numbers, up to 3,000 nematodes per 250 cc of soil. These nematodes were found in all soil samples in the Coimbatore district, but were very infrequent in those of South Arcot district.

Spiral nematode : Of this two species were identified from sugarcane fields of Coimbatore, *Helicotylenchus dihystera* (Cobb, 1893); Sher, 1961 and *H. retuses* Siddiqi and Brown, 1964.

Lance nematode: *Hoplotaimus indicus* Sher, 1963 was found in varying numbers from a large number of the soil samples surveyed.

Reniform nematode : Rotylenchulus renifomis Linford and Oliveira was also found in very high numbers in many of the samples from Coimbatore. However, as in case of lesion nematode, they were absent in South Arcot soils. The pathogenicity of this nematode to sugarcane is still very doubtful because no mature females were isolated from sugarcane roots. Mature females were found in weeds in sugarcane fields. Sugarcane might be immune to this nematode (Raman, 1964).

Stylet nematode : *Tylenchorhynchus martini* Fielding and *Tylenchorhynchus* sp. were found in large numbers in South Arcot soil samples, however, they were absent from Coimbatore soils.

In addition to above mentioned major genera, *Criconemoides sphaerocephalus* deGrasse, 1967, *Caloosia longicaudata* (Loos, 1948) Siddiqi and Goodey, 1963, *Hemicriconenoides mangiferae* Siddiqi, 1960 and *Trichodorus acaudatus* Siddiqi, 1960, *T. mirzai* Siddiqi, 1960 and *Xiphinema* spp. were found in varying numbers in samples analysed.

During these surveys, it was found that many sugarcane fields in and around Coimbatore areas showed varying degrees of chlorosis. Such conditions were found generally in patches in a field distributed at different points. Chlorosis was seldom distributed over the entire fields. The crop exhibited symptoms similar to that of iron deficiency the leaves being pale to whitish and the entire plant was stunted in growth with excessive tillering. Srinivasan (1958) has shown that one of the causes of chlorosis is a nematode which resembles *Radopholus similis* and a fungus *Pythium graminicolum*. According to him, the nematode is associated with reduced absorption of iron and the coincidence of the two organisms result in a synergistic severity of the disease. It is to be

mentioned here that the nematode *Radopholus similis* was not found in any of the numerous samples examined and has not been reported by any author from sugarcane soils of Coimbatore. In all probability, it is a misidentification and the nematode species is possibly *Pratylenchus* spp. which is also endoparasitic and belong to the same family *viz.*, *Pratylenchidae*, and is associated with a fungus complex and root rot of various crops causing the same symptoms as mentioned by the author (Anon, 1959; Jenkins, 1948; Mountain, 1954; and Pitcher, 1965). In the present survey, this nematode, together with the spiral nematode, *Helicotylenchus*, was found in large numbers in the chlorotic patches. Simultaneously, when the non-chlorotic healthy patches adjacent to the chlorotic patches were sampled, they revealed a marked difference in population of the nematodes (Table I).

TABLE I

Nematode populations in the chlorotic and non-chlorotic regions of the same cane fields in Coimbatore ditstrict

Area		Nematode population	
		Chlorotic clump	Non-chlorotic clump
Semmedu	(a)	4,059	810
	(b)	1,352	491
	(c)	1,280	200
Sugarcane Breeding Institute Farm	(a)	3,109	1,711
	(b)	2,400	867
	(c)	2,195	840
	(d)	4,100	833
Sarcar Samakulam		4,268	419
Tudiyalur	(a)	2,833	200
	(b)	6,238	—

The nematode associated were in all cases *Pratylenchus* and *Helicotylenchus* as dominant forms.

From the preliminary data presented above, it can be concluded that there is a constant association of very high population of nematodes with chlorotic conditions in the field. Chlorosis in sugarcane is essentially physiological and explained as being induced by lime domination and other factors of soil, resulting in the poor availability of iron. But from the present study, the role of the nematodes in inducing or aggravating the chlorotic conditions in sugarcane cannot be overlooked. In fact, nematode infestation in many other crops have been identified with chlorosis (Christie, 1959). What is needed, is a critical study of the nature and extent to which the composition of nematode population in sugarcane soils will contribute to the initiation and intensity of chlorosis. Such an effort may help in evaluating the benefits that result from nematode control in sugarcane soils.

The authors wishes to express her sincere thanks to Shri H. David, Entomologist, Sugarcane Breeding Institute, Coimbatore, far his kind cooperation and help rendered during this study and also for criticallly reviewing this paper. She also extends her gratitude to Dr. J. Thuljaram Rao, Director and Dr. S. S. Shah, former Director of the Sugarcane Breeding Institute, for providing all the facilities required for studies. Thanks are also due to Council of Scientific and Industrial Research, New Delhi-49, for providing the funds necessary for the research, which was carried out as Scientists' Pool Officer at this Institute.

References

ANONYMOUS, 1959, Effects of nematodes and fungi singly and in combination on the growth of sugarcane. *Rep. Hawaiian Sug. Plrs' Ass. Exp. Stn.*, pp. 18-20.

BARBER, 1919, The growth of sugarcane. III. *Inter Sugar Jour.* XXI (251): 601-605.

CHANDY, K. C., KAREEM, A. A. AND VENKATARAMAN, T., 1963, Record of a few nematodes on sugarcane in Madras State. *Indian J. Sugarcane Res. and Dev., 7*: 136-137.

CHRISTIE, J. R., 1959, Plant nematodes. Their bionomics and control. *Gaonesville, Florida, Agricultural Experiment Stations, University of Florida.* 256 pp.

COBB, N. A., 1906, Free living nematodes inhabiting the soil about the roots of cane and their relation to root diseases. *Bull. Div. Path. Physiol. Haawiian Sug. Pirc' Ass. Exp. Stn., 5*: 163-195.

COBB, N. A., 1915, *Tylenchus similis,* the cause of the root disease of sugarcane and banana. *J. agric. Res., 4*: 561-568.

DAVID, H., 1960, On the host range of root-knot nematode. *Indian J. Sugarcane Res. Dev., 5*: 56-57.

DAVID, H. AND THIRUVENGADAM, C. R., 1961, Eelworm in sugarcane. *Proc. Conf. Sugcan Res. Dev. Wkrs.* Indian, *4*: 528-532.

JENKINS, W. A., 1948, Root-rot disease complex of tobacco in Viginia. I. Brown root-rot. *Phytopathology, 38* (7): 521-541.

MOUNTAIN, W. B., 1954, Studies on nematodes in relation to Brown root-rot of tobacco in Ontario. *Canadin Jour. Botany, 32*: 737-759.

NAGARAJA RAO, K. S., MUTHUKRISHNAN, T. S. AND ABRAHAM, E. V., 1961, Nematodes affecting sugarcane in Madras. *Indian J. Sugarcane Res. Dev., 5*: 163.

PITCHER, R. S., 1965, Inter-relationships of nematodes and other pathogens of plants. *Helminth. Abst., 34*: 1-17.

ROMAN, J., 1964, Immunity of sugarcane to the reniform nematode. *J. Agric. Univ. P. Rico, 48*: 162-163.

SIDDIQI, M. R., 1960, Two new species of the genus *Trichodorus* (Nematoda : Dorylaimoidea) from India. *Proc. helminth. Soc. Wash., 27*: 22-27.

SIDDIQI, Z. A., PRASAD, A. R. AND ANSARI, M. N. A., 1961, The record of parasitic nematodes sugarcane in Bihar. *Curr. Sci., 30* : 193-194.

SRINIVASAN, K. V., 1958, A Pythium root-rot and chlorosis comple, of sugarcane. *Madas Agric. J.*, 45 : 89.

VARADARAJAN, G., SATHIAMURTHY, A. S., GOVINDARAJAN, K. AND RAJAN, S. D., 1974, Problems of nematodes in sugarcane. *Cooperative Sugar, 5* (8) : 1-2.

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