MICROARTHROPODS AND SOIL ECOSYSTEMS

T. N. ANANTHAKRISHNAN[1]

The decisive influence of soil microarthropods, not to mention of other invertebrates in the establishment of diverse patterns in the decomposition of organic matter and the succession of fauna therein involved cannot be underestimated. Results achieved in this direction in many countries sufficiently indicate the need for active cooperation between soil biological and pedological research in determining the fertility of the soils. It is being increasingly realised that many soil microarthropods play a useful role as indicator organisms in relation to soil fertility. The contributions made in edaphic studies through the publications of monographs and books by Kubiena (1955), Haarlov (1960), Nielsen (1955), Kuhnelt (1961), Gisin (1952), Doeksen and Van der Drift (1963) in Europe, Murphy (1955), Kevan (1955), Macfadyen (1962), Edwards (1962), Burgess and Raw (1967), Wallwork (1970, 1976) in England and Morikawa (1957) and Yosii (1955) in Japan are among the most outstanding and a beginning has been made over the last decade in this direction in India as well. With its variety of soil and climate excellent opportunities exist for extensive soil faunal studies particularly with reference to their population dynamics, vertical migrations and a possible correlation of abundance of certain indicator species with soil fertility.

The soil is a complex of physico-chemical and biotic factors and the great diversity of organisms found therein, combined with the physical difficulties of studying them, not to mention the patient, laborious and time consuming task of isolation and identification of the multitude of forms are no doubt factors responsible for the slow progress of this science in this country. All the same one cannot ignore the importance of ecological problems pertaining to the soil, an investigation into which may demand a preliminary exploratory work involving qualitative studies or an inquiry concerning the relative abundance of a wide range of species over a wide range of habitats or the determination of the absolute abundance of some species in a single habitat. Investigations on the edaphic community may lead to the discovery of "life-forms" or "lebens-formen", so characteristic of the soil dwelling Collembola wherein we come across similar modifications even within diverse forms according to the depth or layers of edaphon they inhabit. Thus for example, *Tullbergia, Isotomodes, Folsomides,* etc. are euedaphic living in the depth of soil. All of them are Characterised by their elongate body facies small size (at most 1 mm long), similar segmentation, musculature and easily flexible non-pigmented or feebly pigmented bodies, reduction or the total absence of ocelli and with short and simple hairs and smaller appendages. *Brachystomella, Hypogastrura, Friesea,* etc. are hemiedaphic, including forms living on water surface (neustonic), moss, bark or lichens (xeromorphic) characterised by moderately long antennae, well developed

[1] Zoological Survey of India, 34 Chittaranjan Avenue, Calcutta-700 012.

pigment and ocelli. Epigeic forms (living on vegetation or upper surface of litter, combining both hyperedaphic and epiedaphic forms) are characterised generally by eight ocelli, well developed pigmentation, long antennae and furcula, e.g., *Orchesella, Bourletiella, Callyntrura,* etc. In addition are the Troglomorphs (e.g., *Cyphyoderopsis, Trogolaphysa,* etc.), characterised by the absence of ocelli and pigment, long antennae and modified unguis and Synecomorphs living in the nests of ants and termites, characterised by the absence of ocelli and pigment (cf. Troglomorphs), modified mouth parts, well developed furcula and legs and the development of unusual scales and setae (e.g. *Delamarerus, Pseudocyphoderus, Calobatinus,* etc.). Even among cryptostigmatid mites life forms exist, the hemiedaphic forms often showing further modifications in relation to their subdivision into hygrophilous, mesophilous, xerophilous conditions and incidental correlation of the form of the pseudostigmatic organ with the moisture gradient of the environment. Marked specialisation for inhabiting particular depths and associated morphological adaptations are shown by the geophilids, symphylids, pauropods and other microarthropods and such microhabitats within a major community have also been termed '*synusia*'.

Preliminary qualitative studies on the composition of the microarthropods inhabiting the surface litter (L layer), decaying organic matter (F layer), pasture soil and manured soil are essential aspects of soil microarthropod investigations. Murphy's classification of the fauna into the microfauna (.001-1 mm), meiofauna (0.1-1.6 mm) and the macrofauna (1.6 to several mm) appears a useful measure, the majority of the meiofauna lying at the 3-4 cm level, of which a good number occur in the F layer, 1-2 cm below the surface. In pasture soil, F layer is absent due to the fact that the rate of the decomposition at the surface is sufficiently high to prevent its formation and this kind of soil is usually with a low humus content; during the rainy season, soluble bases are leached out; during the dry season iron and aluminium compounds are oxidised giving the soil a characteristic red or yellow colour. These soils are more correctly called "Latosols" or "Feralitic soils". The dominant microarthropods are the Collembola, mites, symphylids and to some extent the pauropods thrive well in the upper layers. Below this in the mineral soil, the microcaverns or pore spaces are not suitable for the existence of all microarthropods in addition to the absence of sufficient organic matter. Therefore there is a preponderence of these dominant microarthropods in the upper layer of soil and particularly during the hotter months when there is a danger of exposure of the litter to strong sunlight, the fauna migrate to the lower layers. As such the principal factors inducing the vertical migration are the nature of the microcaverns, food, temperature, humidity and predation at the surface. Many symphylids like *Scutigerella* sp., *Symphylella* sp., *Symphylellopsis* sp. show seasonal vertical migrations in soil in response to soil temperature and moisture. Such vertical migrations are also known to occur in response to feeding, moulting and reproductive cycles (Ovipositional). This is also the case with mites and collembola and even the possibility of a diurnal rhythm in vertical movements has been suggested.

Data regarding the vertical migration of microarthropods in Indian soils are very meagre. However Choudhuri & Roy (1971), in their studies on the vertical distribution of some species of Collembola in the gangetic alluvium, observed that *Sphaeridia, Proisoto-*

ma, Alloscopus, Isotomurus and *Sminthurinus* were all more concentrated in the middle layer (5-10 cm), while the maximum number of individuals of *Seira* occurred in the lower layer (10-15 cm).

Symphylids and pauropods are noticeably absent from the L layer (though mites are more abundant), while their number is very meagre in the F layer below it. They are in sufficiently large numbers in the pasture soil and manured soil as has been observed in banana plantation soils. The Collembola of the 'L' layer such as *Callyntrura, Lepidocyrtus, Entomobrya, Isotoma, Salina* and *Dicranocentrides* are large sized, pigmented, with well developed eyes and spring and extremely active and can often be seen to penetrate the soil to a limited extent, while those in the F layer are totally different, being small, slender, unpigmented with reduced eyes and spring as in *Tullbergia, Onychiurus, Xenylla, Isotomodes, Folsomina, Folsomides* and *Folsomia* which move along the walls of the soil microcaverns. The most important single factor governing the distribution of Collembola is moisture and the possibility of the Collembola acting as indicators of soil water condition has been suggested. In other words the water content of the soil could reflect the species composition of the population. For instance, the mesophil fauna such species of Collembola as *Folsomia brevicauda, Friesea mirabilis, Isotoma sensibilis* occur, as against the only Xerophil species *Tetracanthella wahlgreni* (Hale 1963). The mite fauna are present both in the L and F layers in considerable numbers, the Oreibatid mites being more abundant in the L layer than the F layer. The Tyroglyphid and Tetranychid mites however are generally recorded only in meagre numbers. Some of the dominant species of soil mites, collembola etc. characteristic of grassland, forest and cultivated soils from India are represented in Table I.

Considerable specificity of microarthropods, particularly amongs the collembola exists in accordance with the different ecotopes. Mitra, *et al.* (1977) observed the specificity of Collembolan species in accordance with six ecotopes (including five vegetational sites) at the Eden gardens, Calcutta. The existence of both qualitative and quantitative population differences in three sites, viz., forest, new clearing and tea fields and the total absence of the litterine genera of Collembola like *Lobella, Lepidocyrtus, Dicranocentrus, Callyntrura, Salina, Dicyrtoma,* etc. at the newly cleared sites, were indicated by Prabhoo (1976) who also observed a similarity of fauna in the forest and tea field soils.

The species composition of the litter may be said to indicate the soil edaphon of the future, because on the litter fauna depends the widely varying degree of decomposition necessary for the enrichment of the soil. It provides a typical instance of what can be called a metabiotic process wherein one series of organisms provide favourable conditions for the next. The role of Collembola in the initial break down of litter followed by the millipedes and the earthworms is well known. They are known to actively remove material, ingesting them into the gut and produce faecal pellets which are added to the soil, thereby providing readily available material to the decomposers. The mechanical effect of the breakdown of litter by the millipedes is enormous and as a result of frequent migrations up and down the soil profile, they are said to effect a mixing up of the mineral and organic portions of the soil. Under neutral and slightly alkaline conditions, the millipedes, isopods and annelids establish themselves and play an important role in modifying and mixing the surface litter with the lower horizons of the soil. Under acid conditions such species are inhibited and mites, dipteran larvae and Collembola typify the fauna which do not significantly change the character of the horizon. It was on the basis of the millipede, isopod and insect larval activity in the soil that Kubiena (1955) introduced the 'moder' and 'mull-like moder' concepts of the humus forms according to which forms inhabiting sandy, base deficient soils constitute the moder species (mites, collembolans and insect larvae), while the base rich clayey soils form the 'mull-like moder' species of which the millipedes form the largest proportion followed by enriched earthworm and isopod population. However the actual number, the biomass and relative efficiency of each group is dependant more upon the basic features of the soil as mentioned above, as well as of the diverse factors which tend to modify the soil environment. It is because of such variable interactions that reliable estimates pinpointing the effective role of each group of soil animals have not been possible, though in general it has been estimated that animals consume 10-20% of the total organic matter supplied to the soil. A moderate temperature and moisture, with the availability of decaying organic matter on the soil surface constitute the optimal conditions for the growth and multiplication of such microarthropods as symphylids. To cite an example, at a temperature of 36°C and 65% RH the average population of *Symphylella* sp. for 110 c. of soil was 420, while at temperatures of 29-32°C and 86-90% R.H. the average population was found to be 2935 and in between these ranges of temperature and humidity the population range was 1194-2080 individuals. (Ananthasubramanian & Ananthakrishnan 1962). The study of the abundance of the microarthropods in a variety of soils is considered significant because it is seen that fertilising the soil with organic manure increases the edaphic composition tremendously, in particular the collembolans and the symphylids. The Collembola are very abundant in the surface manure and helps in its decomposition after which, the manure fauna changes into a true soil fauna through the compost fauna. It has been estimated that the collembolan fauna of compost is 1,30,000 per metre^2 surface upto a depth of 10 cm.

The forest floor in Tropical forests provides a good example of surface litter zones Ananthakrishnan (1973) has sufficiently emphasised this aspect in relation to mycophagous thrips. In litter, thrips are usually confined to the uppermost layer on entire leaves, and in the lower layers are mites, collembola, beetles etc. and only a few thrips. Leaf litter provides a more or less uniform semipermanent habitat and thrips are never common in wet litter and are abundant in litter resulting from diverse tree and shrub flora which are very characteristic of the Western Ghats. The movement of microarthropods between the different horizons of the mineral soil and litter is influenced by the graded series of relative humidities. Species of Cryptostigmatid mites of the fauna *Steganacarus, Oppia, Platynothrus, Adoristes* etc., mesostigmatid species of *Trachytes*, the predatory *Pergamasus, Macrocheles* sp. are more common in surface litter. Assessment of the relative efficiency of each group of organisms in term of litter decomposition is a difficult problem since animal activities may alter litter in such a way as to effect the species composition.

The major contributors to the litter in such forest areas as of the Western ghats involve species of *Mesua* (Guttiferae), *Ternstroemia* (Ternstroemiaceae), *Dipterocarpus* (Dipterocarpaceae), *Pterospermum* (Sterculiaceae),

TABLE 1

SOME DOMINANT MICROARTHROPODS IN GRASSLAND, FOREST AND CULTIVATED SOILS IN INDIA

SOIL MICROARTHROPODS	GRASSLAND	FOREST	CULTIVATED SOIL
COLLEMBOLA	*Lepidocyrtus suborientalis*	*Lepidocyrtus (Acrocyrtus)* sp.	*Isotomina thermophila*
	Cyphodersus albinus	*Cyphoderus javanus*	*Xenylla* sp.
	Megalothorax minimus	*Brachystomella* sp.	*Proisotoma* sp.
	Folsomides parvulus	*Lobella siva*	*Megalothorax* sp.
	Isotomina thermophila	*Folsomides exiguas*	*Folsomides* sp.
	Arrhopalites sp.	*Sminthurus* sp.	*Pseudosinella* sp.
	Pseudosinella sp.	*Sminthurides* sp.	*Isotomurus* sp.
	Sphaeridia sp.	*Isotomina interrupta*	*Folsomina* sp.
	Isotomurus ciliatus		
	Isotomiella minor		
	Sminthurus sp.		
	Brachystomella curvula		
	Pseudochorutes sp.		
	Tullbergia sp.		
	Salina bengalensis		
	Lobella maxillaris		
ACARINA	*Laeioseius reticulatus*	*Hypoaspis miles*	*Scheloribates* spp.
	Papillacarus indicus	*Scheloribates* spp.	*Oppia* sp.
	Epilohmannia pallida	*Epilohmannia* sp.	*Rhysotritia* sp.
	Archegozetes magna indicus	*Scutacarus vestigialis*	*Gamasodes assamensis*
	Allonothrus indicus		*Lamellibates bengalensis*
	Scheloribates spp.	*Scutacarus tackei*	
	Rhysotritia sp.	*Scutacarus hamatus*	
	Hypoaspis bengalensis	*Imparipes longisetosus*	
	Macrocheles hyatti	*Pygmephorus spinosus*	
	Gamasodes assamensis	*Bakerdania kashmirensis*	
	Allothrombium australiense		
	Oppia spp.		
	Holostaspella parornata		

DIPLURA	*Parajapyx grassianus indica* *Japyx indicus* *Indjapyx pruthii* *Lepidocampa gravelyi*	*Lepidocampa (Lepidocampa)* *Juradii bengalensis* *Japyx* spp.	—
PROTURA	*Acerentomon* sp. *Eosentomon* sp. *Protentomon* sp.	*Acerentomon* sp. *Eosentomon* sp.	—
SYMPHYLIDS	*Scutigerella* sp. *Symphylella* sp. *Symphylellopsis* sp.	*Symphylellopsis* sp. *Symphylella* sp. *Scutigerella* sp.	*Scutigerella immaculata*

Pterocarpus (Leguminosae), *Terminalia* (Combretaceae), *Syzigium* (Myrtaceae) *Barringtonia* sp. (Lecythidaceae), *Tectona* (Verbenaceae), *Dalbergia* (Leguminosae), *Mallotus* (Euphorbiaceae), *Lagerstroemia* (Lauraceae), *Kigelia* etc. (Bignoniaceae). Many Tubuliferan thrips species inhabit this fungus infested litter and these mycophagous species are important members of this specialised niche. The dominant species inhabiting the litter are *Gastrothrips karnyi, Nesidothrips alius, Kleothrips gigans, Elaphrothrips productus, Hoplandrothrips flavipes, Hoplothrips fungosus, Diceratothrips usitatus, Nanothrips parviceps, Azaleothrips amabilis* and *Stigmothrips limpidius*. Ananthakrishnan (1973) provides a detailed account of the various species inhabiting the saprophytic fungal· zone. The conspicuous polymorphism in leaf production and the constant non-synchronus leaf fall make available abundant litter which provides an ideal microenvironment constituting a saprophytic fungal zone. The destruction of forests naturally limits litter production and interferes with the process of litter decomposition through the agency of micro-orthropods.

Therefore, regular examination of the litter and F layers in a variety of habitats should reveal an ever increasing and abundant population of diverse microarthropods which should be correlated with the nature of the litter and in view of the largely saprophagous and fungal feeding habits there is ample scope for research into the role of these fauna in the sequential breakdown of organic mattter as well the changes in the fauna such as the Collembola and mites associated with plant succession. Further the catalytic action of the animals on soil metabolism appears to be a new line of investigation, the dead bodies, exuviae and most important of all the faecal matter of soil animals providing enriched sites for other organisms in the process of development of mature soils.

References

Ananthasubramanian, K. S. and Ananthakrishnan, T. N. (1962): Microarthropods of the pasture soil. *Bull. Ent. 3*: 18-21.

Ananthakrishnan, T. N. (1973): Mycophagous Tubulifera of India (Thysanoptera: Insecta) Occ. Publ. No. 2 *Ent. Res. Unit. Loyol. Coll.* Madras, pp. 144.

Burgess, A. and Raw, F. (1967): Soil Biology. Academic Press. London and New York.

Choudhuri, D. K. and Roy, S. (1971): Seasonal fluctuation and vertical distribution of the genus *Lepidocyrtus* (Collembola: Insecta) in some uncultivated fields of gangetic West Bengal. *Rev. Ecol. Biol. Sol. 8*(2): 253-259.

Doeksen, J. and Van der Drift, J. eds. (1963): Soil organisms, North Holland, Amsterdam.

Edwards, C. A. (1962): Springtail damage to bean seedlings. *Plant Pathol. 11*:67-68.

Gisin, G. (1952): Oekologische studien uber die collembolen des Blattkomposts. *Rev. Suisse Zool.*, *59*:543-78.

Hale, W. G. (1963): The Collembola of eroding blanket bog-soil organisms (ed. J. Doeksen & J. Van der Drift): 406-413.

Haarlov, N. (1960): Microarthropods from Danish soils, ecology and phenology. *Oikos*, suppl., *3*:1-165.

Kevan, D. K. McE. (1955): Soil Zoology. (Butterworths, London).

Kubiena, W. L. (1955): Animal activity in soils as a decisive factor in establishment of humus forms. Soil Zoology, 73-82. (Butterworths, London).

Kuhnelt, W. (1961): Soil Biology. 1-395 (Faber & Faber, London, 1961).

Murphy, P. (1955): Ecology of the fauna of forest soils. Soil Zoology, 99-124. (Butterworths, London).

Macfadyen, A. (1962): Extraction techniques for soil arthropods. *Advan. Ecol. Res.*, *1*:1-34.

Morikawa, K. (1957): Terrestrial fauna of Kashima Islets in the Bay of Tanbe, Wakayama Penfecture. *Publ. Seto mar. biol. Lab. 6*:233-234.

Mitra, S. K., Hazra, A. K. and Sanyal, A. K. (1977): Ecology of Collembola at the Eden gardens, Calcutta. *Ecol. Bull.* (*Stockholm*) *25*:539-544.

Nielsen, C. D. (1955): Survey of a year's results obtained by a recent method for the extraction of soil-inhabiting enchytrarid worms. Soil Zoology: 202-214. Butterworths, London.

Prabhoo, N. R. (1976): Soil micro-arthropods of a virgin forest and adjoining tea fields in the Western ghats in Kerala—A brief ecological study. *Ori. ent.* Ins., *10*(3): 435-442.

Wallwork, J. A. (1970): Ecology of soil animals. McGraw-Hill, pp. 283. London and New York.

———— (1976): Distribution and diversity of soil fauna. Academic Press. London and New York, pp. 355.

Yosii, R. (1955): Meerinsekten der Tokara inseln VI. Collembolen. *Publ. seto marine Biol. Lab.*, 2-3, 379-401.