

PROGRESS IN SOIL BIOLOGY AND ECOLOGY IN INDIA

Edited by :

G. K. VEERESH



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UNIVERSITY OF AGRICULTURAL SCIENCES
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PREFACE

The publication contains the papers presented at the 2nd All India Symposium on Soil Biology and Ecology held at Bangalore in April 18-20, 1979. The symposium was held under the joint auspices of United Nations Development Project, Indian Council of Agricultural Research and the University of Agricultural Sciences. The publication of the proceedings has been made possible by a grant from the Indian Council of Agricultural Research.

The proceedings of the First All India Symposium on Soil Biology and Ecology held at Bangalore from 22nd to 26th November 1976, edited by C. A. Edwards and G. K. Veeresh, and published by the University of Agricultural Sciences, has been well received. This publication is another attempt to bridge the gap in the knowledge of soil biology and ecology in this country.

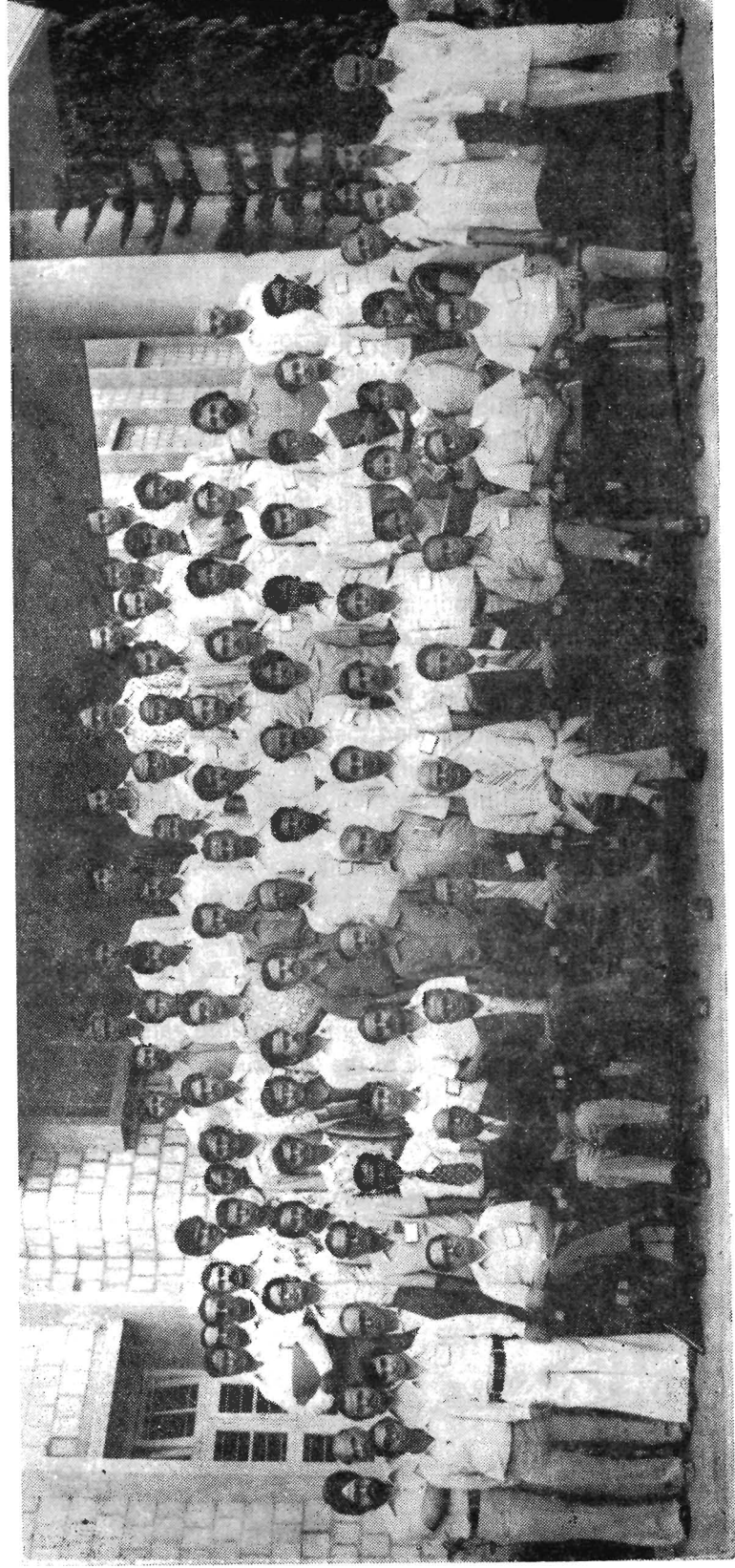
The Department of Entomology, University of Agricultural Sciences has given a lead not only in organising the two symposia on Soil Biology and Ecology but also in offering courses in soil biology at postgraduate level. An All India Summer Institute on Soil Biology, Ecology and Management of soil pests financed by ICAR is being organised at this centre in July 1981. It is hoped that this publication in addition to the first one, will greatly help in providing necessary material for teaching and planning further research in this country.

The financial support given by the ICAR for publication, the U. A. S for having brought out this as one of its technical series and the nice printing done by Raja Power Press, Malleswaram, Bangalore are acknowledged. The painstaking effort put by Mr. B. Mallik of the Department of Entomology in proof checking of the material deserves special mention.

G. K. VEERESH

PARTICIPANTS OF THE SECOND ALL INDIA SYMPOSIUM ON SOIL BIOLOGY AND ECOLOGY

APRIL 18 to 20, 1979, UNIVERSITY OF AGRICULTURAL SCIENCES, BANGALORE



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1. SOIL MICROORGANISMS

1.1 RESPONSE OF GRAM TO *RHIZOBIUM* INOCULATION AS INFLUENCED BY DIFFERENT IONIC TREATMENTS

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ABSTRACT

An experiment was conducted at the Punjab Agricultural University, Ludhiana during the year 1977-78 on a loamy sand soil to study the effect of seed soaking in potassium dihydrogen orthophosphate (0.5 and 1.0 per cent), copper sulphate (0.05 and 0.1 per cent) solutions and sodium molybdate application (12.5, 25.0 and 37.5 g/ha seed rate), on the efficiency of *Rhizobium* (strain F 75) inoculation in gram variety G 130. *Rhizobium* inoculation significantly increased the number and dry weight of nodules over uninoculated control. Further increase in nodulation was obtained when *Rhizobium* inoculation was combined with sodium molybdate. However, no significant differences in the final dry matter and grain yield were recorded either due to *Rhizobium* inoculation alone or due to any other treatment. The trend in yield indicated beneficial effect of seed soaking in potassium dihydrogen orthophosphate solution.

INTRODUCTION

Gram (*Cicer arietinum*) is one of the most important pulse crops of India. The average yield per unit area is, however, very low, partly because of poor nitrogen fixation by symbiotic *Rhizobium*. The response of *Rhizobium* inoculation in gram has not been well established and the reports regarding its efficacy are contradictory. Non-availability of certain micronutrients may be one of the reasons for limiting its response in gram. Significant interactions between molybdenum and *Rhizobium* in different legume crops have been reported by Hagstrom and Berger (1963), Giddens (1964), Anthony (1965), Thompson and Anthony (1965) and Burton and Curley (1966). Significantly higher yields of gram have also been obtained by seed soaking in potassium dihydrogen orthophosphate and copper sulphate solutions by Kaul and Sekhon (1974 and 1976). An experiment was conducted to study the effect of potassium dihydrogen orthophosphate, copper sulphate and sodium molybdate on the efficiency of *Rhizobium* inoculation in gram.

MATERIAL AND METHODS

Field investigations were undertaken at the Punjab Agricultural University, Ludhiana, during 1977-78 on a loamy sand soil low in organic carbon and available nitrogen and medium in available phosphorus and potassium. The ten treatments were : control-uninoculated dry and water soaked seeds, *Rhizobium* (strain F 75) inoculation alone, inoculation plus seed soaking in potassium dihydrogen orthophosphate (0.5 and 1.0 per cent), copper sulphate (0.05 and 0.1 per cent) solutions and sodium molybdate application at the rate of 12.5, 25.0 and 37.5 g/ha seeds. These were compared in a randomised block design with three replications. The seeds, after soaking in various solutions for four hours, were inoculated, dried and sown. Sodium molybdate was mixed dry during inoculation of seed. Gram (var. G 130) was sown during the second fortnight of October (optimum time for sowing gram in Ludhiana). Uniform dose of 15 kg N and 50 kg P_2O_5 /ha was drilled at the time of sowing.

RESULTS AND DISCUSSION

Rhizobium inoculation alone as well as in combination with different ionic treatments increased the number and dry weight of nodules over uninoculated control in 60 and 95 days old plants, however, these differences were significant in 95 days old plants only (Table I). Maximum number and dry weight of nodules were recorded when *Rhizobium* inoculation was combined with sodium molybdate, which indicates the beneficial effect of molybdenum on the efficiency of *Rhizobium*. Burton and Curley (1966) also reported increase in the number of nodules when molybdenum was applied to inoculated seeds. However, this initial gain in nodulation was not reflected in the plant growth as is evident from the plant height which was not significantly influenced by any of the treatments. This is also evident from the final dry matter yield as well as periodic dry matter accumulation at 60 days stage which were also not significantly influenced either by *Rhizobium* inoculation alone or by any other treatment (Table II).

Rhizobium inoculation also failed to increase the grain yield significantly, though an increase of 70 kg/ha was obtained over uninoculated control. None of the molybdenum doses affected the efficiency of *Rhizobium* with regard to the grain yield. Hence the initial increase in nodulation due to the application of molybdenum was not associated with increase in grain yield which is indicative of the fact that there was no direct correlation between nodulation and the grain yield. Burton and Curley (1966) also reported non-significant differences in the grain yield of soybean due to the combined effect of *Rhizobium* and molybdenum whereas Hagstrom and

Berger (1963) and Dhillon *et al.* (1977) obtained a significant increase in the grain yield. Though the differences were not significant, yet in addition to 70 kg/ha increase in the grain yield obtained with inoculation alone, a further increase of 60 and 100 kg/ha was obtained when *Rhizobium* inoculation was associated with seed soaking in 0.5 and 1.0 per cent potassium dihydrogen orthophosphate solutions.

TABLE I
Effect of Rhizobium inoculation and different ionic treatments on gram

Treatment	60 days after sowing			95 days after sowing		
	No. of nodules per plant	Nodules dry weight per plant (mg)	Plant height (cm)	No. of nodules per plant	Nodules dry weight per plant (mg)	Plant height (cm)
Uninoculated (control)	14.7	39.5	20.6	14.7	29.5	37.4
-do- (water soaked)	20.1	51.5	20.4	18.9	59.1	33.0
<i>Rhizobium</i> inoculation alone	21.4	58.4	25.2	17.6	55.9	36.5
Inoculation+ KH_2PO_4 (0.5%)	17.6	60.5	19.5	20.2	68.5	36.4
-do- + KH_2PO_4 (1.0%)	20.1	67.5	22.9	17.7	54.0	39.4
-do- + $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (0.05%)	21.0	63.4	21.1	16.4	69.9	36.2
-do- + $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (0.1%)	16.4	43.6	19.1	12.3	50.7	33.8
-do- + $\text{Na}_2\text{MoO}_4 \cdot 2\text{H}_2\text{O}$ (12.5 g/ha seed)	25.1	67.5	21.9	23.4	96.2	34.0
-do- + $\text{Na}_2\text{MoO}_4 \cdot 2\text{H}_2\text{O}$ (25.0 g/ha seed)	20.7	67.4	20.5	24.8	84.7	33.4
-do- + $\text{Na}_2\text{MoO}_4 \cdot 2\text{H}_2\text{O}$ (37.5 g/ha seed)	20.9	73.1	21.4	26.4	94.5	36.2
C.D. at 5%	N.S.	N.S.	N.S.	3.8	12.1	N.S.
C.V. %	25.2	29.8	9.9	21.4	10.7	24.9

respectively. Seed soaking in copper sulphate solution had a depressing effect on grain yield as well as final dry matter accumulation. Contrary to this, Kaul and Sekhon (1974 and 1976) reported a significant increase in the grain yield by seed soaking in 0.5 and 0.05 per cent solutions of potassium dihydrogen orthophosphate and copper sulphate, respectively. Thus, this needs further investigation.

TABLE II
Effect of Rhizobium Inoculation and different ionic treatments on dry matter and grain yield in gram

Treatment	Plant dry weight per plant (g)		Final dry matter (kg/ha)	Grain yield (kg/ha)
	60 days after sowing	95 days after sowing		
Uninoculated (control)	1.31	4.90	2270	1390
-do- (water soaked)	2.26	3.99	2530	1280
<i>Rhizobium</i> inoculation alone	2.23	4.88	2460	1460
Inoculation+KH ₂ PO ₄ (0.5%)	1.58	7.60	2510	1520
-do- +KH ₂ PO ₄ (1.85%)	1.85	6.00	2560	1560
-do- +CuSO ₄ .5H ₂ O (0.05%)	1.62	4.86	2390	1380
-do- +CuSO ₄ 5H ₂ O (0.1%)	1.34	4.22	1730	1110
-do- +Na ₂ MoO ₄ .2H ₂ O (12.5 g/ha seed)	1.55	6.08	2140	1410
-do- +Na ₂ MoO ₄ .2H ₂ O (25.0 g/ha seed)	1.95	6.20	2440	1430
-do- +Na ₂ MoO ₄ .2H ₂ O (37.5 g/ha seed)	2.26	7.40	2360	1450
C.D. at 5 %	0.70	0.70	N.S.	N.S.
C.V. %	23.3	7.4	131	104

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1.2 RESPONSE OF LENTIL TO *RHIZOBIUM* INOCULATION AS INFLUENCED BY NITROGEN, MOLYBDENUM AND OTHER IONS

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ABSTRACT

An experiment was conducted at the Punjab Agricultural University, Ludhiana during the year 1977-78 on a loamy sand soil, low in organic carbon and medium in available phosphorus and potassium to study the effect of seed soaking in 0.05 per cent copper sulphate, 0.5 per cent iron sulphate, 0.5 per cent potassium dihydrogen phosphate solution and also of molybdenum (12.5 g and 25 g/ha seed) and nitrogen (15 kg/ha) application, the efficiency of *Rhizobium* (strain L 31-76) inoculation in lentil (*Lens culinaris*) variety L9-12.

Inoculation of lentil seeds with *Rhizobium* alone as well as with different ionic treatments significantly increased the number and dry weight of nodules over uninoculated control both at 60 and 90 days stage of plant growth. However, there was no significant difference in the plant height and plant dry weight at both these stages except that seed soaking in 0.5 per cent FeSO_4 solution could increase the plant dry weight significantly at 90 days stage.

A significant increase in the grain yield due to *Rhizobium* inoculation was obtained where seeds were soaked in FeSO_4 and CuSO_4 solution over uninoculated control. Application of molybdenum had no effect on the grain yield as compared to inoculation alone. Application of nitrogen at 15 kg N/ha increased the grain yield by 7.4 per cent over inoculation alone and 17.0 per cent over uninoculated control.

1.3 RESPONSE OF HORSEGRAM GENOTYPES TO INOCULATION WITH A STRAIN OF *RHIZOBIUM* AS INFLUENCED BY NATIVE STRAINS

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ABSTRACT

One hundred genotypes of horsegram were tested for their symbiotic ability with a given effective strain and native strains of *Rhizobium*. The effect of inoculation under natural conditions was compared with that of native strains.

In general, the effective strain promoted early flowering compared to the native strains. The inoculation with the effective strain showed significant increase in plant weight and nodule number per plant at flowering stage over the native strains. Host-genotypic variation with respect to their symbiotic ability was evident as reflected by the significance of variance for the nodule number and plant weight under inoculation.

A specific combination of a strain of **Rhizobium** and a host-genotype seems to be very important in symbiosis as evidenced by their significant interaction for the production of nodules. It is concluded that the competition of native rhizobia with the inoculated strain has very less retarding effect on the symbiosis.

The efficiency of an inoculated strain of *Rhizobium* depends mainly on two factors : the ability of the strain to compete and dominate over the native strains (Damirgi *et al.*, 1967 ; Brockwell and Dudman, 1968) and the compatibility of the genotype with the inoculated strain (Hamatova, 1963 ; Saubert and Scheffler, 1967). Some studies have indicated that the compatible interaction between a specific host genotype and a particular native strain in the soil may modify the competing ability of the inoculated strain (Dadarwal and Sen, 1976). This may adversely affect the efficiency of the inoculation. Keeping this in view, the present investigation was carried out with the following objectives : i) To find out the efficiency of an introduced strain to nodulate the host and to assess the competing ability of the introduced strain with the native strains ; ii) to know the host-genotypic variation for the inoculation with a rhizobial strain under natural conditions ; and iii) to find the effect of host genotype on the competition between the introduced and the native strains of *Rhizobium*.

MATERIAL AND METHODS

The experiment was conducted in 800 polythene bags of 6" x 12" size during the *khari* season of 1978. The bags were filled with $\frac{3}{4}$ of sand and $\frac{1}{4}$ of soil collected from the fields where horsegram was grown during the last two years. About 40 seeds of each of 100 genotypes of horsegram were soaked in water over-night. Half of the seeds of each genotype were inoculated with broth culture of UASB 70 strain and were sown in 4 plastic bags. The remaining 20 seeds of each of the 100 genotypes were sown uninoculated in 4 separate bags. The 100 genotypes sown in 800 polythene bags, were arranged randomly. When the seedlings emerged, only two per bag were retained. The plants were regularly supplied with nitrogen-free nutrient solution (Summerfield *et al.*, 1977). The plants were harvested at two stages : First harvest was done on the 25th day, all the plants from two polythene bags from each treatment were harvested and treated as two replications. The remaining two bags were harvested on the 50th day. The observations recorded were days to flower, nodule number, plant dry weight, root length and shoot length. But the data on nodule number and plant dry weight for first harvest only is reported here.

RESULTS AND DISCUSSION

The data on days taken for flowering showed an indication of the induction of early flowering due to inoculation compared to the uninoculated treatment. The range of days for flowering in the inoculated treatment was from 22 to 35 days, while the genotypes in the uninoculated treatment flowered from 29 to 53 days.

The number of nodules per plant and dry weight at first harvest are presented for 10 selected entries in Table I. Since, no nitrogen was supplied to the plants the

TABLE I
Mean plant dry weight and nodule number per plant for 10 of the 100 genotypes in inoculated and uninoculated treatments

Acc. No.	Plant weight (g)		Mean	Nodule Number		Mean
	Uninoculated	Inoculated		Uninoculated	Inoculated	
1	0.245	0.440	0.3425	16.0	10.5	13.25
2	0.310	0.395	0.3525	5.5	14.5	10.00
3	0.230	0.520	0.2600	23.0	7.0	15.0
4	0.305	0.625	0.4650	7.0	15.5	11.25
5	0.270	0.385	0.3275	10.5	14.5	12.50
6	0.320	0.680	0.5000	7.0	5.5	6.25
7	0.22	0.475	0.3475	5.0	13.0	9.00
8	0.42	0.595	0.5075	5.5	14.0	9.75
9	0.25	0.405	0.3275	6.0	15.0	10.50
∴						
100	0.345	0.495	0.4200	7.5	20.5	14.00
Mean	0.234	0.458	0.3456	10.495	12.865	11.20

growth was weak and hence they showed slightly lower dry matter values. The analysis of variance for nodule number and plant dry weight are given in the Tables IIa and IIb respectively.

The range for nodules per plant in the uninoculated treatment was 2.5 to 23.0 and is almost similar to that of inoculated treatment (3.5 to 28.5). This indicates that large number of naturalised rhizobia exist in the soil for horsegram. However, inoculation showed significant effect on the number of nodules produced per plant (Table IIa). An average of 10.5 nodules were recorded in the uninoculated treatment as against 12.87 nodules per plant in the inoculated treatment and this diffe-

rence was significant, indicating that the introduced strain is efficient in nodulating the host compared to the native strains. Similarly the mean dry weight per plant of the 100 genotypes was significantly increased by the inoculation (0.459g) over the uninoculated treatment (0.231g). This shows that the inoculated strain had in

TABLE IIa
Analysis of variance for nodule number

Source	Df	SS	M.S.S.	F. Value
Replication	1	1.21	1.21	
Treatments	199	9199.1	46.26	1.841**
a) Inoculation	1	561.69	561.69	22.3698**
b) Genotypes	99	4006.76	40.47	1.6118*
c) Interaction	99	4630.96	46.77	1.8507**
Error	199	4996.76	25.1093	—
Total	399	14197.07		

general a compatible reaction with horsegram genotypes and so could compete efficiently with native strains. But this was not true with all the genotypes (Table 1).

Nutman (1949, 1954) reported the nodule formation is under a single gene control. But the fact that none of the host genotypes tested here were resistant to the infection and also that there was a continuity in the number of nodules among

TABLE IIb
Analysis of variance for plant weight

Source	Df	SS	M.S.S.	F. Value
Replication	1	1.0861	1.0861	—
Treatments	199	10.3122	0.0518	2.978**
a) Inoculation	1	5.0131	5.0131	288.1019**
b) Genotypes	99	3.7250	0.0376	2.1609**
c) Interaction	99	1.5741	0.0159	0.9138 NS
Error	199	3.4761	0.0174	
Total	399	14.8744	—	—

these genotypes shows that the nodule formation is a quantitative trait and is probably a polygenic character. Daderwal and Sen (1976) have arrived at similar conclusions in soybean, bengalgram and peas.

A significant interaction between the host genotype and the inoculation treatments was observed for the nodule number per plant (Table IIa) but not for plant weight (Table IIb). This shows that there are different factors governing the formation of nodules and efficiency of these nodules. In other words, the genetic factors governing these two processes are independent of each other. Similar reports are available in red clover (Nutman, 1967), pea, Bengalgram and soybean (Daderwal and Sen, 1976) and in pea (Holl *et al.*, 1977). A comparison of plant dry weight and nodule number per plant (Table I) also supports this conclusion. In some genotypes the increase in nodule number due to introduced strain is associated with increased plant weight (eg., in genotypes No. 2, 4, 5, 7, etc..) while in some other genotypes decrease in number of nodules due to inoculation has resulted in increased plant dry weight (eg. in genotypes No. 1, 3, 6, etc..). This also supports the existence of high host-*Rhizobium* interaction for the symbiotic process like nodulation. Similar accounts are given by Mytton (1975) in *Vicia faba* and Mytton *et al.* (1937) in white clover. Hence the ability of the introduced strain to compete and form effective symbiosis may be highly modified by the host genotype and its interaction with introduced and native strains. This shows that considerable importance should be given to the host genotypes also while screening and testing the efficiency of the rhizobial strain.

In spite of such host genotypic variation for nodulation and their interaction with native and inoculated strains of *Rhizobium* the latter showed increased efficiency in symbiosis over the native strains as indicated by the increased plant dry weight in almost all the genotypes.

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ABSTRACT

Field trials were conducted in randomised block design during **Sornavari** 1977 and **Samba** 1977-78 seasons with the rice varieties ADT 31 and IR 20. Blue green algae at the rate of 10 kg/ha were inoculated to the soil on the 7th day after transplantation of rice crop along with different fertilizer treatments. The composite culture of blue green algae consisting **Aulosira**, **Anabaena**, **Nostoc**, **Tolypothrix**, **Plectonema** and **Aphnothece** were used in the study. The treatments included were: (1) Control (no nitrogen and no blue green algae), (2) Blue green algae (BGA) alone, (3) 25 kg N/ha, (4) 25 kg N/ha + BGA, (5) 50 kg N/ha, (6) 50 kg N/ha + BGA, (7) 75 kg N/ha, (8) 75 kg N/ha + BGA, (9) 100 kg N/ha (10) 100 kg N/ha + BGA. Increased grain yield was obtained due to the inoculation of blue green algae. It was observed that at every low level of fertilizer nitrogen with algal supplementation, the crop yield was comparable to that in the next higher level of nitrogen, thus compensating the effect of 25 kg N/ha.

INTRODUCTION

The ability of blue green algae and their role in fixation of nitrogen and their effect on rice crop has been well established by several investigators (Jagannathan and Kannaiyan, 1977 ; Srinivasan, 1977 ; Venkataraman, 1977). Recent researches have shown that blue green algae can be used as biological fertilizers for rice cultivation (Venkataraman, 1977). In submerged rice fields, biological nitrogen fixation is essentially an algal process contributing about 30 kg N/ha (Watanabe *et al.*, 1977). Blue green algae add about 20-30 kg N/ha/season resulting in about 10-20 per cent more yield (Jagannathan and Kannaiyan, 1977; Srinivasan, 1977). Further the availability of phosphorus is enhanced (Arora, 1969) with improvement in the physical and chemical properties of soil (Venkataraman, 1972). Increase in protein content of the grains apart from yield was reported by Gupta and Shukla (1967). Venkataraman (1972) and Singh (1978) reported the role which the growth promoting substances, produced by the algae, play in rice crop. The response of high yielding rice varieties to blue green algae inoculation was reported by Goyal and Venkataraman (1970) and Singh (1978). In the present study an attempt has been made to find out the effect of blue green algae inoculation on grain yield of rice crop.

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MATERIAL AND METHODS

Field trials were conducted in randomised block design with four replications during *Sornavari*, 1977 (June-Sept.) and *Samba*, 1977-78 (October - February) seasons. The rice varieties ADT 31 and IR 20 were raised during *Sornavari* and *Samba* seasons. Blue green algae at the rate of 10 kg/ha were inoculated to the soil on the 7th day after transplantation along with different fertilizer treatments. The composite culture of blue green algae consisting *Aulosira*, *Anabaena*, *Nostoc*, *Tolypothrix*, *Plectonema* and *Apharothece* were used. The treatments were (1) control (no nitrogen and no blue green algae), (2) Blue green algae (BGA) alone, (3) 25 : 50 : 50 kg NPK/ha, (4) 25 : 50 : 50 kg NPK/ha+BGA, (5) 50 : 50 : 50 kg NPK/ha, (6) 50 : 50 : 50 kg NPK/ha+BGA, (7) 75 : 50 : 50 kg NPK/ha, (8) 75 : 50 : 50 kg NPK/ha+BGA, (9) 100 : 50 : 50 kg NPK/ha and (10) 100 : 50 : 50 kg NPK/ha+BGA. In all the treatments P and K were applied basally as super phosphate and muriate of potash while N was applied as urea in split doses during transplanting and 25 days after transplantation. The grain yield was recorded.

RESULTS AND DISCUSSION

The results of the grain yield is presented in Table I. The treatments with N fertilizer and blue green algae application have shown increase in grain yield.

TABLE I
Effect of blue green algae on rice crop

Treatment	Sornavari 1977				Samba 1977-78			
	Mean grain yield (kg/ha)		Per cent increase over control		Mean grain yield (kg/ha)		Per cent increase over control	
	ADT-31	IR-20	ADT-31	IR-20	ADT-31	IR-20	ADT-31	IR-20
100 kg N+BGA	3446	4562	38.6	92.1	2992	3490	27.1	52.7
100 kg N	3329	3908	33.9	64.6	2898	3213	23.1	40.6
75 kg N+BGA	3304	3771	32.9	58.8	2614	3034	11.1	32.8
75 kg N	3283	3312	32.0	39.5	2580	2946	9.6	28.9
50 kg N+BGA	2884	2978	16.0	25.4	2561	2819	8.8	23.4
50 kg N	2873	2875	15.5	21.1	2501	2594	6.3	13.5
25 kg N+BGA	2859	2875	15.0	21.1	2561	2512	8.8	9.9
25 kg N	2571	2887	3.4	21.6	2440	2489	3.7	8.9
0 kg N+BGA	2516	2771	1.2	16.7	2434	2478	3.4	8.5
Control	2487	2375	—	—	2354	2285	—	—

The application of blue green algae alone significantly increased the grain yield when compared to uninoculated control. The rice varieties ADT 31 and IR 20 responded well with the application of blue green algae. In the two seasons maximum grain yield was recorded in both the varieties in plots treated with 100 kg N plus blue green algae. There was no wide variation in grain yield between treatments and varieties. The grain yield was more or less similar in both *Somavari* and *Samba* seasons. It is evident from the results that inoculation of blue green algae has definite beneficial effect on rice crop.

The positive effect of blue green algae on grain yield of rice crop, observed in the present study, is in conformity with the reports of Sankaran *et al.* (1967), Goyal and Venkataraman (1970), Venkataraman (1977), Watanabe *et al.* (1977), Singh (1978) and Kannaiyan (1978), who obtained higher yields using blue green algae. This is attributed to the increase in plant height, number of tillers and grain weight (Srinivasan, 1977 ; Jagannathan and Kannaiyan, 1977).

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1.5 EFFECT OF INDUSTRIAL EFFLUENTS ON SOIL MICROORGANISMS AND PLANT GROWTH

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ABSTRACT

Effluents from different industries engaged in the manufacture of (a) chemicals like caustic soda, bleaching powder etc., (b) aluminium and (c) polyvinyl chloride (PVC) pipes were analysed for their physical and chemical properties.

There was a decrease in bacterial population in soil due to addition of effluent from chemical and PVC pipe industries while an increase was observed with that of aluminium industry. No actinomycetes developed in chemical industry effluent added soil. Fungal population, however, got reduced on addition of all the three different effluents. Variations were observed in the occurrence of *Azotobacter* population.

A high per cent mortality of blackgram and redgram was observed when they were irrigated with effluents of chemical and PVC pipe industries while the effluents from Aluminium industries enhanced the growth of these two plant species.

It is well known that industries discharge large quantities of effluents directly to the rivers or to the nearby lands. These effluents are bound to adversely affect the ecosystem depending upon the constituents of the effluents. The study on the effluents from certain chemical industries and their effect on soil microorganisms and plant growth are reported here.

MATERIAL AND METHODS

Effluents of industries located at Mettur about 120 km from Coimbatore engaged in the manufacture of (a) Chemicals like caustic soda, bleaching powder etc. (b) aluminium and (c) polyvinyl chloride (PVC) pipes were collected. These were analysed for their reaction (pH), electrical conductivity (EC), dissolved oxygen (DO), bio-chemical oxygen demand (BOD), chemical oxygen demand (COD), chlorides, suspended, dissolved and total solids. The procedures suggested by U.S. Environmental Protection Agency (Anon., 1978) was followed. The effluents from these industries were added to the garden land soil on alternate days and the changes in the populations of bacteria, actinomycetes, fungi and *Azotobacter* were observed. Seeds of blackgram (*Phaseolus mungo* L.) and redgram (*Cajanus cajan* (L) Millsp) were sown in earthen pots and irrigated with the effluents of different industries. Mortality percentage of these plants were assessed after 30 and 60 days of sowing.

RESULTS AND DISCUSSION

The results (Table I) revealed that the pH of the effluent of chemical factory was 12.0 while that of PVC pipe industry 2.7, aluminium factory effluents recorded a pH of 7.9. While the EC of the effluents of aluminium industry was only 3.6, the PVC pipe industry and chemical factory effluents recorded an EC of 715.0 mmhos/cm. Although slight variations were observed in the DO, BOD and COD between the effluents of industries, they were well within the admissible rates fixed by ISI. Maximum quantity of chloride (3700 mg/l) was present in PVC industrial effluents followed by chemical factory (1850 mg/l) and aluminium (110 mg/l) industrial effluents. Total solids to the tune of 8180 mg/l were present in the PVC industrial effluents while chemical industrial effluents recorded 4624 mg/l and Aluminium industrial effluents 3648 mg/l which are higher than the standard.

Addition of effluents of Aluminium industry enhanced the microbial population on 10th and 20th day although effluents of chemical industry and PVC pipe industry reduced the population on 20th day. The population of actinomycetes increased upon the addition of PVC pipe industrial effluents, whereas aluminium industry effluent reduced them. In soils added with chemical industry effluent they were absent. Interestingly enough, all the three effluents reduced the fungal population at both periods of sampling. There was, in general, a stimulation in *Azotobacter* population in soil added with different effluents although PVC industrial effluents reduced the population on 20th day (Table II). Very little information is available on the influence of effluents on soil microbial population. Mazina and Khletsikova (1975), Oblisami and Rajannan (1977) reported decrease in microbial populations in soil added with effluents of polyvinyl chloride and chemical industries.

Results on the mortality of blackgram and redgram due to addition of different effluents revealed that effluents of Aluminium industry, enhanced the survival of the two plant species (Table III). However, the mortality of both the plant species was higher, when they were irrigated with effluents of chemical industry and PVC pipe industry which corroborates with the earlier findings of Oblisami and Rajannan (1977). A maximum hundred per cent mortality of the two plant species was observed with the chemical industry effluent which is in agreement with the reports of Hassen-Porath *et al.* (1972) and Ravikovitch (1974) who reported that the growth of cotton and pea seedlings was inhibited by the chloride induced salinity. In the present study also, the greater mortality of both the plant species after irrigating them with effluents of PVC industry and chemical industry may perhaps, be due to their pH which is 2.7 or 12.0 respectively, or the high chloride content in the effluents.

TABLE I
Physical and chemical properties of different industrial effluents

Effluent	pH	E.C. (mmhos/ cm.)	D.O. (mg/l)	BOD (mg/l)	COD (mg/l)	Chloride (mg/l)	Dissolved solids (mg/l)	Suspended solids (mg/l)	Total solids (mg/l)
Chemical industries	12.0	715.0	9.0	420	940	1850	4524	100	4624
Aluminium industries	7.9	3.6	2.0	290	400	110	3392	256	3648
PVC pipe industries	2.7	715.0	4.0	460	800	2700	8076	104	8180

TABLE II
Effect of industrial effluents on soil microbial population (Population expressed on moisture free basis)

Effluent	10th day					20th day				
	Bacteria (x10 ⁶)	Fungi (x10 ³)	Actinomy- cetes (x10 ³)	Azotobacter (x10 ³)	Bacteria (x10 ⁶)	Fungi (x10 ³)	Actino- mycetes (x10 ³)	Azoto- bacter (x10 ³)		
Chemical industries	1.31	0.61	0.0	0.97	4.65	0.68	0.0	1.85		
Aluminium industries	1.17	1.37	0.27	0.44	6.35	1.38	0.44	2.10		
PVC pipe industries	0.71	1.15	0.99	0.37	4.63	1.71	1.29	0.31		
Tap water (control)	1.08	1.76	0.33	0.25	5.37	1.84	0.36	1.43		

TABLE III

Mortality (per cent) of crop plants irrigated with effluents from different industries

Effluent	Blackgram		Redgram	
	30th day	60th day	30th day	60th day
Chemical industry	73.2	100.0	78.0	100.0
Aluminium industry	2.0	4.3	11.4	18.2
PVC pipe industry	27.8	91.7	72.9	98.0
Tap water (control)	5.3	5.6	16.2	18.4

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1.6 EFFECT OF PARTICULATE POLLUTANTS FROM CEMENT-KILN ON SOIL MICROFLORA AND CROP PLANTS

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ABSTRACT

Particulate pollutants cause an imbalance in the soil ecosystem affecting the plant systems. Studies on the effect of cement-kiln dust particulate pollutants on the survival of **Azotobacter** and **Rhizobium** revealed that there was a significant reduction in the population of both organisms in the polluted soil. Similarly, a reduction in the amount of total nitrogen in **Azotobacter**-inoculated cement dust polluted soil was observed.

Field observations of the polluted and non-polluted area in the vicinity of a cement factory located at Mudukkarai near Coimbatore showed that there was a reduction in plant population, nodule number and nodule weight in greengram and cowpea.

1.7 EFFECT OF SAGO FACTORY EFFLUENTS ON MICROFLORA IN AGRICULTURAL ECOSYSTEMS

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ABSTRACT

Sago and starch industries dispose off large quantities of effluents which because of acidic nature caused by the proliferation of anaerobic bacteria, may affect the soil microbial population and crop growth.

A study on the irrigation of the aerated effluents of sago and starch factories to different crops and the changes in the rhizosphere microflora revealed an increase in bacterial population in the rhizosphere soils of paddy, sorghum, pearl millet and ragi. Similarly *Azotobacter* population enhanced in the rhizospheres of sorghum and maize after irrigating with aerated effluent. However, there was a reduction in the fungal and actinomycetes population in the rhizospheres of paddy, sorghum, maize, pearl millet and ragi when compared to the non-aerated effluent.

1.8 EFFECT OF FERTILIZATION AND RATOONING ON THE MICROFLORA OF SOIL AND RHIZOSPHERE OF SORGHUM

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ABSTRACT

Application of N, P and K at the rate of 75, 30 and 15 kg per acre respectively to main and ratoon sorghum crops considerably altered the soil microbial population. In general application of fertilizers markedly increased the rhizosphere microbial population at vegetative, flowering and grain maturation stages of plant growth, compared to the unfertilized plants. The increase was highest at the flowering stage of the plant. Bacteria were found to occur in highest number followed by actinomycetes, fungi and azotobacters, both in the rhizosphere and nonrhizosphere soils. Ratooning of sorghum did not alter the soil microbial population over the main crop. The rhizosphere effect (R : S) of sorghum on the soil microorganisms tested did not alter much due to the application of fertilizers and ratooning.

Application of heavy doses of fertilizers is considered to be essential for cultivating the high yielding sorghum varieties. Such soil amendments altering the quality and quantity of soil microorganisms have drawn the attention of many workers in the past (Louw and Webley, 1959 ; Sundar Rao and Chayanulu, 1961 ; Kaufman and Williams, 1964 ; Bagyaraj and Rangaswami, 1967). Selective activities of bacteria and suppression of fungi and azotobacters due to addition of increasing doses of ammonium sulphate was shown by Bagyaraj and Bhat (1970) in wheat crop. In the present study effect of heavy fertilization and ratooning of sorghum on the quantitative occurrence of bacteria, fungi, actinomycetes and azotobacters in the rhizosphere and non-rhizosphere soils is reported.

MATERIAL AND METHODS

The field experiment was conducted in the black soils of Agriculture College Farm, Dharwad with hybrid sorghum CSH-1. Fertilized and unfertilized plots were laid out in Randomized Block Design with four replications. The fertilized plots received N as ammonium sulphate, P as superphosphate and K as muriate of potash at the rate of 75, 30 and 15 kg per acre respectively. Nitrogen was applied in two equal split doses at the time of sowing and 25 days after sowing. Control plots received no fertilizers. Farm yard manure was applied uniformly to the experimental plots at the rate of 5 cart loads per acre. Microbial populations in the rhizosphere and nonrhizosphere soils were estimated at vegetative (50 days), flowering (70 days) and at grain maturing (105 days) stages of crop growth following the procedure of Timonin (1940). For microbial growth, Waksman's medium No. 77 for azotobacters, Martin's rose bengal Streptomycin agar for fungi, soil extract agar for bacteria and actinomycetes were used. After the harvest of main crop, ratoon sorghum was taken and treatments and observations for ratoon crop were same as for the main crop.

RESULTS

Soil application of N, P and K fertilizers at the rate of 75, 30 and 15 kg per acre respectively, considerably increased the soil microbial population in general over the unfertilized treatment both in the main and ratoon sorghum crops (Table I and II). This increase was more in the rhizosphere soil than the nonrhizosphere soil. In general the data also indicated that the rhizosphere of sorghum harboured markedly higher number of microorganisms than the nonrhizosphere soils. The sorghum rhizosphere effect (R : S) on bacteria, actinomycetes, fungi and azotobacters varied from 7 to 25. However, N, P and K fertilization did not alter the rhizosphere effect (R : S) of sorghum on the microorganisms tested, either in the main or

ratoon crop. Sorghum rhizosphere harboured maximum number of bacteria followed by actinomycetes, fungi and azotobacters. In general soil microbial population was highest at flowering stage, followed by vegetative stage and grain maturation stage. Ratooning of sorghum did not alter the soil microbial population markedly.

TABLE I
Effect of fertilization on the rhizosphere microorganisms of sorghum crop

Treatment		Azotobacter (x 102)			Microbial population/g of dry soil						Actinomycetes (x 10 ⁶)		
					Fungi (x 10 ⁴)			Bacteria (x 10 ⁶)					
		V	FL	GR	V	FL	GR	V	FL	GR	V	FL	GR
Fertilized	R	16.8	40.0	11.3	45.3	60.0	33.0	56.8	106.7	69.8	7.4	12.2	7.6
	S	1.5	2.5	1.7	3.2	5.4	4.1	4.8	7.6	5.7	0.4	1.0	1.0
	R:S	11.2	16.1	6.9	14.4	11.1	8.1	11.8	14.1	12.3	18.4	12.2	7.6
Control	R	11.9	28.6	12.9	35.6	20.9	23.8	39.6	37.1	18.3	4.9	6.7	5.9
	S	1.3	1.8	1.4	1.4	2.4	1.7	3.1	2.2	1.8	0.4	0.7	0.6
	R:S	8.9	15.6	9.0	24.9	8.6	13.6	12.9	16.6	18.3	12.0	9.4	9.7

V = Vegetative Stage ; FL = Flowering stage ;
GR = Grain maturing stage ; R — Rhizosphere soil ;
S — Nonrhizosphere soil

TABLE II
Effect of fertilization on the rhizosphere microorganisms of ratoon sorghum crop

Treatment		Azotobacter (x 10 ²)			Microbial population/g of dry soil									Actinomycetes (x 10 ⁶)		
					Fungi (x 10 ⁶)			Bacteria (x 10 ⁶)								
		V	FL	GR	V	FL	GR	V	FL	GR	V	FL	GR			
Fertilized	R	16.4	33.7	20.8	32.7	59.2	29.2	94.6	128.6	89.6	5.5	19.4	14.6			
	S	2.2	2.5	1.8	3.5	4.8	2.5	6.8	9.7	7.1	0.7	1.8	1.8			
	R:S	7.5	13.6	11.8	9.9	12.4	11.9	14.0	13.2	12.7	7.8	11.0	8.3			
Control	R	14.4	15.9	12.6	24.4	23.0	17.5	43.3	40.7	36.9	8.3	8.0	7.8			
	S	1.2	1.6	1.1	2.1	2.3	1.6	2.4	4.9	2.3	1.0	1.1	0.6			
	R:S	12.1	9.9	11.7	11.9	10.0	11.1	18.2	8.3	16.3	8.3	7.2	13.0			

DISCUSSION

Increase of soil bacterial population due to application of higher levels of ammonium sulphate has been reported by Venkatesan, (1962) and Bagyaraj and

Rangaswami (1968). In the present study N, P and K fertilization markedly increased the soil microbial population including bacteria, actinomycetes, fungi and azotobacters. In an earlier study with wheat, Bagyaraj and Bhat (1970) found that application of ammonium sulphate (14 to 68 kg/acre) increased the bacterial population but decreased considerably the number of actinomycetes, fungi and azotobacters. Interestingly, the decrease in the number of azotobacters due to fertilization was only in the nonrhizosphere soils but not in the rhizosphere soils of wheat. Thus there seems to be some kind of interaction of crop, soil environment and microorganisms in the root zone. Effect of marked increase in soil microbial number due to fertilization on the crop growth and yield require further investigation.

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1.9 STUDIES ON THE BIOLOGICAL CONTROL OF TAKE-ALL OF WHEAT

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ABSTRACT

A crop of oats after any cropping practice such as continuous wheat or wheat pasture or native pasture reduced the incidence of take-all. Enumeration of different groups of microorganisms in the rhizosphere of wheat cropped with and without the suppressive soil and their antagonistic activity against *Gaeumannomyces graminis* revealed that a violet pigmented antagonistic *Pseudomonas* was fostered by the suppressive soil. Low counts of hyphae on the roots and disease rating in the rhizosphere of treatment receiving suppressive soil suggest the involvement of these bacteria in take-all decline suppressive factor.

Take-all is a serious disease of wheat caused by the soil borne fungus *Gaeumannomyces graminis* (Sacc.) Arx. and Oliver var. *tritici* Walker. Severity of the disease reaches the maximum after 2-3 years of wheat monoculture and subsequently declines, this is referred to as 'take-all' decline (Shipton, 1975). This decline is documented to be due to the development of a suppressive factor, which is biological in nature, in the soil. There are various theories on mechanisms of take-all decline, all suggesting the involvement of antagonistic microflora in the rhizosphere (Smiley, 1978). However, there are contradictory reports on the loss of suppressive factor due to rotation of wheat with other crops. Hence an experiment was set up to study the suppressive properties of soils cropped continuously with wheat (in the presence and absence of the pathogen) and rotated with other crops.

MATERIAL AND METHODS

The experiment was carried out at the Division of Soils, C.S.I.R.O., Adelaide, Australia. Kreig's sand, fumigated with methyl bromide, was used as the standard base for raising wheat. The different soils were tested for suppressiveness by mixing 1 part of the test soil with 100 parts of the standard fumigated soil and inoculating with 0.2 per cent ground-oat-kernel inoculum of *G. graminis* var *tritici* (Gg). The different treatments are given in Table 1. The pots, with eight seedlings of 'Halberd' variety wheat, were maintained in a growth chamber at 15°C with 12 hour light day. When the plants were four weeks old the roots were washed free of soil and the disease rating was done following the scale described by Shipton *et al.* (1973).

Rhizosphere microflora of wheat in the first 5 treatments, which included a typical suppressive soil as one of the treatments, was analysed. Twelve-day-old seedlings were used for the analysis of the rhizosphere microflora. Six segments of roots, each 2 cm long, representing 1 to 3 cm region from the seed end, along with the closely adhering soil represented the rhizosphere sample. Serial dilutions were prepared and plated on appropriate media for enumeration.

Antagonism of the rhizosphere bacteria to *G. graminis* was tested by inoculating the centre of the potato dextrose agar plates with a plug of *G. graminis* one day after spot inoculation of 4 bacterial isolates near the edge of the petridish. The antagonistic activity was read by the zone of inhibition of the fungal growth after 8 days incubation at 25°C.

Trophic response of *G. graminis* hyphae to host roots was done by counting the number of runner hyphae crossing the eye piece graticule (Holden, 1974). Root samples of 2 cm, representing 1-3 cm region, were washed with the detergent

sodium meta hexa phosphate and stained with Jones-Mollison stain for 3½ min. before counting.

RESULTS AND DISCUSSION

Suppressive property of different soils as revealed by disease rating system is given in Table I. The results clearly indicated that the standard suppressive soil used in this study was quite effective in checking the disease. The soil used as

TABLE I
Suppressive properties of different soils

Sl. No.	Abbreviation of the treatment	Treatment	Disease rating
1	2	3	4
1.	C	No amendments	0
2.	D Gg	0.2% dead Gg	0
3.	L Gg	0.2% live Gg	4.22
4.	L Gg + SS	0.2% live Gg + 1% suppressive soil	2.21
5.	L Gg + NSS	0.2% live Gg + 1% non-suppressive soil	3.22
6.	WW - W	0.2% live Gg + Denial Bay (D.B.) soil continuously cropped to wheat in field followed by a crop of wheat grown in laboratory without Gg	4.00
7.	WP - W	0.2% live Gg + 1% D. B. soil cropped to pasture-wheat in field followed by wheat grown in laboratory without Gg	4.25
8.	NP - W	0.2% live Gg + 1% D. B. soil cropped to native pasture in field followed by wheat grown in laboratory without Gg	3.41
9.	WW - W+Gg	0.2% live Gg + same as 6 but with Gg	3.69
10.	WP - W+Gg	0.2% live Gg + same as 7 but with Gg	2.96
11.	NP - W+Gg	0.2% live Gg + same as 8 but with Gg	3.00
12.	WW	0.2% live Gg + 1% D. B. soil continuously cropped to wheat in field	4.13
13.	WP	0.2% live Gg + 1% D. B. soil cropped to wheat pasture in field	3.50
14.	NP	0.2% live Gg + 1% D. B. soil cropped to native pasture in field	3.80

1	2	3	4
15. WW - M	0.2% live Gg	+ 1% D. B. soil continuously cropped to wheat in field followed by medic in laboratory	3.71
16. WP - M	0.2% live Gg	+ 1% D. B. soil cropped to wheat-pasture in field followed by medic in laboratory	4.32
17. NP - M	0.2% live Gg	+ 1% D. B. soil cropped to native pasture in field followed by medic in laboratory	4.57
18. WW - O	0.2% live Gg	+ 1% D. B. soil continuously cropped to wheat in field followed by oats in laboratory	3.29
19. WP - O	0.2% live Gg	+ 1% D. B. soil cropped to wheat-pasture in field followed by oats in laboratory	3.86
20. NP - O	0.2% live Gg	+ 1% D. B. soil cropped to native pasture in field followed by oats in laboratory	3.00

non-suppressive soil was not completely non-suppressive but did possess some amount of suppressiveness. Soils cropped continuously to wheat recorded higher disease rating, perhaps the soils were free from *G. graminis*. According to Vojinovich (1973) take-all decline occurs or the suppressive factor develops only in the presence of *G. graminis*. The present results are in conformity with this view. Another interesting observation is that a crop of oats, after any cropping pattern helps to reduce the incidence of take-all.

The rhizosphere of wheat seedlings amended with dead *G. graminis* recorded maximum total bacterial counts. The treatment receiving suppressive soil recorded maximum fungal population. Though the counts of pseudomonads in the treatment with suppressive soil are low they constituted 26 per cent of the Gram-negative bacteria in the rhizosphere while in the treatment receiving non-suppressive soil, pseudomonads constitute only 4 per cent of the Gram-negative bacteria, suggesting the occurrence of a larger proportion of non-pseudomonad Gram-negative bacteria in their rhizosphere.

Studies on antagonism of the rhizosphere bacteria to *G. graminis* indicated that there were practically no antagonists amongst total bacteria and spore formers

against *G. graminis* while Gram-negative and pseudomonads exhibited antagonistic activity, thus supporting the earlier view on mechanism of suppressiveness (Cook and Rovira, 1976 ; Smiley, 1978). A violet pigmented *Pseudomonas* causing 12 mm inhibition of *G. graminis* was found to occur only in the treatment with suppressive soil.

Trophic response of *G. graminis* hyphae to roots hosts in presence of the suppressive soil is given in Table II. The results reveal that the suppressive soil is more inhibitory to *G. graminis*, upholding the recent view which suggests that hyphal density is a measure of suppressiveness (Wildermuth and Rovira, 1977). This

TABLE II
G. graminis hyphae on wheat roots as influenced by suppressive soil

Treatment	Counts of hyphae crossing lines on eye piece graticule	Remarks
C	0	
D Gg	0	
L Gg	6.38	Mostly dark runner hyphae
L Gg + SS	2.56	Mostly fine infection hyphae
L Gg + NSS	4.25	Dark runner hyphae few, fine infection hyphae more

indicates that the violet pigmented *Pseudomonas*, showing antagonistic activity against *G. graminis* *in vitro* (in plates), is also active *in vivo*, i.e., in soil. Possibilities of using this bacterium or suppressive soil enriched with this bacterium for the biological control of take-all of wheat needs further investigation.

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1.10 SAPROPHYTIC ACTIVITY OF *SCLEROTIUM ROLFSII* SACC. IN SOIL, UNDER DIFFERENT CONDITIONS

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ABSTRACT

The estimation of saprophytic activity of *Sclerotium rolfsii* Sacc. under various soil conditions was attempted, using a baiting method given by Avizohar-Hershenson and Shackel (1968). However, the baiting technique was standardized using different plant parts, of which sorghum seed was found as an excellent bait for the fungus. The saprophytic activity was measured by percentage colonization of sorghum baits.

Maximum saprophytic activity of the fungus was observed in low soil moisture levels (i.e. 10 and 30 per cent moisture holding capacity) than at high soil moisture levels (i.e. 50 and 70 per cent). However, there was no activity observed at zero per cent. Activity, at 10 per cent was still observed at 35 days, whereas the fungus survived for less than 21 days in other higher levels. Effect of organic amendments, viz., groundnut oil cake, farm yard manure, paddy hull and wheat bran which were incorporated to soil revealed that groundnut oil cake and farm yard manure suppressed the activity to a great extent throughout.

Among seven pesticides (including soil fungicides and soil insecticides) tried, Agallol and Counter-5G were effective throughout in suppressing the saprophytic activity of the fungus in soil.

1.11 DISTRIBUTION OF MICROORGANISMS AND THEIR INFLUENCE ON THE BIOGAS GENERATION IN VARIOUS AGRICULTURAL WASTE INCORPORATED TREATMENT

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ABSTRACT

Biogas fixation of agricultural waste materials is perhaps the most important technology for obtaining the much needed fuel gas, methane, through microbiological process for cooking lighting and other purposes. There is a scope for maximum utilization of farm wastes for this purpose. In order to study the effect of incorporation of various agricultural wastes like chopped maize cob, cotton stalk, paper pulp and weeds like calotropis, parthenium, along with cow dung and old slurry in relation to biogas production, experiments were carried out in five litre capacity anaerobic digesters in this laboratory. The experiments progressed as a continuous fermentation process, without any further addition of cow dung etc. and the gas produced was measured at 24 hr. intervals for a period of 2 months. Incorporation of parthenium along with cow dung gave the maximum gas production of 1756 cc/day, compared to control of 663 cc/day. Water hyacinth and paper pulp incorporation also gave increase in gas generation of 33.24 and 30.30 per cent respectively.

The maximum population of anaerobic methanogens were found in treatments that gave maximum gas production. The control showed the least among the treatments. Though the parthenium incorporated treatment gave higher count of total bacteria and cellulolytic organisms, the other treatments showed varying results. The relative distribution of coliforms and faecal streptococci are discussed.

1.12 SEASONAL DYNAMICS OF MICROFUNGAL POPULATION IN SOME CROP FIELDS OF SAMBALPUR

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ABSTRACT

Ecological studies of the microfungi from the crop fields of Sambalpur were made over a period of 13 months. Twenty eight species including 5 phycomycetes, 3 ascomycetes, 20 fungi imperfecti and 1 sterile mycelia were isolated. Sixteen fungal species are new records from this region. Phycomycetes, the litter growing fungi, were confined to the upper soil layer and their population decreased with increase in soil depths, except in summer season. Of the Ascomycetes *Neocosmospora vasinfecta* was isolated from all soil depths except in summer. All *Aspergillus* species, especially *A. niger* and *A. terreus* were found cosmopolitan in their distribution. Number of fungal colonies as well as number of fungal species decreased with increase in soil depths, except in summer months. Number of fungal colonies and fungal species were found to be minimum in summer and maximum during winter. Significant positive correlations have been observed between growth of fungal colonies and soil organic matter content and moisture.

1.13 ENZYME ACTIVITY IN SURFACE SOILS UNDER SOME SUBTROPICAL PASTURES

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ABSTRACT

Enzymes in soil are involved in decomposition process and have importance for soil classification. Activities of amylase, cellulase, invertase, protease and urease were studied in some eleven pasture soils of Western part of Orissa. The study type differed with regard to moisture regime of soil, pH, organic matter and nitrogen content. All the sites, except one, contained more than 5 g per cent soil moisture (5 g per cent-17 g per cent). Invertase activity was higher compared to other enzymes. Soils poor in nitrogen and containing less than 2 per cent organic matter, less than 3 per cent soil moisture with 5.7 pH showed lowest value of enzyme activity. Enzyme activity was more in soils containing higher percentage of organic matter and nitrogen. Significant (at 1 per cent level) positive correlations exist between enzyme activity and organic matter and nitrogen content in soils. Amylase shows significant positive correlation with reducing sugars. Cellulase is significantly and positively correlated with activities of urease, protease and invertase. Invertase showed significant positive correlation with activities of urease and protease.

2. General Soil Fauna

2.1 PRELIMINARY OBSERVATIONS ON THE MICROARTHROPOD FAUNA OF PADDY FIELDS AND ADJOINING UNCULTIVATED SOILS IN SOUTH KERALA

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ABSTRACT

Comparative study of the microarthropods of paddy fields and adjoining uncultivated soils revealed that the latter was richer quantitatively in soil microarthropods. The major groups of microarthropods like Collembola, Acari and Diptera larvae were present in both paddy fields and uncultivated sites. The Acari was the dominant group of microarthropods in both sites. It appeared from the present study that prolonged inundation was the most prominent factor adversely affecting the soil microarthropods in the paddy fields as the typical soil microarthropods found localized in the paddy clumps, escaping long term submergence, were absent in the soil from inundated fields.

INTRODUCTION

Soils of natural systems like forest and grassland and the animal life in them have been extensively dealt with by Kevan (1962), Wallwork (1976) and others, who have also stressed the importance of soil fauna in influencing the physico-chemical properties of the soil. By participating in the breakdown of litter and thus hastening the recycling of mineral matter, soil animals play a decisive role in the perpetuation of the productivity of soils. Agricultural importance of soil fauna in general and earthworms in particular has been emphasized by Raw (1961). Whatever beneficial effects that are available to the agricultural soil due to the activity of soil fauna is found affected by agricultural practices. The effects of ploughing have been studied by Hammer (1949) in a Danish farm and Kruger (1952) in temperate soils. Edwards and Lofty (1969) provide a concise account of the effects of various pesticides on soil microarthropods. In South India the soil fauna of paddy fields needs special attention because paddy is grown extensively. The present report is of a preliminary study on the microarthropod fauna of post-harvest paddy fields and that of the adjoining uncultivated soils to bring forth the quantitative difference of the microarthropods in the two systems. It also evaluates the effect of inundation of paddy field on soil microarthropods.

MATERIAL AND METHODS

The studies were carried out in three paddy fields and their adjoining uncultivated soils, the latter subjected to slight disturbances by interferences at the time of cultivation. Two crops of paddy were grown annually in the three fields, with a crop rotation in Field I during January-March. Fertilizers like potash and urea were applied. Dimecron, Lebaycid and Hinosan were used against pests and diseases. However, Field III did not receive any pesticides. The fields were inundated with water up to 5-8 cm.

Immediately after harvest in September 1978 and January 1979, when the fields were still inundated clumps of paddy tillers were carefully cut using sharp scissors and kept in separate polythene bags, each clump formed a sample unit. Number of such clumps of tillers in 1 sq m were considered for computing the population of microarthropods in the paddy fields. Soil sample units from the adjoining uncultivated sites were cores of soil (surface area 12.57 sq cm) taken using a steel core to a depth of 10 cm. The extraction of the microarthropods was carried out in ordinary dry funnels of Berlese-Tullgren type for 24-30 hours. The emerging microarthropods were collected in tubes containing 70 per cent alcohol or dilute picric acid solution. The analyses were done with reference to population density, relative abundance and Collembola/Acari ratio. The moisture content per cent and other physico-chemical characteristics of the soil were determined by methods described by Piper (1944).

RESULTS

The data regarding the mean population density of different microarthropod groups per m² in three paddy fields and three uncultivated soils, the relative abundance of different microarthropod groups and Collembola/Acari ratio in different sites are given in the table. The physico-chemical characteristics of the uncultivated soils in three sites were determined in September 1978 and January 1979. In September 1978, the moisture content of the uncultivated soil in the three sites, I, II and III was 5.71, 21.86 and 14.05 per cent, the pH value 6.2, 6.4 and 6 and the organic matter content 11.5, 3.6 and 14.2 per cent respectively. The moisture content was more in January 1979 in all the three sites. The values were 15.6, 30.1 and 18.3 respectively in sites I, II and III. Only slight difference was observed in the pH and organic matter content. The pH in the three sites was 5.8, 6.4 and 6.2 and the organic matter content 11.4, 3.4 and 14.1 per cent in Sites I, II and III respectively. The water holding capacity of the three sites were 38.66, 33.48 and 10.07 per cent respectively. Physico-

Number/Relative abundance, Densities of microarthropod groups (number/m²) and CO/A ratio in paddy fields and adjoining uncultivated soils during the post-harvest periods (Based on data collected in September 1978 and January 1979)

Microarthropod groups	Site I				Site II				Site III			
	Pady field I		Uncultivated soil I		Paddy field II		Uncultivated soil II		Paddy field III		Uncultivated soil III	
	(No. of clumps of tillers per m ² ± 49)	No. (RA %)	Den- sity	No. (RA%)	(No. of clumps of tillers per m ² ± 49)	No. (RA%)	Den- sity	No. (RA%)	(No. of clumps of tillers per m ² ± 33)	No. (RA%)	Den- sity	No. (RA%)
Collembola	87	14.15	305	71	19.46	4709	97	13.4	340	135	42.85	8949
Acari	389	64.86	1362	245	67.09	16237	387	53.43	1354	156	49.52	10342
Oribatei	247	63.5*	864	180	73.47*	11933	243	62.79*	850	122	78.21*	8088
	(167)		(15)			(118)				(93)	(68)	
Mesostigmata	142	36.5*	498	39	15.92*	2583	144	37.21*	504	34	21.79*	2254
	(111)		(28)			(89)				(11)	(19)	
Prostigmata	0	0	0	26	10.61*	1721	0	0	0	0	0	0
Diptera larvae	78	13	273	1	0.27	66	277	31.37	794	10	3.17	663
Other												
arthropods	46	7.67	160	48	13.15	3188	13	1.82	46	14	4.44	929
Total	600		2100	365		24200	724		2534	315		26883
Collembola/Acari Ratio	1:4.47			1:3.45			1:3.98		1:1.16		1:4.1	1:3.21

* Number of sample units 14 in paddy fields and 12 in uncultivated soils, (RA%) Relative abundance % *% of Total Acari (In brackets are given the numbers of nymphs separately).

chemical characteristics of the paddy field soils were not determined since they remained inundated and soil microarthropods were not present in the soil in that condition.

DISCUSSION

The present study revealed that inundation causes considerable damage to microarthropods in the paddy field soils. Soil samples collected from the three inundated fields did not have microarthropods in them. Thus, it appeared prolonged inundation was a prominent factor adversely affecting the soil microarthropods, whereas, these were found localized in the clumps of tillers, escaping long term submergence. Deleterious effects of agricultural practices on soil microarthropods have been shown by Trehan (1945) Salt *et al*, (1948) and Edwards and Lofty (1969). Prabhoo (1976) has shown that conversion of natural sites into man-managed agricultural system influences the soil fauna qualitatively and quantitatively. Raw (1961) states that cultivation decreases the diversity and abundance of arthropod fauna. In the present findings the highest numbers were recorded in uncultivated soils, which is in agreement with the findings of Raw (1961) and Prabhoo (1976). But here the climatically conditioned influences as suggested by Tischler (1955) appear to play the prominent role. Prolonged inundation affects the microarthropods adversely. Tischler (1955) noted that the course of fluctuation of animal population in arable land depends upon the cultivation and the use of soils as well as on the climatically conditioned influences. The continuous rainfall in the period under study caused the fields to remain under water for months together at a stretch. Haarlov (1942) in Greenland found that vegetational tufts of *Carex*, *Eriophorum* and *Juncus* separated by water filled drainage channels, were often high enough above the water table to qualify as dry habitats for the distribution of microarthropods. A somewhat similar situation is found here

The number of microarthropods per square metre in the paddy fields is lower than that of the uncultivated soils. The total population varied from 1.69 thousands/m² to 2.53 thousands/m² in the paddy fields. Bhattacharya and Joy (1978) noted a population size of 1.64 thousands/m² in a paddy field at Sriniketan. They also found a lower population of microarthropods in paddy fields compared to the fodder field and fallow grassland. The microarthropod population was higher in all the three uncultivated sites in the present study than that of the fallow grassland in which Bhattacharya and Joy (1978) recorded highest population out of the 4 sites studied. The population of microarthropods in three uncultivated sites ranged from 20.88 thousands/m² to 27.7 thousands/m². These sites had dense

grass cover and the undisturbed nature of the soil might account for a large number of microarthropods. Singh and Mukharji (1973) recorded total arthropod fauna varying from 9.45 thousands/m² to 16.87 thousands/m² in a study of soil microarthropods in some fields at Varanasi.

Acari was the predominant group in all the three paddy fields and uncultivated sites. Tamura *et al.*, (1969) found that Collembola were more numerous than Acari in a corn field. Acari population ranged from 1.08 thousands/m² to 1.36 thousands/m² in paddy fields and 10.3 thousands/m² to 16.37 thousands/m² in uncultivated soils. Predominance of Acari over other groups has been reported by Ryke and Loots (1967) ; Choudhuri and Roy (1970) ; Singh and Mukharji (1973) Singh and Pillai (1975) and Prabhoo (1976). Among Acari, Oribatei was predominant in all the three paddy fields and uncultivated sites. They constituted 63.5 per cent, 62.79 per cent and 79.3 per cent of total Acari in paddy fields I, II and III respectively and 73.47 per cent, 78.21 per cent and 68.02 per cent correspondingly in uncultivated soils. This finding is at variance from the report of Bhattacharya and Joy (1978) who found that Prostigmata was the most abundant group in paddy fields. In the present observation it was found that Prostigmata was present only in uncultivated sites and that too in small numbers. Singh and Pillai (1975) reported that in cropland soils of Varanasi, Prostigmata was the dominant group. But Singh and Mukharji (1971, 1973) observed that Oribatei was the predominant group in the fields including cultivated soils except in rose garden where Collembola was dominant. Obviously there are regional differences in the relative numbers of various groups of mites in the soil.

PacIt (1956) holds that Collembola/Acari ratio reflects the ecological characteristics of habitats. The Collembola/Acari ratio is shifted in favour of Collembola, at least immediately after harvest in the paddy fields.

The figures of diptera larvae were high in paddy fields compared to the uncultivated sites. This could be due to the availability of better feeding sites and moisture requirements in the paddy fields than in uncultivated soils. Highly moist situations with high organic matter content are known to impart suitable conditions for large number of dipteran larvae, most of which are detritivores. On the contrary the population of other arthropods that included insect orders like Diplura, Araneida Coleoptera, Hemiptera, Thysanoptera, Psocoptera and Hymenoptera, Symphyla and was higher in uncultivated soils compared to paddy fields. This might be due to much more stable conditions of the uncultivated soils that provide suitable dwelling sites.

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3. Protozoa

3.1 EFFECT OF SOIL MOISTURE ON POPULATION DENSITY OF TESTACEA (PROTOZOA)

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ABSTRACT

Protozoa are essentially aquatic organisms. Moisture content of a particular habitat is the most selective feature of the soil environment to which testacea and other protozoa must be adopted.

An attempt was made to determine quantitatively the effect of soil moisture content on testacean population in a grass land site in the Sambalpur University Campus. The study was confined to the upper 10 cm of the soil profile and was done during the summer months. One plot was kept as control. Another plot was watered regularly.

There was a significant ($P < 0.05$) positive correlation between the number of active forms in all soil horizons with soil moisture content. In the watered plots there was a decrease in the number of encysted forms with consequent increase in active forms. In controlled plot there was decrease in the number of active forms and increase in the number of encysted forms. Population density was lower in the controlled plot in comparison to the watered plots.

The generation time of testacea varied from 5.8 to 6.4 days in the watered plots and from 7.3-11.1 days in the controlled plot.

The amount of secondary production was more in watered plot in comparison to the controlled plot. Graphical model representing population parameters of this testacean population has been developed.

3.2 DISTRIBUTION OF SOIL PROTOZOA IN RELATION TO CROPS IN TWO DISTRICTS OF WEST BENGAL

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ABSTRACT

Very little information is available regarding the distribution and ecology of soil protozoans in eastern India. Soil protozoans influence the microbial population of the soil which in turn affects the fertility of the soil.

Twenty alluvial and five tea soil samples were collected from West Dinajpur and Darjeeling Districts of North Bengal respectively. The alluvial soil samples were mainly collected from the grassy, paddy and cereal fields.

After inoculating the soil samples in agar culture medium in the laboratory (26-32°C), it was observed that within the first four days of inoculation the ciliate population builds up and this mainly consists of *Colpoda cucullus*. This population was succeeded by protozoans belonging to the *Rhizopod* group. The amoebae that were observed in grassy, paddy and cereal fields belong to the genera *Acanthamoeba*, *Amoeba* and *Thecamoeba*.

4. Nematoda

4.1 NEMATODES ASSOCIATED WITH SUGARCANE IN MAHARASHTRA

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ABSTRACT

The information regarding the association of soil and plant parasitic nematodes with sugarcane in the States of Maharashtra is lacking. The random survey of eleven intensive sugarcane growing localities from Ahmednagar, Nasik, Kolhapur and Pune districts were therefore carried out in the year 1978-79.

The results of the survey revealed that nine species of plant parasitic and three of soil nematodes were found associated with sugarcane crop in Maharashtra. The plant parasitic nematode species recovered were *Criconemoides* sp., *Helicotylenchus elegans* Roman, 1965 ; *H. indicus* Siddiqi, 1963 ; *H. spp.* ; *Hoplolaimus indicus* Sher., 1963 ; *Macroposthonia sphaerocephala* Taylor, 1936 ; *Paralongidorus* sp. ; *Telotylenchus* sp. ; *Xiphinema* sp. and soil nematode species consisted of *Indodorylaimus* sp. ; *Sicaguttur* sp. and other dorylaimids.

Helicotylenchus sp., *Hoplolaimus indicus* and *Macroposthonia sphaerocephala* were most common in sugarcane fields and were present in every soil sample. *Helicotylenchus elegans* was confined only at Padegaon, Rahuri and Srirampur, however, *Helicotylenchus indicus* had a wider distribution than *H. elegans*. *Telotylenchus* sp. was recovered only from Sangamner (Ahmednagar district) and Pimpalgaon Baswant (Nasik district) but the population was very low i.e., 2/250 ml of soil. Also a low population i.e., 2/250 ml of soil of *Paralongidorus* sp. was found at Rahuri and Sangamner of Ahmednagar district.

Amongst soil nematodes *Indodorylaimus* sp. was most common and recovered in every sample. *Sicaguttur* sp. had a very limited distribution.

Except *Indodorylaimus* sp. and *Sicaguttur* sp., all species of nematodes are reported for the first time from Maharashtra.

4.2 SPECIES DISTRIBUTION OF NEMATODE-FAUNA IN THE BANANA FIELDS OF SOUTH ARCOT DISTRICT, TAMIL NADU

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ABSTRACT

Following frequent reports of nematode attack to banana plantations in and around the Cauvery delta, a survey was conducted in the banana growing areas (Sivapuri and Vallampadugai of the South Arcot District) to assess their distribution. Around 100 soil samples collected in various farmers fields showed a maximum percentage infection at a population of 53/250 gms of soil. Among the banana nematodes, worms like, *Radopholus similis* (90 per cent), *Meloidogyne incognita* (68 per cent), *Pratylenchus coffeae* (51 per cent), *Hoplolaimus* sp. (22 per cent), *Tylenchorhynchus* sp. (22 per cent), *Helicotylenchus multicinctus* (17 per cent) and *Tylenchus* sp. (5 per cent) varied significantly in their infection ratio. *Criconemoides* sp. was totally unseen, although it was enlisted among the nemas attacking the crop.

4.3 NEW RECORD OF ROOT-KNOT NEMATODE (*MELOIDOGYNE* SPP.) ON MUSTARD (*BRASSICA JUNCEA* VAR. *VARUNA* RAI) FROM INDIA

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ABSTRACT

During the course of survey work, the crop of mustard var. *varuna* Rai, was found having unhealthy appearance, at Regional Research Station, Hardoi, Uttar Pradesh. Patchyness and stunted growth with yellowing of leaves was also noticed. The plants showing such symptoms were uprooted and it was found that roots of such affected plants were full of galls varying from small to moderate size. The number of galls ranged from 97 to 160 per plant. The soil samples drawn from the different parts of the field revealed the presence of *Meloidogyne* larvae, *Tylenchorhynchus* and *Hoplolaimus*.

2.2 QUANTITATIVE STUDY OF SOIL ARTHROPODS IN JHUM ECOSYSTEMS

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ABSTRACT

A quantitative study of soil arthropods in different age groups (1 year, 5 years, 10 years and 20 years) of jhum-fallows have been made. Each age group was analysed monthly for the population fluctuations in relation to four different depths (0–10 cm, 10–20 cm, 20–30 cm and 30–40 cm). The population dynamics of soil arthropods is related to a number of environmental factors like pH, conductivity and moisture content. The effects of these factors on the total populations in different seasons is discussed.

It was observed generally that the population was maximum during August and minimum during November in lower soil layers in all the jhum fallows while they were maximum during November-December for the upper soil layers.

2.3 AN ECOLOGICAL STUDY OF SOIL MESOFAUNA FROM SOIL AND LITTER OF EVERGREEN FOREST AND GRASS LANDS IN YUSMARG OF KASHMIR HIMALAYAS

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ABSTRACT

This paper reports the population density of soil and litter mesofauna of evergreen forest and grasslands (protected and grazed) at the altitudes of 2200 m and 2515 m (latitude 33.33° and 34.2°N and longitude 74.28° and 74.55° E) in the south-west of Kashmir. The forest is dominated by *Pinus pindrow*, *Pinus wallichiana*, *Picea smithiana* and other broad leaved plants. The grasslands are dominated by herbaceous plant community of *Cynodon dactylon*, *Trifolium repens*, *Viburnum nerosum* and other plant species. Litter and soil samples were taken monthly. The mesofauna were extracted by Tullgren Funnel.

In all habitats Acari were the dominant group followed by Collembola. Maximum population i.e. 17,599.90/m² of Acari was recorded. Similarly the collembolan population was also maximum (2,083.59/m²) in the forest litter (3.472 kg/m² fresh weight). The total density of mesofauna was 20,707.39/m². Minimum population of mesofauna was recorded in grazed grassland.

Among soil fauna, Acari (11, 800/m²) were dominant in protected grassland. The distribution of other soil fauna is also described in the paper.

2.4 DISTRIBUTION AND ABUNDANCE OF ARTHROPOD SOIL FAUNA IN VARIOUS ECOSYSTEMS OF THE KASHMIR VALLEY

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ABSTRACT

The valleys of Kashmir possess temperate climate with diverse physical factors which have direct bearing on the soil and its pedological fauna. Arthropod life is extremely rich and heterogenous and are represented by overwhelming species and genera which are either endemic or related in varying degrees to palaearctic and subtropical forms. This fauna on the broad ecological basis, in relation to agro-ecosystem, range and aquatic ecosystem, have been analysed.

Many crop pests including cutworms white grubs harbour in soil either temporarily or for most of their life in orchard soil nearly 20 economically important insects have been recorded.

Grass, park and fallow lands have soil mixed with gravel and sand and harbour many important arthropod pests.

Forest ranges are characterised by a close temperate coniferous climax which exercise a profound influence on the physical factors of the valley. The soil is rich in humus and stable litter. More than 20 species of arthropod soil fauna are noted in this ecosystem.

The unique man-made floating lands over the lake waters form a unique abode for dipteran larvae of *Simulium indicum*, *S. hi maayense* (Simuliidae), *Chironomous socius*, *Tendipes*, *Limnophila* (Chironomidae), *Ormosia kashmiri* and *Limonia kashmirica* (Tipulidae).

Ecological factors influencing distribution and abundance of this fauna and their relationship with these ecosystems are discussed in detail.

2.5 DISTRIBUTION AND ABUNDANCE OF SOIL FAUNA IN TWO VEGETATIONALLY DIFFERENT SITES IN KERALA

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ABSTRACT

The present study is part of a general ecological work carried out, to gather information on the species categorisation and frequency distribution of the soil microarthropods in general and oribatid mites in particular, inhabiting two vegetationally different sites in Trivandrum. Among the 14 groups of microarthropods recovered from the first site, with the absence of Hemiptera and Thysanoptera all others were present in the second site, but their population density showed comparatively low percentage except for Diptera, Protura and Symphyla. This may be due to the high percentage of soil moisture and organic matter present in the former site. When the percentage frequency distribution of all the 14 groups of microarthropods was calculated, mites and Collembola occupied first and second positions in the first site, while reverse was the case with the second site. Frequency distribution of all the Oribatid species obtained was considered season-wise and discussed.

2.6 QUANTITATIVE COMPOSITION OF SOIL MESOFAUNA IN TROPICAL ARABLE AND DECIDUOUS FOREST SOILS

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ABSTRACT

The studies on the quantitative composition of soil mesofauna in tropical arable (BHU Campus) and deciduous forest soils (Chandraprabha Sanctuary) were carried out for two years from May, 1976 to April, 1978. In the arable soil, sorghum (*Sorghum vulgare*) and berseem (*Trifolium alexandrinum*) were alternately cultivated throughout the year. Monthly 5 soil samples (10.0 x 7.5 x 22.5 cm) from arable and forest site and 5 litre samples (50 x 50 cm) from forest stand were collected. Soil samples were processed in Ladell's apparatus and litter samples in Tullgren Funnel for extraction of microarthropods. The collected microarthropods were sorted out into various groups to know the community structure.

A total of 15,183 soil animals were obtained from 360 samples (120 from each habitat) collected in two years of investigation period. The population figures of different soil fauna were converted into microarthropods/m² and their percentage composition has been presented in this

paper. The ratio of Acari and Collembola in three habitats and percentage composition of different groups of Acari are also given in the paper. Acari were dominant in arable and forest soil while in forest litter Collembola dominated. Percentage composition of different groups of Acari in all three habitats studied was more or less similar recording maximum Cryptostigmata followed by Prostigmata and Mesostigmata with invariably low density or Astigmata.

2.7 PRELIMINARY OBSERVATION ON SOIL FAUNA OF GRASS LAND AND CULTIVATED SOIL OF HEBBAL, BANGALORE

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ABSTRACT

One year, weekly samples, each of ten from cultivated and grass land soils of Hebbal, were put to extraction through Tullgren Funnel and analysed to know the effect of cultivation and irrigation on the soil fauna population. Collembola and Acari constituted major fauna in both types of soils. Insects and symphyla were the next major groups. The collembolan population increased with higher precipitation in grass land compared to cultivated field. Acari, insects and symphylans did not vary in their number between cultivated and uncultivated soils and irrigation had no effect. Millipedes were absent in both the soils in the month of September-October and February-March. Centipedes were not recorded in June. Lumbricids were not found in September-October although these were not dry months. Isopods, pauropods, pseudoscorpions and spiders were in negligible numbers and were occasionally collected. Soil temperature had effect on collembolan fauna, being lower at higher temperature (24.61°C) and higher at lower temperature (19.20°C), whereas, the acari number did not vary with the soil temperature.

4.4 QUALITATIVE AND QUANTITATIVE STUDIES OF PLANT AND SOIL INHABITING NEMATODES ASSOCIATED WITH PADDY CROP IN BURDWAN DISTRICT (WEST BENGAL)

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ABSTRACT

An intensive survey was made in December, 1977 at three blocks of Burdwan district (West Bengal) to make the qualitative and quantitative studies of parasitic and soil inhabiting nematodes associated with paddy crop. Several observations were made in the field itself and enquiries were also made about the management practices.

Upon analysis, these samples have yielded 17 known phytophagous nematode species belonging to 13 genera and 9 families. Apart from these parasitic species, 9 known soil inhabiting nematode species have also been identified. In addition to these known species, one new species of the order Tylenchida and 5 new species of the order Dorylaimida have been described (in press). Males of two known species have been reported for the first time.

Among the plant parasitic species, *Hirschmanniella garicilis* (de Man, 1980) Luc & Goodey, 1963 was found in all the samples. This was found dominating over other parasitic species in 46 per cent samples. The occurrence of *Ditylenchus* spp., *Tylenchorhynchus mashhoodi* Siddiqui and Bashir, 1959 and *Helicotylenchus crenacauda* Sher., 1966 has been noted in 81 per cent, 76 per cent and 56 per cent samples respectively. *Ditylenchus* spp., *T. mashhoodi* and *H. crenacauda* were dominating in 36 per cent, 13 per cent and 16 per cent of samples respectively. The species of the genera *Hoplolaimus* Daday, 1905 and *Macroposthonia* de Man, 1980 were generally present in small number in about 10 per cent samples. The other parasitic species are less abundant.

4.5 EFFECT OF ROOT-KNOT NEMATODE, *MELOIDOGYNE INCOGNITA* ON NODULE BACTERIA, *RHIZOBIUM*, IN COWPEA

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ABSTRACT

Effect of root-knot nematode, *Meloidogyne incognita*, on nodule bacteria, *Rhizobium*, was studied in pot culture experiments. Cowpea, variety C-72, plants were raised in sterilised pot mixture and inoculated with *Rhizobium* alone at one level (seed treatment by fresh rhizobial culture at the rate of 250 grams per acre), *M. incognita* alone at three levels (2000, 2500 and 3000 larvae per plant) and in combination with *Rhizobium*, with ten replications in each.

The number of nodules and the root-knots formed on all the experimental plants were taken after three months of inoculation.

It was found that nodule formation on cowpea was considerably reduced from 0.53 to 0.39, 0.36 and 0.32 per gram of roots in the presence of 2000, 2500 and 3000 larvae of *M. incognita* respectively, thus reducing the nitrogen fixing capacity of the bacteria. Simultaneously the root-knot formation was also reduced from 25.8 to 24.3, 26.5 to 25.6 and 26.9 to 26.1 root-knots per gram of roots in the three inoculum levels of the root-knot nematode, in the presence of the nodule bacteria.

INTRODUCTION

Root-knot nematodes are reported to reduce nodulation in leguminous plants (Nigh, 1966, Taha and Raski, 1969, Balasubramanian, 1970). The present work was undertaken to assess the effect of root-knot nematode on nitrogen fixing bacteria in cowpea, variety C-72.

MATERIAL AND METHODS

The experiment was conducted in earthen pots of 30 x 30 cm, containing pot mixture sterilized at 7 kg/sq. cm for 4 hrs. In one series cowpea (variety C-72) seeds after bacterization (seed treatment by fresh rhizobial culture obtained from TNAU, Coimbatore, at the rate of 250 g per acre) were sown singly. In another series, cowpea seeds were sown singly without bacterization and inoculated with 2000, 2500 and 3000 one day-old larvae of *M. incognita*, after three weeks of sowing. The third series was similar to the second, but the cowpea seeds after bacterization were sown. Three months after inoculation, the plants were carefully removed and observations on plant height, shoot weight, root weight, total number of nodules and root galls were taken. The nodules per gram of roots and galls per gram of roots were calculated.

RESULTS

The plant height was significantly reduced in presence of the root-knot nematode and rhizobium than in rhizobium alone. The mean height of plants under rhizobium alone was 1.95 M, this was reduced by 21.3, 23.8 and 28.2 per cent at the three levels of nematodes tried.

The weight of shoots was 560 g with rhizobium alone, but was significantly reduced by 34.5, 36.2 and 37.5 per cent at the three levels of nematodes tried.

The weight of roots also was significantly reduced in presence of the root-knot nematode and rhizobium by 54.0, 54.0 and 54.6 per cent at the three levels of nematodes tried.

Nodules per gram of roots were calculated and it was found that with rhizobium alone there were 0.53 nodules per gram of roots and it was significantly

TABLE I

Treatments	Height of plant (m)	Weight of shoot (g)	Weight of root (g)	Nodules per g root	Root-knot per g root
Rhizobium alone	1.95	560.0	370.0	0.53	0
Root-knot nematode					
-2000 larvae	1.58	358.0	170.0	0	25.8
-2500 larvae	1.50	358.0	170.0	0	26.5
-3000 larvae	1.40	349.2	168.0	0	26.9
Rhizobium and root knot nematode					
-2000 larvae	1.54	366.8	170.0	0.39	24.3
-2500 larvae	1.50	357.5	170.0	0.36	25.6
-3000 larvae	1.40	351.6	168.0	0.32	26.1
C.D.	0.11	14.63	15.28	0.05	0.51

reduced by 26.4, 32.1 and 39.6 per cent in presence of rhizobium and the root-knot nematode at the three levels tried.

The root galls were reduced by 5.8, 3.4 and 2.9 per cent at the three inoculum levels of the nematode, in presence of rhizobium, compared to the treatments with only nematodes.

DISCUSSION

From the results presented, it is evident that in the presence of the root-knot nematode the beneficial effects of rhizobium are nullified, resulting in reduction in height of plants, weight of shoots and roots and number of nodules. This finding is in conformity with that of earlier workers (Hussaini and Seshadri, 1975). The present study, with cowpea, revealed that the rhizobium also affects the root-knot nematodes, as evidenced by the reduced number of root-knots per gram of roots in the combined presence of the root-knot nematode and rhizobium. This is in contrast to the findings of Hussaini and Seshadri, who reported that in mung-bean the

root-knot nematode has no effect on the rhizobium. Seed treatment as a method of inoculation used in the present studies, as compared to the broth culture used by the earlier workers, might have facilitated the rhizobium, to a certain extent, in establishing quickly than the nematodes.

It can be concluded that root-knot nematodes and rhizobium are mutually affecting each other in their expression on cowpea variety C-72.

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4.6 PLANT PARASITIC NEMATODES OBSERVED IN THE RHIZOSPHERE OF PEPPER AND GINGER IN KERALA

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ABSTRACT

The pepper and ginger growing areas of Kerala were surveyed for the presence of plant parasitic nematodes. All the pepper growing areas were infested with **Meloidogyne incognita**, **Radopholus similis** and **Helicotylenchus** sp., the root-knot nematode being more predominant. An average of 216 **M. incognita**, 29 **R. similis** and 26 **Helicotylenchus** sp., were observed in 250 gms of soil and 24 **M. incognita**, 9 **R. similis** and 2 **Helicotylenchus** sp. in 10 gms of roots. The population of all the above three nematodes were higher in soil and roots of wilted pepper plants than in healthy plants.

All the ginger growing areas covered were infested with **M. incognita**, **R. similis**, **Pratylenchus** sp. and **Helicotylenchus** sp. The number of **M. incognita** in ginger rhizosphere ranged from 22 to 1243 with an average of 502 per 250 gms of soil and in roots 26 to 3219 with an average of 1107 per 10 g of roots. There was an average of 208 **R. similis**, 305 **Pratylenchus** sp. and 76 **Helicotylenchus** sp. per 250 gms of soil and 820 **R. similis**, 412 **Pratylenchus** sp. and 31 **Helicotylenchus** sp. per 10 gms of root.

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TABLE I
Relative susceptibility of pepper varieties to different nematodes

Pepper variety	Population of nematodes in soil (250 g) and roots (10 g)											
	<i>M. incognita</i>				<i>R. similis</i>				<i>Helicotylenchus</i> sp.			
	Soil		Roots		Soil		Roots		Soil		Roots	
	Range	Aver- age	Range	Aver- age	Range	Aver- age	Range	Aver- age	Range	Aver- age	Range	Aver- age
Panniyur I	24-467	231	0-98	24	0-140	37	0-33	11	0-127	34	0-8	1
Karimunda	18-312	131	0-41	18	4-108	43	0-14	8	2-85	53	—	—
Balancotta	26-533	274	2-54	23	0-51	25	0-26	11	0-52	28	—	—
Kalluvally	38-396	240	12-73	32	0-63	33	0-21	8	0-35	16	0-8	2
Kottanadan	32-513	281	0-54	25	0-22	9	0-23	10	9-18	14	—	—
Cheriakaniakadan	47-479	298	8-69	41	9-64	47	0-23	12	2-45	26	—	—
Peringamala local	12-93	56	0-16	6	6-21	13	—	—	0-21	12	—	—

INTRODUCTION

Among pests, nematodes have recently been observed to be a major threat to pepper (Venkitesan, 1972) and ginger (Mammen, 1973) cultivation in Kerala. As precise information on the distribution and extent of damage by nematodes, to these crops is lacking, the present investigation was undertaken.

MATERIAL AND METHODS

Soil and root samples were collected from the base of pepper and ginger plants. The soil was processed by Cobb's sieving and sifting technique (Cobb, 1918) followed by modified Baermann funnel technique (Staniland, 1954). Nematodes from 10 g roots were separately isolated. Nematodes were identified and counted from these suspensions.

RESULTS

Nematodes associated with pepper

It was observed that in all the 5 districts *viz.*, Panniyur, Neriambangalam, Kozha, Mavelikara, and Peringamala, pepper was infested with the root-knot nematode—*Meloidogyne incognita*, burrowing nematode—*Radopholus similis* and

TABLE
Population of nematodes in 250 g soil and 10 g roots

District	No. of samples analysed	<i>M. incognita</i>				<i>R. similis</i>			
		Soil		Root		Soil		Root	
		Range	Average	Range	Average	Range	Average	Range	Average
Kottayam	35	93-974	546	76-3219	1077	11-881	174	4-797	130
Kozhikode	32	26-851	312	49-2159	954	39-766	346	20-1755	427
Malappuram	18	218-837	497	94-2533	818	48-215	134	18-193	79
Ernakulam	15	119-876	552	289-2827	1559	27-167	94	8-24	17
Idikki	14	33-522	246	26-1788	549	28-921	189	27-1205	411
Palghat	10	148-837	586	36-2386	1155	38-386	169	44-149	102
Cannanore	8	22-756	362	54-998	675	76-621	382	169-1201	6791
Quilon	5	339-1243	671	977-1872	1379	81-526	281	49-222	135
Trichur	5	347-1214	697	974-1722	1389	65-363	154	11-169	72
Trivandrum	5	378-973	557	993-2133	1520	58-211	158	32-48	40

spiral nematode—*Helicotylenchus* sp. The population of different species of nematodes observed in 7 varieties of pepper is presented in Table I. In 250 g soils there was an average of 56 to 298 *M. incognita*, 9 to 47 *R. similis* and 12 to 53 *Helicotylenchus* sp. in the 7 varieties studied. In 10 g roots of these, there was an average of 6 to 32 *M. incognita*, 8 to 12 *R. similis* and 1 to 2 *Helicotylenchus* sp.

Nematodes associated with ginger

The results are presented in Table II. It may be seen that *Meloidogyne incognita*, *Radopholus similis*, lesion nematode—*Pratylenchus* sp. and *Helicotylenchus* sp. are associated with ginger in all the localities. In 250 g of soil an average of 502 *M. incognita*, 208 *R. similis*, 305 *Pratylenchus* sp. and 76 *Helicotylenchus* sp. were present and 10 g root contained an average of 1107 *M. incognita*, 820 *R. similis*, 412 *Pratylenchus* sp. and 31 *Helicotylenchus* sp.

DISCUSSION

The results presented show that in all the pepper growing areas studied and all the pepper varieties grown in these areas, are infested with *M. incognita*, *R. similis* and *Helicotylenchus* sp. and all the ginger growing areas surveyed are infested with *M. incognita*, *R. similis*, *Pratylenchus* sp. and *Helicoty-*

II

of ginger in different districts of Kerala

<i>Pratylenchus</i> sp.				<i>Helicotylenchus</i> sp.			
Soil		Root		Soil		Root	
Range	Average	Range	Average	Range	Average	Range	Average
39-778	291	7-1552	354	7-378	71	7-168	44
43-1119	533	23-1824	669	16-275	99	5-98	40
188-863	494	66-1896	423	48-215	134	18-193	79
73-706	363	41-1604	545	10-69	29	3-40	23
112-975	467	78-2238	819	11-176	80	8-26	17
49-638	265	149-1120	596	17-172	84	11-31	13
76-1209	476	26-2288	715	39-216	131	5-185	71
17-96	56	7-1120	351	9-79	30	3-7	5
70-630	250	39-1535	325	18-146	72	11-27	17
66-139	113	25-1775	353	17-46	35	7-9	8

Ienchus sp. Root-knot nematode, *M. incognita*, forms the major group of nematodes on both the crops, with a very large population present both in soil and roots.

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4.7 DISTRIBUTION AND ASSOCIATION OF DIFFERENT PLANT PARASITIC NEMATODES IN KERALA

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ABSTRACT

In general the population of nematodes was very high in the rhizosphere of vegetable crops. Soil basins of banana harboured more number of nematodes than that of arecanut or paddy. The following genera of parasitic nematodes were found in association with the crops : **Helicotylenchus**, **Meloidogyne**, **Hoplolaimus**, **Aphelenchus**, **Nothotylenchus**, **Pratylenchus**, **Creconemoides**, **Tylenchus**, **Tylenchorhynchus**, **Boleodorus** and **Hirschmanniella**.

Helicotylenchus was present in almost all types of soils and in association with most of the crops. The genera **Meloidogyne**, **Hoplolaimus**, **Nothotylenchus**, **Pratylenchus** and **Creconemoides** were seen in association with vegetables, coconut and banana. However the genus **Boleodorus** was found in association with only rubber in laterite soil. The genus **Tylenchorhynchus** was seen in paddy loam associated with paddy. The rice root nematode **Hirschmanniella oryzae** was also seen associated with paddy in sandy loam soil.

Earlier studies have indicated that Kerala soils abound in various types of nematodes. Some of them have already been recognised as potential pests of important crops. An attempt was made, to study the distribution and association of different plant parasitic nematodes with cultivated crops in Kerala State.

MATERIAL AND METHODS

Different localities, with different soil types and crops were selected at random for the collection of soil samples. The soil samples (1000 cc of soil) were collected from the rhizosphere of vegetables, banana, coconut, arecanut and paddy. The soil samples were processed by the method of Christie and Perry (1951).

RESULTS AND DISCUSSION

Counts of parasitic and non-parasitic soil nematodes of the different samples collected are presented in Table I. In general the population of nematodes was very high in the rhizosphere of vegetable crops.

TABLE I
Nematode population in the rhizosphere of different crops

Crop	Counts/500 cc soil		
	Parasitic	Non-parasitic	Total
Vegetables	836.36	941.27	1777.63
Banana	334.75	321.25	656.00
Coconut	152.16	394.16	546.32
Arecanut	137.66	235.34	373.00
Paddy	38.00	300.00	338.00

Since vegetables are irrigated regularly the nematode population is high. The usual practice of generous manuring also appears to have encouraged the sustenance of a very high population of the non-parasitic forms in the soil. Next to vegetables, banana soil gave the maximum population followed by coconut, arecanut and paddy in the descending order.

The different genera of parasitic nematodes found in association with these crops were *Helicotylenchus*, *Meloidogyne*, *Aphelenchus*, *Nothotylenchus*, *Pratylenchus*, *Criconeimoids*, *Tylenchus*, *Tylenchorhynchus*, *Boleodorus*, *Radopholus* and *Hirschmanniella*. Their association with different crops is presented in Table II.

Helicotylenchus was present in almost all types of soils and in association with most of the crops. The genera *Meloidogyne*, *Hoplolaimus*, *Nothotylenchus*, *Aphelenchus*, *Pratylenchus* and *Criconeimoids* were seen in association with vegetables coconut and banana. However the genus *Boleodorus* was found in association with only rubber in laterite soil, The genus *Tylenchorhynchus* was seen in sandy loam

TABLE II
Nematodes associated with different crops

Name of crop	Nematodes
Vegetables	<i>Meloidogyne</i> , <i>Helicotylenchus</i> , <i>Hoplolaimus</i> , <i>Nothotylenchus</i>
Banana	<i>Radopholus</i> , <i>Pratylenchus</i> , <i>Helicotylenchus</i> , <i>Criconemoides</i> , <i>Nothotylenchus</i> , <i>Hoplolaimus</i>
Coconut	<i>Helicotylenchus</i> , <i>Aphelenchus</i> , <i>Tylenchus</i> , <i>Tylenchorhynchus</i>
Arecanut	<i>Helicotylenchus</i> , <i>Pratylenchus</i>
Paddy	<i>Tylenchorhynchus</i> , <i>Hirschmanniella</i>
Rubber	<i>Boleodorus</i>

associated with paddy and coconut. The rice root nematode *Hirschmanniella oryzae* was also seen associated with paddy in sandy loam soil.

4.8 EFFECT OF CULTURAL FILTRATES OF FUNGI ON THE SURVIVAL OF THREE PHYTONEMATODES

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ABSTRACT

Dried cultural filtrates of some soil fungi grown for two weeks were tried at 1/100 and 1/1000 concentrations for their effect of mortality on the common soil phytonematodes of Allahabad Agricultural Institute campus (*Hoplolaimus indicus*, *Tylenchorhynchus brassicae* and *Pratylenchus* sp.) The mortality of *Hoplolaimus indicus* were seen with all the nine fungal cultural filtrates—*Aspergillus niger*, *Trichoderma lignorum*, *Penicillium citrinum*, *Acraphialophora fusicapna*, *Chaetomium globosum*, *Fusarium (martii)*, *Aspergillus sydowii*, *Curvularia lunata*, *Rhizoctonia bataticola*. In case of *Tylenchorhynchus* and *Pratylenchus* sp. only first six and first four respectively were toxic. The observation on mortality with the two different concentrations of filtrates are presented and discussed.

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ABSTRACT

Counts of parasitic and non-parasitic nematodes in different soil samples were made. The population of nematodes varied widely among the soil types studied. The total population of nematodes, parasitic and non-parasitic, were the largest in sandy loam, laterite and black soils.

Parasitic nematodes were more in laterite soil and less in forest soil. Non-parasitic nematodes were relatively more in black and sandy loam soils followed by laterite.

INTRODUCTION

Some soil organisms are capable of causing enormous economic losses by damaging many crop plants. In this respect nematodes rank next only to insects as pests of cultivated crops (Jones and Jones, 1964).

Earlier studies have shown that the Kerala soils abound in various types of nematodes. Some of them have already been recognised as potential pests of many important crops (Nadakal, 1963; Sathyarajan *et al.*, 1966; Nair *et al.*, 1966). Vargheese (1968) showed the influence soil type exerts on their population. An attempt is made here to study the fluctuations in population of nematodes as influenced by the soil types.

MATERIAL AND METHODS

Cultivated field, were selected at random, covering different soil types *viz.*, sandy, sandy loam, red soil, laterite, forest soil and black soil, for the collection of soil samples. A representative sample of 1000 cc of soil was taken for these studies. The samples were kept in polythene bags to prevent drying. Care was taken to ensure that the samples were collected only from soils which were sufficiently moist. The soil samples were processed by the method of Christie and Perry (1951).

RESULTS AND DISCUSSION

Counts of parasitic and non-parasitic nematodes in different soils are presented in Table I.

TABLE II
Nematode population in different types of soils

Type of soil	Counts/500 cc of soil		
	Parasitic	Non-parasitic	Total
Sandy	309.8	536.2	846.0
Sandy loam	469.3	811.1	1280.4
Red soil	579.6	354.1	933.7
Laterite soil	645.5	642.0	1287.5
Forest soil	286.3	371.3	657.6
Black soil	512.0	976.0	1288.0

With regard to the parasitic nematodes, it was observed that the soils collected from the lateritic areas registered maximum population closely followed by black soil, red soil and sandy loam. Sandy soil and forest soil registered the least population.

Population of the non-parasitic forms presented a different picture. Black soil gave the maximum counts followed by sandy loam. Red soil and forest soils supported the least population. Population of the non-parasitic and parasitic forms were comparatively higher in laterite soil. In both cases, forest soil gave the least counts. The forest soils were collected from the cultivated land of Madupetty, situated in the high ranges at an altitude of 4000–5000 feet above M.S.L. The organic matter content of the soils was relatively high. As expected a higher population of the non-parasitic forms was not present. Perhaps the low temperature prevailing in this area has an adverse effect on the growth of nematodes.

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5. Annelid

5.1 PRELIMINARY OBSERVATIONS ON THE HARMFUL EFFECTS OF *MEGASCOLEX INSIGNIS* ON *CARICA PAPAYA*

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ABSTRACT

Contrary to the beneficial effects of earthworms on the structure and properties of the soil and their influence on the decomposition process of organic materials, few workers have reported the deleterious effects on the soil structure and plant growth by the activities of the worms. Earthworms may become potential pests of agriculture due to their habits.

Stem rot of papaya is a common widespread disease which has discouraged the agriculturists of these regions from growing this commercially important plant (*Carica papaya*). *Pythium aphanidermatum* is responsible for this disease.

A small species of earthworm *Megascolex insignis* in a overpopulated condition was observed feeding on deteriorating tissues of a diseased (stem rot) *Carica papaya* plant.

Observations in glass cages, experimental studies in trays and gut content analysis have clearly proved that *Megascolex insignis* is in the habit of feeding on deteriorating tissues of *Carica papaya* plants.

Microbiological examination of the gut contents of *Megascolex insignis* feeding on diseased tissues have not only revealed the presence of disintegrated plant tissues but also *Pythium* propagules

When *Megascolex insignis* feeding on diseased papaya (stem rot) tissues, presumed to be having *Pythium* propagules were introduced near six healthy *Carica papaya* plants (two in laboratory and four in natural environmental condition). Only one in the garden near Sri Mahaveera College, Moodabidri, became the victim of stem rot disease.

More work on these worms carrying stem rot disease seems to be necessary to draw conclusions.

INTRODUCTION

Considerable amount of literature has accumulated on the tremendous importance of earthworms in agriculture, though their exact beneficial effects remain to be demonstrated. In our country conflicting views as to the part played by the earthworms in the ecology of the soil have emanated. While many consider earthworms as beneficial, a few consider them as pests or pathogens carriers.

A few workers (Zicsi, 1954 ; Walton, 1928 ; Patel and Patel, 1959 ; Puttarudriah and Sastry, 1961 ; Otanes and Sison, 1947 ; Chen and Lui, 1963 ; Inoue and Kondo, 1962) have reported earthworms as pests of crops. Certain species of earthworms have been observed to seize fallen leaves and pull them, by their mouth, into the burrows. Some species feed on tender leaves of growing plants, which may result in the death of plants (Edwards and Lofty, 1972).

Adverse effects on the soil structure and plant growth by earthworms has also been reported (Agarwal *et al.*, 1958 ; Puttarudriah and Sastry, 1961). But it is possible that different species with different habits, need not have the same effect on soil structure and plant growth. Further their activities may also vary from soil to soil.

Hutchinson and Kamel (1956) reported that the rate of spreading of certain soil fungi, including pathogens, was very substantially increased when the earthworms were present in the soil. Earthworms can also act as vectors in transmitting the pathogenic fungi, *Fusarium* and *Pythium* (Khambatta and Bhat, 1957 ; Baweja, 1939). Very little is known about earthworms as fungus pathogen transporters in the spread of diseases of plants. Edwards and Lofty (1972) have speculated that earthworms must be very important vectors of plant pathogens.

FIELD OBSERVATIONS

During the first week of August 1974, after a few days of continuous heavy rains near Sri Mahaveera College Staff Quarters, Moodabidri (South Kanara) a *Carica papaya* plant, in a clay-loam acidic soil (pH 5.5), of approximately 2-3 years old, bearing fruits, exhibited the early symptoms of the common stem rot disease.

A large number of very small earthworms in the soil surrounding the softened bark at the base, was observed. These were later identified as *Megascolex insignis* Michaelsen.

LABORATORY OBSERVATIONS

(1) Observations in glass cages :

Glass cages—two sheets of glass held 2 cm apart by a wooden framework—were used. A card-board was placed longitudinally, approximately in the centre. Half the space was filled with small pieces of the decomposing roots and barks of the diseased *Carica papaya* plant, collected from the field. The remaining half was filled with the soil collected from the nearby region of the diseased papaya plant.

Fifteen immature *M. insignis*, which were feeding on the roots of the diseased papaya plant, were introduced to the soil region after pipetting a small amount of water into the glass cage. After few hours, the piece of card-board was removed. Movement of the worms was closely observed. The number of earthworms migrating from the soil towards the deteriorating papaya tissues was recorded (Table I).

TABLE I
Migration of M. insignis in glass cages

Time in hours	Number of worms remaining in the soil region	Number of worms migrated to soil with papaya tissues
0	15	—
6	11	4
12	10	5
24	9	6
48	7	8
72	4	11

(2) Immigration of *M. insignis*

Three enamel trays of size 45 x 30 x 5 cm were taken for this study.

- In the first tray garden soil with 15 immature *M. insignis* was placed at one end. At the other end, with 20 cm gap, deteriorating roots and barks of papaya plant mixed with garden soil (50:50) was placed as bait.
- In the second tray, garden soil mixed with cow-dung (50:50) was similarly placed with 15 immature *M. insignis*. Soil at the other end was similar to the first treatment.
- In the third tray, garden soil with 15 immature *M. insignis* was placed in the centre. At one end of the tray soil with cow-dung (50:50) and at the other end soil mixed with deteriorating papaya tissues (50:50) were placed, leaving a gap of 8 cm. The migration from one region to the other was recorded for 7 days in all the three enamel trays (Table II).

(3) Observations of gut contents :

A few immature *M. insignis*, found gorging on the deteriorating tissues of diseased papaya plant in the field, were collected. They were washed with tap water, killed using 70 per cent ethyl alcohol and dissected to collect all the gut

contents. Direct observation, described by Kubiena (1938) for soil fungi, were made on a portion of the gut contents. The squash preparations of the gut contents

TABLE II
Migration of M. insignis in the enamel trays

Time (in hours)	Number of worms present in different regions						
	first tray		second tray		third tray		
	soil	deteriorating papaya & soil	soil & cowdung	deteriorating papaya & soil	soil	deteriorating papaya & soil	soil & cowdung
0	15	—	15	—	15	—	—
1	13	2	15	—	15	—	—
24	11	4	14	1	12	2	1
48	10	5	13	2	11	2	2
72	8	7	12	3	8	5	2
96	6	9	10	5	7	5	3
120	4	11	8	7	6	6	3
144	4	11	7	8	4	8	3
168	3	12	6	9	2	8	5

were observed under high power of research microscope equipped with a normal incidence illuminator. Some amount of ingesta was fixed in 70 per cent alcohol and centrifuged. The sediments were stained and attempts were made to identify plant materials, fungal hyphae, spores etc.

Observations on *M. insignis* as vectors of stem rot of papaya

(a) Laboratory experiment :

Two young healthy well developed *Carica papaya* plants of about 70-100 cm height were selected and planted in separate wooden boxes of about 60 x 60 x 45 cm size containing garden soil. Similar environments, as observed in the field, were artificially produced within the wooden boxes, by water logging the root system. After a week, fifteen immature earthworms feeding on diseased papaya plants (presumed to be carrying *Pythium* spores or fungal hyphae) were introduced into the soil in the box. The plants were kept under observation for 42 days.

(b) Field experiment :

To examine the ability of these earthworms to transmit the stem rot disease of papaya, under natural conditions, two plants of about 3-4 years in a garden plot

at Bolar, Mangalore and two plants one about one year and the other about 4 years old, in a kitchen garden, near Sri Mahaveera College, Moodbidri, were selected. The soil in Bolar, is well drained, as it is sandy, whereas at Moodbidri it is red loam. Twenty immature *M. insignis* found feeding on the roots of papaya plant and suspected to carry stem rot disease were released near the roots of the healthy plants and observed for 42 days (Table III).

RESULTS AND DISCUSSION

Earthworms feed on a variety of organic material. Most species can easily distinguish between different kinds of food. Since during stem rot of papaya the fibrous root system is attacked, and the roots become soft and spongy, earthworms under our observation might have taken the advantage of feeding on this easily available food material. It is possible that a foul smelling liquid oozing out from the bark cracks of the diseased plants attracts *M. insignis* and the easily available food supply encourages their proliferation around the decaying roots. Observation in glass cages (Table I), enamel trays (Table II) and gut content analysis clearly revealed the preference of *M. insignis* for the deteriorating softened roots and stems

TABLE III
Ability of M. insignis to transmit stem rot of papaya

Sl. No.	Location	pH of soil	Weeks					
			I	II	III	IV	V	VI
1.	Laboratory experiment in wooden box No. 1	6.5	NH	NH	NH	NH	NH	NH
2.	Laboratory experiment in wooden box No. 2	6.5	NH	NH	NH	NH	NH	NH
3.	Field experiment at Mangalore (Ex. No. 1)	5.0	NH	NH	NH	NH	NH	NH
4.	Field experiment at Mangalore (Ex. No. 2)	5.5	NH	NH	NH	NH	NH	NH
5.	Field experiment at Moodbidri (Ex. No. 1)	6.0	NH	NH	NH	NH	NH	NH
6.	Field experiment at Moodbidri (Ex. No. 2)	6.0	NH	NH	NH	SD	SD	SD

Note : (1) NH – Normal healthy papaya plant
 (2) SD – Symptom of Disease in Papaya plant

of *Carica papaya* plants. It also became clear that these worms have a good selective feeding habit. It is interesting to note that the rate of migration of *M. insignis* was fast, and in large numbers, towards the papaya tissues, from the garden soil (Tables I and II). However, from the garden soil mixed with cow-dung (50 : 50) their migration towards deteriorating papaya tissues was slow and in fewer number (Table II). Majority of the earthworms prefer dung as an ideal food source and in natural conditions many species have been observed to be attracted towards this. Guild (1955) has recorded that all species of earthworms prefer dung. However, it is interesting to note that the immature *M. insignis*, exhibit a special preference for the deteriorating tissues of papaya plants, hence they were encountered in large numbers in these regions. Waters (1955) reported that dead roots was the main diet of *Allolobophora caliginosa*. Muller (1950) stated that they feed extensively on fungal mycelia. However, it could not be clearly established whether *M. insignis* migrated towards papaya tissue regions for the decaying tissues or for the fungus present in these tissues.

The gut content analysis of *M. insignis* found feeding on deteriorating papaya tissues revealed the presence of mostly disintegrated epithelium and tissues with some very fine sand grains, some of which were yellowish in colour. Mineral particles presumably coated with organic material, appearing like fine charcoal dust was also observed. Presence of disintegrated epithelium and tissues clearly revealed that these worms were feeding on diseased papaya plant tissues. However, the most interesting aspect of the observation was the presence of few non-septate hyaline coenocytic fungal hyphae and the laterally biciliated bean shaped zoospores, which were evidently those of *Pythium aphanidermatum*. The entrance of the *Pythium* into the gut could be accidental, during the course of feeding on disintegrated papaya tissues. But, the presence of the pathogens makes these worms suspect. Isolation of *Pythium* was not possible perhaps due to its sensitivity to surface sterilizing agents (Warcup, 1967), or due to some other factors.

The two series of tests conducted to confirm the transmission of stem rot disease to healthy papaya plants (Table III) were unsuccessful, except the one carried out near Sri Mahaveera College, Moodbidri, which showed partial success. Since many congenial environmental conditions are essential for the spread of the disease, *M. insignis* might have failed to transmit the disease in the tests conducted. It was not possible to know how long the propagules (viable spores and other inoculum) were retained in a viable condition in the intestine of these worms. Since these worms do not give out casts on the surface, it was not possible to establish the exact effect on the viability of these fungus propagules after their passage through the intestine.

Further experiments to assess the effectiveness of *M. insignis* in transmitting the stem rot disease of papaya is being carried out.

Detailed observations in the field, laboratory migratory studies in glass cages and trays, and gut content analysis have revealed that immature *Megascolex insignis* (a small species of earthworm), feed on the soft tissues of the stem rot infected papaya plants and thus contribute to further the death of these plants. Microbiological examination of the gut contents of *M. insignis* feeding on the diseased papaya roots in the field have revealed not only the presence of plant tissues but also the presence of *Pythium*. Attempts made to know how far these worms act as vectors in transmitting the pathogenic fungi *P. aphanidermatum*, was partly successful.

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5.2 EARTHWORM—AN INDEX OF THE PHYSICAL NATURE OF THE SOIL

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ABSTRACT

Earthworms being the microbiote of the padosphere prevail as the dominant species in the soils of south Madras. They exhibit preference for a particular range of moisture, temperature, pH and soil texture. These factors influence in one way or other the distribution of the worms thereby projecting them as the index of the physical nature of the soil. Statistical significance of the parameters in relation to the distribution of earthworms is also discussion.

INTRODUCTION

Earthworms, the macrobiota of the pedosphere, are known to occur in large numbers in the fields and gardens of the biosphere. An attempt has been made to consider *Megascolex mauritii*, which inhabits the soils of Madras, as an index of the physical nature, moisture content, texture, pH and temperature of the soil it occupies.

MATERIAL AND METHODS

Ten locations, in South Madras, were selected at random, with the area of analysis being confined to 0.1 m² in each location. Biomass of earthworms (Raw, 1959), pH (Soil Survey Manual), temperature (at 10 cm) and moisture were determined. Coarse, medium and fine grain portions of the dry soil were separated using sieves of BSS grades 7, 14, 25, 36, 52, 72, 100 and 200. Locations, in the present study, have been numbered in an ascending order of per cent moisture of the soil.

RESULTS

Biomass increased with the increase in per cent moisture of the soil (Fig. 1) which ranged from 1 to 21.5 per cent in the different locations (Table I). pH ranged between 6.4 and 7.8 (Table I, Fig. 1). Effect of temperature is not well marked, this ranged between 28°C and 32°C in the locations sampled.

Soil composition varied, but generally was clayey sand or sandy clay. Composition of the coarse (BSS grade 7), medium (BSS grades 14, 25, 36) and fine (BSS grades 52, 72, 100 and 200) sand in relation to biomass is given in Table I and Fig. 2.

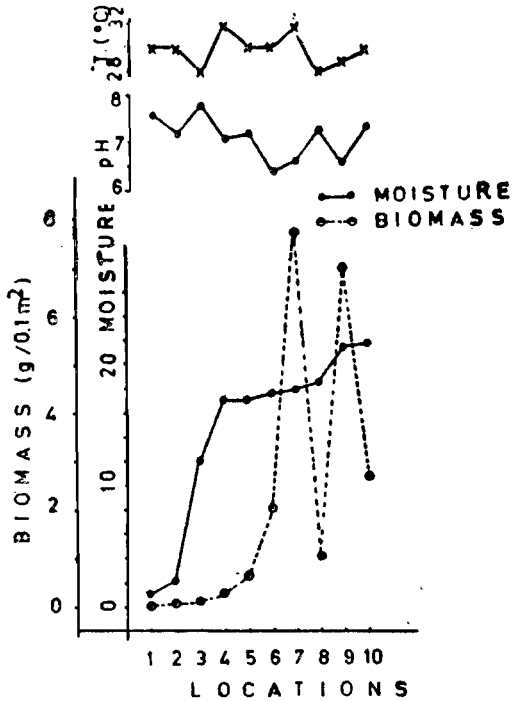


Fig. 1. Biomass in relation to per cent moisture of the soil

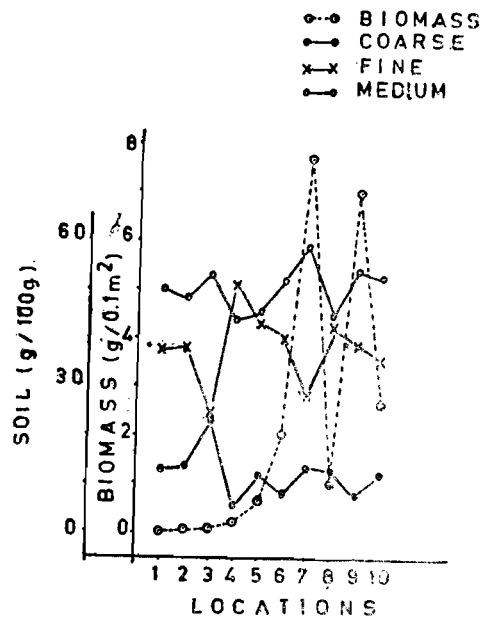


Fig. 2. Biomass in relation to coarse, medium and fine grains of sand in the composition of the soil

TABLE I
Analysis of soil from different locations

Location	Moisture Percent	pH	Temp. (°C)	Coarse %	Sieve Analysis Medium %	Fine %	Biomass (g/0.1 m ²)
1	1	7.6	30	12.9	49.7	37.4	0.0
2	2	7.2	30	13.5	48.3	38.2	0.002
3	12	7.8	28	22.6	53.3	24.1	0.109
4	17	7.1	32	5.5	43.5	51.0	0.230
5	17	7.2	30	11.6	45.6	42.8	0.619
6	17.5	6.4	30	8.1	52.2	39.7	2.094
7	18	6.65	32	13.4	58.9	27.7	7.728
8	18.3	7.3	28	13.1	44.4	42.5	1.001
9	21.3	6.6	29	7.4	53.9	38.7	7.060
10	21.5	7.4	30	12.1	52.4	35.5	2.689

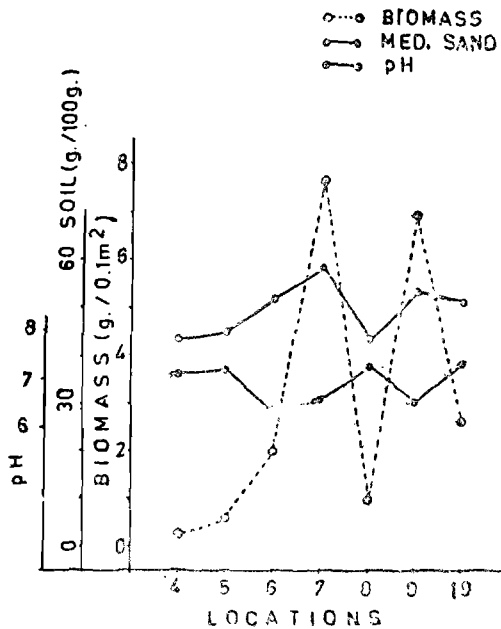


Fig. 3 Biomass, in the preferred moisture range, in relation to pH and medium grade of sand in the soil.

DISCUSSION

Increase in biomass correlates with increase in moisture content of the soil, which conforms with the previous report (Ismail and Kaleemurrahman, 1979), that

progressive burrowing behaviour of the earthworms is displayed between 10 and 30 per cent moisture in the soil. Biomass, which was zero at 1 per cent, negligible at 2 per cent, 7.728 g/0.1 m² at 18 per cent and 7.060 g/0.1 m² at 21.3 per cent moisture, lends support to the view that water is an essential requirement of this terrestrial invertebrate.

That the worms prefer soils with a higher percentage of medium grains, is apparently evident from Fig. 2, which indicates that biomass is considerably low in soils where the quantum of fine grains almost equal or exceed the medium grains. Biomass being more in Location 5 than in Location 4, though having the same moisture percent may be due to two factors (1) The proportion of fine sand which is more than the medium grade in Location 4 and/or (2) the temperature which is higher in Location 4 (32°C) than in Location 5 (30°C).

Lesser biomass in Locations 8 and 10 than in Locations 7 and 9, though the percent moisture was higher in Locations 8 and 10 than in 7 and 9, may be due to the acidic nature of the soil as well as due to the higher percentage of medium sand grains in Locations 7 and 9 (Fig. 3).

Earthworms in the soil thus speak of their habitat. These are more in soils which have more of medium grains, with moisture of about 10 to 25 per cent and are slightly acidic in nature (pH 6.4 - 7.0); slightly alkaline soils (pH 7.0 - 7.8), however, are also tolerated.

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5.3 ENRICHMENT OF SOIL FERTILITY BY EARTHWORM ACTIVITY

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ABSTRACT

Earlier studies indicated that inter-specific zonation exist in three species of earthworms viz. *Pheretima elongata*, *Megascolex mauritii* and *Pontoscolex corethrurus*, irrespective of organic matter of soil layers. The preference of these three species were tested in an earthworm cage ($3' \times 1\frac{1}{2}'$) packed with soil layer composed of different types of organic matter.

The preferential feeding and burrowing activities of *Pheretima elongata* and *Pontoscolex corethrurus* were more confined to the soil layer containing dung than to any other layer. In the next preferential order, these worms preferred layers containing mango, hay, guava and tamarind litter. *Megascolex mauritii* invaded all layers indiscriminately but after 3 weeks concentrated only in soil layer mixed with ash. Greater mineralization and humification of the matter were detected in soil layer with dung and mango litter.

Under field conditions the distribution of these worms varied significantly with reference to leaf litter dominant in that locality. It is therefore concluded that microhabitat niche differentiation in worms is mainly based on the nature of food availability and preference. Probably, to avoid inter-specific competition, the different species have developed preference for specific food which is at certain stage of decomposition.

INTRODUCTION

Earthworms form one of the major biotic fauna, the role of which in preserving the soil fertility and characters has been widely discussed (Lunt & Jacobson, 1944 ; Shrikande and Pathak, 1948 ; Nijhawan & Kanwar, 1952 ; NYe, 1955 ; Satchell, 1958 ; Abaturov, 1972 ; Atlavinite & Vanagas, 1973). Many of these findings suggest that subtle differences exist between the composition of worm casts and that of surrounding soils.

In the present investigation, *Pheretima elongata*, *Lampito mauritii* and *Pontoscolex corethrurus* which showed interspecific zonation in cages with uniform soil conditions (Kale *et al.*, 1977) were further experimented to find out their food preference, degree of decomposition of different types of organic matter and mixing up of the materials in the given area of soil due to preferential feeding and resting zones.

MATERIAL AND METHODS

Earthworms were collected from gardens and maintained in laboratory in culture pots. One hundred adult worms of each species with well-developed clitellar region were used for each set of experiment.

Preparation of organic matter

Powdered dry cow dung, ash, and leaf litter of mango (*Mangifera indica*), guava (*Psidium guajava*), tamarind (*Tamarindus indica*), hay (*Oryza sativa*) were weighed and mixed with red clay loam. The final concentration of organic matter in the mixture was around 15 mg/kg of soil except in ash where it remained 12.6 mg/kg.

Layers of soils in glass cages

Both vertical and horizontal stratification of the soil layers thus prepared from different sources of material was maintained in different glass cages (45 x 90 x 1 cm). Each 15 cm layer differed qualitatively with reference to the organic matter content but not so with regard to quantity except in the layer containing ash.

Chemical analysis

Cages were disturbed four weeks after introducing the worms. The layers were separated and after oven drying at 120°C for 48 hr soils were used for chemical analysis. Oxidizable carbon was estimated titrimetrically according to the method of Walkey and Black (1947), phosphorus was determined colorimetrically (Olsen *et al.*, 1954) and the turbidometric method of Dutta *et al.*, (1963) was adopted for potassium estimations. Calcium was estimated titrimetrically (Jackson, 1967). Humic and fulvic acid ratios were measured according to Kononova (1966).

The analysis were carried out in worm activated soils and in soils unexposed to worm activity for comparison.

RESULTS AND DISCUSSION

Feeding and Settlement

Active feeding and burrowing of *Pheretima elongata* and *Pontoscolex corethrurus* in the first week was restricted to soil layer containing dung than any other layers. Later they spread their activities to other layers in the following order : mango, hay, guava and tamarind leaf litter. *Lampito mauritii* on the other hand invaded all the layers indiscriminately. By the end of three weeks, a majority of worms belonging to all the three species were found settling in the layer of soil mixed with ash.

Soil fertility levels

The analysis of excreta and soils collected from natural inhabitations revealed that variations in humified matter in excreta show an increase or decrease depending on availability of the material in surrounding soil (Table 1). Levels of oxidizable carbon, and minerals like calcium also have shown similar variations (Table 1). Such differences in the composition of available forms of minerals, carbon and

TABLE I
*Composition of soil and castings of earthworms Pontoscolex corethrurus
and Lampito mauritii*

Parameter	<i>Lampito mauritii</i>		<i>Pontoscolex corethrurus</i>	
	Soil	Castings	Soil	Castings
H/F	4.2	6.64	4.2	9.4
C/N	3.2	6.6±	3.2	6.8
Ionisable calcium (µg/g)	12.0	147	12.0	117.0

phosphorus levels are reported by earlier workers in worm casts (Shrikhande & Pathak, 1948 ; Nijhawan & Kanwar, 1952 ; Satchell, 1958). Soil layers mixed with ash, dung, hay and guava showed a higher rate of humification of soil (Table II) than those of controls. The excrements left for burrow packing in the regions of settlement specially in soil mixed with ash and guava leaf matter might have influenced the activity of microflora that has brought about further degradation of organic matter.

TABLE II
Influence of earthworm activity on soil humification (h/f ratios)

Source of organic matter	Control soils	Worm activated soils
Ash	8.7	5.6
Mango	7.4	7.1
Dung	9.3	7.8
Hay	8.7	7.7
Tamarind	7.8	7.3
Guava	9.0	6.3

Increase in available phosphorus, calcium and potassium is highly significant in layers containing organic matter of guava, tamarind and hay (Table III). It can be said from these observations that the nature of available food mostly influences worm activity and in turn soil fertility due to selective feeding and drifting of fine particles of organic matter into soil.

The nature of organic matter available in a given habitat might act as one of the reasons for microhabitat variations observed among these local species.

TABLE III
*Influence of earthworm activity on levels of available potassium, calcium, phosphorus and oxidizable carbon in glass cages
layered with different kinds of organic matter*

Source of organic matter	Available phosphate μg/g soil			Potassium μg/g soil			Calcium μg/g soil			Oxidizable carbon μg/g soil		
	Initial level	% variation after experiment		Initial level	% variation after experiment		Initial level	% variation after experiment		Initial level	% variation after experiment	
Ash	57±10.4	72		249±5.8	86		15±2.0	84		12±0.9		142
Mango	28±8.6	10		97±1.2	82		13±1.2	50		16±0.8		92
Dung	40±1.9	23		136±5.8	77		14±0.8	50		17±2.5		92
Hay	4±1.6	158		48±1.7	123		7±0.4	163		16±1.2		96
Tamarind	5±1.5	142		80±1.2	127		6±0.8	106		15±0.6		100
Guava	6±1.4	148		49±1.1	144		7±1.9	114		13±0.5		104

CONCLUSIONS

Earthworms are selective to choose a particular leaf litter present in the soil for their feeding activity. Worm movements penetrating the layers of soil with different litter, help mixing up of the litter for microbial degradation. Local species exhibit specific, vertical or horizontal zonations in their feeding and locomotor activities. This behaviour might be responsible for the micro habitat variations found among them.

We thank Dr. R. Narayana, Director of Instruction, Basic Sciences & Humanities for his interest in the study and for encouragement.

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5.4 ANTHROPOCHOROUS EARTHWORMS OF LAHAUL VALLEY (HIMACHAL PRADESH) WITH NOTES ON THEIR ECOLOGY

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This article presents the results of a study of the first earthworms that have been collected from the Lahaul Valley in western Himalayas at altitudes ranging from 2700 to 3600 m. As a result, six exotic species belonging to the family Lumbricidae, viz., *Aporrectodea rosea* (Savigny), *A. trapezoides* (Duges), *A. tuberculata* (Eisen), *Bimastos parvus* (Eisen), *Dendrobaena rubida* (Savigny) and *Octolasion tyrtaeum* (Savigny) are recorded. The original home of these species is Europe. In India, lumbricids are believed to be introduced to the hilly areas by the British unintentionally along with the soil around the roots of exotic plants within the last 150 years. Occurrence of anthropochorous (transported by man usually unintentionally) lumbricids in the Lahaul Valley is attributed to their transportation along with the soil around the willow, poplar and other trees from different parts of Himachal Pradesh.

The most important factors influencing the introduction of earthworms seems to be a great adaptability to new environments and a parthenogenetic mode of reproduction. The lumbricids are able to withstand the rigors of an extreme cold climate. Of the six anthropochorous lumbricid species in the Lahaul Valley, 4 are parthenogenetic and in one species parthenogenesis is suspected.

INTRODUCTION

Nothing is known about the earthworm fauna of the Lahaul and Spiti districts of Himachal Pradesh. This article presents the results of a study of the first earthworms that have been collected from the Lahaul Valley at altitudes ranging from 2700 to 3600 m. The material comprises 643 specimens collected by Shri K. K. Mahajan of High Altitude Zoology Field Station, Zoological Survey of India, Solan, during the faunistic survey of the area in 1970 and 1971. All of the worms obtained are referable to six anthropochorous (transported by man usually unintentionally) species belonging to the family Lumbricidae, viz., *Aporrectodea rosea* (Savigny), *A. trapezoides* (Duges), *A. tuberculata* (Eisen), *Bimastos parvus* (Eisen), *Dendrobaena rubida* (Savigny) and *Octolasion tyrtaeum* (Savigny). A set of figures united with dashes, e.g., 2-0-9 before locality in the material means that 2 juveniles, 0 a clitellate and 9 clitellate specimens were collected.

TOPOGRAPHY OF THE AREA

The Lahaul Valley of Lahaul and Spiti districts of Himachal Pradesh lies in the north-western part of India beyond the Great Himalayan Divide. It is physically a

closed unit comprising a vast mountainous area of 5,760 sq. km separated by high ranges from Jammu and Kashmir on the north, Kulu district on the south, Spiti on the east and Chamba district on the west. The general topography of the area is of high mountain ranges and narrow river valleys. The Chandra and Bhaga rivers, which constitute the Chandrabhaga or the Chenab river after their confluence at Tandi, form the drainage system of the valley. The general elevation is above 2700 m with greater part of the area having elevations ranging from about 4000 m to 6000 m, some of the peaks being above 6400 m.

The climate of Lahaul is dry and cold. The average annual rainfall varies between 457 mm and 635 mm depending upon the part of the valley. The whole of the valley is usually covered with snow from the middle of December till the end of April. The maximum temperature at Keylong (the district headquarters) ranges from 7°C in February to 23°C in August while the minimum temperature ranges from -10.5°C in February to 10.1°C in July.

Owing to high elevations and severe climatic conditions the valley does not possess good forests. There are only a few natural and scanty forests of pine, cedar and birch. Willows and poplars have been cultivated near villages wherever irrigation is available. Broadly, the following vegetational zones can be recognized according to the altitude (Mamgain, 1975) :-

1. *Between 2590 to 3350 m* : Maximum vegetation is found in this zone. The common plants are pencil cedar (*Juniperus macropoda*), blue pine (*Pinus excelsa*), birch (*Betula utilis*), spruce (*Picea morinda*), willows (*Salix fragilis*, *S. viminalis*, *S. insignis*), poplars (*Populus nigra*, *P. balsamifera*), *Hippophae* spp., *Pyrus* spp. and walnut.
2. *Between 3350 to 4875 m* : This zone is characterized by the absence of trees. Juniper, birch and *Rhododendron* spp. are found as shrubs and that too up to maximum altitude of about 4270 m.
3. *Between 4875 to 5200 m* : This zone has the minimum vegetation. The most characteristic plant of this zone is *Rheum moorcroftiana* which does not occur below this height.

SYSTEMATIC ACCOUNT

Family Lumbricidae

Aporrectodea rosea (Savigny)

Enterion roseum Savigny, 1826. *Mem. Acad. Sci. Inst. France*, 5 : 182.

Eisenia rosea : Gates, 1972. *Trans. Am. phil. Soc.*, 62 (7) : 104.

Material examined : 9-4-18 ; Keylong, 3150 m ; 16, 18, 21.viii.71. 18-39-56 Sissu, 3100 m ; 28-31.viii.71.

Habitat : Sandy loam soil ; grassland, cultivated fields of barley, potato and buck wheat ; in the vicinity of irrigation channels and willow plantation.

Remarks : The specimens are unpigmented. Spermathecae two pairs near mid-dorsal line at 9/10 and 10/11. Iridescence lacking on spermathecae, testes and male funnels (reproduction parthenogenetic). Length 52-85 mm, diameter 2-2.5 mm ; number of segments 82-125. Clitellum in segments XXV-XXXII (5), XXV/n-XXXII (2), XXV-XXXIII (5) ; tubercula puberatis in XXIX-XXXI (12). The original home of *A. rosea* is in Europe. The species is also found in North and South America, Africa, Asia and Australia. The maximum altitude for this species given by Gates (1972) is 2600 m. The present record extends its range to an altitude of 3150 m.

Aporrectodea trapezoides (Duges)

Lumbricus trapezoides Duges. 1828. *Ann. Sci. Nat.*, **15** : 289.

Allolobophora trapezoides : Gates, 1972. *Trans. Am. phil. Soc.*, **62** (7) : 76.

Material examined : 0-0-16 ; along the Chandra river, about 2 km west of Sissu, 3100 m ; 31.viii.71.

Habitat : Sandy loam soil ; cultivated fields of buck wheat and in the vicinity of willow plantation.

Remarks : Pigmentation is brownish. Spermathecae two pairs in *CD* at 9/10 and 10/11. Iridescence lacking on the spermathecae, testes and male funnels (reproduction parthenogenetic). Length 65-90 mm, diameter 3-4.5 mm ; number of segments 98-160. Clitellum in segments XXVI/n-XXXIV (2), XXVII-XXXIV (9) tubercula puberatis in XXX-XXX III (2), XXX I-XXX III (9) *A. trapezoides* is of European origin. The species is also known to occur in North and South America, Africa, Asia and Australia. According to Gates (1972), this species occurs at a maximum altitude of 1768 m. Subsequently, Julka (1977) records *A. trapezoides* at an altitude of 2682 m in Sikkim. The present record further extends its range to an elevation of 3100 m.

Aporrectodea tuberculata (Eisen)

Allolobophora turgida f. *tuberculata* Eisen, 1874. *Ofvers K. Vetensk. Akad. Forhandl. Stockholm*, **31** : 43.

Allolobophora tuberculata : Gates, 1972. *Trans. Am. phil. Soc.*, **62** (7) : 79.

Material examined : 0-0-12; along the Chandra river, about 2 km west of Sissu, 3100 m; 31. viii. 71. 0-0-1; Madgraon village, about 3 km west of Udai-pur, 2725 m; 10. ix. 71.

Habitat : Sandy soil; under stones in the cultivated fields of buck wheat, maize and kuth.

Remarks : The specimens are without any pigmentation. Spermathecae two pairs in CD at 9/10 and 10/11. Iridescence present on spermathecae, testes and male funnels, and in one specimen a spermatophore was found attached to the ventral surface of body in AA on XXV (amphimictic reproduction). Length 80-115 mm; diameter 3 mm; number of segments 142-159. Clitellum covers segments XXVII-XXXIV (3), XXVII/n-XXXV (1); tubercula puberatis is in XXXI-XXXIII (4). The original home of *A. tuberculata* is in Europe. This species has been recorded from North and South America, Asia and Australia. *A. tuberculata* is known to occur up to a maximum elevation of 2400 m (Gates, 1972). The present record extends its range to an altitude of 3100 m.

Bimastos parvus (Eisen)

Allolobophora parva Eisen, 1874. *Ofvers K. Vetensk. Akad. Forhandl. Stockholm*, **31** : 46.

Bimastos parvus : Gates, 1972. *Trans. Am. phil. soc.*, **62** (7) : 87.

Material examined : 0-0-31; Keylong, 3150 m; 31.vii.70. 0-0-7; Keylong; 14, 16, 18.viii.71. 0-0-2; Sansa, about 1 km of Kirting, 3050 m; 2.ix.71.

Habitat : Sandy soil; cultivated fields of potato, cabbage and barley; near irrigation channels near willow and poplar plantations.

Remarks : The specimens are reddish in colour. Spermathecae absent and testes and male funnels without iridescence (parthenogenetic reproduction). Length 13-34 mm, diameter 1.5-3 mm; number of segments 57-103. Clitellum is in segments XXIII-XXX (4), XXIV-XXX (33). XXIV-XXXI (1); tubercula puberatis is absent. The original home of this species is in North America. *B. parvus* is known to occur in Europe, North America and South America, Asia, South Africa and Australia. This species has been recorded at a maximum altitude of 3330 m (Gates, 1972).

Dendrobaena rubida (Savigny)

Enterion rubidum Savigny, 1826. *Mem. Acad. Sci. Inst. France*, **5** : 182.

Dendrobaena rubida : Gates, 1972. *Trans. Am. phil. Soc.*, **62** (7) : 92.

Material examined : 9-10-60 ; Keylong, on the bank of the river Bhaga, 3150 m ; 31.vii.70. 1-4-9 ; Keylong ; 1.viii.70. 0-0-8 ; Patsu, in the vicinity of P.W.D. Rest House, 3600 m ; 10.viii.70. 0-0-20 ; near Sandher Bridge, about 5 km from Jespa, 3300 m ; 12.viii.70. 0-0-10 ; Khoksar ; on the edge of a pond, 3300 m ; 22.vii.71. 0-3-25 ; Keylong ; 14, 21.viii.71. 0-2-26 ; Jespa, on the bank of the river Bhaga near P.W.D. Rest House, 3245 m ; 24, 25.viii.71. 8-5-24 ; Sissu, on the bank of the river Chandra and in the vicinity of Yading village, 3100 m ; 28-30.viii.71. 0-3-20 ; Sansa, about 1 km west of Kirting, 3050 m ; 2.ix.71. 0-4-12 ; Rappe village, near sulphur spring about 1.5 km east of Kirting ; 4.ix.71. 8-22-132 ; Udaipur, on the bank of the Chenab river, hills along Miyar Nalla and Kukum Seri Forest Nursery, 2725 m ; 7, 9-11.ix.71.

Habitat : Sandy loam and alluvial soil ; under stones in river beds, debris, compost ; cultivated fields of maize, barley and potato ; under bark of fallen logs of willow and poplar trees ; forest nurseries ; grasslands.

Remarks : The specimens are reddish in colour. Spermathecae lacking. Iridescence absent on testes and male funnels (reproduction parthenogenetic). Length 20-47 mm, diameter 2-3 mm ; number of segments 58-102. Clitellum is in XXV/n-XXXI (1), XXV/n-XXXII (3), XXVI-XXXI (45), XXVI-XXXI/n (1), XXVI-XXXII (3) ; tubercula puberatis in XXVIII-XXIX (3), XXVIII-XXX (25), XXIX-XXX (24). This species is of European origin. *D. rubida* is also found in North and South America, Asia, Africa and Australasia. Julka (1977) records this species at an altitude of 3900 m in Sikkim.

Octolasion tyrtaeum (Savigny)

Enterion tyrtaeum Savigny, 1826. *Mem. Acad. Sci. Inst. France*, **5** : 180.

Octolasion tyrtaeum : Gates, 1972. *Trans. Am. phil. Soc.*, **62** (7) : 125.

Material examined : 3-2 0 ; Shansa village near Kirting, 3050 m ; 13.ix.71.

Habitat : Sandy soil ; under decaying leaves of pine and willow.

Remarks : All the specimens are either juveniles or a clitellate, and they could only be determined by the location of tubercula puberatis in XXXI-XXXIV. The original home of *O. tyrtaeum* is in Europe. The species is also found in North and South America, Asia, Africa and Australia. Gates (1972) records this species at a maximum altitude of 2800 m. The present record extends its range to higher elevations of 3050 m.

DISCUSSION

Sixteen species of anthropochorous lumbricids, if '*Allolobophora caliginosa*' known from some localities is considered as one species, have been so far recorded from India. All are exotic. Many of these species are also present in North and South America, Africa, Australia, New Zealand and various oceanic islands. One species, *Bimastos parvus*, is of American (Gates, 1958) and the rest are of European origin. All the sixteen species of Indian lumbricids also occur in the British Isles (Gates, 1958, 1972, 1976) from where they are believed to have been transported to various parts of the world in ballast or in soil around the roots of plants. They are presumed to have been transported to India by the British in this manner during the last 150 years (Gates, 1972). The complete picture of lumbricid distribution (Fig. 1) so far available for India shows that they have been able to establish well only in the hilly regions with temperate-like climate above the elevations of 600 m where maximum number of species are found. The number of species occurring in different hilly regions are : Simla-11, Srinagar-4, Lahaul Valley-6, Mussoorie-3, Naini Tal-5, Darjeeling and Sikkim-8, Ootacamund-9, Mount Abu-1. In these areas, they are not only common but also dominant in some part of the year (Gates, 1958). There are a few instances of lumbricid occurrence in the Indo-Gangetic plains and the Nicobar Islands, but they have not been able to successfully colonize there because of subtropical climatic conditions. According to Gates (1958), the lumbricids have an inherent inability to survive in the less rigorous and more equable climate of the tropical lowlands.

The occurrence of six species of lumbricids in the Lahaul Valley is also attributed to their transportation in the soil around the roots of exotic plants. Evidence is available to show that the exotic plants have been introduced to the Lahaul Valley since 1850.

The most important factors influencing the introduction of earthworms seems to be a great adaptability to new environments and parthenogenetic mode of reproduction. The successful colonization of lumbricids in the Lahaul Valley is attributed to their ability to withstand the rigors of an extreme cold climate and a high degree of tolerance for human disturbances of their habitats. According to Ljungstrom (1972), parthenogenesis is a clear advantage to introduced species when arriving in a new environment as a worm does not have to find a mate to reproduce. Of the six lumbricid species in the Lahaul Valley, 4 are parthenogenetic and in one parthenogenesis is suspected.

The most interesting feature of the earthworm fauna of the Lahaul Valley is the complete absence of the endemic species in the area. It is probable that no



FIG.1 - DISTRIBUTION OF LUMBRICIDS IN INDIA

endemic species exist in the valley. If at all they exist, they are to be found in some special ecological niches.

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5.5 COCOON MORPHOLOGY, HATCHING AND EMERGENCE PATTERN OF TROPICAL EARTHWORMS

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ABSTRACT

Cocoon morphology with regard to shape, size, colour, weight, cocoon hatching and seasonal dynamics of cocoons and juveniles of *Octochaetona surensis* (Michaelsen), *Lampito mauritii* (Kinberg), *Drawida calebi* (Gates) and *D. willsi* (Michaelsen), in relation to soil moisture and temperature have been studied. Cocoons of the four species differed among themselves in their morphology. *O. surensis* and *D. calebi* show their distinction by possession of elaborate ornamentation. The average live weights of the cocoons of *O. surensis*, *L. mauritii*, *D. calebi* and *D. willsi* are 31.5, 22.25, 15.175 and 5.8 mg respectively.

In the laboratory at 25°C and 15 g per cent soil moisture, it has been observed that the incubation periods of *O. surensis* and *L. mauritii* are about 4 weeks and for *D. calebi* and *D. willsi* are 8 weeks and 2 weeks respectively. This soil temperature and moisture condition usually is prevalent in the field during November-December. Maximum number of 175 live cocoons (live weight biomass of about 4 g/m²) occurred during late October to early November, 1977. Negligible to nil number of live cocoons occurred during summer months. At 25°C soil temperature and 15 g per cent soil moisture *D. willsi* usually produces 2 cocoons, adult worm-1, yr-1 in the laboratory. In complete hydric and very dry condition (<5 g per cent moisture content) cocoons never hatch.

These surface living species exhibit a single peak emergence of juveniles in December. Worms undergo diapause when soil moisture level falls $< 10\%$ and soil temperature goes around 30°C . Soil moisture shows significant positive correlation ($r = 0.99$, $p < 0.001$) with per cent of cocoon hatching. Temperature plays an important role in inducing diapause in worms. The unimodal emergence pattern and surface living strategy is associated with high number of cocoon production.

5.6

NEMATODE FEEDING BY TROPICAL EARTHWORMS

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ABSTRACT

An experiment was designed to test nematode feeding by the earthworm *Lampito mauritii* Kinberg. Experimental pots in triplicate with no earthworm, 1, 2 and 4 earthworms per pot were set to study their effect on nematode population in a six week study period. The nematode population in the control pots did not change significantly during the six week study period (t -test at 0.01 level) when compared with 1 week culture post.

With 1 earthworm per pot there was 20.54 per cent, 28.54 per cent, 52.65 per cent, 20.03 per cent and 24.31 per cent decrease with regard to original nematode population in 1, 2, 3, 4 and 6 weeks old cultures respectively. Doubling the predator numbers in the experimental pots did not increase the per cent of decrease of nematodes by two folds. After three weeks of predation there was about 53 per cent reduction in nematode population irrespective of the predator number in the pots. After third week there was significant increase ($t = 5.337$, significant at 0.025 level) in nematode population in experimental pots containing earthworms.

Gut content analysis provided evidence of selective feeding of nematodes by earthworms in soil. There was also evidence of selective feeding of non-parasitic nematodes by earthworms. The non-parasitic forms decreased by a maximum of 90 per cent of the original population in 6 weeks against a maximum of 47 per cent decrease in the parasitic forms during the same period.

It is suggested that earthworms can be utilized to control both non-parasitic and parasitic nematodes in agroecosystems.

5.7 PRIMARY PRODUCTION AND ACTIVITY OF OLIGOCHAETES IN A TROPICAL GRASSLAND IN INDIA

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ABSTRACT

The net primary production in a tropical, protected grassland site (*Eragrostis* sp. dominant, at Sambalpur (21°28'N latitude and 83°50'E longitude) with an annual 1340 mm rainfall was about 965 g dry wt, m⁻², yr⁻¹. Some 60 per cent of this production is due to underground parts. This net primary production amounts to about 3830 K cal, m⁻², yr⁻¹. The average monthly plant biomass was 1283 g, m⁻². Oligochaetes are the dominant soil invertebrates (mean monthly biomass of Oligochaetes amount to 55 g live wt (11 gm dry wt), m⁻²) in the site. The amount of secondary production of Oligochaetes including cocoon production amounts to about 131 g (26 g dry wt) m⁻², yr⁻¹. This amounts to 120 K cal, m⁻², yr⁻¹. The population biomass turnover is about 2.5. The amount of secondary production of Oligochaetes amounted to about 2.7 per cent of the net primary production. This value is in conformity with the values given by Dash et al. (1974) for another tropical grassland of India. The index of utilization (ratio of mean monthly plant biomass to mean monthly Oligochaete biomass) is about 117, a value lower than the value given by Breymer (1974) and Dash (1978).

5.8 FUNGAL FEEDING BY ENCHYTRAEIDAE (OLIGOCHAETA) IN A SUBTROPICAL WOODLAND FROM ORISSA

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ABSTRACT

The food preference of three species of Enchytraeidae have been examined by three techniques: 1. Squash preparations; 2. Culturing of gut contents; 3. Selective feeding on pure fungal cultures.

Enchytraeids ingested large amount of organic material and fungi. Fungal material formed some 30 per cent of the gut contents. Anteclitellar part of the body contained significantly higher per cent of the plant and fungal material than the post-clitellar part.

Analysis of gut contents showed that the litter growing fungi, *Rhizopus nigricans* and *Syncephalastrum racemosum*, *Trichoderma viride* are generally digested by enchytraeids and *Penicillium* sp. and *Aspergillus niger* are not digested. Isolations made from post-clitellar gut content did not generally give rise to fungal colonies except for *Aspergillus niger* and *Penicillium* sp.

6 Mollusca

6.1 IMPACT OF SOIL ON THE DISTRIBUTION OF THE GIANT LAND SNAIL *ACHATINA FULICA*

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ABSTRACT

Assessment of the distribution of a pestiferous land snail, *Achatina fulica* Bowdich has been made from different states of eastern India in relation to soil types, pH value and mineral contents. The states of this part of India are characterized by twelve different types of soil with pH ranging from 4.25 to 8.3 and rich minerals. Observations have revealed that the giant land snail mostly prefers alluvial soils with a high percentage of calcium. The snails, however, thrive well in deltic, saline, forest and mixed red and black soils but not in red, lateritic, laterite and gravelly groups of soil. The pH of the soil, on the other hand, apparently has got no impact on the distribution of this snail species.

It appears that the absence of snails in areas with lateritic, laterite, red and gravelly group of soils may be due to dry, non-humid soils imposing limitation on vegetation. However, the snail's preference to alluvium groups of soil might be attributed to greater absorption and retention of moisture by these groups of soils which, in turn, help luxuriant growth of vegetation and offer suitable humid environment for the snail species concerned.

The giant African land snail, *Achatina fulica*, Bowdich is a serious agri-horticultural pest in India as well as in a number of other countries. In India, it was first introduced in 1847. Thereafter sporadic reports on the occurrence and the extent of damage to economic plants by the snail have appeared in a number of journals from time to time (Annandale, 1907 ; Behura, 1955 ; Ghose, 1962 ; Srivastava, 1966 and Raut, 1978). But very little is known about the factors governing the distribution of these snails in India. With a view to understand the same, extensive field observations have been carried out since 1973 in the Eastern Indian states viz. Assam, Meghalaya, Manipur, Nagaland, Tripura, West Bengal, Bihar and Orissa and in this paper the influence of soil on the distribution of the giant snail is presented.

MATERIAL AND METHODS

The methods followed for the study of distribution and estimation of population of *A. fulica* were similar to those of Raut (1979).

Soil samples taken from the infested areas were analysed in the Soil Testing Laboratories of the State Governments, Indian Council of Agricultural Research Institute and the Universities located in different parts of Eastern India. Data supplied by Roychoudhury *et al.* (1963) and Mukherjee (1974) were also taken into consideration.

OBSERVATIONS

The giant land snail *A. fulica* is usually found active during monsoon and over come the dry-hot period by undergoing aestivation. The period of activity of the snail varies with the length of monsoon prevailing in the locality. It is longer in Gauhati, Imphal, Northern part of Tripura and West Bengal. These areas receive occasional summer and winter rainfall. Hence, the soils in these areas remain moist for a longer period than those of the other parts of Eastern India surveyed and thereby offers suitable living conditions for them. The snails' activity is moisture dependent and the moisture of the soil is the key factor in regulating its activity.

A. fulica is common to abundant in most areas of West Bengal, Assam and Bihar while it is restricted to Dimapur of Nagaland, Nongpoh and Phulbari of Meghalaya, Imphal of Manipur, Kumarghat of Tripura and to some parts of Balasore, Myurbhanj and Keonjhar district of Orissa. There are different kinds of soils characterising the Eastern Indian states and distribution of the snail in relation to soils has been shown in Fig. 1. The density varies from 24 to 36 with an average 32 snails per square metre area in alluvial groups (Gangetic and Bindhya alluvial, terai, testa, saline and deltaic) of soil and calcareous mixed with alluvial soils. There have been observed 25 to 32 with an average 29 snails and 10 to 22 with an average 19 snails per square metre from the areas with mixed black and mixed red soils respectively. The snails were not found from areas with red, lateritic and gravelly types of soils.

The pH of the soils was widely variable from one area to the other (Table I). The mineral contents, *viz.*, N, Mg, K₂O and CaO were also variable (Table I). The CaO percentage in some alluvial soils, mixed black and mixed red was a little higher than those of other soils and the snail populations in CaO - rich soils were also higher in comparison to other soil types.

The texture of the soil was variable from one locality to other. In general, alluvial groups of soil are sandy to clay loams, mixed red soil is sandy loam in nature while mixed black soil is generally black clay. Coastal soils are sandy and sandy clay. All these soils are porous and can retain moisture well. On the other hand, laterite, lateritic, red and gravelly groups of soil are hard, non-porous and have very limited power of water absorption. These soils become too hot during dry summer.

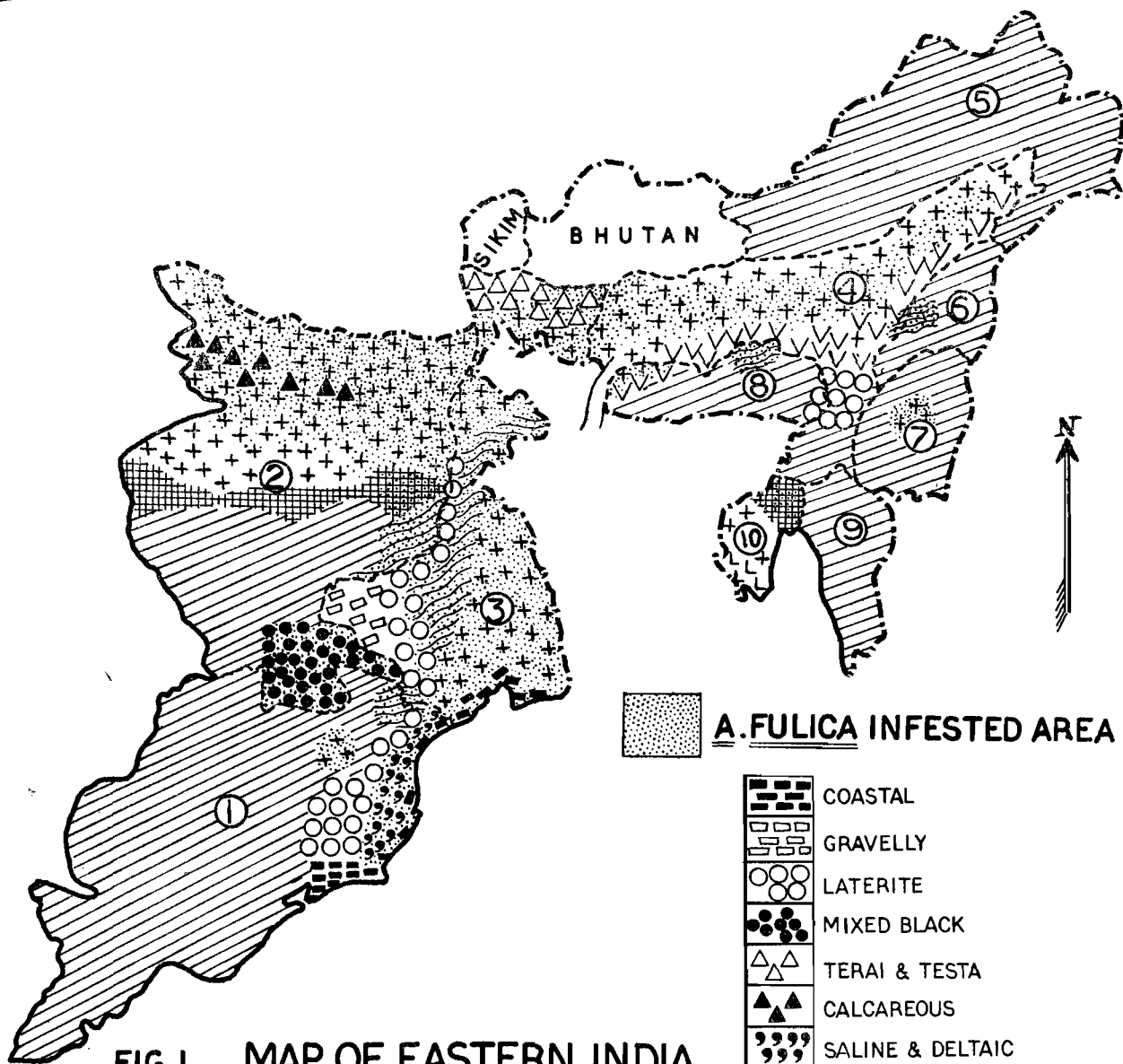


FIG.1. MAP OF EASTERN INDIA
SHOWING DISTRIBUTION OF ACHATINA
FULICA IN RELATION TO SOILS

- ① ORISSA ② BIHAR ③ WEST BENGAL ④ ASSAM
⑤ ARUNACHAL PRADESH ⑥ NAGALAND ⑦ MANIPUR
⑧ MEGHALAYA ⑨ MIZORAM ⑩ TRIPURA

	COASTAL
	GRAVELLY
	LATERITE
	MIXED BLACK
	TERAI & TESTA
	CALCAREOUS
	SALINE & DELTAIC
	ALLUVIAL
	MIXED RED
	RED
	FOREST
	LATERITIC
	YELLOW

TABLE I
Analysis of soils of Eastern India (Per cent dry weight)

Soils	pH	N	Mg	CaO	K ₂ O
Alluvial*	5.5 – 8.2	0.111	0.051	0.14	0.079
Calcareous	8.0 – 8.3	0.065	0.001	0.29	0.03
Coastal	6.1 – 8.2	1.06	0.15	0.56	0.9
Forest	7.0 – 8.0	0.06	0.16	0.04	0.006
Gravelly	5.5 – 7.2	0.04	0.005	0.34	0.01
Laterite and Lateritic	5.5 – 6.5	0.05	0.44	0.02	0.014
Mixed Black	4.2 – 6.0	0.04	0.002	0.7	0.01
Mixed Red	4.7 – 7.2	0.05	0.34	0.35	0.01
Red	4.5 – 7.2	0.052	0.002	0.3	0.01
Saline and Deltaic	6.5 – 7.6	0.32	0.046	0.7	0.77
Teraï and Testa	0.7 – 5.8	0.11	0.082	0.15	0.042

* Including Gangetic, Bindhya and Riverine alluvial soils.

DISCUSSION

In the year 1847, while the giant snail *A. fulica* was first introduced in Calcutta, there was a doubt whether it will survive at all ; if ever it survived, how far can it spread ? But within a decade of its introduction it had spread a good deal. The first report was from Barrackpore (25 km north of Calcutta), the second one from Rajmahal of Bihar (150 km north-west of Calcutta) and after a few years, from North Bengal, Orissa, Bihar and other parts of India. The reason for such rapid dispersal and distribution of the snail may have been the moist soil and humid environment with dense vegetation on one hand and its inherent power of aestivation on the other to over come unfavourable period of draught and dehydration.

The ecological conditions of Eastern India where different kinds of alluvial soil, mixed black soil and mixed red soils are found, are favourable for the snails' survival and multiplication. The snails prefer alluvial groups of soil most. But are also thriving well in some areas having mixed black and mixed red soils. The absence of this snail species from areas with laterite, lateritic, red and gravelly group of soils suggests that the soil may impose certain limiting factors in distribution. It is probably due to the fact that laterite, lateritic, red and gravelly group of soils become too hot in sunny summer days and are incapable of retaining moisture. On the other hand, alluvium soils and to some extent mixed black and mixed red soils can conserve moisture well, thereby are suitable for luxuriant growth of vegetations, and in turn, offer suitable humid environment to the animals living there.

The density of the snail is higher in areas with alluvial soils and a gradual decline is recorded in mixed black and mixed red soils. The looseness of the alluvial soils, is helpful for the snail to burrow deep into the soil for laying eggs and aestivation. This ensures rapid multiplication and low mortality. The mixed black and mixed red soils are to some extent hard and stiff, susceptible to quick drying and heat. These conditions are comparatively unfavourable for healthy propagation and survival. As a rule the snail aestivates during dry-hot period for as long as eight months (Raut and Ghose, 1977 ; Raut, 1978) in some areas of this part of India. The aestivating snails tolerate gradual dehydration of body water up to a certain period but finally the snails die, if prolonged (Raut and Ghose, In press). This phenomenon is obviously met with the snails occupying areas covered by mixed black and red soils. The snails, if ever are brought to the areas with gravelly, laterite and lateritic soils, would face the severness of the unfavourable conditions and probably may not be able to survive. However, at present *A. fulica* is not found in red soils but it is expected that in near future it would be able to spread in these areas with red soils, as these, in most cases, are admixture of alluvial soils with sand and clay. And, now a days, inplantation is going on in these soils by the forest department.

Apart from soil moisture, other factors like pH, N, Mg, K₂O, CaO have got little importance in distribution of land snails. *A. fulica* can survive equally well in acid and alkaline soils with any percentage of N, K₂O, Mg and CaO, though a preference for soils with high percentage of calcium may be noticed. Burch (1955), in a study of land snails in eastern Virginia, found an increase in numbers with increase of calcium, magnesium, potassium and organic contents of the soil. Fromming (1956) noted no effect from the addition of trace metals to the soil. Carrick (1942) found that *Agriolimax agrestis* withstands a wide range of pH. Burch (1955) reported that land snails are abundant at pH 6.3 to 6.7. Three greenhouse snails studied by Karlin (1956) were flourishing on acid soil with pH range of 5.5 to 6.2. In his study of land pulmonates in Britain, Boycott (1934) listed 8 of 102 species as obligatory calciphiles, 11 more as nearly so, and 45 as indifferent to a calcareous substrate. One species, *Zonitoides excavata*, is actually negative to limey soils inhabiting acid heaths and woods. According to Bishop (1977) abundance of litter feeding animals may be related to the carbon to nitrogen ratio and the calcium content of the litter. However, the snails need calcium for the growth of shell and formation of outer calcareous covering of the egg.

From the foregoing account it may be concluded that the distribution of the gaint land snail is dependent on a number of abiotic factors like humidity, temperature and rainfall but the type, nature and texture of soils have also an important role to play.

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7. Myriopoda

7.1 OBSERVATIONS ON THE MATING HABIT OF THE MILLIPEDE, *STREPTOGONOPUS JERDANI* (DIPLOPODA : ARTHROPODA)

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ABSTRACT

Observations on the breeding habit of the millipede, *Streptogonopus jerdani* (Pocock) revealed that mating took place during the months of June and July. Before copulation the females were observed carrying the males on their backs. Soon after, the female was seized by the male with the help of gnathochilarium and gonopods were charged into the female genital pore. Copulation lasted for 10 to 20 minutes. No coiling was observed during mating.

The millipede, *Streptogonopus jerdani* (Pocock) was reported to occur for the first time in Karnataka by Rangaswamy and ChannaBasavanna (1969). The male and female reproductive patterns of this species have been studied (Rangaswamy *et al.*, 1976). The paired genital opening is situated on the second sternite and in male the seventh segment bears paired gonopods ventrally in place of the first pair of legs and this distinguishes males from females.

The specimens of *S. jerdani* collected during June-July, 1978 at the Agricultural College Campus, Dharwad, were maintained in glass jars containing loose moist soil and humus in the laboratory for studying their mating habit.

The female is elongate, cylindrical, dark brown in colour and slightly long and stouter than the male. The body consists of 19 segments and measures 28 mm in length and 3.5 mm in width. The male is also dark brown in colour and measures 25 mm in length and 3 mm in width with elongate cylindrical body consisting of 19 segments and is slightly smaller than the female.

In the present studies mating took place under confinement, observations were also made on mating under field conditions. The male was aggressive, approached the female from behind and climbed on its back, the female then moved for sometime carrying the male on its back. This is an unique feature found only in this species. Later the female settled at a place at which time the male, moving towards the ventral surface of the female, seized the gnathochilarium of the

female with the help of the mandibles and embraced most of the female's body with a broader grasp. In this position the last seven segments of the female laid outside, the remaining segments being firmly grasped by the male during copulation. Before the copulation, the male charged its gonopods into the female genital pore, moved them forwards and backwards for a few minutes and then became closely applied to the female. The copulation lasted for 10 to 20 minutes.

During copulation, the position assumed by male and female varies in different species. In *Phyllogonostreptus nigrolabialis* (Newport) the male has been reported to coil around the female (Rangaswamy, 1969), while in *Polydrepanum* sp. and also *Chondromorpha severinii* Silvestri the male and female lay side by side and no coiling was involved during copulation (Rangaswamy, 1973 and Rangaswamy *et al.*, 1971). In *S. jerdani* too coiling was not noticed during mating.

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7.2 RELATIVE RATES OF LITTER DECOMPOSITION AND HUMIFICATION OF VARIOUS SOILS BY THE MILLIPEDE *JONESPELTIS SPLENDIDUS*

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ABSTRACT

Polydesmoid Millipede *Jonespeltis splendidus* was reared and fed on different types of soils such as sandy loam, sandy soils, clay loam, clayey soils and loamy soils etc. As these animals are soil and litter feeders, they preferentially and selectively ingest decaying organic matter along with the soil and deposit organic residues of humus in the form of flat, bipartite crumbs which are darker in colour than the surrounding soils. Analyses of these crumbs yielded results indicating significant increases in the oxidizable carbon, total carbon and the C/N ratios in the soils they fed upon. The organic matter or the litter was also analysed to estimate different humification factors, and it was found that the total carbon, oxidizable carbon, total nitrogen and the C/N ratios were more compared to those of the surrounding soil. The ratios of humic to fulvic acids were compared, and were found to be low in the excrements than in the soils and litter, indicating humification of the soils by these millipedes. Among the various types of soils used in the experiments, the sandy loam was found to undergo humification at a faster rate. The above results suggest that the soil fertility is increased consequent to the presence of these millipedes.

INTRODUCTION

Arthropods and earthworms are the primary (biotic) factors in converting forest litter to the organic portion of the humus (Eaten and Chandler, 1942). According to Edwards (1967) millipedes consume large amount of litter, and are one of the most important groups involved in litter breakdown in temperate woodlands. Among diplopods, polydesmids digest woody plant residues and are able to mix organic and inorganic material in soil (Kuhnelt, 1976). Romell (1935) reported that millipedes of the genus *Fontaria* (Polydesmidae) contribute to the mull formation by feeding on soft decayed leaves. Kubiena (1950) emphasized diplopods as major macroarthropods responsible for maintenance of soil structure and fertility.

Millipedes are found in three different strata in the woodland habitat :

- 1) on the floor and aerial parts of vegetation,
- 2) in litter and soil,
- 3) under barks and rotten woods.

The flat back, polydesmid millipedes are soil and litter dwellers. These are instrumental in comminuting forest floor litter (Gere, 1956 ; Bocock, 1963). The direct effect of the millipede activity on the decomposition of leaf litter is its acceleration due to comminution and providing extensive surface area for the microbial activity. Among the number of indirect effects, which are associated with millipede activities, are the transformation of plant residues to humic substances, formation of complex aggregates in the soils, mixing up of the organic matter with mineral parts of the soils and improving aeration and drainage by their burrowing activity.

All these effects are well accomplished by the activity of the polydesmid millipede *Jonespeltis splendidus*.

Millipedes exhibit food preference (Schmidt, 1952; Barlow, 1957; Drift, 1965), and are highly selective like the earthworms (Satchell, 1967 ; Kale *et al.*, 1977). This selection may be due to the influences of acceptance and rejection factors present in the food, which the millipedes might be capable of distinguishing like the insects (Diether, 1937; Thornsteinson, 1953, 1960; Kheiralla, 1966). Millipedes are saprophagous, preferably feed on the dead decomposing plant material. Highly moist and decomposed leaf litter is palatable to millipedes, perhaps due to their soft texture attained after leaching out the polyphenols and tanin materials which are not acceptable to soil animals in general. This may be one of the rejection factors in the food along with several others unknown.

MATERIAL AND METHODS

The experiments were conducted in the laboratory. In the first experiment the millipede, *Jonespeltis splendidus*, was reared on different types of soils such as brown sandy loam, black sandy loam, red clay, black clay, brown loam, black loam, brown clay loam and black clay loam. These soils were used, because the millipedes were observed in all types of soils.

In the second experiment millipedes were reared on different types of leaf litter spread over a layer of sandy loam soil, in different glass troughs. The leaf litter used were mango (*Mangifera indica*), cassia (*Cassia javanica*), coffee plantation leaf litter of MRS, UAS., Bangalore and mixed deciduous leaf litter of Lalbagh Garden, Bangalore.

In both the experiments the animals were allowed to establish themselves well in their microhabitat. Fresh excrements were collected. Control experiments were simultaneously maintained. The humificative factors such as organic carbon, total nitrogen, C/N ratio and H/F ratio of the soil, litter and excrements were determined.

Chemical analyses

Per cent oxidizable organic carbon was estimated volumetrically by oxidation of samples with potassium dichromate in conc H_2SO_4 (Walkley-Black, 1947).

Total per cent nitrogen content was determined by micro-kjeldhal method. Digestion of the samples were carried out by boiling in conc. H_2SO_4 in the presence of selenium, K_2SO_4 and $CuSO_4$ as catalysts. The percentage total nitrogen was estimated titrimetrically after distillation of the digested samples.

The humus compounds such as humic and fulvic acids were extracted into 0.01 M NaOH over a boiling water bath for eight hours. The optical densities of the extracts were measured at 465 nm and 665 nm using a Beckman DV-2 spectrophotometer.

The rate of humification of the different soils and the decomposition of the leaf litter are indicated in the excrements by the changes in oxidisable C, total N, and H/F ratios.

RESULTS

Changes in OC, total N, C/N ratio and H/F ratios of different soils used in the experiment are shown in Table I. Among the soils tested the excrements with brown

TABLE I
Changes in humification parameters of soils due to defaecation activities of mixed populations of Jonespeltis splendidus

Sl. No.	Type of soil	O.C(%)	N(%)	C/N	H/F
1.	Brown Sandy loam	1.75	0.23	1.76	—11.8
2.	Black Sandy loam with peat & Muck	1.71	—0.69	2.6	2.59
3.	Red Clay	2.55	0	1.15	1.72
4.	Black Clay	—1.05	0.28	—0.87	—1.0
5.	Brown loam	—2.10	0	—0.90	—0.2
6.	Black loam	8.33	—0.28	4.24	—0.03
7.	Brown Clay loam	0.60	—0.29	0.03	—0.84
8.	Black Clay loam	4.50	0.28	1.81	0.48

sandy loam seem to be highly humified during the passage through the gut, where the H/F ratio is lowered to a larger extent, compared to the other type of soils.

Though greater increment of oxidizable carbon and C/N ratios is observed with black loam.

The degradation of different litter types due to millipede activity is shown in Table II. Both OC and total N are depleted sufficiently in all types of litter. The activities reduced 50 per cent of OC of the mango and *Cassia* litters, though mango litter contains more OC than *Cassia*. The decrease in all the humificative parameters

TABLE II
Decomposition rates of different litter types by the millipede, Jonespeltis splendidus, in sandy loam soils

Type of litter	OC (%)	N (%)	C/N	H/F
Mango litter	22.05	4.34	5.08	13.66
Excrement	11.85 ±	0.047 ±	10.96 ±	7.10 ±
(4)	0.653	0.047	0.200	0.875
<i>Cassia</i> litter	14.55	2.71	7.10	13.22
Excrement	7.45 ±	1.02 ±	7.28 ±	6.92 ±
(4)	1.145	0.094	0.475	1.514
Coffee litter	37.05	3.79	9.77	22.00
Excrement	9.40 ±	1.82 ±	5.16 ±	6.38 ±
(4)	0.975	0.184	0.240	0.317
Mixed deciduous litter	31.05	4.34	9.27	14.00
Excrement	13.20	1.36	9.71	5.88

Number in parenthesis denotes the sample size.

is large in coffee litter than in any other type studied. Table III shows the humification by males and females. It is evident from the table that the rate of humification by females is not significantly different than that by the males.

TABLE III
Changes in humification parameters of soil due to defaecation activities of the male and female adults Jonespeltis splendidus

	OC(%)	N(%)	C/N	H/F
Control (Red Clay Soil)	0.45	0.43	1.04	18
Excrement of males	1.75 ± 0.229	0.61 ± 0.113	2.47 ± 0.843	9.87 ± 2.390
Excrement of females*	1.5 ± 0.122	0.456 ± 0.026	3.29 ± 0.260	11.52 ± 3.20

* mean ± S.D. of 6 experiments.

DISCUSSION

From the above results it could be inferred that the millipede, *Jonespeltis splendidus*, is active in all the microhabitats provided. Their main requirements for survival is the moisture content, besides the presence of leaf organic matter. It was noted that this millipede preferred sandy loam soils to other types of soils. The relative rates of humification of the soils is dependent on the types of soil and litter.

Millipedes are able to consume any type of litter which is soft and decomposing. Though they were more populated in Lalbagh garden compared to the coffee plantation at Hebbal, they seem to favour the litter of coffee plantation to larger extent than any other litter type. However in Lalbagh soils too they are highly contributing to the enrichment of soils by maintaining the C/N ratio at 1:10₄ (Table II).

In the experiment on food preference, the millipede preferred mango leaf litter to the other types. From the other experiments on the feeding rates, it could be concluded that the millipede, *Jonespeltis splendidus*, ingests large quantities of less nutritive food (soils) than highly nutritive food. This has been proved by Khierallah (1966) in other millipedes.

The authors wish to acknowledge Dr. R. Narayana, Director of Instruction, College of Basic Sciences and Humanities, University of Agricultural Sciences, for his encouragement.

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8. Arachnida

8.1 SOME SOIL PROSTIGMATID MITES (ACARINA) FROM BIHAR

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ABSTRACT

Twelve species of prostigmatid mites belonging to Cunaxidae, Cheyletidae, Stigmaeidae and Tydeidae from soil samples from in and around Patna are treated in this paper. The list of the species are as follows : Cunaxidae—*Cunaxa setirostris* (Hermann), *Dactyloscirus pataliputraensis* sp. nov., *Neocunaxoides andrei* (Baker and Hoffmann), *Cunaxa* sp., *Cunaxoides* sp. nov. ; Cheyletidae—*Cheyletus eruditus* (Schränk), *C. fortis* Oudemans, *Acaropsis docta* (Berlese) ; Stigmaeidae—*Agistemus* sp., *Cheyllostigmaeus* sp.; Tydeidae—*Pronematus tenuisetosus* Meyer and Rodriguez, *Triophtydeus* sp. ; Erythraeidae—1 Undet. species ; Trombiculidae—Undet. species. Among these *Neocunaxoides andrei* (Baker and Hoffman), *Pronematus tenuisetosus* Meyer and Rodriguez and the genera *Dactyloscirus* and *Triophtydeus* are new reports for India.

INTRODUCTION

Our knowledge of the soil acarine fauna is, by and large, limited to the mesostigmatid and oribatid mites and practically nothing is known about the soil prostigmatid mites from India. This is obviously so, since the soil prostigmatid mites are minute and extremely soft bodied, many either do not come out while extracting, as some die at the time of heating of soil samples, or get damaged making them unsuitable for studies. However, during the studies by the Coordinated Research Project on Soil Microarthropods of India, regular soil samples were taken from sugarcane, maize and sorghum fields from in and around Patna during May-December, 1978 and a good number of prostigmatid mites could be collected. The present paper is based on a part of that collection and deals with the families : Cunaxidae, Cheyletidae, Stigmaeidae and Tydeidae. Of the 12 species treated, one under *Dactyloscirus* (Fam. Cunaxidae) is described as new and one species each under Cunaxidae and Tydeidae are new reports for India. The genera *Triophtydeus* and *Dactyloscirus* are also reported here for the first time from India. All the families treated here are by and large associated with plants and hence their reports from soil are indeed interesting. Some specimens of Trombiculidae and Erythraeidae are also represented in the collection but their specific identity could not be ascertained for the present.

Family : **Cunaxidae**

1. *Cunaxa setirostris* (Hermann)

Scirus setirostris Hermann, 1804, *Mem Apteologique*, 62

Material examined : 1♀, Patna, Sekhpura, 18.v.1978, ex soil from maize field.

Remarks : This is a cosmopolitan species and from India it has been reported in Uttar Pradesh from soil by Singh and Mukherji (1971).

2. *Cunaxa* sp. ?

Material examined : 1♀, Patna, Mithapur Agricultural Farm, 14.viii. 1978, ex. soil from sorghum field.

Remarks : So far this genus is known from India by one species. The present specimen is quite interesting and appears to be a new one.

3. *Cunaxoides* sp. nov.

Remarks : This genus has so far not been reported from India and not much information is available from the world either (Smiley, 1975). Absence of conspicuous dorsal shield, propodosoma and hysterosoma striated, palpi 3-segmented and distal segment claw like are some of the characteristic features of this species. This species appears to be an undescribed one. In view of the present material being in damaged conditions, the species is not described for the present until further material is available.

4. *Neocunaxoides andrei* (Baker and Hoffman) ?

Cunaxoides andrei Baker and Hoffman, 1948, *An. Esc. Nac. Cenc. Biol. Mex.* 5 : 249-250.

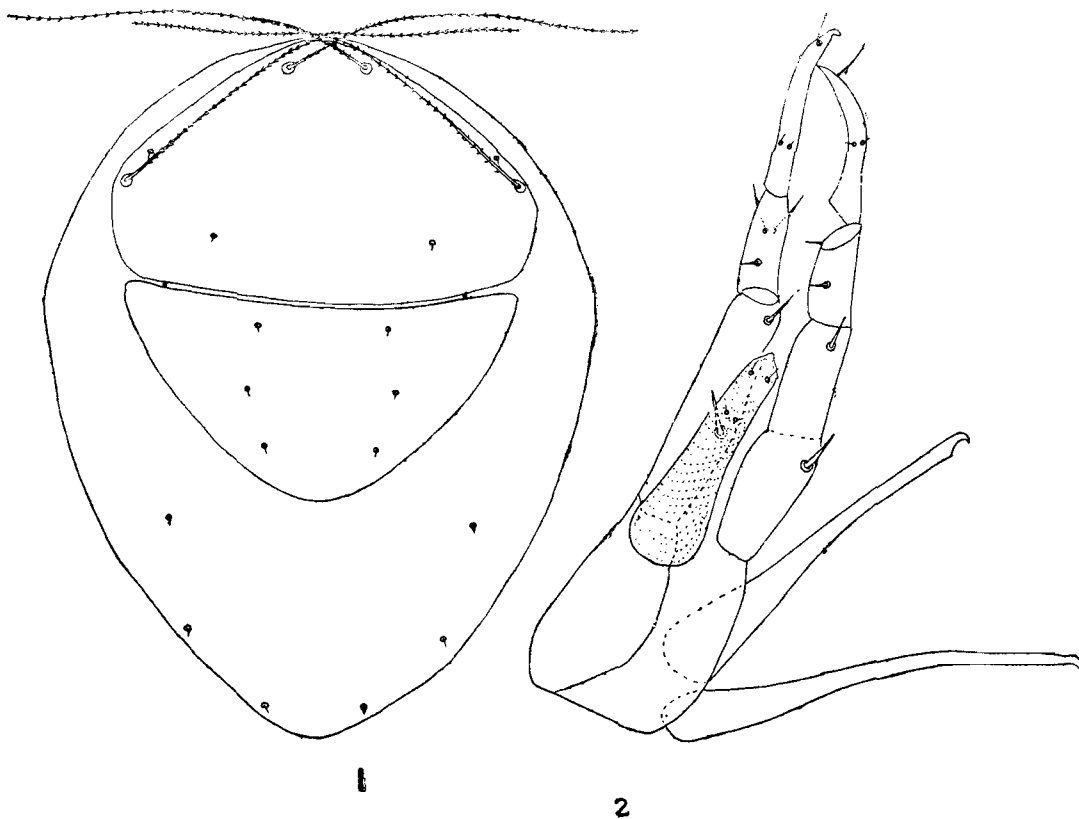
Material examined : 1♀, Patna, Mithapur Agricultural Farm, 31.V.1978, ex. soil taken from maize field.

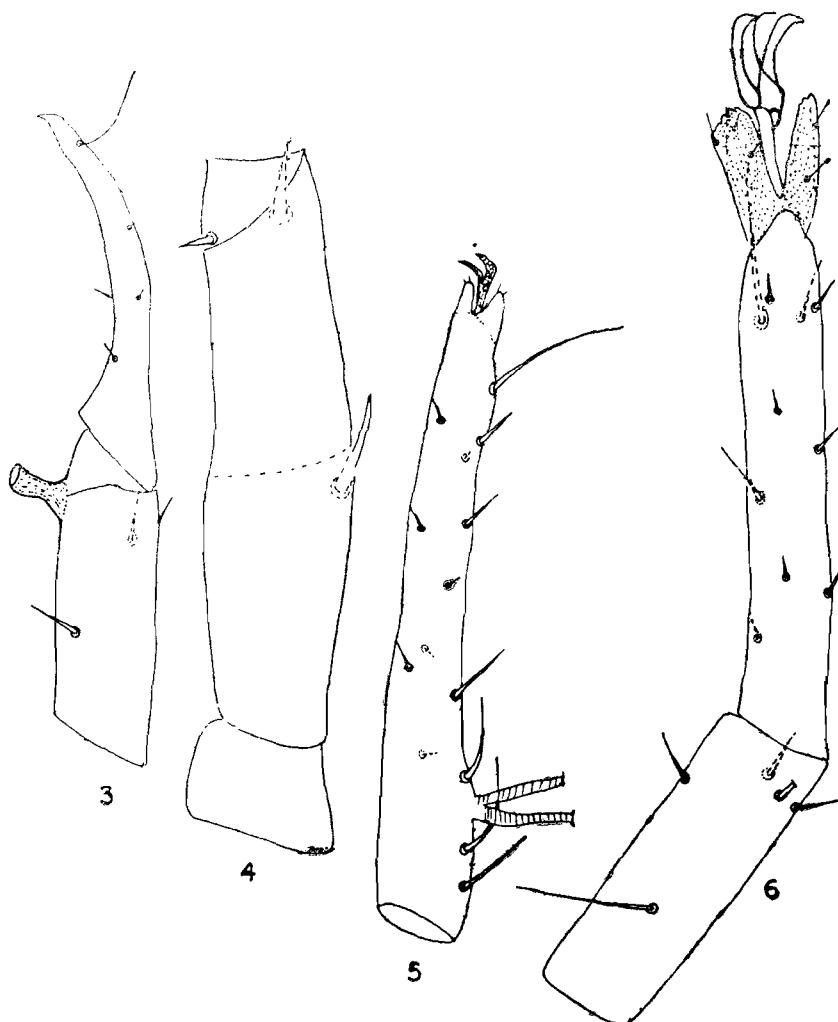
Remarks : No report of this genus as well as of the species has so far been made from India. This species was reported from Virginia, USA and in all probability the present material is same as *andrei* though the specialised seta on the palp tibiotarsus, the characteristic feature of species, is not prominent.

5. *Dactyloscirus pataliputraensis* sp. nov.

Female : Palp 300 μ long, 5-segmented but basifemur and telofemur are almost of inseparable nature, chaetotaxy of palp : trochanter-none ; basifemur —

one outer lateral spine ; telofemur—one outer lateral, along with another spine like process adjacent to it (visible on one side) ; genu one spine inner lateral—one anterior lateral, one anterior ventral and one strong hollow tube like process inner-lateral ; tibiotarsus—2 small setae innerlateral, 2 setae mediodorsal and one long setae at distal tip ; distal tip fine claw like slightly bent inwards. Chelicera attenuate gradually, being broadest at the base, tapering at the tip, does not extend up to base of palp genu, fixed digit absent, movable digit small with a tiny seta at the tip. Gnathosoma broadest at base, reticulate with 2 pairs of setae, those which are at the tip are longer than the other pair. Propodosoma almost with subtriangular shield with 2 pairs of finely branched sensory setae and 2 pairs of simple setae. Hysterosomal shield almost triangular with 3 pairs of short simple setae, a pair of setae present between propodosomal and hysterosomal shields. Coxae I-II contiguous, connected with lateral apodemes ; coxae III-IV contiguous, coxal setal formula not discernible. Genital plate with 4 pairs of simple setae ; 3rd pair much longer than others. Legs I-II directed anteriorly, legs III-IV directed posteriorly. Setation of basifemur, telofemur, genu, tibia and tarsus of legs I,II, III and IV are as follows—I : 4, 4, 5+3 solenidia, 3+2 solenidia, 15+2 solenidia ; II : 4, 4, 4+2





Figs. 1-6 *Dactyloscirus pataliputraensis* sp. nov. Female : 1. Dorsal surface ; 2. Gnathosoma ; 3. Genu and Tibiotarsus of pedipalp ; 4. Trochanter, basifemur and telofemur of pedipalp ; 5. Tarsus of leg I ; 6. Tibia and tarsus of leg IV.

solenidia, 4, 12+1 solenidion ; III : 3, 3, 5, 6, 12 ; IV : 2, 4, 7, 3+1 trichobortia, 12. Tarsi I-IV with 2 claws, tarsi bitid, one part being much broader and thicker than the other part. Dorsal surface of tibia and tarsus reticulate.

Male : Unknown

Holotype : ♀, INDIA : Bihar, Patna, Mithapur Agricultural Farm, 31.xii.1978, ex soil from sugarcane field.

Remarks : This species is easily separated from *D. eupaloides* Berlese, 1916 by chaetotaxy of palp and presence of strong but tubular process on genu of palp and by leg chaetotaxy.

Family : **Cheyletidae**

6. *Cheyletus eruditus* (Schrank)

Acarus eruditus Schrank, 1781, *Enumeratio Insectorum Austriae Indigenorum*, p. 513

Material examined : 3♀♀, Patna, Mithapur Agricultural Farm, 14.viii.1978, ex soil from sorghum field.

Remarks : Though this mite is widely distributed in the world, most of the records of this species are from storage where it preys on acarid mites and young stages of psocids and beetles (Hughes, 1976). Recently, a large population of this mite was seen in different granaries of Bihar. The record of this species in soil is interesting and new in India.

7. *Cheyletus fortis* Oudemans

Cheyletus fortis Oudemans, 1904, *Ent. Ber. Ned. Ver 1* : 161.

Material examined : 1♀, Patna, Mithapur Agricultural Farm., 21.xii.1978, ex soil from maize field.

Remarks : The previous records of this species in India are from the bark of trees and stored potato (Prasad, 1974). Gupta and Datta Ray, 1975 reported it from house dust from West Bengal. So far the occurrence of this species from soil was unknown and therefore the present record is interesting.

8. *Acaropsis docta* (Berlese) (= *Acaropsis sollers*)

Cheyletus docta Berlese, 1886, *Acari Myriapoda et Scorpiones hucusque in Italia reperta, Prostigmata* 33(1).

Material examined : 2♀♀, Sekhpura, 14.viii.1978, ex soil from sugarcane field.

Remarks : This is also a cosmopolitan species but most of the records are from storage where it is a predator. In India the previous records are from Haryana and West Bengal and for the first time it is recorded from soil.

Family : **Stigmaeidae**

9. *Agistemus* sp.

Material examined : 1♀, Patna, Sekhpura, 15.v.1978, ex soil from sugarcane field.

Remarks : The normal habitat of the members of this genus is plants, where they predate on phytophagous mites and rarely a deviation has been noticed. Therefore, the occurrence of this species in soil is interesting. So far only two species, viz., *A. fleschneri* Summers and *A. industani* Gonzalez, both occurring on plants, are known from India. In all probability the present species appears to be a new one but will be described with the availability of further material.

10. *Cheyllostigmaeus* sp.

Material examined : 2♀♀, Patna, Mithapur Agricultural Farm, 31.v.1978, ex soil from sugarcane field.

Remarks : No species of this interesting genus has so far been recorded from India. However, recently, Gupta and Ghosh (in press) reported an unidentified species of this genus from Andaman-Nicobar Islands, collected on *Ficus* sp. Earlier to the present report, the occurrence of this species from soil was unknown.

Family : **Tydeidae**

11. *Pronematus tenuisetosus* Meyer and Rodriguez

Pronematus tenuisetosus Meyer and Rodriguez, 1966, *Garcia Orta*, 13 : 20.

Material examined : 2♀♀, Patna, Mithapur Agricultural Farm, 15.xi.1978, ex soil from sugarcane field.

Remarks : Earlier record of this species was from plant in Mozambique. Therefore, the present report of this species is not only new from India but also its occurrence in soil is quite interesting. Until now only two species of this family are known from India and both the records are from plants.

12. *Triophtydeus* sp.

Material examined : 1♀, Patna, Mithapur Agricultural Farm, 14.viii. 1978, ex soil from sorghum field.

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8.2 ON THE POST-EMBRYONIC DEVELOPMENT OF *GALUMNA FLABELLIFERA ORIENTALIS* (ACARI : ORIBATEI), AN INTERMEDIATE HOST OF THE CESTODE PARASITE, *MONIEZIA* SP.

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ABSTRACT

Under controlled conditions of temperature and relative humidity the postembryonic development of a species of Oribatid mite, *Galumna flabellifera orientalis* Aoki, 1965 was studied in the laboratory with their preferred food items, previously confirmed from the feeding experiments of this mite. Adults separated from the litter and soil by means of modified Tullgren funnel apparatus were fed by partly decomposed leaves of *Artocarpus* sp. Eggs were laid in June and December, often in crevices of food substances. They were smooth, small and solitary. An average of 4.5 days were found necessary for the eggs to hatch into an inactive larva, these took 1-2 hours for hardening before they started feeding. Subsequent protonymphal, deutonymphal, tritonymphal and adult stages were attained after respective moulting coupled with an increase in the body size at every stage in the development. The larval and all the nymphal stages, unlike the adult, showed a positive preference to the species of the fungus, *Alternaria* in which they made tunnels to hide themselves. A premoult period ranging from 2-3 days was noticed in all the life-stages, maximum being observed in the case of tritonymph. Successful completion of the life cycle of this mite depends on the availability of preferred food items and with *Alternaria* species of fungus the time taken by each of the life stage was found to be comparatively low i.e., 2.75, 2.25, 1.75 and 3.50 days from larva to tritonymph respectively. The duration of the tritonymph was maximum as was in the premoult period of the same stage and this can be attributed to the time needed for the external and internal morphological changes. With a relative humidity of 92 per cent and a temperature of $31 \pm 1^\circ\text{C}$ the mite required 25 days to reach the adult stage.

8.3 CRYPTOSTIGMATID POPULATION OF THE SOIL OF A BANANA PLANTATION IN RELATION TO SOME EDAPHIC FACTORS

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ABSTRACT

Population fluctuation of cryptostigmatid mites *in toto* and some of its major species were studied in a banana plantation at Santiniketan in relation to moisture content, pH and organic carbon content of the soil for two consecutive years. In all 30 species of cryptostigmatid mites were collected from the site. Of these, only three species viz., *Scheloribates albialatus*, *Oppia nodosa* and *Pilobatella berlesae* were dominant with a relative abundance of > 5 per cent and another five species were regarded as sub-dominant with a relative abundance of > 2 per cent. Although density of the mites varied from month to month in different species, cryptostigmata in general, showed a pronounced population peak during post-monsoon period particularly in the month of October. A less pronounced peak was also noted in the pre-monsoon period during May or June depending upon the onset of rains. All the three edaphic factors under consideration showed a strong significant positive correlation ($P < 0.01$) with the Cryptostigmata population. Preferred ranges in the factor for each dominant and sub-dominant species have also been discussed.

INTRODUCTION

Ecological investigations on soil inhabiting microarthropods in India started with the work of Trehan (1945). Later on Choudhuri and Roy (1967, 1971 and 1972); Mukherji and Singh (1970); Choudhuri and Banerjee (1975); Singh and Pillai (1975); Prabhoo (1976) and Bhattacharya and Joy (1978) have added considerable information regarding the ecology of soil microarthropods in general or of Collembola and Acari. Very little information is available regarding the community study or population fluctuation of Cryptostigmata. Banerjee (1974) has made a modest attempt in this direction. In the present paper cryptostigmatid population of a perennial banana plantation at Sriniketan has been studied in relation to moisture content, pH and organic carbon content of the soil.

MATERIAL AND METHODS

Soil samples were collected at monthly intervals for two consecutive years from February 1976 to January 1978. During each sampling, 9 soil samples of $5 \times 5 \times 10$ cm were collected at random, in the morning between 08.00 and 09.00 hr. A total of 211 samples were collected from the plots and Cryptostigmata were

extracted by means of a battery of 'Tullgren funnels'. Moisture content of the soil was determined by 'Torsion balance moisture meter', pH by a glass electrode digital pH meter and organic carbon was estimated following Walkey and Black's (1934) rapid titration method. Density of *Cryptostigmata in toto* as well as of dominant species (relative abundance > 5 per cent) were correlated with the monthly variations of the edaphic factors. An attempt has also been made to find out the preferred ranges for each edaphic factor for the dominant and subdominant species.

OBSERVATIONS

Cryptostigmata in banana plantation constituted 43.2 per cent of the total acarine fauna and was the most predominant group of mites. Average population density of *Cryptostigmata* was 4388/m² but varied from month to month. *Cryptostigmata* in general showed a pronounced population peak during postmonsoon period, in the month of October, and a less pronounced peak was also noticed in the pre-monsoon period, during May or June (Fig. 1).

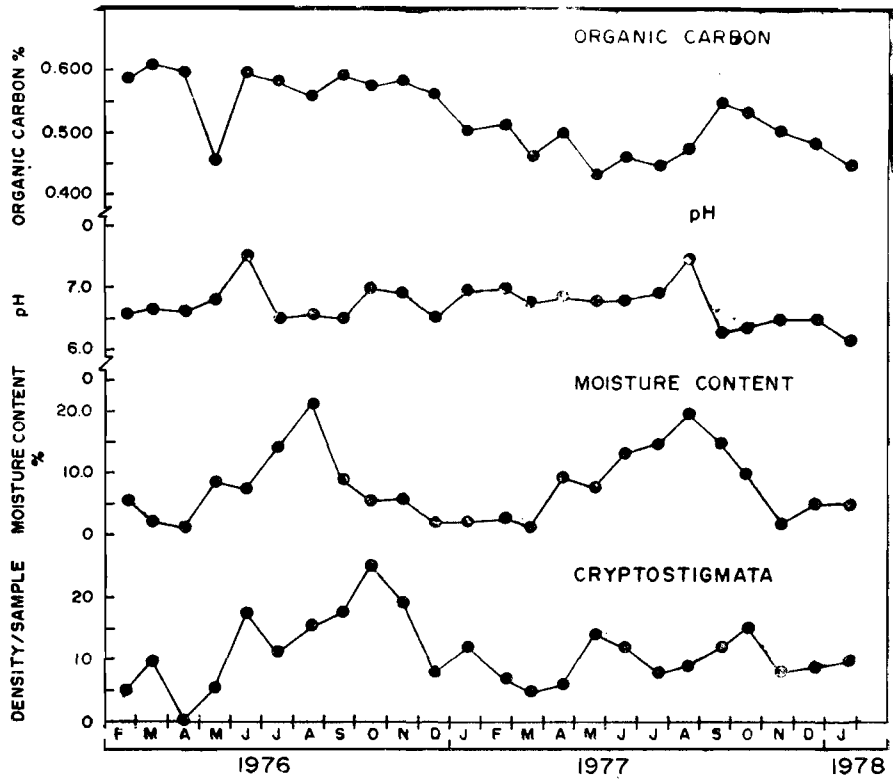


Fig. 1 Monthly variation in the density of cryptostigmatid mites and the three edaphic factors in banana plantation.

TABLE I
Number and relative abundance of cryptostigmatid species in banana plantation

Species	N	(R.A.%)
1	2	3
1. <i>Eohypochthonius vilhenarum</i> (Balogh)	62	2.681 S
2. <i>Brachychthonius cricoides</i> (Weis-Fogh)	7	0.303
3. <i>Haplochthonius simplex</i> Willman	15	0.649
4. <i>Cosmochthonius emmae</i> Berlese	28	1.211
5. <i>Mesoplophora</i> sp.	2	0.086
6. <i>Hoplophorella</i> sp.	17	0.735
7. <i>Epilohmannia pallida pacifica</i> Aoki	15	0.649
8. <i>Allonothrus russeolus</i> Wallwork	43	1.859
9. <i>Archezogetes longisetosus</i> Aoki	23	0.994
10. <i>Malaconthrus</i> sp.	1	0.043
11. <i>Cyrthermannia vicinicornata</i> Aoki	39	1.686
12. <i>Daemeobelba</i> sp.	1	0.043
13. <i>Oribatula</i> sp.	5	0.216
14. <i>Microzetes auxillaris</i> Grandjean	55	2.378 S
15. <i>Eremulus flagellifer</i> Berlese	19	0.821
16. <i>Fosseremus quadripertitus</i> Grandjean	16	0.692
17. <i>Tectocephus sarekensis</i> Tragardh	31	1.340
18. <i>Oppia nodosa</i> Hammer	298	12.884 D
19. <i>Oppia</i> sp.	54	2.335 S
20. <i>Brachioppia</i> sp.	20	0.847
21. <i>Ramusella</i> sp.	16	0.692
22. <i>Lanceoppia</i> sp.	2	0.086
23. <i>Multioppia</i> sp.	2	0.086
24. <i>Suctobelba elegantula</i> Hammer	3	0.130
25. <i>Paralamellobates bengalensis</i> Bhadhuri & Raychaudhuri	86	3.718 S
26. <i>Galumna</i> sp.	15	0.649
27. <i>Eporibatula</i> sp.	92	3.978 S
28. <i>Scheloribates albialatus</i> Hammer	1203	52.010 D
29. <i>Chaunoproctus clavisetosus</i> Bhadhuri, Bhattacharya & Chakraborti	27	1.167
30. <i>Pilobatella berleseii</i> sp. nov.	117	5.058 D
Total Cryptostigmata	2314	43.16% *

D - Dominant species R.A. 5%

S - Subdominant species R.A. 2% (—)5%

* - of acarine fauna

In all 2314 cryptostigmatid mites, belonging to 30 species, were collected during the present investigation. On the basis of the relative abundance, 3 species, viz., *Scheloribates albialatus* Hammer, *Oppia nodosa* Hammer and *Pilobatella berlesei* sp. nov. were designated as dominants and 5 species, viz., *Eohypochthonius vilhenarum* Balogh, *Microzetes auxillaris* Grandjean; *Oppia* sp., *Paralamellobates bengalensis* Bhaduri and Raychaudhuri and *Eporibatula* sp. were considered as subdominants (Table I).

Only organic carbon content of the soil showed a significant positive correlation with *S. albialatus* and *P. berlesei* populations. Other factors showed an insignificant correlation (Table II). To find out the zone of preferendum, values of each edaphic factor were divided into 5 ranges and the percentile deviation on the basis of number of individuals collected from each range has been plotted in Fig. 2. It may be noticed that all the dominant and subdominant species preferred comparatively dry soil condition (moisture content <10 per cent) except for *Eporibatula* sp. and *Oppia* sp. which were found widely distributed in different moisture regimes notwithstanding the fact that maximum number of *Eporibatula* sp. were collected from the moisture range exceeding 20 per cent. Turning to the pH of the soil, all the common species except *E. vilhenarum*, *M. auxillaris* and *Oppia* sp., preferred slightly acidic to almost neutral pH range; whereas *E. vilhenarum* and *M. auxillaris* have definite preference for a slightly acidic condition, i.e., they have a narrow range of preference for pH. *Oppia* sp., in contrast, preferred a more acidic pH range. The affinity of the cryptostigmatid mites towards higher range of organic carbon content of soil was very clearly evident except for *O. nodosa* which seems to prefer a wide range of organic carbon content of soil.

DISCUSSION

Predominance of Cryptostigmata compared to other groups of Acari, in the banana plantation, has also been shown by Block (1970), as in the present investigation. This, however, is in conflict with the findings of Singh and Pillai (1975) who found prostigmata to be the most common group of Acari in banana plantation. Population density of these mites was, however, observed to be more compared to those observed by either Block (1970) or Singh and Pillai (1975). Such a higher population density may be attributed to high amount of organic carbon in the soil.

A prominent post-monsoon peak and a less significant pre-monsoon peak for Cryptostigmata as in this investigation has already been reported by Bhattacharya and Raychaudhuri (1977) for a waste land at Santiniketan. Similar postmonsoon peak for Cryptostigmata has also been reported by Prabhoo (1976) and a premonsoon or

TABLE II
Correlation between *Cryptostigmatid* species and edaphic factors

Groups	Moisture			P	pH			P	Organic carbon			P
	r	t			r	t			r	t		
<i>Scheloribates albiolatus</i>	+0.260	x		—	+0.247	x		—	+0.462	2.446		<0.05
<i>Pilobatella berlesii</i>	+0.005	x		—	+0.122	x		—	+0.603	3.548		<0.001
<i>Oppia nodosa</i>	+0.001	x		—	+0.302	x		—	-0.239	x		—
<i>Cryptostigmata</i>	+0.237	x		—	+0.169	x		—	+0.293	x		—

x - Insignificant value

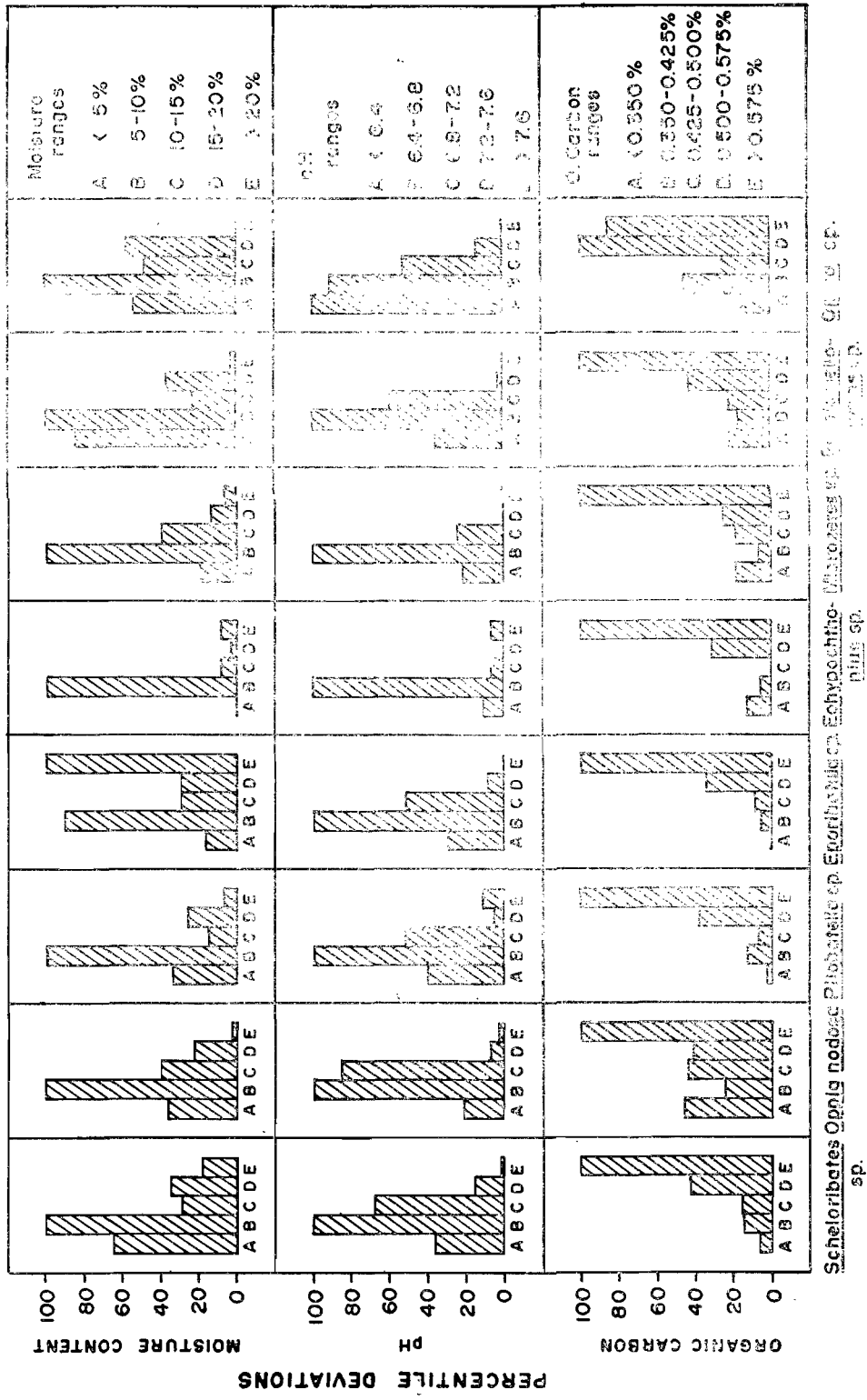


Fig. 2 : Distribution of the major cryptogammatid species in relation to different ranges of edaphic factors in Banana plantation

late summer peak was observed by Loots and Ryke (1966) in tropical Africa. In contrast to these Banerjee (1974) noticed minimum population level in the month of May.

Importance of moisture content in relation to the density of microarthropods have been stressed by Mukherji and Singh (1970) ; Choudhuri and Roy (1972) and Singh and Pillai (1975). Although Bhattacharya and Raychaudhuri (1977) considered it to be the most important single factor causing changes in the density of Cryptostigmata, yet it seems that in banana plantation organic carbon plays more important role. Ryke & Loots (1967) ; Banerjee (1974) ; Choudhuri and Banerjee (1975) and Singh and Pillai (1975) also suggested that Cryptostigmata in general prefer soils with high organic carbon.

Turning to the pH it may be seen that most of the mites preferred a rather acidic condition. Edwards and Lofty (1974) also found that cryptostigmatid mites were more common in the acidic plots. However, they opined that influence of pH on mite population was slight. This is in conformity with the insignificant correlation coefficient between pH and population density of Cryptostigmata in banana plantation.

Although different species varied in their range of preferences with respect to different factors yet it may be said that most of the common cryptostigmatid species in the banana plantation preferred a rather, acidic soil rich in organic carbon.

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8.4 ECOLOGY OF SOIL ORIBATID MITES IN AN UNCULTIVATED FIELD OF GANGETIC DELTA OF WEST BENGAL IN RELATION TO SOIL pH AND SALINITY

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ABSTRACT

Present observations form a part of an extensive ecological study of soil oribatid mites in relation to soil pH and salinity in an uncultivated field at Sagar Island, 24-Parganas, West Bengal. During this investigation from January, 1977 to December, 1977 at monthly intervals, ten genera of oribatids were recorded and formed 52.25 per cent of the total acarine population. Of these, **Scheloribates** Barlese, 1908 was the most common and occupied 60.25 per cent of the total adult population. The remaining genera in order of dominance were as follows: **Rhysotritia** (12.65 per cent), **Lamellibates** (9.64 per cent), **Haplochthonius** (2.41 per cent), **Hoplophthiracarus** (2.41 per cent), **Hoplophoralla** (2.41 per cent), **Oppia** (1.80 per cent), **Haplozetes** (1.20 per cent), **Cosmochthonius** (0.60 per cent) and **Euscheleoribates** (0.60 per cent). Seasonal changes of oribatid population appeared to show two peaks, one in May and the other in November. The nymphae of oribatids were found in all months and showed two population peaks namely in February and November. The pH of soil ranged from 6.1 to 8.0 and salinity from 29.41 mmhos/cm to 0.55 mmhos/cm. Maximum pH and salinity of soil was noticed in November and April and minimum in December and September respectively. A positive correlation between oribatid population and soil pH and salinity was recorded.

INTRODUCTION

Soil dwelling oribatid mites play a major role in the complicated process of decomposition and soil formation resulting in the increase of soil fertility. But until recently very little attention has been given to the ecology of soil oribatid mites of deltaic soil.

Weigmann (1971 & 1973) made some ecological observations of oribatid mites in saline soil. But his studies were restricted only to qualitative and quantitative aspects. The role of soil factors like pH and salinity in governing the oribatid population of deltaic soil has so far not been studied by the oribatid ecologists of India and abroad. Only the role of pH on the population structure of oribatid mites in laterite and alluvial soil was studied by Bhattacharya and Raychaudhuri (1977) and Choudhuri and Banerjee (1977). Results presented here refer to the effect of soil pH and salinity on the oribatid mite population and their seasonal fluctuation at Sagar Island, 24 - Parganas, West Bengal.

MATERIAL AND METHODS

The study-site located at the north-east corner of Sagar Island, is the largest delta in the Western sector of Sundarbans. This delta is surrounded by estuarine water, river Hoogly flows in the north and western side and river Mooriganga in the eastern side. The southern part of the Island faces the Bay of Bengal.

For this study three uncultivated plots, each 5 m² were selected. The plots were covered with a thick carpet of grass of different species and the predominant plants were *Acanthus illicifolius* Linn. (Acanthaceae), *Jatropha* sp. (Euphorbiaceae), *Derris scandens* Benth. (Papilionaceae), *Pongamia pinnata* (L.) Merr. (Papilionaceae), *Clerodendron inerme* (L.) Gaertn. (Verbenaceae), *Tylophora indica* Merr. (Asclepiadaceae), *Coccinia indica* W. & H. (Cucurbitaceae) and *Cayratia carnosa* Gageo. (Vitaceae). A part of the sampling site was found to prevail under shade throughout the day. Altogether 36 soil samples were drawn from a depth of 5 cm at monthly interval over a period of twelve months (January - December 1977). Each plot was sampled by stainless steel samplers each having 5 cm depth and 17.36 sq. cm. surface area and the extraction of materials from the soil was carried out in an expedition funnel apparatus (Macfayden, 1953). An electric bulb (40 W) was used as the source of heat which produced a temperature of 38°-39° C inside the apparatus. Soil of the study site was alluvial in nature, sandy and greyish in colour. The soil pH value was recorded from soil suspension by an electric pH meter as described by Piper (1942). In this method 100 ml of aerated distilled water was added to 20 g of soil in a flask and stirred for one hour. The pH value was then recorded after the

TABLE I
Per cent population of different oribatids in different months

Months	J	F	M	A	M	J	J	A	S	O	N	D
Genera/Species												
<i>Scheloribates</i> sp.	66.57	53.58	64.29	—	64.52	29.42	77.78	36.37	60.00	62.50	32.27	60.00
<i>Rhyotritia ardua</i>	—	—	—	65.00	—	47.05	—	—	—	—	—	—
(c.t. Koch) var												
<i>Otaheitensis</i>												
Hammer, 1972												
<i>Lamellibates palustris</i>	—	—	10.71	—	9.68	—	—	—	—	—	29.03	20.00
Hammer, 1958												
<i>Haploclthonius</i> sp.	—	—	7.15	—	—	—	—	27.27	20.00	25.00	12.90	—
<i>Hoplophthiracarus</i> sp.	—	10.71	—	5.00	—	—	—	—	—	—	—	—
<i>Hoplophorella</i> sp.	—	—	—	—	12.90	—	—	—	—	—	—	—
<i>Oppia</i> sp.	—	—	—	5.00	—	—	—	18.18	—	—	—	—
<i>Haplozetes</i> sp.	—	—	—	10.00	—	—	—	—	—	—	—	—
<i>Cosmochthonius</i> sp.	—	—	3.57	—	—	—	—	—	—	—	—	—
<i>Euschelorbates</i> sp.	—	—	—	—	3.23	—	—	—	—	—	—	—
Nymphae	33.33	35.71	74.28	15.00	9.67	23.53	22.22	18.18	20.00	12.50	25.80	20.00

glass electrode was immersed in freshly shaken suspension. The soil salinity was determined by an electrical conductance bridge. The suspension was prepared as described above and the conductance was measured by the conductance cell.

RESULTS

The Oribatids extracted from the site during this study period is presented in Table I. Altogether ten genera of Oribatids were obtained and formed 52.25 per cent of the total acarine population. Of these, the dominant genus was *Scheloribates* which shared 60.25 per cent of the total adult population. *Rhysotritia ardua* (c. t. Koch) var. *otaheitensis*, *Lamellibates palustris* and *Haplochthonius* sp. comprised 12.65 per cent, 9.64 per cent and 8.44 per cent respectively. Per cent population of the other six genera such as *Hoplothiracarus* sp., *Hoplophorella* sp., *Oppia* sp., *Haplozetes* sp., *Cosmochthonius* sp., and *Euscheloribates* sp. was very low and showed significantly irregular distribution. Large number of oribatid nymphs were extracted and distributed in all months comprising 20.57 per cent of the total oribatid population.

Monthly fluctuations of the total population of oribatids showed two distinct peaks, one in May and the other in November (Fig. 1). Minimum number was extracted during December-January.

From Fig. 1 it appears that the soil factors like pH and salinity had some effect on the seasonal fluctuation of Oribatid population. Table II shows that the

TABLE II
Number of Oribatids and values of soil factors in different months

Months	No. of Oribatids	pH	Salinity (mmhos/cm)
January	6	6.8	11.10
February	28	6.95	19.42
March	28	7.00	3.99
April	20	7.00	29.41
May	31	7.85	21.09
June	17	6.75	6.99
July	9	6.35	1.99
August	11	7.8	4.27
September	15	7.7	0.55
October	8	7.35	9.43
November	31	8.0	2.55
December	5	6.10	6.10

highest percentage of oribatids occurred in the month of May and November when the corresponding pH and salinity (except November due to rain) were comparatively high. In contrast to this, the lowest percentage of oribatid population was associated with relatively low pH and salinity.

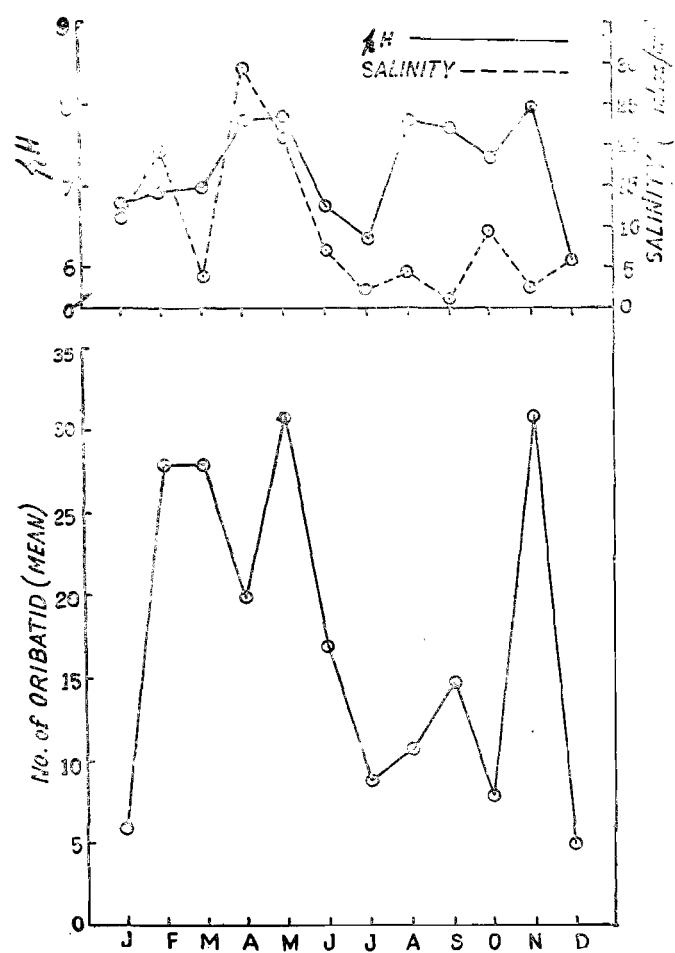


Fig. 1 Monthly fluctua-
tion of Oribatid popula-
tion at Sagar Island in relation
to soil pH and salinity.

The correlation coefficient values of 0.508 and 0.308 between oribatid popu-
lation and pH and salinity, respectively, shows there is positive correlation.

DISCUSSION

A study of seasonal fluctuation of oribatid population from soils of Gangetic
delta has not been hitherto undertaken. Comparison of the present findings with the

observations in other non-deltaic soils of West Bengal revealed that the oribatid population in laterite soil (Bhattacharya and Raychoudhuri, 1977) showed two peaks, one in September-October and other in May-June which was partly similar to the present trend of fluctuation. On the other hand the findings of Choudhuri and Banerjee (1975 and 1977) in Gangetic alluvial soil showed a single population peak during July-August which was different from the result of the present deltaic soil study. This difference in population fluctuation appears to be due to the influence of estuarian climatic and soil factors.

Bhattacharya and Raychaudhuri (1977) observed negative correlation between oribatid population and soil pH. But in the present study a positive correlation was noticed, maximum percentage of population was recorded when soil salinity was relatively high which was again related to the alkalinity of soil i. e. high pH. It may be assumed that the salt tolerant oribatid species were present in the deltaic soil. Weigmann (1971 & 1973) observed that large number of oribatid species were salt-tolerant and the fauna of the inland salt soils mainly consists of salt-tolerant species typical for grass land.

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8.5 ECOLOGY OF THE TRAP-DOOR SPIDER *ACANTHODON CONSTRUCTOR*

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ABSTRACT

Acanthodon constructor (Ctenizidae, Mygalomorph) is a common trap-door spider of Tambaram, Madras. Observations made on the nest, 15 females, 4 males and 9 egg cocoons, during the period June-July, 1978 in Tambaram, are reported here.

The spider constructs a tubular retreat in the soil lined with silk, more frequently in hard red soil, and less in loose mud. They seem to prefer bare soil to soil overgrown with thick vegetation. These are easily detected on roadsides and in areas with scant vegetation, some also construct burrows on mud walls of huts in villages.

The burrow is a straight tube, 10 to 14 cm long with a diameter of about 10-12 mm. The inner walls of the tube is lined with silk and the distal end is slightly curved. The opening is closed by a wafer-type of lid made of silk, but camouflaged on the outside to merge with the surrounding mud. Dead bodies of ants, beetles and crickets are found at the distal end of the tube.

The burrowing operation is done with the help of the powerful chelicerae and legs. The chelicerae bear a rastellum on its outer margin with 11-13 teeth, that are particularly suited for this. In addition, the palp and the first pair of legs have stout tibia and tarsus, that carry 2 to 3 rows of spines. The tarsus ends in short and blunt claws.

Sexual dimorphism is marked. Females are large (24 mm). They do not leave the burrows, but hold on to the lid from inside with the hind pair of legs. Males are smaller (17 mm) with thinner legs. These wander at night. Nine egg cocoons collected contained on an average 55 eggs. The egg cocoon is boat shaped with rugose and thick lower part.

It is interesting to note that these primitive spiders are closely linked with the soil, and have established soil relations in their orientation and construction of burrows. Their food comprises primarily of insects like beetles, ants, crickets and grasshoppers that cross the entrance of their burrows.

SOME ASPECTS OF BIOLOGY OF THE PSEUDOSCORPION *LAGYNOCHTHONIUS HYGRICUS* (CHTHONIIDAE : CHELONETHI)

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ABSTRACT

Some aspects of feeding, reproduction, moulting and hibernation in the pseudoscorpion *Lagynochthonius hygricus* has been studied under laboratory conditions. *Lagynochthonius* is a predator of Collembola and other microarthropods. When Collembola were offered, *Lagynochthonius* was found to reject *Xenylla*, *Lobelia* and adults of *Cryptopygus*, it occasionally fed on young of *Cryptopygus*, *Lepidocyrtus* and *Seira* and showed a marked preference to *Alloscopus* and *Cyphoderus*. Only the liquified internal organs of the collembolans are sucked by the predator leaving behind the exoskeleton. The sexes differ in size and the genital area. The males deposit spermatophores and females pick them up. The fertilized female soon constructs a brood nest and while in the nest she lays 15-20 eggs which remain suspended around the gonopore. Within 10 days the embryonic development is completed and the protonymphs hatch out. The protonymphs undergo three successive moults and become adults in 30-45 days. There is, it appears heavy mortality of the juveniles under laboratory conditions. They moult in the moulting nests, the nests are constructed for moulting during the immature stages, for brooding by the female and for hibernating by both sexes. Hibernation occurs from December to February and the animal remains in the nest without taking food for about 3 months. It is almost impossible to collect *Lagynochthonius* from the field during the above period.

INTRODUCTION

The activity of collembola in the soil is important in improving the structure of the soil. Among the biotic factors affecting collembolan population, predation comes to the forefront. The major predators of collembola are pseudoscorpions, mesostigmatid mites, Araenae, Diplura, beetles and chilopods. Of these, the pseudoscorpions apparently have a definite role in regulating the collembolan population in the field.

Although pseudoscorpions are considered as predators of collembola, all species do not predate on collembolans. And whether all species of collembola in a habitat are fed by a particular species of pseudoscorpion is questionable. The prey preference can influence the community structure of the collembola. Simon (1966) has observed feeding preference of *Neobisium muscorum* on different species of collembola. Such selective feeding by other species of pseudoscorpions is yet to be studied.

The present study was undertaken in order to bring to light some aspects of feeding, reproduction, moulting and hibernation of *Lagynochthonius hygricus*.

MATERIAL AND METHODS

The collembola which were found to coexist with *Lagynochthonius hygricus* in the field, viz., *Lobella*, *Xenylla*, *Cryptopygus*, *Seira*, *Lepidocyrtus*, *Alloscopus* and *Cyphoderus* were used in predation experiments. Collembola were cultured in the laboratory on yeast, litter and distilled water on a base of charcoal and plaster of paris in plastic vials of size 3.5 cm x 4 cm. For culturing pseudoscorpions, a simple method described by Weygoldt (1969) was followed. Predation experiments were conducted with four individuals of a species of collembola per *L. hygricus*. The number of individuals of a species eaten at a definite interval was noted. Five replications were maintained. Adults of *L. hygricus* were starved for two days prior to their use in predation experiments.

RESULTS AND DISCUSSION

Feeding

During the daily observations, the pseudoscorpion rejected *Xenylla*, *Lobella* and *Cryptopygus*, occasionally fed on *Seira* and showed a marked preference to *Cyphoderus*, *Alloscopus* and *Lepidocyrtus* (Table I). The average body length of the collembolans eaten by the pseudoscorpion varied from 1.2 to 2 mm. In accordance with the predators' predatory mechanisms, prey will be having several protective mechanisms such as warning colouration, noxious taste, smell, texture, paralysing effect etc. on predator. Red coloured *Lobella*, bluish *Xenylla*, blue green *Cryptopygus* are not fed upon by *Lagynochthonius hygricus*, whereas mostly unpigmented forms such as *Cyphoderus*, *Alloscopus* are more preferred. Hence colour seems to have an influence on the selective feeding of *L. hygricus* (though *Lepidocyrtus* is an exception). Secretion of Onychiurids and Hypogastridae is known to have a paralysing and benumbing effect even on large insects (Panic, 1963). Probably the hypogastrurid *Xenylla* has such an influence on the predator.

Simon (1966) found that collembolans not eaten by *Neobisium* had either poisonous secretions, thick hairs or well developed furcula. Our studies are not in complete agreement with Simon (1966). *Cyphoderus*, *Alloscopus*, *Seira* etc., which are preferred by *L. hygricus* possess well-developed furcula and hairs. *Cyphoderus* which is of medium size (1.2 mm) is highly relished by *Lagynochthonius hygricus* and even the protonymph of the latter can feed on adult *Cyphoderus*. Feeding in *L. hygricus* is a continuous process which may last for about 40-60 minutes under the laboratory conditions. When *Cyphoderus* is supplied to starving *L. hygricus*, very soon the latter recognises the prey and seems to follow the latter, sometimes jumping after it for a distance of about 1 cm. The process of attacking, capturing and killing the

TABLE I
Feeding preference of Lagynochthonius hygricus on Collembola

Prey species	Average No. of prey eaten/2 days/ predator	Character of prey species	Average body length of the prey in mm
<i>Lobelia</i>	Nil	Well pigmented (red coloured) scaleless, short haired and furcula absent	1.1
<i>Xenylla</i>	Nil	Well pigmented (blue back) scaleless, short hairs and furcula small	0.8
<i>Cryptopygus</i> : adults	Nil	Pigmented, scaleless, short hairs, furcula short	0.9
Immature	1.2 were attacked but none eaten	Young ones white in colour	
<i>Seira</i>	1.00	Lightly pigmented, scales and long hairs present on the body, furcula well developed	1.8
<i>Alloscopus</i>	1.8	Lightly pigmented (yellowish), scales and long hairs on the body, furcula developed	1.5
<i>Lepidocyrtus</i>	3.0	Fairly pigmented, scales and long hairs on the body, furcula well developed	1.3
<i>Cyphoderus</i>	3.2	Unpigmented, scales and hairs present, furcula well developed	1.2

(There were five replicates for each species of collembola, with four collembola and one *L. hygricus* of size 1.8 mm in each replicate).

prey follow in quick succession. The cheliceral action completely kills the prey. For feeding *L. hygricus* usually inserts the chelicera into the body of the prey and moves them alternately in quick succession. During this act *L. hygricus* injects a liquid into the body of the prey and then sucks in the whole liquified internal organs of the prey. At the end of feeding the remainder of the prey is discarded as a small ball. *Cyphoderus* of size 1.5 to 2 mm are left as balls of .03 to .05 mm. These balls are only chewed exoskeletons and some muscular bits. Immediately after feeding *L. hygricus* starts cleaning the entire oral area with the help of a silky secretion and the serrulae of Chelicera. All stages of *Cyphoderus*, except eggs, are fed upon by *L. hygricus*.

Reproduction

In *L. hygricus* males are smaller than females. An adult male produced about 10–15 spermatophores within a day. Sperms are stored in globular sperm packages which are attached on a stalk within the spermatophore. A single spermatophore will be having a number of sperms. Spermatophores are usually deposited on the smooth side walls of the culture bottle or on litter particles. When a male and female *L. hygricus* comes near, no mating behaviour except some vibratory movements of their pedipalps are seen. Fertilized female undergo a series of changes both in body and behaviour. Size of the abdomen increases, colour changes from dark to light brown. She becomes sluggish and moves beneath the litter particles or to some hidden corners of the culture bottle and selects a suitable place for constructing brood nests. She then brings materials such as litter particles, pieces of wood, sand grains etc., to the building site. These materials are cemented together with the help of oral secretions. First a circular basement is constructed, then the walls are constructed upward till it touches the supposed roof such as leaf litter or side wall of the bottle. The inner walls of the nest are smoothened with a silky secretion. The nest thus constructed by a female around her will have a diameter of 3–4 mm and a height of 2–2.5 mm and is mostly globular in shape. Within the nest the female lays about 15–20 eggs which are suspended around the female gonopore. For the development of eggs to protonymph it takes about 10 days. After hatching the mother and young remain in the nest for 4–9 days, the mother then disperses the colony by breaking the nest and letting the protonymphs out of the nest. From a single nest about 8–15 protonymphs come out following the mother. Newly hatched young ones are white transparent. These then undergo three successive moults—protonymph to deutonymph, deutonymph to tritonymph and tritonymph to adult. Adults are not seen to moult further. Moulting takes place within moulting nest and each moulting stage can be identified by examining the number of trichobothria on the exuvia of the moulted instar within the nest (Gabbut, 1962). Within the moulting nest, the nymphs do not move. Even after ecdysis the organism remains for a few more days within the moulting nest. The size of the moulting nest depends on the stage of the organism. Thus the average diameter and height, respectively, of the nest was found to be 1.2 mm and 0.9 mm for the 1st moult, 2 mm and 1 mm for the 2nd moult and 3.5 mm and 1.5 mm for the 3rd moult. The total duration of development varies for both the sexes, the males take about 35–40 days and females 40–45 days.

Hibernation

During winter *L. hygricus* are found hibernating within hibernating nests. At this time it is difficult to collect them by the Berlese funnel method of extraction of the soil. Only during favourable seasons they undergo breeding. Some of the

TABLE II

Duration of life stages of Lagynochthonius hygricus

Repli- cates	Time of egg laying after building nest (in days)	Size of nest (mm)		Incubation period (days)	No. of days spent by protonymph in the nest	No. of pro- tonymphs coming out of the nest	No. of pro- tonymphs becoming adult	No. of days for the pro- tonymphs to become func- tional adult		No. of days required for completing life cycle
		diameter	height					♂	♀	
1	1	3.5	2.5	9	4	15	1 ♀ + 2 ♂	30	42	55
2	2	4	2.5	10	9	8	1 ♀		42	61
3	1	4	2	10	6	14	1 ♀ + 1 ♂	33	42	58
4	1	3.5	2	10	9	8	1 ♀ + 1 ♂	40	45	64
5	3	3.5	2	10	9	7	1 ♂	40		59

L. hygricus cultured in the laboratory were also found hibernating within their nests. Moulting nests can be distinguished from hibernating nests by the presence of exuvia. Light does not seem to be a hindrance to nest construction. For months together they remain in the nest without any food and the organism looks inflated and unable to move. When the period terminates, they come out of the nest. But if the nest or the organism is disturbed before that period, they come out of the nest and die.

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9. Insecta

9.1 SOME ASPECTS OF REPRODUCTION IN *CYPHODERUS JAVANUS* (ENTOMOBRYIDAE : COLLEMBOLA)

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ABSTRACT

Ability of *Cyphoderus javanus* to reproduce when reared on different types of food materials was tested under laboratory conditions. The animals fed on decaying leaves, fungus, lichen and yeast and thrived up to a period of 95 days, moulting regularly on the first three types of food but without oviposition. The females oviposited only when fed on yeast. The yeast fed female began to oviposit on the 14th day of hatching at 27°C. Each oviposition was invariably preceded by a moult. The clutch size of the yeast fed female varied from 7-19 eggs with a mean of 13.5 eggs. The number of times of oviposition varied from 6 to 13 during the life span of a female. *Cyphoderus* also was found to reproduce parthenogenetically as isolated female laid eggs. In the unfertilized female the clutch size was smaller and the number of ovipositions lesser compared to the normal fertilized female. The maximum life span of a yeast fed female was observed to be 102 days with a mean of 80.8 days and the individual laid, on an average, 148 eggs.

INTRODUCTION

The process of reproduction, primarily for the perpetuation of the species is of great ecological significance. The population abundance and therefore, the productivity of any species is mainly determined by the reproductive rate as well as the fecundity of that species. The reproductive rate of Collembola in general is influenced by several factors. Food is one of the major factors. Though many workers have studied the biology of various species, only very few have tried to establish the role of food on reproduction. Similarly the physical factors such as temperature may also determine the reproductive rate of Collembola, because variation in the ambient temperature will inversely affect the duration of life cycle as well as the gap between successive ovipositions which will determine the total number of eggs produced. Hale (1965) established the importance of temperature on various aspects of reproduction in about 15 temperate species. Only very few workers have attempted to study the influence of food and other factors on the reproductive rate of the tropical species. Since, the abundance of a species in a habitat would be greatly deter-

mined by the type of food available, through its influence on fecundity, the present work proposes to shed some light on the influence of food on oviposition and fecundity of a tropical species—*Cyphoderus javanus*.

MATERIAL AND METHODS

The specimens for the present study were largely obtained from the field, underneath a jack fruit tree, *Artocarpus indica*, in the University Campus. Sufficient quantity of soil along with litter and decaying leaves was collected and the extraction of the live specimens was done using a modified Tullgren Funnel method (Haarlov, 1947). The live specimens thus extracted were reared in specially prepared culture chambers. The culture chambers used were plastic containers of 5 x 3.5 cm with a substratum of plaster of paris and animal charcoal at 5 : 1 ratio (Snider, Sheddy and Butcher, 1969). Food preference experiments were done by offering the different types of food either individually or mixed in the culture chamber. Fecundity was fixed as suggested by Hale (1965), by estimating the average egg batch size, by the isolation of gravid females until oviposition and by keeping pairs.

RESULTS

Cyphoderus javanus was found to feed on decaying leaves, fungus on the yeast pellets, lichen and yeast in the laboratory. It was observed that about 70 per cent of the total number of individuals always had a tendency to feed on yeast, when all the food types were provided in the same culture chamber. Yeast seemed to be the most preferred food, on which the species thrives and reproduces well, whereas, the individuals fed with decaying leaves, fungus and lichen did not oviposit at all, though these could thrive up to a maximum of 95 days, during which regular moulting was observed. These individuals after starvation for one week when provided with yeast began to oviposit within a week. Each oviposition was found to be invariably preceded by a moult. In the normal laboratory temperature of 27°C, the female fed with yeast was found to oviposit on the 14th day of hatching. The eggs were scattered in small pits or crevices on the substratum, excuviae, fungal mycelia or on or around the food substance.

In the females fed with yeast the clutch size varied from 7 to 19 eggs with a mean of 13.5. The number of times of oviposition during the life time of an individual female was found to vary from 6 to 13. In one case there were only two ovipositions. Every adult moult was generally, but not invariably followed by egg laying.

TABLE I
Clutch size and fecundity of the yeast fed female

Replicates	1	2	3	4	5	Mean
Number of eggs laid	182	161	103	110	73	125.8
Number of moults during the life span of the adult	14	11	9	10	6	9.8
Number of ovipositions	13	11	8	8	6	9.1
Longevity in days	81	90	51	102	80	80.8
Clutch size	14.0	14.6	14.7	12.2	12.1	13.5

The female *Cyphoderus* was found to reproduce parthenogenetically in isolation. In such unfertilised females the clutch size was smaller and the number of ovipositions lesser (Table II), compared to normal fertilised females. The mean clutch size of the parthenogenetic female was observed to be 8.4 while that of normal fertilised female was 13.5. It was also observed that parthenogenetic eggs develop into males.

In the longevity and fecundity experiments, where a pair of individuals was reared in each culture chamber, it was found that after the death of one of the pair, if the remaining happened to be a female, the female oviposited. Though one such

TABLE II
Clutch size and fecundity of parthenogenetically reproducing female

Replicates	1	2	3	4	5	Mean
Number of times of oviposition	6	4	4	3	4	4.2
Number of times of moult during the life span of adult	6	5	4	4	5	4.6
Total number of eggs laid	54	30	30	27	39	36.00
Longevity in days	58	70	74	67	72	68.2
Clutch size	9.0	7.2	7.2	9.0	9.7	8.4

female lived for about 100 days after the death of its mate and laid as many as 91 eggs, another female lived for only about 25 days and laid only 42 eggs. This observation confirms the parthenogenetic reproduction in the species.

DISCUSSION

Collembola are known to feed on a variety of food materials (Christiansen, 1964; Sinder *et al.*, 1971). Food is not only the source of energy and nutrients for growth and maintenance, but it also plays a decisive role on reproduction, particularly in the females. Few workers have noted that different kinds of food would significantly alter the reproductive rate in these insects (Snider *et al.*, 1971). Sharma and Kevan (1963) found that *Pseudosinella alba* thrives successfully on decaying leaves, but reproduce satisfactorily only when the food is supplemented with yeast. This condition is similar in *Cyphoderus javanus*. But unlike *Cyphoderus*, *Pseudosinella* avoids fungal mycelia. *Folsomia similis*, similar to *Cyphoderus javanus*, fed on fungus, decaying leaves, and yeast (Sharma and Kevan, 1962), but a mixture of decaying leaves and yeast proved to be satisfactory. *Lepidocyrtus orientalis*, another entomobryid was found to feed and reproduce on yeast, decaying leaves of jack fruit tree and with a lesser fecundity on algae (Prabhoo, 1967). Though *Cyphoderus javanus* is an unspecialised feeder in the field, it was found to prefer yeast to decaying leaves and lichen in the laboratory. Although, it could thrive on the latter two food materials, it could apparently reproduce only when fed with yeast. This is probably due to the lack of essential substances in foods other than yeast, necessary for the maturation of the eggs. This is evidenced from the fact that the females feeding on food substances other than yeast, but not ovipositing, after starvation for a week, when refed with yeast, successfully laid eggs within a week. Contrary to these studies Waldorf (1971) found that yeast was a probable source of a substance inhibiting oviposition in a species of *Sinella*. Though different species may feed on the same food material, the relative percentage of the quantity of food consumed by each species varies (Muraleedharan and Prabhoo, 1978).

In *Cyphoderus* the number of eggs laid during one oviposition varied from 7 to 19 with a mean of 13.5 at 27°C. Variations in the clutch size has been observed in other species. Sharma and Kevan (1963) reported maximum number of eggs to be 15 and minimum 6 for *Pseudosinella pettersini* and 16 and 5 for *P. alba* at 24°C. Prabhoo (1967) observed a maximum number of 41 eggs in *Lepidocyrtus orientalis*. Though *Cyphoderus* is almost of the same size as *Lepidocyrtus*, the former lays only about half the number of eggs as that of *Lepidocyrtus*. The maximum number of ovipositions observed in *Cyphoderus* was close to the average of 13 ovipositions of *Folsomia candida* (Snider, 1972).

The subject of parthenogenesis in Collembola has been briefly reviewed by Marshall and Kevan (1962). *Folsomia candida* exhibits obligatory parthenogenesis (Goto, 1960; Goto and Ogel 1961; Marshall and Kevan 1962; Green 1964a; and Snider 1973). McLegan (1932) noted a degree of parthenogenesis in *Sminthurus*

viridis. Choudhuri (1958) reared *Onychiurus parthenogeniticus* through many generations without obtaining males. *Cyphoderus javanus* is parthenogenetic, as isolated females lay eggs (Kurup and Prabhoo, 1976). In the unfertilised females the clutch size was smaller and the number of ovipositions lesser when compared to that in the normal fertilised females, perhaps indicating a limited nature of this type of reproduction. The haploid eggs laid by parthenogenetic females develop into males and this type of reproduction is referred to as haploid facultative arrhenotoky (Richards and Davis, 1976). The facultative parthenogenesis producing males is less advantageous than the female producing one, but apparently more advantageous than a non-parthenogenetic condition. *Entomobrya* species is parthenogenetic, producing both females and males (Arunkumar, 1978). Hale (1966) and Christiansen (1964) have suggested that the species other than *Folsomia candida* are atleast capable of facultative parthenogenesis. *Cyphoderus javanus* seems to fall under this category (Kurup and Prabhoo, 1976).

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9.2 FEEDING CYCLES IN THE COLLEMBOLAN *CYPHODERUS JAVANUS*

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ABSTRACT

Feeding in *Cyphoderus javanus* was studied in the laboratory, at the fluctuating room temperature of 26–32°C and at the constant temperature of 25°C, by incubating 10 to 15 eggs under each condition and observing the feeding and moulting in each individual from the time of hatching. Eighty per cent of the individuals at the room temperature started feeding 12–24 hours after hatching, while at 25°C only 37 per cent of the individuals started feeding only 36–48 hours after hatching. Feeding was cyclic and discontinuous, being interrupted by fasting periods during moulting. The non-feeding period following a moult is the fasting period I and the non-feeding period preceding the next moult is the fasting period II. Both fasting periods were of 12–24 hours duration. But the alimentation periods varied in the two groups. Seventyseven per cent of the intermoult periods of the individuals at the room temperature and 55 per cent of the intermoult periods of the individuals at 25°C had feeding cycles of which 23 per cent and 14 per cent respectively had alimentation periods which were discontinuous i.e., an actively feeding period followed by a non-feeding period of less than 24 hours which was again followed by an active feeding period. In 53 per cent of the individuals at the room temperature durations of the actively feeding period was less than 12 hours, 28 per cent had durations of 12–48 hours and 19 per cent had durations of more than 48 hours while in the individuals at 25°C, the aforesaid categories of actively feeding periods were 13 per cent, 35 per cent and 52 per cent respectively. Feeding rates in all individuals increased from the fifth instar onwards, the increase being more pronounced in the individuals at room temperature. The present study showed that *Cyphoderus javanus* could be found with empty gut during intermoult periods also and that low temperature had a retarding effect on the feeding process.

9.3 SEASONAL VARIATIONS OF COLLEMBOLAN POPULATION IN ARABLE SOIL

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ABSTRACT

The population trend of collembolans in arable soil was studied for 24 months from May 1976 to April 1978. In arable fields where sorghum (*Sorghum vulgare*) and berseem (*Trifolium alexandrinum*) were alternatively raised as fodder crops throughout the year was selected. Frequent irrigation and interculture operations were done during cropping seasons in addition to the

application of organic manures and chemical fertilizers. Monthly 5 soil samples (10.0 x 7.5 x 22.5 cm) with the help of rectangular iron sampler were collected and brought to the laboratory for extracting soil animals by Ladell Apparatus. The animals were counted and the population per metre square was calculated. Soil temperature and soil moisture were recorded to know their relationship with collembola.

Higher collembolan population during monsoon months (July, August and September) was recorded when soil moisture was high with low soil temperature and decline in collembolan population during summer months (April-May) was apparent with high soil temperature and low moisture content.

9.4 COLLEMBOLAN COMMUNITY IN TWO CONTRASTING ENVIRONMENTS OF WEST BENGAL

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ABSTRACT

The paper presents a part of an ecological investigation of collembolan community in different ecosystems of West Bengal. Two sites, one at Kurseong in the district of Darjeeling and the other near the University Campus at Burdwan were selected. The plot at Burdwan was in the gangetic plain and experienced moderate amount of rainfall (90-120 cm per year) and fairly high temperature. Vegetation was rather sparse with herbs and shrubs. The alluvial soil was light grey, slightly alkaline in reaction and were low in humus content. The plot at Kurseong at 4000 ft altitude with 200-300 cm rain/year and thickly vegetated, supported a fauna which was numerically high and contained four species, namely, *Onychiurus himalayensis*, *Folsomia octoculata*, *Sminthurinus bimaculatus* and *Entomobrya* sp, while the population at Burdwan was numerically low and was represented by three species namely, *Lepidocyrtus suborientalis*, *Cyphoderus assimilis* and *Lobella maxillaris*. In both the plots the population was at the minimum level in summer months while it was at its peak in monsoon at Burdwan and in winter at Kurseong. The probable reason for the difference in faunal make up and also in the trend of fluctuation is discussed.

INTRODUCTION

Ecology of the collembolan community in undisturbed soils, agricultural grass-land and wood land soils have been studied by workers like Murphy (1953); Sheals (1957) ; Poole (1961) ; Dhillon and Gibson (1962) ; Davis (1963) ; Rapoport and Najt (1966) ; Kaczmarek (1975) ; Tamura (1976) and Rougon (1976). In India Choudhuri and Roy (1972) Hazra (1978) ; and Choudhuri *et al.* (1978) have studied

the qualitative and quantitative composition, seasonal variation and vertical distribution of collembolan population in the undisturbed soils of Gangetic West Bengal. But have failed to give any picture of the collembolan community in contrasting environments prevailing therein. The present investigation is an attempt to evaluate the qualitative composition of collembolan population in two contrasting plots of West Bengal having different environmental conditions.

Location and characteristics of the sampling sites

Two sampling sites, one at Kurseong in the district of Darjeeling and the other near Burdwan University Campus, were selected for this study. The plot at Kurseong was in Himalayan West Bengal being situated at an altitude of about 1475 meters above sea level and experienced an appreciably low temperature and high amount of rainfall (200-300 cm/year). The plot was undisturbed, thickly vegetated and contained good number of herbs and shrubs like *Pteris quadriaurita* (Pteridaceae), *Craniotome versicolor* (Labiatae), *Achyranthes aspera* (Amaranthaceae) etc. and also some pine trees (*Pinus* sp.). Soils of the plot were greyish black in colour, loose in consistency rich in organic matter and fairly acidic. The plot at Burdwan was in the Gangetic plain and experienced moderate amount of rainfall (90-120 cm/year) and fairly high temperature. The plot was rather sparsely vegetated and

TABLE I
Characteristic features of the sampling sites

Site	Altitude from sea level	Vegetation	Average annual rainfall	Soil moisture (%) (mean)	Soil pH (mean)	Soil temp. (°C) (mean)	Organic carbon (%) (mean)
Kurseong	1475 m	<i>Pteris quadriaurita</i> (Pteridaceae)	275 cm	15.6	5.9	16.6	2.3
		<i>Craniotome versicolor</i> (Labiatae)					
		<i>Achyranthes aspera</i> (Amaranthaceae)					
		<i>Pinus</i> sp.					
Burdwan	30 m	<i>Croton sparciflora</i> (Euphorbiaceae)	115 cm	8.9	7.3	26.5	0.95
		<i>Oldenlandia</i> sp. (Rubiaceae)					
		<i>Boerhaavia repens</i> (Nyctaginaceae)					

contained herbs and shrubs like *Croton sparciflora* (Euphorbiaceae), *Oldenlandia* sp. (Rubiaceae) and *Boerhaavia repens* (Nyctaginaceae) etc. Soils of the plot were alluvial in nature, light grey in colour, slightly alkaline and low in humus content. Characteristic features of both the sites are presented in Table I.

MATERIAL AND METHODS

Twelve samples (2 samples in each season) were collected from each plot in three different seasons viz., summer (April), monsoon (August), and winter (December) of two successive years (1977 and 1978). They were collected by a steel borer as employed by Dhillon and Gibson (1962) and the cores were extracted by Tullgren funnels as modified by Macfadyen (1953). Samples were collected upto a depth of 6 cm from the surface. During each sampling, soil temperature was recorded with the help of a soil thermometer and moisture by an infra red moisture balance. The pH of soil suspension was determined by an electric pH meter and organic carbon was estimated by the 'Rapid Titration Method' of Walkley and Black (1934).

RESULTS

Collembolan population encountered in the plots were different in species composition as well as in numerical abundance (Table II). The plot at Kurseong supported a population which was numerically high and composed of species like *Onychiurus himalayensis*, *Folsomia octoculata*, *Sminthurinus bimaculatus* and *Entomobrya* sp. The plot at Burdwan had a population which was numerically low and contained three species, viz., *Lepidocyrtus suborientalis*, *Cyphoderus assimilis* and *Lobella maxillaris*. *O. himalayensis* occupied the top most position in numerical abundance at Kurseong while *L. suborientalis* was the dominant form at Burdwan.

Analysis of population in different seasons showed that the trend of fluctuation in both the plots were rather different. Summer months in both the cases however, witnessed the minimum population. But the population attained its peak in different seasons. It was at its peak in monsoon at Burdwan and in winter at Kurseong (Table II). The monsoon at Kurseong and winter at Burdwan supported moderately high populations. The dominant forms like *O. himalayensis* (at Kurseong) and *L. suborientalis* also exhibited the same pattern of fluctuation as the total population.

Soil factors, on analysis in both the cases, were found to be appreciably different (Table III). The values of pH ranged between 5.6 to 6.1 at Kurseong while

TABLE II
Collembolan fauna encountered in two sampling sites in different seasons

Species	Summer (April)		Monsoon (August)		Winter (December)	
	1977	1978	1977	1978	1977	1978
Site—Kurseong						
<i>Onychiurus himalayensis</i>	42	31	52	42	88	92
<i>Folsomia octoculata</i>	11	14	17	10	31	36
<i>Sminthurinus bimaculatus</i>	9	13	6	8	14	10
<i>Entomobrya</i> sp.	5	7	2	9	8	3
Site—Burdwan						
<i>Lepidocyrtus suborientalis</i>	17	21	38	47	23	29
<i>Cyphoderus assimilis</i>	13	16	28	23	18	21
<i>Lobella maxillaris</i>	9	4	15	11	10	9

it was between 7.1 and 7.4 at Burdwan. Soil temperature was appreciably high at Burdwan ranging between 20.5°C and 31.1°C but it was significantly low at Kurseong and ranged between 9.5°C and 21.2°C. Moisture in both the cases were at its highest

TABLE III
Mean values of soil factors and mean number of collembola in different seasons

Season	Temperature (°C)	Moisture (%)	pH	Organic carbon (%)	Collembola (mean)
Site—Kurseong					
Summer	21	6.6	6.10	2.6	66
Monsoon	19	28.0	5.85	2.4	73
Winter	10	12.2	5.75	2.6	141
Site—Burdwan					
Summer	30.2	6.3	7.25	0.75	40
Monsoon	29.7	11.8	7.30	1.25	81
Winter	20.3	8.6	7.35	0.85	55

level in monsoon months but it exhibited a very wide range of variation at the Kurseong site. Percentage of organic carbon in all the samples of Kurseong was found to be higher in composition than those obtained from Burdwan.

DISCUSSION

The plots under study were remarkably different in their soil conditions, faunal make up and in the trend of seasonal variation. The distinctiveness of the faunal composition in both the cases were due to the differences in microclimatic conditions. High altitude, low temperature, different types of vegetation, high amount of rainfall, low pH etc., were the characteristic features of the sampling site at Kurseong. The plot at Himalayan West Bengal supported a larger fauna in comparison to that of Gangetic plain which might be due to prevalence of moist humid climate, relatively greater amounts of plant remains and high organic content and thus providing a stable food supply. Lean population during summer months in both the cases were probably due to increased surface temperature, low moisture level and relatively lower concentration of organic carbon. The monsoon peak observed in the Burdwan plot was due to high amounts of organic matter, fairly good soil moisture content and moderate soil temperature. But soil moisture was too high during monsoon months at Kurseong which probably hindered the population increase. In winter months however, all the soil factors attained their optimum condition and supported a maximum population at Kurseong.

In view of the findings of the present investigation it can well be assumed that the difference in the qualitative and quantitative composition as well as the seasonal variation of collembolan population at different sites are due to the local differences in the substrate composition which are likely to exert profound influence on the pattern of population structure.

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9.5 STUDIES ON THE DISTRIBUTION OF COLLEMBOLA POPULATION IN TWO DIFFERENT SOIL CONDITIONS (GANGETIC ALLUVIUM AND LATERITE SOIL) IN RELATION TO SOME MAJOR EDAPHIC FACTORS

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ABSTRACT

Qualitative and quantitative observations of subterranean collembola together with major edaphic factors in two different soil conditions in West Bengal were made for three consecutive years. Altogether 3,314 individuals were extracted from both the sites, belonging to 11 genera and 17 species.

Maximum collembolans were encountered from the site with alluvium soil (65.08 per cent) than the other with laterite soil (34.91 per cent), *Lepidocyrtus heterolepsis* was the most dominant species and occurred only in the alluvial soil.

The regression and coefficient of correlation analysis between the monthly abundance of collembola and the soil factors like phosphate, nitrate and moisture showed statistically high significant correlation ($P < 0.01$).

INTRODUCTION

Various investigators namely Bawjea (1939); Glasgow (1939); Murphy (1953); Bellinger (1954); Choudhuri (1961); Dhillon and Gibson (1962); Christensen (1964); Hale (1966); Choudhuri and Roy (1972); Mitra *et al.* (1977) and Hazra (1978a,b) have studied the ecology of soil-microarthropods particularly Collembola and Acarina. But no attention has been paid as yet to compare the ecological behaviour of Collembola in different soil conditions. In the present study the population and distribution of Collembola in gangetic alluvium of the district of 24-Parganas and in laterite soil of the district of Bankura of West Bengal has been compared in relation to the soil factors like phosphate, nitrate and water contents of soil.

Topography and characteristics of sampling sites

Two sampling sites edaphologically and climatologically distinct from each other were selected. Altogether six plots, three from each site, were taken. Each site was 7 meter square, uncultivated and undisturbed having the vegetational cover as mentioned below.

Site A : It was located at Barrackpur Lat Bagan campus on the bank of river Ganges in the district of 24-Parganas and received an annual rainfall ranging between 92.40 and 123.20 cms. Soil of this site was alluvial in nature, grey in colour and clay loam in texture. It was covered with a number of herbs, shrubs and trees, viz., *Eclipta alba* (Compositae), *Euphorbia hirta* (Euphorbiaceae), *Paspalum* sp. (Graminae), *Lantana camara* (Verbinaceae), *Coccinia cordifolia* (Cucurbitaceae), *Scopalia dulcis* (Scrophulariaceae), *Mangifera indica* (Anacardiaceae), *Ficus religiosa* (Urticaeae) etc.

Site B : It was located at Bankura Christian College Campus on the bank of the river Gandheswari (a seasonal river) in the district of Bankura and received an annual rainfall ranging between 69.30 and 89.32 cms. Soil of the site was laterite in nature, reddish brown in colour and sandyloam in texture. It was covered with a number of herbs and shrubs like *Echinichloa colonum* (Graminae), *Lantana camara* (Verbinaceae), *Vernonia cineria* (Compositae), *Shorea robusta* (Dipterocarpaceae), and *Bambax malabaricum* (Bombacaceae).

MATERIAL AND METHODS

Altogether 216 soil samples were drawn from each site, 72 from each plot at monthly intervals for a period of three successive years (January, 1971 to December, 1973) by means of a soil auger (Auerbach and Crossley, 1960). The collembolan fauna were extracted from the soil samples by means of an extraction apparatus described by Murphy (1960). Nitrate and phosphate contents were estimated by colorimetric method, while moisture content was determined by means of an infra-red moisture balance.

OBSERVATIONS

Analysis of Collembolan population : A total of 3,314 collembola were collected, from both the sites. Six species belonging to 4 genera constituted nearly 50 per cent of the total collected (Table 1). These were *Lepidocyrtus heterolepis*, *Cyphoderus albinus*, *Cyphoderus* sp., *Lepidocyrtus* sp., *Isotomina thermophila* and *Proisotoma* sp. in order of dominance. Of the six dominant species *Lepidocyrtus heterolepis* showed

the highest population (8.17 per cent). *Sphacridia* sp. showed the minimum population (2.11 per cent) being confined to site A (Table I). On comparison of the populations sitewise, site A showed large population (65.08 per cent) than site B (34.91 per cent). Only one species *Isotomina thermophila* was common to both the sites.

TABLE I
Species and their density in different years

Species	Site—A					Site—B				
	'71	'72	'73	Total	%	'71	'72	'73	Total	%
<i>Lepidocyrtus heterolepis</i>	71	98	102	271	8.17	—	—	—	—	—
<i>Cyphoderus albinus</i>	71	127	70	268	8.08	—	—	—	—	—
<i>Megalothorax minimus</i>	56	49	33	138	4.16	—	—	—	—	—
<i>Sminthumes</i> sp.	35	38	18	91	2.74	—	—	—	—	—
<i>Folsomides</i> sp.	43	48	42	133	4.01	—	—	—	—	—
<i>Isotomina thermophila</i>	67	92	80	239	7.21	69	82	87	238	7.18
<i>Hypogastrure</i> sp.	29	39	58	126	3.80	—	—	—	—	—
<i>Lobella (Lobella) maxillaris</i>	51	56	32	139	4.19	—	—	—	—	—
<i>Pseudosinella</i> sp.	38	51	57	146	4.40	—	—	—	—	—
<i>Isotomina</i> sp.	48	69	47	164	4.94	—	—	—	—	—
<i>Entomobrya</i> sp.	55	58	75	188	5.67	—	—	—	—	—
<i>Sphaeridia</i> sp.	20	29	21	70	2.11	—	—	—	—	—
<i>Isotomurus ciliatus</i>	54	68	62	184	5.55	—	—	—	—	—
<i>Cyphoderus</i> sp.	—	—	—	—	—	82	94	87	263	7.9
<i>Lepidocyrtus</i> sp.	—	—	—	—	—	83	88	87	258	7.78
<i>Proisotoma</i> sp.	—	—	—	—	—	82	67	75	224	6.75
<i>Folsomides</i> sp.	—	—	—	—	—	72	50	52	174	5.25

Seasonal variation of population : The population peaks (maxima) appeared during the months of July-August (monsoon season). Gradually the curve sloped down upto November due to the prevalence of low density, followed by a second time partial rise in population in December and January (winter season) and a steep fall in the month of May (summer) (Figs. 1 and 2).

Analysis of edafic factors : The Soil factors considered here exhibited a good deal of fluctuation from month to month and also from season to season in both the sites (Tables 2a, b). Moisture was maximum in July-September (monsoon season) and minimum in April-June (summer season). Of the two sampling sites the phosphate content of the site A was relatively high than that of the site B ; It was maximum in April-June, moderate in October-December and very low in July-August

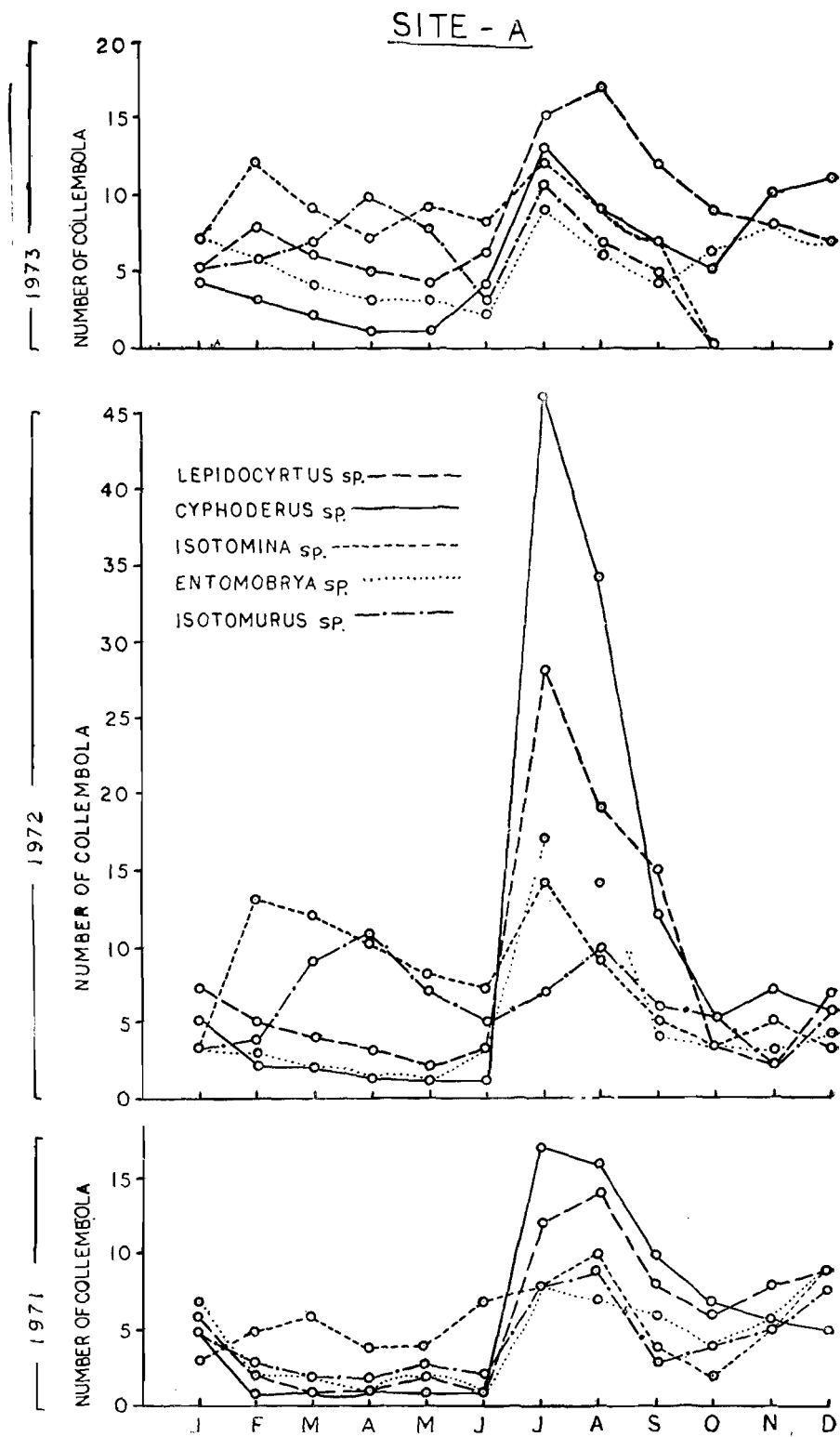


Fig. 1 Monthly fluctuations of population of Collembola in Site-A

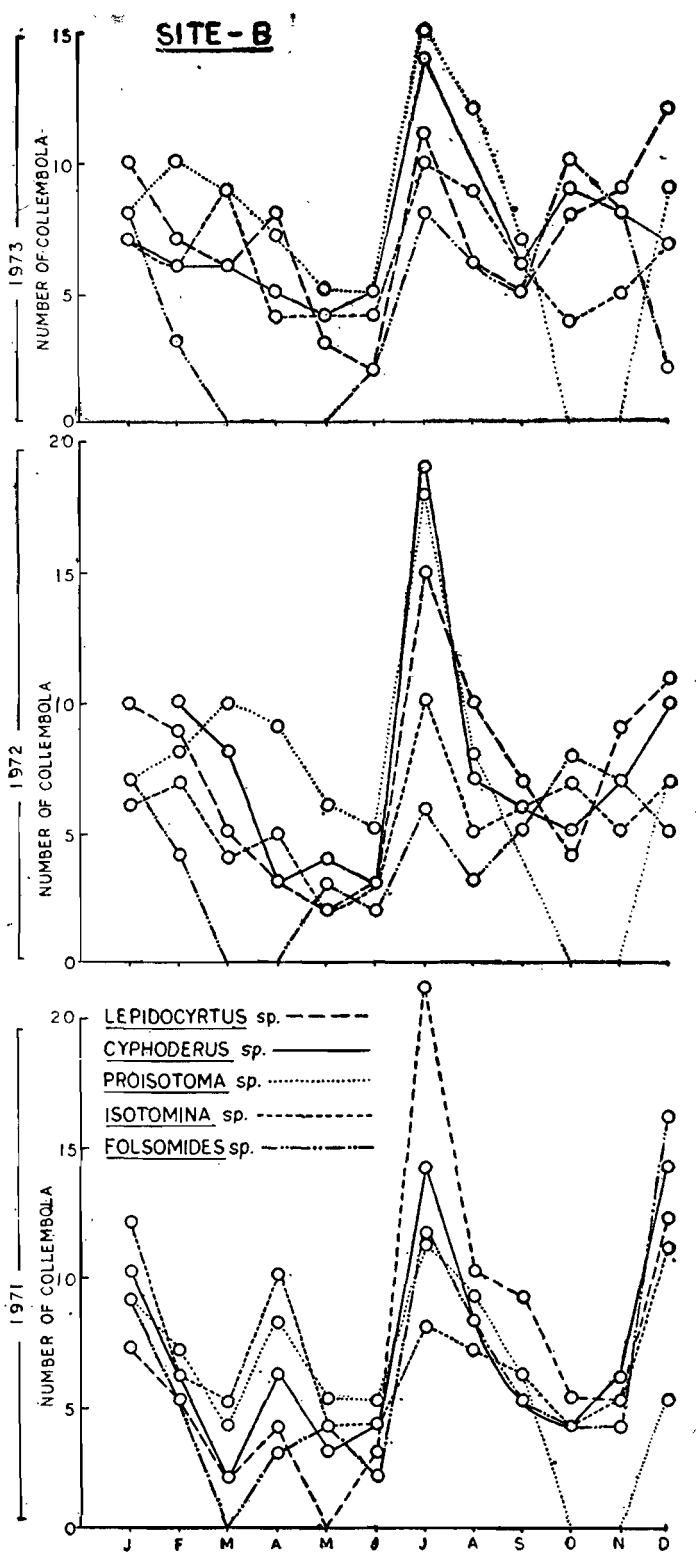


Fig. 2 Monthly fluctuations of population of Collembola in Site-B

TABLE IIa
Soil factors and number of Collembola in site—A

	Collembola (number)			Phosphate (ppm)			Nitrate (ppm)			Moisture (%)		
	'71	'72	'73	'71	'72	'73	'71	'72	'73	'71	'72	'73
Jan.	73	68	62	.40	.43	.37	2.40	2.65	2.70	10.00	9.5	13.50
Feb.	22	53	50	.43	.46	.38	2.30	2.42	2.05	7.50	8.2	11.20
March	15	44	42	.49	.48	.46	2.60	2.30	1.90	7.00	7.0	10.50
April	13	36	36	.57	.51	.49	2.70	2.52	1.60	7.50	7.40	7.20
May	19	24	34	.61	.56	.64	2.05	1.80	1.30	6.00	6.00	9.50
June	21	27	39	.66	.65	.61	1.80	1.90	1.50	6.50	6.0	10.00
July	108	206	120	.41	.41	.38	3.10	2.95	3.10	17.50	18.5	17.50
August	115	178	97	.43	.40	.41	2.95	2.80	3.00	16.00	16.0	15.50
Sep.	68	61	68	.43	.43	.45	2.70	2.70	2.35	15.50	15.5	14.50
Oct.	33	29	31	.46	.46	.43	2.80	2.90	1.90	13.50	11.0	13.50
Nov.	48	33	33	.56	.53	.49	2.00	2.60	2.20	10.00	9.0	13.00
Dec.	103	55	64	.36	.39	.51	2.50	2.70	2.60	9.5	8.2	10.50

TABLE IIb
Soil factors and number of Collembola in site—B

	Collembola (number)			Phosphate (ppm)			Nitrate (ppm)			Moisture (%)		
	'71	'72	'73	'71	'72	'73	'71	'72	'73	'71	'72	'73
Jan.	47	42	40	.11	.11	.10	1.70	1.60	1.85	7.00	6.50	7.50
Feb.	29	38	32	.14	.16	.14	1.67	1.50	1.70	6.00	5.50	6.50
March	13	27	30	.18	.19	.15	1.60	1.33	1.50	5.60	6.00	6.00
April	31	20	24	.20	.21	.23	1.20	1.27	1.10	5.00	5.00	5.50
May	16	17	16	.19	.20	.25	1.10	0.80	0.40	4.50	5.20	4.50
June	18	16	18	.18	.18	.22	1.05	0.90	0.60	5.00	5.00	4.00
July	66	68	58	.10	.10	.17	2.00	1.86	2.10	14.50	15.00	13.50
August	42	33	43	.10	.10	.13	1.90	1.80	1.90	12.08	16.50	12.00
Sep.	31	28	29	.13	.14	.14	1.27	1.33	1.40	12.00	13.00	12.50
Oct.	17	24	31	.16	.18	.19	1.40	1.60	1.30	11.00	11.50	10.50
Nov.	20	28	30	.17	.15	.13	1.40	1.65	1.00	7.00	7.20	9.00
Dec.	58	40	37	.14	.14	.14	1.67	1.60	1.50	6.00	6.50	8.50

and to some extent in January. As in phosphate, values of nitrate were higher in the site A than in the site B ; it was maximum in monsoon months, minimum in May-June and moderate in winter months as well as in March (winter fall). The mechanical analysis of the soil samples (Table III) showed higher percentage of silt in the Site A and higher percentage of coarse sand in the site B.

TABLE III
Mechanical analysis of soil samples

Site	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)
A	1.85	21.00	56.65	20.50
B	58.00	25.50	15.5	1.00

Interaction with soil factors

To ascertain the interaction of the soil factors with the population of collembola the correlation coefficient values between collembola and soil factors were calculated (Table IV). The data reveal that in both the sites significant positive correlation exists between the density of Collembola and both nitrate and

TABLE IV
Result of statistical analysis

Site	Mean	Value of r	Regression equation of number of Collembola (Y) on soil factors (X). $Y=a+bx$
Y:No. of Collembola	59.17	—	
Phosphate	0.48	— 0.5607**	$Y=199.20-291.72x$
A Nitrate	2.42	0.4533**	$Y=-38.16+40.22x$
Water content	11.07	0.7387**	$Y=-37.36+8.72x$
Y:No. of Collembola	32.14	—	
Phosphate	0.16	— 0.6643**	$Y=70.02-236.78x$
B Nitrate	1.35	0.4858**	$Y=6.98+18.64x$
Water content	8.29	0.5241**	$Y=14.81+2.09x$

**Significant at 1% level

moisture content, while significant negative correlation exists between the density of collembola and phosphate content (Fig. 3 to 8). Statistical analysis (Table V) clearly shows existence of differences between the sampling years and also between the months of the sampling years. Further it indicates that the monthly variation are reasonably constant throughtout.

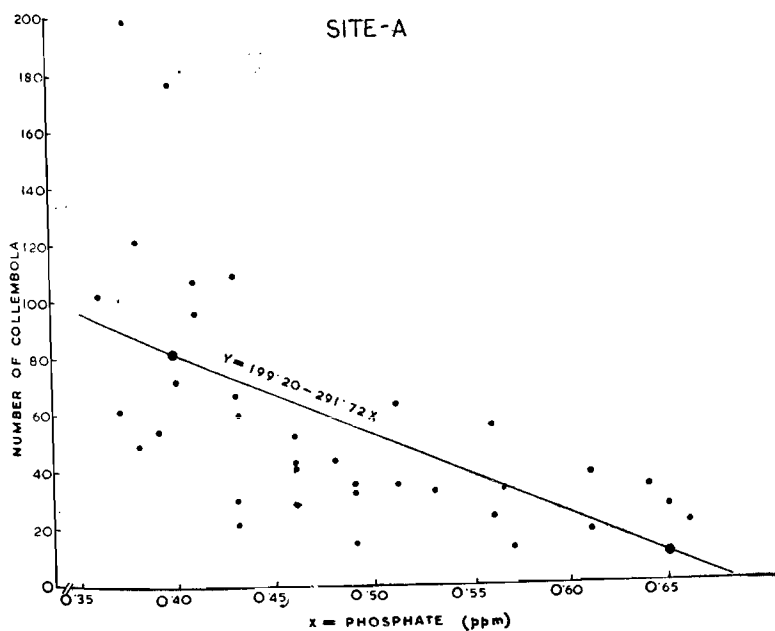


Fig. 3 Regression line of collembola on phosphate (ppm) in Site-A

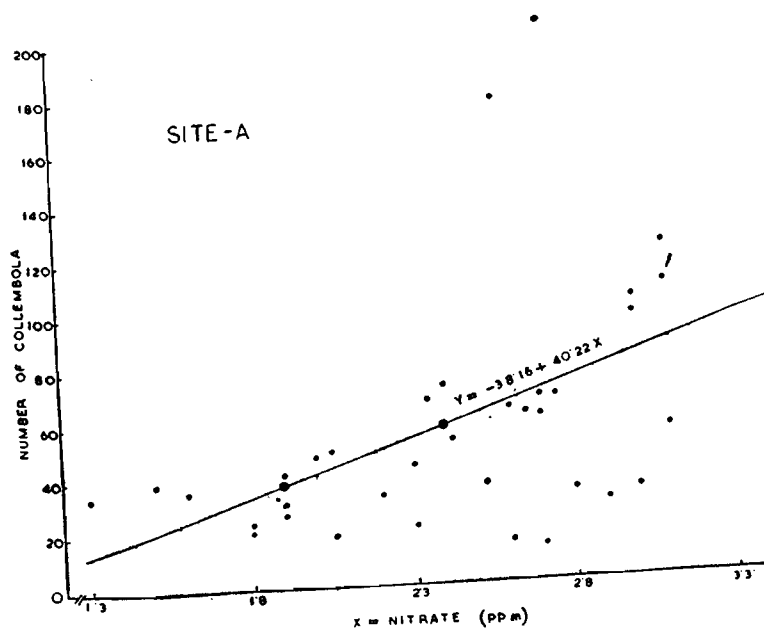


Fig. 4 Regression line of Collembola on nitrate (ppm) in Site-A

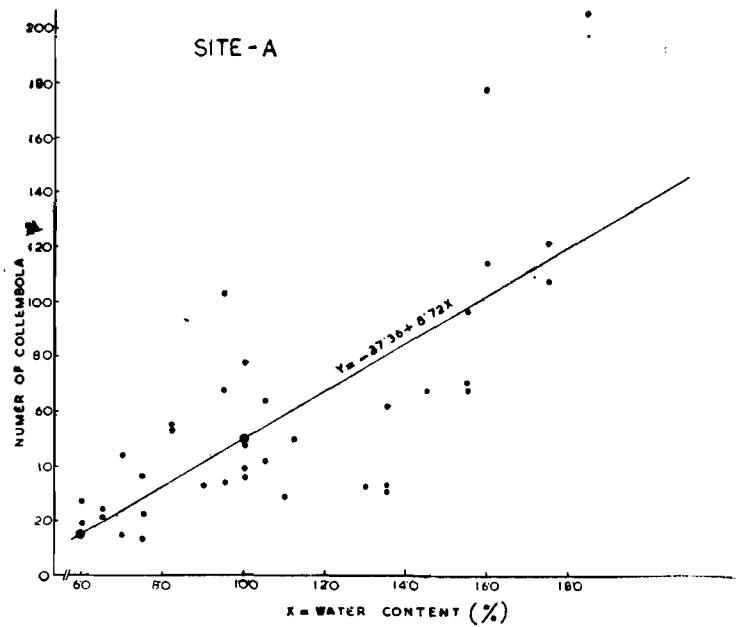


Fig. 5 Regression line of Collembola on moisture (%) in Site-A

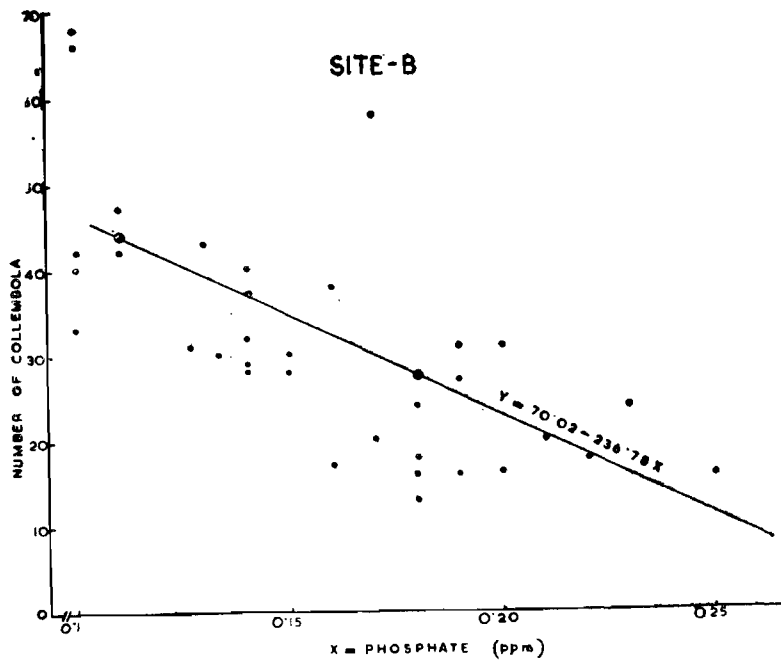


Fig. 6 Regression line of Collembola on phosphate (ppm) in Site-B

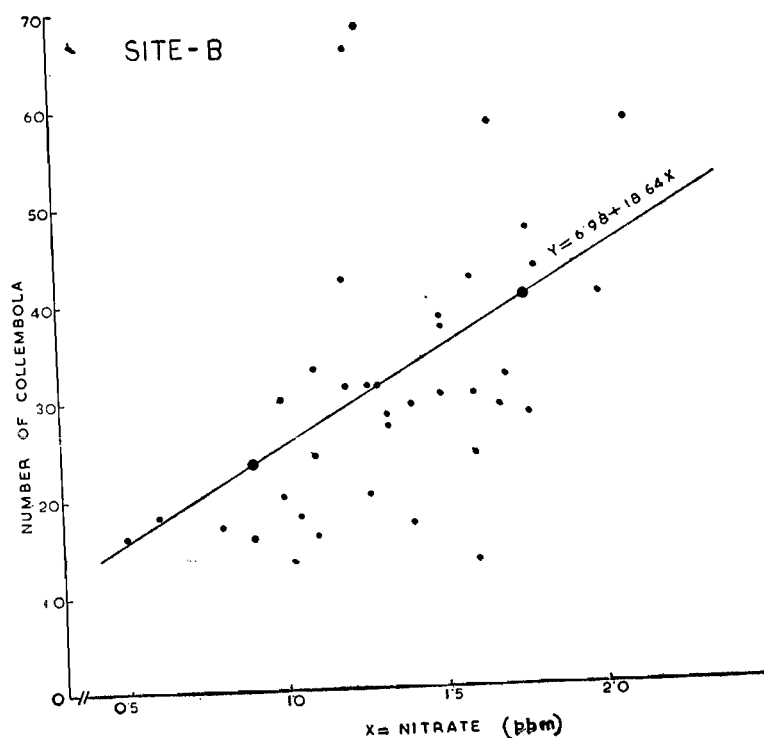


Fig. 7 Regression line of Collembola on nitrate (ppm) in Site-B

TABLE V
Analysis of variance

Sites	Degrees of freedom		Sum of squares	Mean square	Frequency
A	Year	2	1428	709.00	1.4026
	Month	11	53870	4897.27	9.6880**
	Error	22	1121	505.50	
	Total	35	66409		
B	Year	2	2	1.00	0.0265
	Month	11	61.79	561.73	14.8724**
	Error	22	831	37.77	
	Total	35	7012		

** Significant at 1 per cent level.

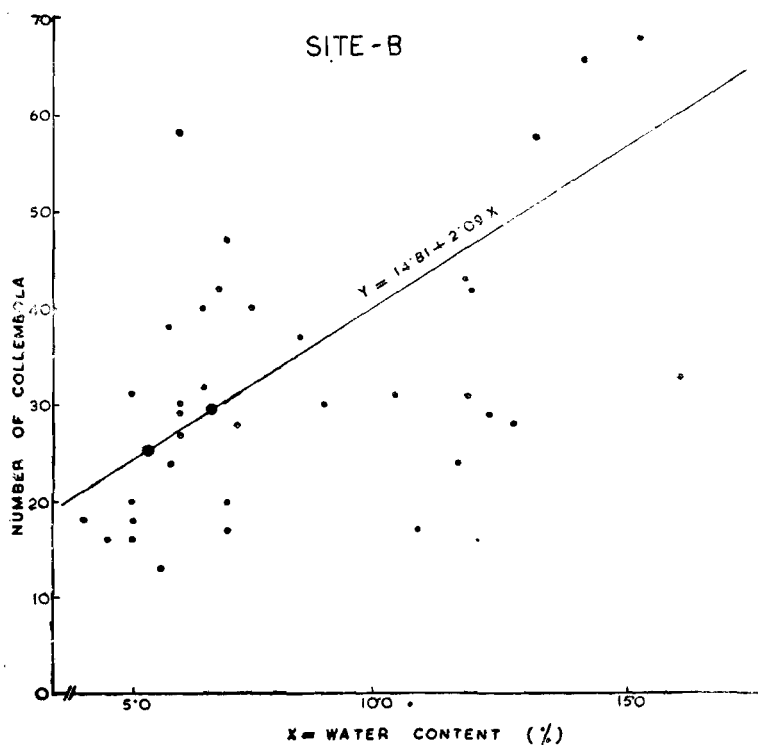


Fig. 8 Regression line of Collembola on moisture (%) in Site-B.

DISCUSSION

The mechanical analysis of soils of the two sampling sites showed wide textural differences between them. The number of collembolans collected were maximum during monsoon months in both sites when both nitrate and water content were maximum, this observation conforms to the findings of Choudhuri and Roy (1971) and Hazra (1978). Phosphate content however, was minimum during this period in both soil conditions. The two sites varied also remarkably in their species composition. The number of genera/species were relatively more in the site-A, having 13 species, than in the site B, having only 5 species. *Isotomina thermophila* being recorded from both the soil conditions should be considered as "ubiquitous". All other species, being however restricted to one site or the other, perhaps, indicate their low range adaptive capacity to diverse conditions. Highest number of collembola was associated with the alluvial soil, this might be due to the prevalence of more favourable situation in the alluvial soil, like higher moisture and nitrate content in comparison to that of the laterite soil. This contention can be justified

from the correlation and regression analysis, wherein we see a positive correlation between the number of collembola and nitrate and moisture content, whereas a negative correlation exists between the number of collembola and phosphate content of the soils. Therefore, it might be inferred that a shift in the moisture and nitrate status of soil would exert profound influences in determining the population of collembola in soil. In contrast to moisture and nitrate the role of phosphate in determining the population-structure of collembola seemed to be dubious.

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9.6 CHANGES IN THE POPULATION STRUCTURE OF COLLEMBOLA AND ACARINA IN A GRASSLAND ECOSYSTEM AT CALCUTTA

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Collembola and Acarina form the major component in any soil ecosystem. Their population structure is largely governed by their mutual interactions.

In the present communication, which forms a part of long term observations (1975-78), some aspects of their population structure in a grassy plot of land at Calcutta are incorporated. For this study soil samples were drawn weekly, round the year, and the data obtained during 1975-76, are presented here.

In general, acarines were found to dominate collembolans quantitatively during this period. The former exhibited highest population during winter in 1975 while in 1976 they exhibited a premonsoon peak. Collembolans, however, exhibited two peaks in population almost in the same season during both the years—one occurring during monsoon period (June-July) and another during prewinter (October).

Regression in the density of Collembola and Acarina populations and their correlations with the abiotic factors, viz., relative humidity and temperature, were also analysed.

Population studies of Collembola and Acarina have received considerable attention of soil biologists owing to their preponderance and omnipresence in every kind of soil ecosystem. Quite a good amount of data has accumulated through years in India and other parts of tropics of the world. But most of the works attempt to correlate changes in the population structures of either Collembola or Acarina, with various abiotic and edaphic factors.

Collembolans and acarines remain bound together in any soil environment owing to their preference to almost identical microclimatic conditions including food preference, both being mostly saprophagous and thus their population is largely governed through mutual interactions. It is in this context, present observations dwell on the interactions of populations of these two predominant and competing soil microarthropods in a grassland ecosystem managed at the Eden Gardens, Calcutta. Two physical factors, viz., temperature and relative humidity which affect both almost equally are also taken into consideration.

MATERIAL AND METHODS

The plot was sampled weekly with stainless steel samplers each having an inner cross sectional area of 8.55 sq cm. Soil samples were taken up to a

depth of almost 3 cm and placed inverted in a modified expedition funnel apparatus (Macfadyen, 1953; Mitra *et al.*, 1977, 1978). The description of the plot and the composition of the plant community is same as provided by Mitra *et al.* (1977, 1978). Altogether 309 samples were extracted during this period, *i.e.*, at the rate of *c.* 3 samples every week.

RESULTS AND DISCUSSION

Altogether twenty species of Collembola were collected from the site. *Cyphoderus albinus* (Nicolet), *Megalothorax minimus* Willem, *Folsomides parvulus* Stach, *Cryptopygus thermophilus* (Axelson), *Arrhopalites* sp., *Sphaeridia* sp., *Lepidocyrtus* sp., *Sinella* (*Sinella*) sp., *Pseudachorutes* sp., *Tullbergia* (*Stenaphorura*) sp., *Lepidocyrtus* (*Lepidocyrtus*) sp., *Salina bengalensis* Mitra occur predominantly. Acarines are mostly represented by *Scheloribates*, a few Mesostigmatids and some Trombidiformes.

Population of both Collembola and Acarina exhibited a sort of rhythmic changes, one dominated the other periodically through weeks, during the period under observation. On one occasion during December, 1975 (24.12.75) large number of juvenile mesostigmatids were obtained in a single core of soil sample presumably due to the fact that the core covered the entire population just after eclosion or before the nymphs got opportunity to disperse. This obviously resulted in the great numerical dominance of Acari over Collembola at this site during this period. If this influx of Acari population on this single date is ignored, then the changes and balance in population of both Collembola and Acarina remained fairly uniform during this period.

Monthly changes in the total number of Collembola and Acarina in relation to relative humidity and temperature are presented in Fig. 1. During June, 1975 to November, 1975, collembolans dominated acarines, followed by a sharp peak of population of the latter during December, 1975 obviously for the reason mentioned above. This dominance of Acari continued till April, 1976. Peak population of Collembola, however, occurred during June, 1976 followed by another moderate peak during October, which quantitatively coincides with the population obtained for Acari during August, September and October in 1976. This peak in population of both Acari and Collembola declined during October and November. Subsequently, (*i.e.*, December, 1976 to April, 1977) acarines dominated Collembola followed by a rise of population of the latter during May, 1977. It is thus obvious that acarines dominated collembolans quantitatively during most of this period. The former exhibited highest population during winter in 1975 while in 1976 they exhibited premonsoon peak. Collembolans, however, exhibited two peaks in population almost in

GRASSLAND (MANAGED)

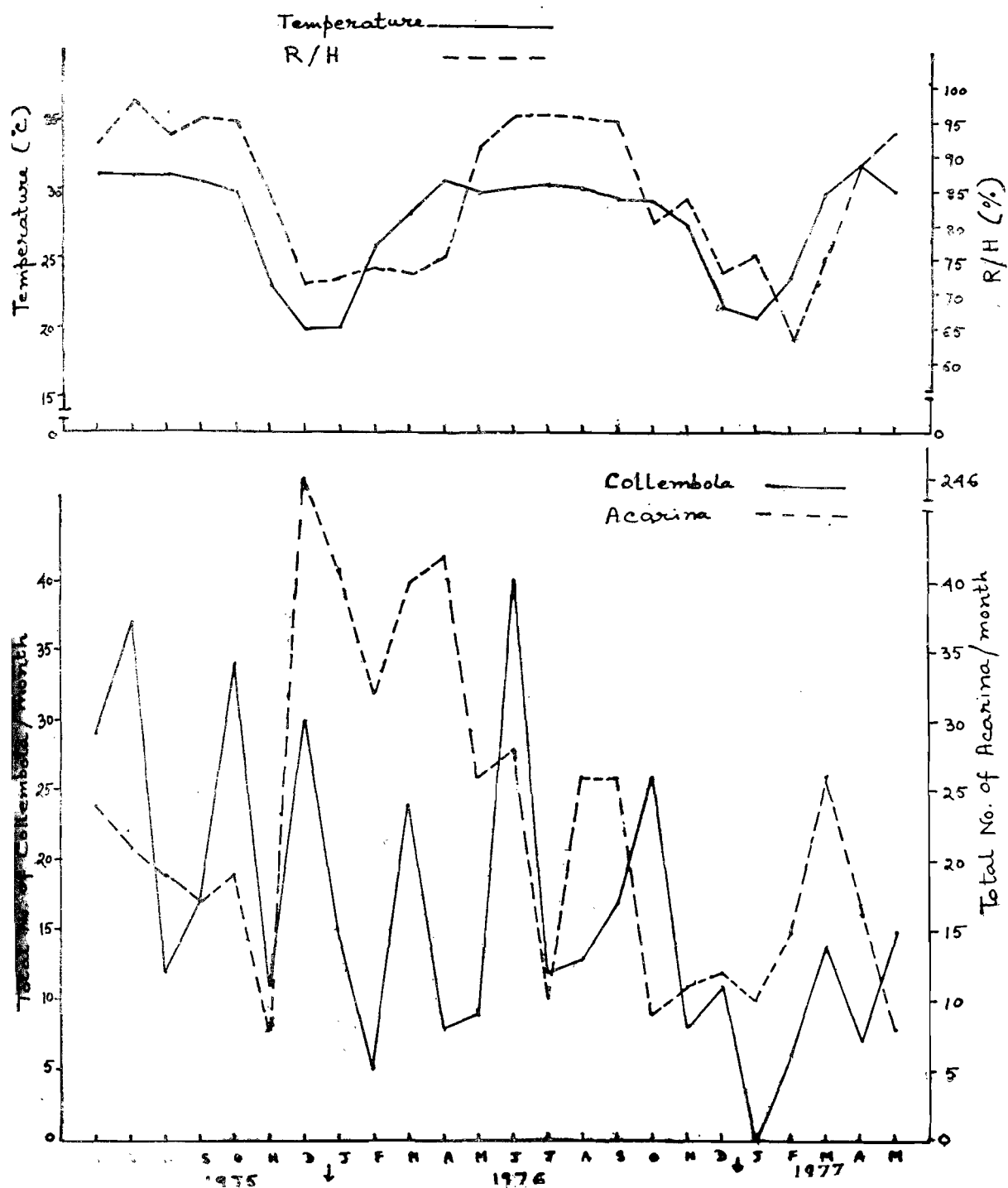


Fig. 1 Monthly changes in the total collembolan and acarine populations during 1975-77 in relation to relative humidity and temperature

the same season during both the years : one occurring during monsoon period (June-July) and another during prewinter (October).

It is seen that higher temperature and relative humidity resulted in an increase of population of Collembola while, lower temperature and humidity were preferred by Acarina and in such conditions they exhibited peaks during most of the period under observation.

CONCLUSION

The managed grassland ecosystem, on which present communication is based, supports the largest number of genera/species of Collembola (Mitra *et al.*, 1977, 1978) in comparison to various biotopes studied at the Eden Gardens, Calcutta. It also supports, at least quantitatively a good acarine fauna. Grassland ecosystems (natural or managed) with limited disturbance by herbivorous animals, provide an uniform microclimatic conditions, almost round the year and thereby provide a safe and permanent refuge for soil microarthropods, especially the euedaphic forms. Further, the rate of energy turnover in grassland soil is high as compared to forest soil, and this, therefore, serves as a permanent source of food for saprophagous animals. Being mostly saprophagous, Collembola and Acarina play, therefore, an important role in faster mineralisation, in the grassland ecosystem. The total number of Collembola and Acarina, however, appears less at the site under investigation apparently due to the dimension of samplers used as well as periodic human interference.

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ABSTRACT

Japyx solifugus is a small blind insect occupying deep porous litter, humus layers and crevices between moist soils of the garden in the University campus. It is a solitary insect rather widely distributed in the shady areas, occurring with frequency of 2 to 4 insects per square meter. The total body length of the insect is between 3.02 mm. and 5.90 mm. The body weight is between 1 and 3 mg.

The insect is predominantly white or yellow in colour and completely blind. It is strongly thigmotactic and negatively phototactic. It has well developed antennae which are from 29 to 45 segmented. This insect feeds mainly on humus and other decaying material which is in abundance in the niche. It can be reared in the laboratory in glass vials containing adequate soil rich in humus content. Reared insects are preferably kept in shaded and cool areas and the soil is moistend regularly. This is the first record of *Japyx* from Poona.

INTRODUCTION

Diplura is a lesser known group of Apterygote insects, commonly encountered in the soil ecosystem. These insects are totally blind (Fig. 1) and hide themselves in soil crevices or humus beds. Very little is known about their ecology, development, distribution, food and feeding habits. Their role in soil ecosystem is also overlooked. Diplurans are divided into two families, Campodeidae and Japygidae. The present paper gives some aspects of bioecology of *Japyx solifugus* from the family Japygidae. This is also the first record of a Japygid from Poona.

MATERIAL AND METHODS

Insects selected for the present study were collected from Poona University Garden. They were located under sapling bags or earthen pots. The top soil layer was disturbed by a shovel and the insects were collected alongwith the soil. They were brought to the laboratory in clean specimen tubes. Frequency of animals per square meter in different parts of the garden was studied.

These insects were studied under a binocular microscope with calibrated oculometer. The body length and the weight of each insect was measured. This data of about 30 animals was subjected to regression analysis, to study length-weight relationship. Regression formula used was $Y = a + bX$. Where 'Y' is the

total body length and 'X' is total body weight. It was assumed that the body weight is an independent variable and the body length a dependant variable. The values of a and b were calculated. A comparison was made between the expected values and observed values. Regression coefficient was calculated by a formula

$$r^2 = \frac{(\sum XY)^2}{\sum X^2 \times \sum Y^2} \text{ which was } 0.94. \text{ (Lewis and Taylor, 1967).}$$

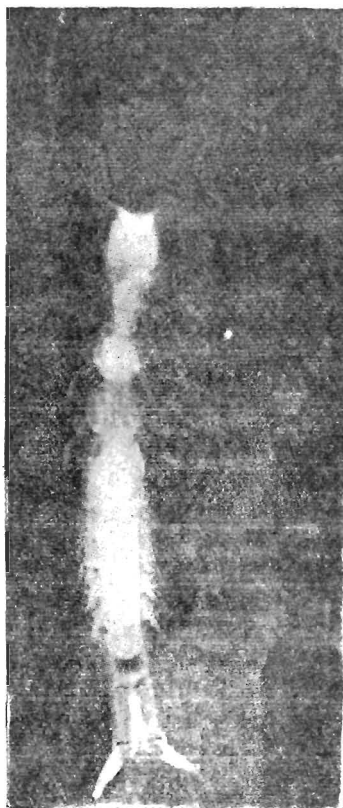


Fig 1 *Japyx solifugus*

Biochemical composition of *Japyx* was carried out with the help of the homogenate prepared from 20-25 insects. Total glucose was estimated by Phenol - Sulphuric acid method (Whistler and Wolform, 1962) and proteins were determined by standard Lowry's methods (Lowry *et al.*, 1951). The results of glucose and proteins were expressed in mg/g wet weight.

The mechanical and chemical analysis of the soil was carried out for the parameters such as pH, EC, water holding capacity, texture, amount of Ca, Mg, Na, K, Cl, HCO_3 , SO_4 etc.

RESULTS AND DISCUSSION

These insects are very small in size usually weighing between 1 and 3 mg. The length-weight relationship when subjected to regression analysis shows that there is a good relation between the two. Length weight relationships are usually parameters studied for growth pattern of animals. Regression analysis data has been graphically represented (Fig. 2).

The graph shows a distinct relationship between the total length and total body weight

Biochemical composition of insects indicate that there is predominance of carbohydrates which are probably the food reserves of the insect. The protein contents of the insect, however, appears to be low (Table II).

The quantitative estimation of relative abundance of these insects shows that they are very sparsely distributed. Only about 2 to 4 insects are found per square meter which is low as compared to the other soil fauna.

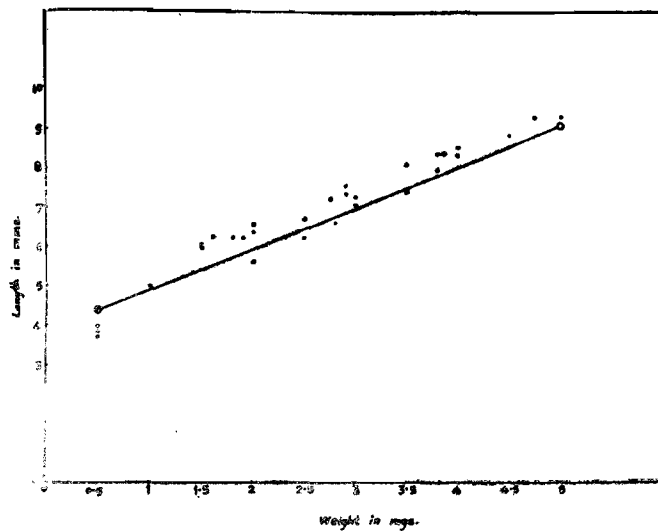


Fig. 2 Regression analysis data of *Japyx solifugus*

TABLE I
Length/weight Relationship in Japyx solifugus

Obs. No.	'X' Weight in mg (Observed)	'Y' Length in mm (Observed)	(Y) Length in mm (expected)
1	2	3	4
1	0.5	4.00	4.43
2	1.8	6.29	5.96
3	1.5	6.14	5.61
4	3.0	7.29	7.37
5	3.5	8.14	7.96
6	2.9	7.57	7.25
7	3.8	8.43	8.31
8	2.0	6.57	6.19
9	1.9	6.29	6.08
10	1.0	5.00	5.02
11	0.5	3.71	4.43
12	3.8	8.00	8.31
13	4.5	8.86	9.14
14	4.0	8.57	8.55
15	5.0	9.29	9.73

1	2	3	4
16	2.8	7.29	7.14
17	3.0	7.14	7.37
18	2.5	6.86	6.78
19	3.5	7.43	7.96
20	4.0	8.43	8.55
21	1.6	6.29	5.72
22	0.5	3.71	4.33
23	3.0	7.29	6.19
24	2.0	6.43	6.19
25	2.0	6.57	6.78
26	1.8	6.29	5.96
27	0.5	3.86	4.43
28	2.8	7.29	7.14
29	1.5	6.00	5.61

$\bar{X} = 2.4567, \sum x^2 = 225.37$ (uncorrected)

$\bar{Y} = 6.7297, \sum y^2 = 1423.8815$ (uncorrected)

$\sum XY = 548.135$ (uncorrected)

Corrected $\sum x^2 = \text{uncorrected} \sum x^2 - n(\bar{x})^2 = 44.3088$

$\sum y^2 = \text{uncorrected} \sum y^2 - n(\bar{y})^2 = 65.2157$

$\sum xy = \text{uncorrected} \sum xy - n(\bar{y})(\bar{x}) = 52.14941$

$$b = \frac{\sum xy}{\sum x^2} = 1.1770$$

$$a = \bar{y} - bx = 3.8382$$

$Y = 3.8882 + 1.1770$ multiplied by 'X'.

$$r^2 = \frac{(\sum xy)^2}{\sum x^2 \times \sum y^2} = 0.94$$

The soil analysis data (Table III) indicates that it is a silty-clay loam with considerable porosity and has moderate water holding capacity. Coupled with these favourable properties of the soil is the protection afforded by the earthen pots or the sapling-bags, forming a perfect niche for this shade loving insect.

TABLE II
Biochemical composition of Japyx solifugus

Glucose	—→	1.550	mg/g wet weight
Protein	—→	0.966	mg/g wet weight

Due to continuous watering and use of manures, the soil is rich in humus, which probably forms the food of these insects.

Although some workers have indicated that *Jaypx* species are active predators feeding upon soil dwelling sluggish insects like campoda (Kuhnelt, 1961), our laboratory studies do not support this. Preliminary investigations have shown that the

TABLE III
Analysis of soil sample

Mechanical analysis		Chemical analysis		
1. Coarse Sand	11.80	1. CaCO ₃	2.5 %	
(> 0.2 mm)		2. HCO ₃	4.4 Milli equivalent/ltr.	
2. Fine Sand	32.76	3. Cl	4.0	— „ —
(0.2 to 0.02 mm)		4. Ca	6.0	— „ —
3. Silt	28.80	5. Mg	2.0	— „ —
(0.02 to 0.002)		6. Na	3.0	— „ —
4. Clay	26.64	7. K	0.012	— „ —
(< 0.002)		8. SO ₄	Nil	— „ —
5. Texture	Silty clay loam			
6. Water holding capacity	57.00			
(Saturation percentage)				

pH → 8.4, E.C./mmhos/cm → 0.93 (of saturation extract)

insects largely rely on soil humus and soil fungi/bacteria as food source (Kevan, 1955). Attempts to rear these insects in the laboratory and study their development food, feeding habit etc., are being made. The position of these insects in the food-web of soil ecosystem is not very clear.

Our thanks are due to Dr. H. Steinmann for helping us in identification of the insect. Thanks are due to the Director of Irrigation Research and Development, Pune, for co-operating in soil analysis. Thanks are also due to the Head of the Zoology Department, Poona University, for extending necessary facilities.

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9.8 RECENT FINDINGS ON THE BIONOMICS AND CONTROL OF WHITE GRUBS IN KARNATAKA

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ABSTRACT

Further studies on white grubs have thrown new light on their biology and ecology. Studies made on the migration and dispersal of *Holotrichia serrata* revealed that the adults do not go beyond 300 meters from the place of emergence and majority settle to lay eggs around 30 meter radius. The larval migration was maximum up to 8 meters under row crops and much less in grassland. Emergence of adults of *H. serrata* occurs only from first week of April after the rains. Early rains in February–March did not help the emergence of beetles. Adults of *H. rufoflava* were found active till the end of July and more number of beetles of this species were collected in June–July compared to *H. serrata* which almost stopped by the middle of May. Several species of *Autoserica* adults were found active throughout the year and rains had no effect on their emergence, although more number of adults were found after summer rain. Eggs were found inside adults collected in September. Adult collection followed by application of 6 kg of phorate 3–4 weeks after first summer rain was found more effective and economical in control of white grubs.

9.9 SEASONAL ACTIVITY OF SCARABAEIDS AS EVIDENCED BY LIGHT TRAP CATCHES

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ABSTRACT

To understand the activity of Scarabaeid beetles during different months in a year, a light trap study was made for one year during 1978. A total of 5212 beetles including 27 species coming under five sub-families : Scarabaeinae, Aphodiinae, Dynastinae, Rutelinae and Melolonthinae were collected on 212 days during the year. Scarabaeinae and Aphodiinae and one species of Melolonthinae were trapped throughout the year. Others were seasonal in occurrence. Adult catches are correlated with rainfall and discussed.

INTRODUCTION

Family Scarabaeidae is the largest beetle family among the best known of the eight families, mainly because of their interesting habits and great economic importance. Majority of Scarabaeids being nocturnal and concealed, normally escape notice. Some of the beetles are highly attracted to light and others shun direct light (Veeresh, 1974 ; 1977). Stray cases of encountering beetles during seasons other than normal emergence period, prompted to undertake this study. A fluorescent light trap was set up at the Main Research Station, University of Agricultural Sciences, Hebbal, during 1978. Daily collections at 8 a.m. were brought to the laboratory and sorted out for different groups and recorded along with rainfall data. Collections were made on 212 days during the year from January to December. During October and November collection was possible for only one and three days respectively, due to disruption in the trap.

RESULTS AND DISCUSSION

Beetles collected during the year are presented in Tables I and II. Wet days in the month is as shown in Table III. The trapped beetles represented commonly available Scarabaeids attracted to light. A total of 5212 beetles, comprising 27 species (Table), coming under five subfamilies – Scarabaeinae, Aphodiinae, Dynastinae, Rutelinae and Melolonthinae were collected. The Scarabaeinae constituted 67-78 per cent, being highest and the next highest group was Melolonthinae with 15.7 per cent of the total beetles collected. The Aphodiins, Rutelins and Dynastins constituted 6.58, 5.35 and 4.56 per cent, respectively.

TABLE I

No. of Scarabs collected during different months in the year 1978.

Months No. of collection days	Jan. 27	Feb. 19	Mar. 19	Apr. 20	May 25	June 17	July 23	Aug. 25	Sept. 9	Oct. 1	Nov. 3	Dec. 24	Total
	27	19	19	20	25	17	23	25	9	1	3	24	
Rain fall in mm. during the months	--	2.6	--	69.2	76.0	30.6	168.0	104.2	132.6	79.2	51.8	17.8	
<i>Sub family of Scarabaeidae</i>													
1 Scarabacinae	204	149	145	654	1673	117	25	144	103	10	73	236	3533
2 Aphodiinae	190	30	26	24	21	27	6	3	--	3	5	8	(67.78%) 343
3 Dynastinae	--	--	--	16	14	7	186	8	5	1	1	--	(6.58%) 238
4 Rutelinae	--	--	2	139	133	1	4	--	--	--	--	--	(4.56%) 279
5 Melolonthinae	4	20	26	182	530	13	14	18	10	--	--	2	(5.3%) 812
													(15.71%)

Species of scarabs collected during the year.

I Scarabacinae	1	2	3	4	5	6	7	8	III Dynastinae	IV Rutelinae	V Melolonthinae
	<i>Onthophagus dama</i> F.	<i>O. quadridentatus</i> F.	<i>O. ramosus</i> Wied	<i>Catharsius molossus</i> L	<i>Onthophagus</i> sp. 1, 2, & 3	<i>Aphodius moistus</i>	<i>A. (Paraphodius) Elongatulus</i> F.	<i>Aphodius</i> sp.	9 <i>Oryctes rhynoceros</i> L.	10 <i>Phyllognathus dionysius</i>	16 <i>Holotrichia serrata</i> F.
									11 <i>Anomala ruficapilla</i> Burm.	17 <i>H. rufiflava</i> Br.	17 <i>H. rufiflava</i> Br.
									12 <i>A. bengalensis</i> BL	18 <i>H. rustica</i> Burm.	18 <i>H. rustica</i> Burm.
									13 <i>A. varicolor</i> F.	19 <i>Autoserica nathani</i> Fry	19 <i>Autoserica nathani</i> Fry
									14 <i>A. dorsalis</i> F.	20 <i>A. atratula</i> Br.	20 <i>A. atratula</i> Br.
									15 <i>Adoratus versutus</i> Ar.	21 <i>Schizonychia ruficoilis</i>	21 <i>Schizonychia ruficoilis</i>
										22 <i>Apogonia rouca</i> F.	22 <i>Apogonia rouca</i> F.
										23 <i>A. ferruginea</i> F.	23 <i>A. ferruginea</i> F.

TABLE II

Species of Melolonthine beetle's Collected during different months in the year 1978

No. of days collected	Month	Month												Total
		Jan 27	Feb 19	Mar 19	April 20	May 25	June 17	July 23	Aug 25	Sept 9	Oct 1	Nov 3	Dec 24	
	Rainfall in m.m.	—	2.6	—	69.2	76.0	30.6	168.0	104.2	132.6	79.2	51.8	17.8	
1	<i>Holotrichia serrata</i> F.	—	—	—	11	26	—	—	—	—	—	—	—	37
2	<i>H. rufiflava</i> Br.	—	—	—	4	18	—	—	—	—	—	—	—	22
3	<i>H. rustica</i> Burm	—	—	—	2	6	—	—	—	2	—	—	—	10
4	<i>Autoserica nathani</i> Frey	4	20	21	59	45	7	12	16	8	—	—	3	195
5	<i>A. atratula</i> Br.	—	—	—	—	11	—	—	1	—	—	—	—	12
6	<i>Schizonycha ruficollis</i> F.	—	—	—	92	273	1	3	—	—	—	—	—	369
7	<i>Apogonia rouca</i> F.	—	—	—	—	4	—	1	—	—	—	—	—	5
8	<i>A. ferruginea</i> F.	—	—	—	—	53	4	4	—	—	—	—	—	61

Scarabaeins occurred throughout the year with a peak emergence in May. Aphodiins also occurred throughout the year except in the month of September which was second highest rainfall month with 132.6 mm rain, the highest being in July with 168.0 mm rain. Majority of Aphodiins came in January (50.5 per cent) with a sharp decline in the preceding and succeeding months. They were present on all the 27 days of collection in that month with a minimum and maximum of 2 and 24 beetles, respectively. It was interesting to note that January was a rainfree month when highest number of Aphodiins were trapped. Perhaps rainfree cooler part of the year is best suited for these adults to emerge. On the other hand Dynastins came in large numbers (79 per cent) during July, when the total precipitation was highest (168 mm) in 13 rainy days. Dynastins seem to require rains over a continuous period as is seen during July with a maximum of 168 mm rain scattered over 13 days, compared to six and five rainy days in April and May with 69.2 and 76.00 mm rain respectively when only 8 and 6 per cent of Dynastins were trapped. During June, although the number of wet days were as many as in July (Table III), total precipitation was only 30.6 mm and the Dynastins collected were only 3 per cent. Perhaps the emergence of Dynastins tapered sharply in that month for that year as the numbers were drastically reduced in the subsequent months (Table I).

Rainfall has great influence on the emergence of Rutelins and Melolonthis (Veeresh, 1977). These two groups came in large number during April (139 and 182) and May (133 and 530) during the weeks preceding rainfall (Table 1). Although,

TABLE
Rainfall in mm in different

Date/ Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
January	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
February	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
March	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
April	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4.8
May	—	—	—	—	—	—	—	—	—	—	—	15.1	—	13.0	0.5	—
June	—	—	—	—	—	2.8	—	—	—	—	0.4	—	—	—	3.0	—
July	—	—	—	—	—	—	15.7	2.8	—	9.0	—	—	—	—	—	18.5
August	0.5	—	4.7	0.8	—	—	—	5.6	0.2	1.5	—	—	—	—	0.5	—
September	—	—	—	0.7	—	—	—	—	—	—	—	32.0	—	—	5.7	—
October	8.5	1.1	—	—	—	—	—	—	—	2.0	—	7.5	—	—	—	—
November	1.2	—	1.4	5.3	23.7	1.1	6.5	—	—	—	—	—	—	6.1	—	—
December	—	—	—	—	—	—	—	4.0	0.7	—	—	—	—	—	—	—

Table I shows Melolonthins catch in all the months except October and November, only *Autoserica nathani* was responsible for this according to Table II. This species seems to have not been influenced by the rainfall pattern, in spite of its peak emergence in April and May along with other Melolonthins. The reasons for no collection of this species during October and November is perhaps due to less number of collection days during that period. In fact the authors had the opportunity of collecting gravid *A. nathani* during this period from the fields and this was the only known Melolonthin beetle having two generations in a year.

According to Table I, there were clear months during which no Dynastins and Rutelins were collected. The same trend was seen in respect of Melolonthins also except for the *Autoserica* species.

CONCLUSIONS

It was difficult to know the original population of Scarabaeids in the locality to judge whether all were trapped or some were left out. Even these, which were trapped, may be only a fraction of the total fauna as it is known that some species are inhibited by the direct light (Veeresh, 1977). However, the present study reveals that some scarabs are active throughout the year and some restrict their adult activity to a limited part of the year. This type of study will also help to monitor the pest species, in addition to some species which are highly attracted to light (Veeresh, 1974)

III

months during 1978

17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	2.6	—	—	—	—	—	—	—	—	—	—	—	—	—	2.6
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14.8	0.1	—	—	—	—	—	0.3	—	12.3	—	6.9	30.0	—	—	69.2
—	—	—	—	—	29.3	—	15.5	—	2.6	—	—	—	—	—	76.0
4.5	—	0.9	0.4	—	0.4	—	—	4.6	0.4	—	4.4	3.2	5.6	—	50.6
—	100.0	1.3	8.5	0.3	2.4	—	—	0.6	—	1.8	0.3	—	—	6.8	168.0
10.5	0.6	23.7	2.0	7.2	8.3	6.5	30.5	—	—	—	0.7	—	0.3	—	104.2
—	—	—	0.9	7.1	3.0	6.0	—	—	1.2	32.5	—	3.0	40.0	—	132.1
—	48.7	—	—	—	—	—	9.4	—	—	2.6	—	—	—	—	79.8
—	—	—	—	—	—	—	—	6.5	—	—	—	—	—	—	51.8
—	—	—	—	—	—	—	—	—	2.4	1.4	9.3	—	—	—	17.8

The authors are highly indebted to Dr. G. P. ChannaBasavanna, Professor and Head, for the facilities provided and Mr. C. A. Viraktamath in assisting in the light trap collection.

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9.10 DISTRIBUTION AND ABUNDANCE OF SCARABAEID BEETLES IN CENTRAL U.P.

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ABSTRACT

Periodical survey during 1977 and 78 revealed that white grubs pose serious threat to a variety of **kharif** crops grown in Central U.P., particularly, in various pockets of the districts Mainpuri, Badaun, Sitapur, Bareilly, Hardoi, Kanpur and Etah. Light traps clearly indicate that in addition to **Holotrichia consanguinea** Blanch., which has alarmed the growers, a number of other white grub species, are also involved. The following are the collections of chafer beetles made from various localities of Central U.P. : **Anomala bengalensis** Blanch., **Anomala dorsalis** Fabr., **Anomala varicolor** Gyll., **Anomala variance** Cliv., **Apogonia ferruginea** Fabr., **Adoretus** spp., **Holotrichia consanguinea** Blanch., **Holotrichia problematica** Br., **Mimela** spp., **Schizonycha ruficollis** Fabr.

The pattern of distribution and abundance of these beetles reveal that the predominant species are **Holotrichia consanguinea** and **Anomala bengalensis**.

9.11 INVESTIGATIONS ON WHITEGRUBS INFESTATING SUGARCANE

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ABSTRACT

Whitegrub infestation in sugarcane crop was first observed in 1976 in the Rajasthan Canal Command Area. Since then the population is increasing. During this study, grubs were first recorded in May, 1978 and continued till October, 1978 but later started declining, till December. Maximum population of the grub was recorded during July, 1978.

INTRODUCTION

The first report of whitegrub menace in Rajasthan appeared in 1959 from the Govt. Agriculture Research Farm, Tabiji (Ajmer) and since then its activity was on constant increase, so much so that in the year 1964-1965 it was reported from 9 districts of the state, due to which it was not possible to raise any crop during *kharif*. Investigations carried out by Kaul *et al.*, 1966; Rai *et al.*, 1969; Sharma and Shinde, 1970; Shinde and Sharma, 1970, 1971; Srivastava and Khan, 1963 and Anon, 1970 makes no mention of its presence in the Sri Ganganagar district, which is partly in the Rajasthan Canal Command Area. In 1976 it was first observed damaging sugarcane crop and since then its population created alarming situation for the cultivation of not only sugarcane crop but other crops like pulses and groundnut. This offered an opportunity to study in detail about the periodicity and population trend of this pest.

MATERIAL AND METHODS

To start with 12 fields were selected randomly, these being irrigated by Anupgarh branch and Suratgarh distributory. Observations on the grub population per cubic foot soil were recorded periodically from April, 1978 to January, 1979. The data so collected are tabulated in Table I.

RESULTS AND DISCUSSION

No grubs were recorded in the month of April, 1958. In the month of May the population ranged between 0 and 9 per cubic foot soil. Thereafter it started increasing. Maximum grub population recorded was in July which was 21 per

cubic foot of soil, but it was only at one location and other locations it ranged between 0 and 8. The increase in population continued till August but afterwards there was gradual decline up to December, 1978 when the population ranged between 0 and 7 per cubic foot soil.

It was noticed that the last instar larvae were found as early as in May. Thus it negates earlier beliefs that whitegrub infestation starts after the onset of rains when its adults emerge from soil. It was also observed that the first instar

TABLE I
Whitegrubs population during 1978 in R.C.P. area in sugarcane

St. No.	Average whitegrub population per cubic foot soil															
	May, 1978				July, 1978				Aug., 1978				Oct., 1978			
	1*	2*	3*	T†	1	2	3	T	1	2	3	T	1	2	3	T
1.	7	1	1	9	4	2	2	8	3	4	1	8	1	2	4	7
2.	4	3	1	8	7	9	5	21	5	7	4	16	6	5	5	16
3.	5	3	0	8	2	3	3	8	4	5	3	12	1	3	1	5
4.	1	2	2	5	1	3	4	8	2	2	4	8	1	3	3	7
5.	4	2	1	7	2	1	3	6	4	3	3	10	2	1	2	5
6.	2	0	0	2	1	1	2	4	0	0	2	2	0	0	1	1
7.	0	0	0	0	0	0	2	2	0	1	2	3	0	0	0	0
8.	2	2	0	4	1	1	2	4	1	2	1	4	0	0	3	3
9.	3	0	0	3	3	1	1	5	0	0	1	1	0	0	3	3
10.	0	1	0	1	0	2	2	4	0	0	2	2	0	0	0	0
11.	—	—	—	—	—	—	—	—	0	0	2	2	1	1	2	4
12.	—	—	—	—	—	—	—	—	0	3	5	8	0	0	2	2

*1, 2, 3—instar no.

†T—Total

larvae were present as late as December, 1978, though the population was less. Similar observations were recorded in 1977, though not quantitatively. Therefore it was felt that some species other than *Holotrichia consanguinea* Blanch. may be present. In order to confirm these observation studies were conducted with light trap. The species collected and identified were *Holotrichia rustica* Burm.; *Anomala bengalensis* Blanch.; *Rhynaptica equiviceps* Attr.; *Apogonia uniformis* Blanch.; *Anomala ruficorpilla* Burm.; *Dyscinetus trachyphygus*; *Schizonycha ruficollis* F. These investigations are to be continued in order to ascertain the periodicity of each of these species and their population.

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9.12 WHITE GRUB MENACE IN TEAK NURSERIES IN THE MAHARASHTRA STATE

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ABSTRACT

White grubs cause serious damage in teak nurseries. Since the nursery is maintained for 12 months which coincides with the annual life cycle of the grubs. Considering the economics 50 per cent BHC at 400g/bed of 40 'x4' is recommended.

INTRODUCTION

The larvae of the cockchafer beetles belonging to the Subfamily - Melolonthinae, Family - Scarabidae, popularly known as 'white grubs' are one of the serious insect pests common to agriculture and forestry. They are known to cause severe damage to number of agricultural crops during *kharif* season, feeding on roots of growing young plants. But in forestry however, the problem was noticed only few years ago.

With the development of forestry research and the programme of large scale plantation of teak in forest areas, undertaken by the Forest Development Corporation, reports of wide spread damage in Maharashtra and Madhya Pradesh, by white grubs to teak seedlings in nursery beds have appeared. According to one estimate, in 1974, about 2.6 million seedlings out of 4.0 million in Lohara nursery of FDC-MH alone were destroyed by the white grubs.

The beetles collected in Zaran nursery (Chandrapur) were identified as *Holotrichia serrata*. Raodeo and Deshpande (1974) also reported *H. serrata* as the most predominant species in Maharashtra. Earlier workers (Amin and Dabral-unpublished) reported the common occurrence of two species of white grubs namely, *Holotrichia consanguinea* Blanchard and *H. insularis* Brensk in Maharashtra and Madhya Pradesh.

Nature of damage and distribution

The problem of white grubs in teak nurseries basically differs from agricultural crops in many ways as follows :

1. White grub is a polyphagous pest feeding on the roots of a number of crops. It is observed that plants with a tap root system are highly susceptible to the attack of the grubs, whereas, plants with adventitious root system like sorghum can withstand much larger populations.

Teak has a deep tap root system compared to most agricultural crops. The grubs move to a much greater depth than in field crops and hence application of insecticides to the top few inches of soil has no significant effect on the control of grubs. For effective control of the grubs, therefore, a much higher dose of insecticides is required.

2. Nursery beds are very well prepared and raised well above the ground to maintain good drainage. Soil is loose and well prepared which provides most conducive conditions for the development of the grubs.

3. Duration of teak seedlings in nursery bed is about 12 months. The grubs, which have an annual life cycle complete their life cycle in the nursery beds undisturbed and emerge as adults from the beds before the teak seedling are uprooted.

Adults after emergence, feed on a variety of food plants which are available in plenty around nursery area. All these practices and conditions provide very congenial conditions for the rapid multiplication of the pest.

4. The problem is aggravated further by the practice of raising teak seedlings in half of the nursery area in the alternate year. The beetles emerging from their

old quarters find new nursery beds in close vicinity ready for further breeding. Thus the insect is assured of all congenial conditions for its multiplication.

5. Teak nurseries provide favourable site for oviposition to the pest much earlier in the season *i.e.*, during May and June when agricultural crops are yet to come up.

Lohara, Zaran and Mohaghata nurseries in Vidarbha, Wada and Kasa, nurseries in Western Maharashtra are among the important ones where white grub damage is quite serious and occurs every year. The grub menace is spreading to new areas wherever monoculture is being introduced. Kasa nursery (FDCM, Dahanu division) which was established only 5 years ago had no white grub problem for the first two years. It started appearing in 3rd and 4th year and now quite an extensive damage is noticed in large areas of nursery.

White grubs have been reported to do serious damage to agricultural crops in *kharif* season in Ahmadnagar, Buldhana, Dhule, Jalgaon, Kolhapur, Osmanabad, Parbhani, Sangli, Satara, and Wardha districts of Maharashtra state (Patil and Haste, 1975 and Raodeo 1975).

Control of white grubs

Efforts were made to control this pest by chemical methods like soil treatment and treating host trees with insecticides. Adults were collected from ground, lodged by shaking trees, during night hours using petromax. Chemical control methods used so far are summarized briefly as follows :

During 1973 and 1974 intox and anatox dusts applied at 80 or 120 g or mixing 150 g anatox with 150 g BHC (10 per cent dust) or 250 g BHC (10 per cent dust) per bed did not prove effective.

In 1975 lowest teak seedling mortality of 8.42 per cent was observed with Sevin 400 g/bed in 50 litre of water followed by 9.62 per cent with BHC 50 per cent W.P. 400 g/bed and 10.04 per cent with DDT 50 per cent W.P. 400 g/bed. In 1976 almost similar trend was obtained with mortality ranging between 4 and 5 per cent. However, the results were not very consistent and statistically non-significant. But on the basis of cost BHC 50 per cent W.P. at the rate of 400 g/bed of 40'x4' size was found to give a good control of the grubs. But in later years this insecticide also did not prove very satisfactory.

9.13 STUDIES ON THE WHITEGRUB, *HOLOTRICHIA CONSANGUINEA*, IN THE PUNJAB. I. BIOLOGY, BEHAVIOUR AND CONTROL OF BEETLES

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ABSTRACT

The biology, behaviour, and control of *Holotrichia consanguinea* (Blanchard) were studied at Ludhiana (Punjab) during 1974-78. The beetles started emerging in large numbers only after first heavy rains (24-30 mm) during June. They emerged between 1745-2020 hours and congregated on certain preferred hosts such as *Zizyphus jujaba*, *Prunus dulcis*, *Psidium guajava*, *Lagerstroemia indica*, etc. The feeding, mating and oviposition activities were confined during nights only. Different biological parameters of the pest have been investigated. Molasses 5 per cent solution did not attract the beetles. For chemical control of the beetles carbaryl (Sevimol 40 LV) as 0.2 per cent spray proved most effective followed by quinalphos (Ekalux 25 EC) and fenitrothion (Sumithion 50 EC) as 0.1 per cent sprays.

INTRODUCTION

Holotrichia consanguinea (Blanchard) appeared in an epidemic form on sugarcane at Dalmianagar in Bihar during August, 1956 and caused about 80 per cent damage (Gupta and Avasthy, 1957). Since then it has been reported causing serious damage to pearl-millet, sorghum, maize, wheat, paddy, groundnut, pulses, vegetables and grasses (Kalra and Kulshreshtha, 1961; Desai and Patel, 1965; Patel *et al.*, 1967; Rai *et al.*, 1969; Raodeo *et al.*, 1976; Pal, 1977 and Yadava *et al.*, 1977).

In the Punjab, it is becoming a serious pest of groundnut. No attempts have been made to study its biology and control in the Punjab except some observations on the behaviour and control of the beetles by Bindra and Singh (1971). The results of studies on the behaviour, biology and control of the beetles are reported in this communication.

MATERIAL AND METHODS

The studies were carried out at the Research Farm of the Punjab Agricultural University, Ludhiana during 1974-78.

Biology and behaviour: The beetle emergence was observed during dusk hours with the help of torches for about one month starting from the first showers received during June to early July. Observations were recorded on some biological aspects of the beetle.

The mated pairs were collected daily and confined separately on *rukmanjani* (*Lagerstroemia indica* Linn.) twigs fixed in pots, filled with moist soil and covered with glass chimneys. The beetles were transferred to a fresh set of twigs everyday in the morning. The soil from the pots was shifted daily to record the date on which the female started laying eggs. Finally the oviposition and pre-and post-oviposition periods were calculated. Eggs laid by each female were collected separately everyday till the female died and the total number of eggs laid was accounted for the fecundity. The eggs obtained were transferred to a petri-dish containing moist sand. Observations on incubation period were recorded twice a day from July to October.

The period between observed emergence of the beetle and its death was taken as longevity. This was noted separately for male and female beetles.

Testing molasses as an attractant : Five per cent solution of molasses alone and in combination with carbaryl (Sevin 50 WP) at 0.1 per cent were sprayed on seven plant species to study whether the beetles were attracted to it. The plant species included *ber* (*Zizyphus* sp.), mulberry, grapevine, bouganvillia, grape fruit, lemon and almond. Defoliation and the dead beetles collected underneath the sprayed trees were the two criteria to judge the attractiveness of molasses for the beetles. The observations were recorded for two days after the treatment.

Chemical control of beetles : Five insecticides viz., carbaryl (Sevin 50 WP and Sevimol 40 LV), fenitrothion (Sumithion 50 EC), quinalphos (Ekalux 25 EC) and endosulfon (Endocel 35 EC) were tested against the beetles. The insecticides were sprayed on *ber* trees using a manually operated knapsack sprayer. The experiment was laid out in a randomised block design with 3 replications and one tree represented each treatment. The efficacy of the insecticides was judged on the basis of the dead beetles collected daily in the early morning hours from underneath the sprayed trees.

First spray was given on June 17, 1978 and post-treatment observations were recorded for 3 days. Since there was a heavy rain (34 mm) on June 20, 1978, a second spray was given in the afternoon of 21.VI.78. The observations could be recorded on 22nd June only owing to the continuous rains (56 mm) from June 22-26, 1978.

RESULTS AND DISCUSSION

Biology and Behaviour—Beetle emergence and mating : The time from the emergence of the first beetle in an area to that of the last was considered as the time of emer-

gence. It ranged between 1945 and 2020 hours throughout the period of emergence from mid June to mid July. On emergence the beetle produced a special buzzing sound. It hovered around for about a minute near the host plant and then settled on the terminal shoot of *rukmanjani*. This corroborates the earlier findings of Bindra and Singh (1971) and Yadava and Saxena (1977). However, Veeresh (1977) reported that *H. serrata* beetles emerged from the soil between 1930 and 2030 hours at Bangalore (Karnataka).

Female beetles emerged first and soon after settling on the host plants protruded the genitalia from their posterior end. Subsequently the males also emerged, flew around and caught hold of the female in superior position. Within moments it started copulation and assumed a perpendicular position to the female. The female was observed feeding even when in coitus. After copulation the male flew away and settled on the same or a different host plant and started feeding. The period for which the pair remained in coitus ranged between 2 and 9 minutes and the mean mating period was 4.3 ± 1.3 minutes ($n=43$). Yadava and Saxena (1977) reported it to vary from 5 to 7 minutes at Jobner (Rajasthan).

The data presented in Table I revealed that under laboratory conditions the pre-oviposition period ranged between 2 and 92 days. However, the mean pre-oviposition period was 23.3 ± 18.2 days. According to Majumdar and Teotia (1965) it was prolonged to 195.2 days (normal 53.4 days) in *H. serrata* when winter prevails between adult emergence and egg-laying.

Oviposition : In the field, the females moved down to the soil for egg laying and again returned to their host for feeding. This continued throughout the night. Similarly in captivity the beetles used to come out for feeding on the twigs of *rukmanjani* supplied as food. Eggs were laid in the soil. The female continued to lay eggs for 1 to 104 days in the laboratory ($n=93$). The mean oviposition period was 35.4 ± 33.0 days (Table I). Oviposition period in *H. serrata* was reported to be 2-3 weeks (Veeresh, 1975).

A total of 1675 eggs were laid by 93 beetles collected during June 22 to July 1. On an average one female laid 18.0 ± 14.0 eggs. Gupta and Avasthy (1957) and Patel *et al.* (1967) reported that egg-laying capacity of *H. consanguinea* was only 6-10 eggs. It appeared to be on the higher side in this part of the country. According to Veeresh (1977) the fecundity was 25-30 eggs per female in case of *H. serrata*.

An interesting observation was that some beetles laid eggs of two different shapes and sizes. In general the eggs laid in July-August were spherical and measured 3.03 ± 0.07 mm in length and 2.60 ± 0.04 mm in breadth. The eggs laid

TABLE I
Different biological parameters of H. consanguinea beetles

Date of release	No. of pairs released	Fecundity			Pre-oviposition period (days)	Oviposition period (days)	Post-oviposition period (days)	Longevity	
		Total eggs laid	Range	Mean				Male (days)	Female (days)
June, 22	2	12	2-10	6.0	38-92	1	3(1)*	36	41
23	5	95	3-31	19.0	35-80	6-66	2-83(3)	29-92	43-124
24	1	28	28	28.0	18	33	24(1)	40	75
25	2	76	19-27	38.0	6-36	50-76	8(1)	64	64
26	7	158	1-46	22.6	8-49	1-92	3-41(5)	4-105	34-109
27	11	235	1-71	21.3	5-83	1-85	1-30(8)	5-72	26-114
28	20	342	1-44	17.1	4-76	1-101	5-72(10)	4-96	21-129
29	19	248	3-34	13.1	6-44	1-92	3-75(11)	7-33	40-128
30	9	168	7-43	18.6	3-32	1-98	11-64(6)	21-57	53-127
July 1	17	313	1-52	18.3	2-46	1-104	3-42(8)	6-85	18-126
Mean				18.0	23.3	35.4	26.7	35.7	80.2
SE				14.0	18.0	33.0	19.3	19.3	26.9

* Figures in parenthesis are the number of beetles observed

in September-October were oblong and measured 3.12 ± 0.03 and 1.90 ± 0.03 in length and breadth respectively. Only spherical eggs were noted during July, but a mixture of both shape and sizes was noticed during the remaining period under observation. However, the number of oblong eggs was more. Great variation has been reported in the egg size. According to Prasad and Thakur (1959), the eggs were 1-5 mm in diameter whereas these were oval and creamy white measuring 2.8-3.44 mm in length and 1.5-2.00 mm in width as observed by Rai *et al.* (1969). Dutta (1971) reported 3 mm and 1.79 mm as length and breadth respectively, which is nearly 10 times the measurements recorded by Patel *et al.* (1967).

The incubation period varied according to the season (Table II) and shape and size of the eggs (Table III). The shortest (7.7 ± 1.6 days) and the longest (14.0 ± 2.5 days) incubation period was observed during first fortnight of July and second fortnight of October, respectively. About 8.2 ± 2.9 days were required for the spherical eggs to hatch as against 10.2 ± 1.4 days for the oblong shaped eggs.

TABLE II
Incubation period of the eggs of H. consanguinea during different months

Month of collection	Incubation period during		Mean (days)
	First fortnight (days)	Second fortnight (days)	
July	7.7 ± 1.6 (42)*	9.7 ± 1.6 (262)	9.4 ± 1.5
August	8.9 ± 1.2 (313)	9.2 ± 1.7 (153)	9.0 ± 1.4
September	10.1 ± 1.4 (188)	10.3 ± 1.9 (113)	10.2 ± 1.6
October	12.1 ± 1.3 (42)	14.0 ± 2.5 (7)	12.4 ± 1.7

* Figures in parenthesis are the number of eggs observed.

TABLE III
Incubation period of two types of eggs of H. consanguinea during different periods

Month of collection	Incubation period (days)	
	Oblong eggs	Spherical eggs
August	9.4 ± 1.1 (136)*	7.6 ± 2.1 (37)
September	10.5 ± 1.3 (272)	7.5 ± 2.1 (27)
October	12.1 ± 1.4 (43)	13.0 ± 2.8 (9)
Mean	10.2 ± 1.4 (451)	8.2 ± 2.9 (73)

* Figures in parenthesis are the number of eggs observed.

In general the egg stage has been reported to last for 2-10 days (Gupta and Avasthy 1957; Patel *et al.*, 1967; Rai *et al.*, 1969) and 2-3 weeks (Prasad and Thakur, 1959). This variation appeared to be due to the change in the season during which eggs were collected as well as the variation in the size of eggs.

TABLE IV
Chemical control of beetles of H. consanguinea

Treatment	Concentration (%)	Number of dead beetles per plant				
		18.VI.78	19.VI.78	20.VI.78	22.VI.78	Mean*
Carbaryl (Sevin 50 WP)	0.1	23	11	19	34	22b
Carbaryl (Sevimol 40 LV)	0.1	18	5	12	33	15b
Carbaryl (Sevimol 40 LV)	0.2	82	24	63	65	59a
Endosulfan (Endocel 35 EC)	0.1	22	1	2	23	12b
Fenitrothion (Sumithion 50EC)	0.1	32	20	56	16	31b
Quinalphos (Ekalux 25 EC)	0.1	60	17	49	11	34b

*Mean of three replications ; figures followed by the same letter are non-significant as per Duncan's multiple-range test.

First spray on 17.VI.78; Second spray on 21.VI.78

Longevity : After the completion of oviposition, the beetles survived for 1-83 days. The mean post-oviposition period was 26.7 ± 19.3 days ($n=54$). In general the female beetles lived longer than the males. On an average female beetles had a longevity of 80.2 ± 36.9 days as against 35.7 ± 19.3 days in case of males. Kalra and Kulshreshtha (1961) also reported that *H. consanguinea* beetles lived as long as 3 months.

Testing molasses as an attractant

There was a good amount of defoliation on the trees of *ber* and almond when sprayed with molasses (5 per cent solution) alone or in combination with carbaryl 0.1 per cent. The number of dead beetles collected from underneath the trees of *ber* and almond sprayed with carbaryl + molasses was 18 and 32 respectively. On the other hand neither any dead beetle was found under the trees of mulberry, grape-vine, bouganvillea, grape-fruit and lemon nor these showed any defoliation whether sprayed with molasses alone or molasses + carbaryl. It showed that 5 per cent molasses solution did not act as an attractant for the beetles. It further confirmed the earlier reports that *ber* and almond trees served as preferred hosts for *H. consanguinea* (Sukhija and Khangura, 1978).

Chemical control of beetles

The data in Table IV reveals that carbaryl (Sevimol 40 LV) at 0.2 per cent proved most effective as significantly higher number of dead beetles (59/plant) were found underneath the sprayed trees. Although the differences among the remaining treatments were non-significant, yet quinalphos and fenitrothion showed greater promise than endosulfan and carbaryl (Sevin 50 WP and Sevimol 40 LV) as 0.1 per cent sprays. Bindra and Singh (1971) reported that carbaryl 0.1 per cent and fenitrothion 0.05 to 0.1 per cent were effective for controlling the beetles.

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9.14 **POPULATION DENSITY OF GRUBS OF *HOLOTRICHIA***
***CONSANGUINEA* IN RELATION TO DIFFERENT HOST PLANTS AND SPACE**

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ABSTRACT

Population of white grubs at varying distances from the host trees of adults was maximum beyond 20 m. Though these were found up to 150 m from the trees, area of maximum concentration varied with the host tree species.

INTRODUCTION

The root feeding grub, *Holotrichia consanguinea* Blanchard, is a serious pest of all *kharif* crops grown in sandy soils. During the last two decades the pest has spread widely throughout Rajasthan. In epidemic form it has been prevalent in ten districts of the State. The nocturnal adults feed on a wide range of fruit and avenue trees and lay eggs in the adjoining cultivated fields. A little attention has been paid to study the behaviour of adults specially their return from host trees for egg laying. It was, therefore, contemplated to study the population density of grubs at varied distances from the host trees.

MATERIAL AND METHODS

Ninety six stations in eight villages were selected. In each village 3 trees each of Neem (*Azadirachta indica*), Babul (*Acacia arabica*), Khejra (*Prosopis spicigera*) and Ber (*Zizyphus jujuba*) in fields with history of regular occurrence of white grub damage were selected. Pits of 30 x 30 x 30 cm were dug around each tree at various distances (four pits/distance). The investigations were carried out during the peak period of activity of the grubs in 1978 and 1979.

RESULTS

It is evident from Table I, that in the immediate vicinity (within 10 m) of the host trees, population of the grubs was relatively low as compared to the population at least 20 m away. Maximum population was observed beyond 20-30 m depending upon the type of the host tree. Density of the grubs declined as one

moved farther. Population beyond 150 to 200 m from the host trees was observed to be quite low.

TABLE I
Average number of grubs of Holotrichia consanguinea Blanch. per pit around the host trees of adults, during 1978 and 1979

Host trees of adults	Year	Distance from host trees of adults (m)							
		10	20	30	50	100	150	200	250
Neem	1978	0.25	2.00	3.38	2.50	4.13	3.25	0.50	2.50
(<i>Azadirachta indica</i>)	1979	0.25	0.40	2.35	2.60	1.90	0.75	0.40	0.20
Babul	1978	1.17	2.00	5.50	2.80	1.50	0.33	2.50	0.83
(<i>Acacia arabica</i>)	1979	0.45	0.60	1.75	2.10	1.85	0.85	0.35	0.35
Khejra	1978	1.17	2.33	1.00	3.17	0.33	1.00	0.33	0.67
(<i>Prosopis spicigera</i>)	1979	0.40	0.80	2.25	1.75	1.00	0.60	0.25	0.10
Ber	1978	5.00	2.67	1.33	1.66	1.00	—	—	—
(<i>Zizyphus jujuba</i>)	1979	1.33	1.27	2.00	0.80	0.67	—	—	—

From the data it is evident that the zone of maximum grub population is directly correlated to the height of the host tree. The return flight of the adult beetles is diagonal and not vertical.

9.15 DESCRIPTION OF LARVAE OF *LEUCOPHOLIS BURMEISTERI* AND *L. LEPIDOPHORA* (SCARABAEIDAE : COLEOPTERA)

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ABSTRACT

Leucopholis burmeisteri Brenske was collected from an arecanut garden at Central Plantation Crops Research Institute, Vittal in September 1976. *L. lepidophora* Blanchard was collected during the same period from Shirgale and Tyagali villages of North Kanara District. The description is based on the third instar larvae and the cast skin of 3rd stage larvae reared to the adult stage. Detailed description of cranium, clypeus, antennae, mandibles, maxillae, hypopharynx, epipharynx, legs, body areas, anal slit, raster and spiracles are given with illus-

trations. A comparative study is also made to distinguish the two species based on larval characters.

INTRODUCTION

Leucopholis burmeisteri Brenske and *L. lepidophora* Blanchard are common in the hilly areas of Karnataka and Kerala. These have been reported feeding on the roots of arecanut palm (Puttarudraiah and ChannaBasavanna, 1957 ; Rajamani and Nambiar, 1970. At times these have been noted to cause severe damage. Hitherto the description of immature stages of these have not been attempted. The present paper embodies the description of the larva of the two species.

***Lecopholis burmeisteri* Brenske**

Leucopholis burmeisteri Brenske, 1894 ; *Mem. Soc. Ent. Belg.* 11 : 30.

This description is based on six, third instar larvae and cast skin of two, third instar larvae reared to adult. Larvae were collected from the arecanut garden at Central Plantation Crop Research Institute, Vittal, Karnataka, in September, 1976.

Cranium : Smooth, brown, slightly narrower than prothorax. Clypeo-frontal suture well marked, frontal sutures distinct ; epicranial suture about one third of one of the frontal sutures, brown with slightly impressed enlargement. Anterior frontal setae (AFS) 14-16 in number, in a single transverse line. Anterior angle bearing three long setae, post-frontal setae (PFS) in an irregular patch of 10-11 on each side. Four dorso-epicranial setae (DES) beset obliquely on each side of epicranial suture. A group of 15-20 long and short setae on the antennal ring support.

Clypeus : Sub-trapezoidal; divided into an anterior whitish, membranous, preclypeus (PC) and a large heavily sclerotized postclypeus (PSC) furnished with one long and one short seta on the lateral aspect of each side, two short setae present in the mid-portion near the sagittal line.

Labrum : Dark brown, pitted with few punctures and angular at the middle of each lateral outline. Median transverse ridges complete, distinctly wrinkled. Anterior projection with two long and two short setae. Anterior to the incomplete transverse ridge and along the lateral margin two setae, in front of complete median transverse ridge two long setae and posterior to which six setae on each side.

Antennae : Shorter than cranium, four segmented; apical segment sub-ovate with elongate dorsal sensory spot and 7-8 tectile pegs, second segment bearing 5-6 punctures and 3-4 setae, first segment bearing 6-7 setae.

Mandibles : Strong, stout, as long as cranium, scissorial area with slightly wavy cutting blade. Scrobis (SCR) prominent carrying 10-12 punctures. Dorso-molar region (DMR) of right mandible with 18-20 setae in an irregular patch and a single circular patch near the third lobe bearing 15-20 phobae-like structure. Dorsomolar part of left mandible beset with 8-9 setae in a single line and 6-7 phobae-like structure in a circular patch. Basolateral region with 9-10 setae.

Maxillary lobes : Cardo (CAR) sub-rectangular, setose and without granules, stipes (STP) elongate and furnished with 18-20 pointed stridulatory teeth (SD). Apical segment of maxillary palpus (MP) with sensory groove and 10-15 tactile pegs; first, second and third segments about equal in length.

Hypopharynx and labial palpus : Resemble *Holotrichia* sp.

Epipharynx : Corypha and acroparia (ACR) continuous, bearing many long, pointed setae. Plegmata (PLM) well developed, each plegmatium consisting of 15-17 rod shaped plegmata. Proplegmata, zygom and epizygum absent. Acanthoparia with 15-17 coarse, sickle shaped setae. Gymnoparia with fine, small setae. Haptomera' region with five macrosensilla and equal number of microsensilla. Heli strong stout, 20-24 in number and arranged in three series. Dexiotorma and laeotorma stout. A patch of phobae located at the inner end of each torma extending towards the pedium. Haptolachus composed of two triangular sclerotized plates, two macrosensilla and 25-30 crepidial punctures. Crepis thin and broad laterally.

Legs : Strong and well developed. Prothoracic and mesothoracic claws about equal in length, enlarged at the base, tapering gradually and gently curved at the tip. Metathoracic claw with a large rounded base but reduced in size.

Body area : Prothorax, mesothorax and metathorax each with three dorsal areas. Prothorax with series of fairly long setae and a thinly sclerotized long plate Prescutum, scutum and scutellum of meso- and metathorax furnished with fine setae in transverse rows. Dorsum of first abdominal segment covered with moderately long, fine setae. Dorsum of second to sixth abdominal segments each covered with a transverse patch of short pointed setae interspersed sparsely with long setae. Prescutum and scutum of seventh abdominal segment each with a transverse patch of short pointed setae interspersed with long fine setae, scutellum without pointed setae. Dorsum of eighth abdominal segment with long fine setae. Ninth and tenth abdominal segments not completely united and with sparse long fine setae.

Anal slit : Anal opening Y-shaped, dorsal anal lobe with short, pointed setulae, interspersed with fine setae. Lower anal lobe furnished with few hamate setae and long fine setae.

Raster : With moderately oblong septula (S), a pair of palidia and a pair of tegilla (TE). Each palidium consists of 20–26 stout, pointed depressed pali arranged in an irregular row with slight posterior diversion. Preseptular hamate setae 40–45 in number. Each tegillum comprised of 50–60 long, flat distally bent hamate setae. Barbula (B) furnished with long, dense setae.

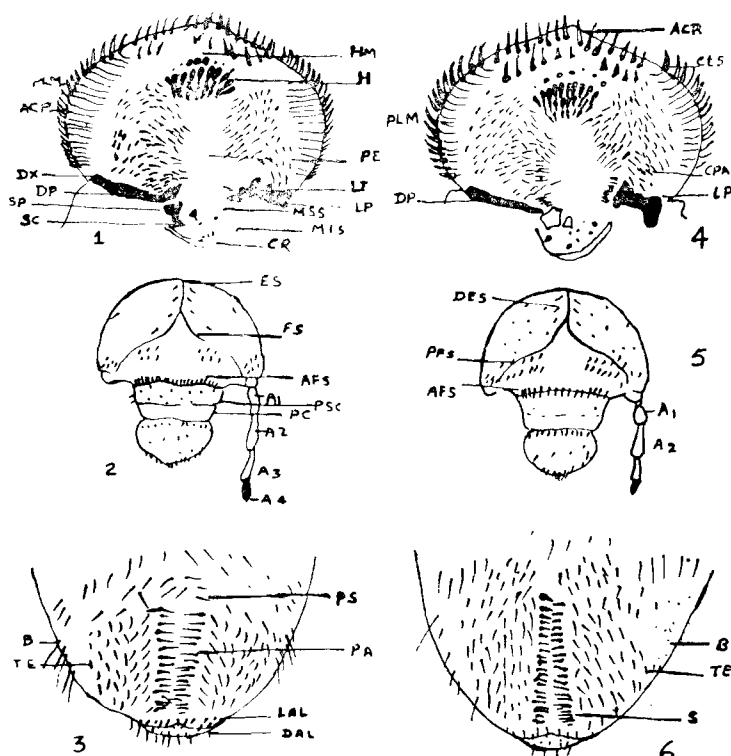


Fig. 1-3 : *L. lepidophora* ; 4-6 : *L. burmeisteri*
(1 & 4 - epipharynx, 2 & 5 - head, 3 & 6 - venter of last abdominal segment)

Spiracles : Respiratory plate of the thoracic spiracle about 1.59 to 1.64 mm long and 0.45 mm wide, abdominal spiracles about 0.85 to 0.96 mm long and 0.22 mm wide. Almost all abdominal spiracles more or less similar in size.

Full grown larva stoutly built, yellowish white and 80–85 mm long.

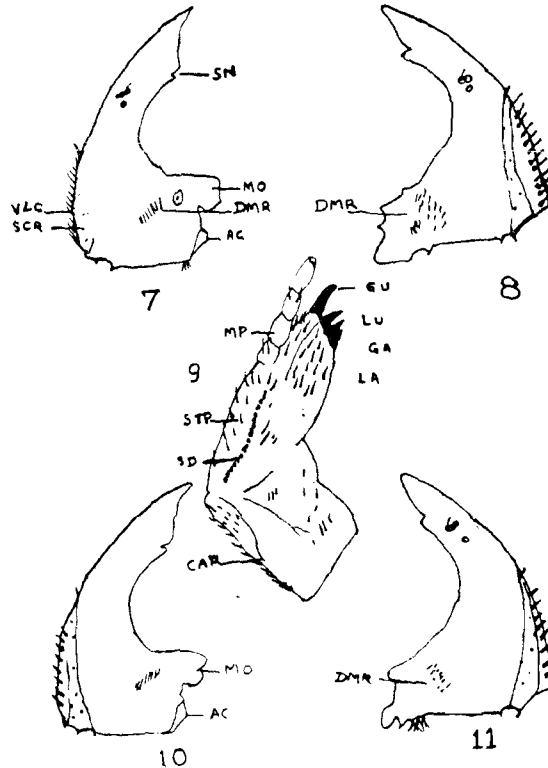
Adult : Reddish brown, chesnut colour, body slightly flattened, 33–35 mm long and 16–17 mm wide. Appendages and elytra covered with oval, pointed, yellowish scales. Clypeus large and completely covered with scales. Lateral margin of pronotum truncate and anterior margin with numerous fine fringed hairs. Scutellum small and slightly emarginate posteriorly. Pygidium tapering posteriorly.

Leucopholis lepidophora Blanchard

Leucopholis lepidophora Blanchard, 1850, *Cat. Coll. Ent.*, **1** : 158

This description is based on four, third instar larvae and cast skin of two, third instar larvae reared to adult. Third instar larvae were collected from Shirgale and Tyagali villages of North Kanara District, Karnataka.

Cranium : Resembles *L. burmeisteri*. Maximum width of the head capsule ranges from 9.54 to 10.23 mm. Anterior margin of frons with 24–25 setae in a



Figs. 7-9 : *L. burmeisteri* ; 10-11 : *L. lepidophora* (7 & 10 – dorsum of left mandible, 8 & 11 – dorsum of right mandible, 9-dorsum of left maxilla)

transverse line (AFS). Post-frontal setae 6–7 in number, arranged in two series on each side. Antennal ring with 25–28 setae. Four dorso-epicranial setae obliquely set on either side of epicranial suture (ES).

Clypeus and Labrum : Similar to *L. burmeisteri*.

Antennae : Longer than cranium ; apical segment sub-elliptical with slight constriction at the distal end and provided with 10-12 tactile pegs, dorsal sensory

spot oval, first, second and third segments about equal in length, basal segment bearing 12-13 setae.

Mandibles : Dorsomolar region (DMR) of left mandible beset with 8-9 setae and that of right mandible with 10-12 setae. Scissorial part of left mandible with wavy cutting blade, comparatively larger than right mandible, Basolateral region with about 10-12 setae. Scrobis (SCR) deeply sunken with 9-10 punctures. Venterolateral carina (VLC) bearing 8-9 setae.

Maxillary Lobes : Cardo setose, without granules ; maxillary stipes elongate, with 16-19 stridulatory teeth. Second segment of maxillary palpus bearing two setae and 2-3 punctures, first segment with two setae. Maxillary articulating skin without granular spots.

Hypopharynx and labial palpus : Resemble the genus *Holotrichia*.

Epipharynx : With rounded lateral margins. Acroparia with long pointed spine-like setae. Zygum and epizygum absent, plegmatia present, each plegmatium consists of 24-28 plegmata (PLM). Acanthoparia (ACP) provided with 20-22 coarse setae. Haptomerum (HM) with 6 macrosensilla and 4-8 microsensilla. Heli (H) about 22-24 in number arranged in three series. Pedium (PE) longer than wide. Dextiotorma (DX) and laeotorma (LT) well developed. Inner ends of tormae furnished with longitudinal patch of phobae (DP and LP). Sclerotized plate (SP) triangular, sense cone (SC) elongate. Two macrosensilla and 20-24 crepidal punctures present in haptolachus. Crepis (CR) broad.

Body areas resemble *L. burmeisteri*.

Anal slit : Anal opening Y-shaped, dorsal anal lobe (DAL) and lower anal lobe furnished with moderately long and short setae.

Raster : Septula longitudinal, extending from the middle part of anal slit. Each palidium (PA) with 19-20 long, pointed and fine spine-like pali. Posterior half of the pali in two irregular series. Preseptular hamate setae present. Each tegillum with 40-45 long hamate setae. Barbula (B) with long fine setae.

Spiracles : Thoracic spiracle 1.45 to 1.58 mm long and 0.46 mm wide, first abdominal spiracle 0.82 to 0.92 mm long and 0.20-0.23 mm wide.

Full grown larva stout and 80-85 mm long.

Adult : Black oval, about 32-34 mm long and 15-18 mm wide. Body covered with whitish oval scales which are not too closely set as in *L. burmeisteri*. Labrum large and covered with setae. Elytra and pronotum dark, black and shining.

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9.16 SEASONAL ACTIVITY AND POPULATION DENSITY OF GROUND DWELLING BEETLES OF DOOARS AREA, WEST BENGAL

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ABSTRACT

Pit-fall trap experiment was conducted in Dooars area of West Bengal during March 1977 to February 1978. A total of 17090 beetles were collected during the period ; seasonal activity and density of these ground dwelling beetles are discussed.

INTRODUCTION

Pit-fall traps are widely used for capturing arthropods found on ground surface. In the recent years, much work has been carried out in different parts of the world to observe the activity of the surface dwelling insects using pit-fall traps. Several authors have achieved satisfactory results using this method to study population density ; Aheran (1971) with desert tenebrionid beetles ; Briggs (1961) with two species of Carabidae ; Evans (1969) with surface beetles ; Greenslade (1965) in studies on ecology of British Carabidae, Nelson (1970) with Carabids by mark-recapture technique ; Gist and Grossley (1973) with beetles, spiders and other insects ; Wilbur and Landlehr (1974) in estimation of population size and Oppenheier on ecology of dung beetle community (unpublished). Very little attention has been given in India, particularly to study the population ecology of the ground dwelling beetles of Dooars area of North Bengal. Hence a project was undertaken to collect and study the population fluctuation of the ground dwelling beetles by pit fall traps and to know the abundance in a tea garden, a paddy field and a forest of Dooars.

MATERIAL AND METHODS

The study was done at Khutimari forest near Gayer Kata, 42 km north east of Nagrakata Meteorological Office of Jalpaiguri district, West Bengal. Three different

adjoining ecological areas namely, forest floor, tea garden and paddy field were selected for trapping.

The forest was of the tropical moist deciduous type, with a dense canopy. There was also a dense growth of shrubs, ferns and plants of the family Asteraceae. The majority of the shrubs were under 75 cm to 1m in height. The forest floor was covered with decomposed and fallen leaves of sal, simul and other trees.

The tea garden was located 150 m south west of the forest. Tea bushes were covered with leguminous shade trees. Water drainage of the tea garden was well maintained and application of pesticides was done at regular interval.

The paddy field was situated 50 m south of the forest. It was well protected by a wire-fencing, especially in the forest side, from the village cattle and wild animals like elephant, deer etc.

The pit-fall traps are made of galvanized tin of 21 cm depth and 9 cm diameter. The opening is laid in flush with the soil surface. During transportation of the traps to laboratory from field with the collection, a lid is used. A wooden shade (22 cm x 12 cm) is positioned over the open traps in the field to prevent litter deposition inside the traps. The opening of the fish-baited traps were fastened with a wire net having 2 cm diam. pore to prevent feeding by carnivores and rodents.

Initially 9 traps, 3 of which were baited with 200 g of rotten fish, 3 with 200 g of fresh cow dung and 3 without any bait *i.e.* empty, were placed in each of the three ecological areas mentioned above. The rows of the fish baited and dung-baited traps were placed approximately 3 m apart and the distance between successive traps was about 2 m. Empty pit fall traps were placed diagonally in between the fish and dung baited trap rows.

Collection was made twice a month throughout the study, the traps were emptied and replaced with new baits between 8.00 and 10.00 hours every fortnight. Daily temperature and rainfall were recorded throughout the study with the use of a maximum and minimum thermometer and rain-gauge respectively.

RESULTS

Specimens numbering 17090, belonging to 17 families of Coleoptera were caught during this study. The most abundant families were Scarabaeidae and Staphylinidae which together cover 88 per cent of the total beetles collected. In a total of 106 species collected, maximum number of species belonged to Scarabaeidae (34) closely followed by Staphylinidae (26), Carabidae (16), Histeridae (5), Tene-

brionidae (5), Chrysomelidae (5), Elateridae (2), Scydmaenidae (2), Ptilidae (1), Leiodidae (1), Silphidae (1), Curculionidae (1), Nitidulidae (1) and Bostrychidae(1).

Seasonal incidence : The number of beetles trapped show a seasonal variation during the year of study. Maximum number (2229) of catches were made during August, followed by October (2029). Highest incidence of the predominant family Scarabaeidae was in the month of August, whereas of Staphylinidae was in the month of February. It is evident that the collection of Scarabaeidae reached its peak during monsoon and post monsoon when both temperature and relative humidity were high, on the other hand, Staphylinidae reached its peak incidence during late winter, and when the temperature and relative humidity were low.

Area preference : Of the 17 families caught between March, 1977 and February, 1978 from the three ecological areas i.e., forest floor, tea garden and paddy field, the forest floor was found to be most rich in ground dwelling beetles (6370) followed by paddy field (5690) and tea garden (5030). Scarabaeidae was found to be the most predominant family in each of these three sites. Staphylinidae was more abundant in the paddy field than in other two sites.

Bait preference : Of the 17090 examples caught during the study, maximum numbers (13807) were attracted to fish baited traps, followed by dung baited and minimum in empty traps. This general pattern of incidence prevailed in most of the representatives of families. However in Ptilidae, the pattern was different where, maximum numbers were attracted in dung baited traps and the number was almost insignificant in other traps.

We are grateful to the Director, Zoological Survey of India for laboratory facilities, and staff and students of Birpara High School, specially Mr. A. C. Kundu, Headmaster, for various kinds of help and co-operation. We are thankful to Mr. T. K. Pai, Coleoptera Section, Zoological Survey of India, for reading the manuscript and other assistance.

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9.17 **BIOLOGY AND ALTERNATIVE HOST PLANTS OF ASH WEEVIL,**
MYLLOCERUS UNDECIMPUSTULATUS MACULOSUS
(CURCULIONIDAE : COLEOPTERA)

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ABSTRACT

The ash weevil live and reproduce throughout the year in South India, there are at least five generations in a year with one or more overlapping generations. The adults feed on leaves, bracts and squares of cotton and the larvae feed exclusively on roots of cotton. Adults are polyphagous and the host plants are listed. The egg to egg development of ash weevil ranges from 45-65 (56-35) days. Damage to terminals of tap root and root-lets result in loss of nutrients and water through root system and hence result in wilting.

INTRODUCTION

Since the introduction of American cotton varieties (*Gossypium barbadense* and *G. hirsutum*) the ash weevil, *Mylocerus undecimpustulatus maculosus* Desb., hitherto not a pest, has attained the status of an economic pest in cotton in certain pockets of southern cotton tract and the same was first reported in Sea Island Cotton (Vijayaraghavan, 1965). Since then sporadic outbreaks of ash weevil was reported in several places of Coimbatore district and the ash weevil problem became very serious on cotton at Udumalpet (S. India) (Reed, 1976). High yielding hybrids and American varieties suffer regularly due to ash weevil in several places of Tamil Nadu and intensive and extensive cultivation has highly aggravated the problem. Apart from cotton, the ash weevil is reported to be a minor pest of pearl millet (Singh and Singh, 1977). Apart from a few notes on the bionomics (Trehan, 1928), control measure (Kumar and Lal, 1966) and record of unusual occurrence (Kareem *et al.*, 1977) its biology and alternative host plants are not well documented. Hence the same is reported here, briefly, for the first time from S. India.

MATERIAL AND METHODS

Adults in copula, collected from cotton field, were reared on cotton leaves, in petri dishes. They readily mate and oviposit in the laboratory. The larvae were provided with tender root bits of cotton and fresh chips of potato and carrot and were always kept covered with moist soil. The food and soil were renewed every three days. The eggs were also released in potted plants and their development

was continuously observed. Root damage was assessed by examination of the roots of wilted plants from the experiment fields, for this purpose extensive field survey was made and during such surveys natural enemies were also recorded. The damage to vascular bundles of the root was observed from sections of the damaged root under a binocular microscope. The duration of various instars were statistically analysed.

RESULTS AND DISCUSSION

Eggs are generally laid in clusters and at times single eggs are also laid. Invariably the adult females before laying eggs, move down to the tap roots, select the site for oviposition, and oviposit 2-3 cm, below the soil surface, close to the tap root. The larvae are apodous type. Emerging from the egg shell, the larvae move about along the root system for feeding. The larvae reach a depth of 20-25 cm. The larvae feed extensively on the root tissue. Feeding on the tap root does not hamper the tissues of the vascular system; the epidermis and underlying parenchyma are scrapped (Fig. 1) but when the larvae feed on the terminals of the tap root, the vascular bundle is damaged (Fig. 2) and the feeding of the larvae on rootlets (Fig. 3),



Fig. 1

Fig. 2

Fig. 3

Fig. 1. Scrapping of parenchyma. Fig. 2. Damage to vascular bundle.

Fig. 3. Root-lets fed by the grubs.

completely or partially, make the rootlets unfit for nutrients and water transportation. Further the feeding spots are vulnerable for the entry of pathogens. So far no other pathogenic organisms were identified to be associated with wilting in cotton. Vijaya-

raghavan (1965) reported wilting only when the crop was old and at the time of boll bursting and Reed (1976) also made similar observations. During the present study it was noticed that cotton seedlings of the age 15-25 days also wilt due to attack of ash weevil larvae. Wilting seedling appears to be suffering due to root rot with drooping leaves. Even slight injury to roots of the growing seedling causes severe damage resulting in wilting. Huge population which is built up during summer months, on summer cotton, attack the seedlings of winter cotton in the subsequent season. Therefore intensive cultivation of cotton should be avoided wherever ash weevil is a menace. Pupae are exarate type. Usually pupae are noticed at a depth of 8-13 cm. The duration of various instars are given in Table I. The adults emer-

TABLE I
Duration of different stages of *M. U. maculosus*

Stage of life cycle	Number observed	Duration (in days)		S.D.
		Range	Mean	
Pre-oviposition period	40	2-4	3	± 0.45
Incubation period	1100	2-4	2.85	± 0.86
Total larval period	40	35-42	38	± 2.24
Pupal period	31	8-12	10	± 1.57
Longevity of adult male	37	24-39	30	± 5.0
Longevity of adult female	31	36-45	40	± 3.45
Oviposition period	22	27-35	31	± 2.5

ging from the pupal case leave the soil, move to the food source and feed on the leaves. Apart from leaves, the adults feed on the bracts and squares of cotton, whereas the larvae feed exclusively on cotton. The adults are polyphagous, feeding on a variety of host plants, they feed on all cultivated varieties of cotton (*G. barbadense*, *G. hirsutum*, *G. arboreum* and *G. herbaceum*), brinjal (*Solanum melongena*), castor (*Ricinus communis*), soyabean (*Glycine javanica*), sunflower (*Helianthus annus*), maize (*Zea mays*), sorghum (*Sorghum vulgare*), wheat (*Triticum* spp.), finger millet (*Eleusine coracana*), sunnhemp (*Crotolaria juncea*), *Glyricidia maculata*, *Sesbania grandiflora* and *Cassia* spp. The adults live and reproduce throughout the year, there are at least five generations in a year, with one or more overlapping generations. The adults are found to be abundant during October-February (winter months) at Coimbatore (S. India), with subsequent wilting of cotton during late January-March (boll bursting period).

The author is grateful to Dr. J. G. Bhatt, Project Coordinator and Head, Central Institute for Cotton Research, Regional Station, Coimbatore, for the facilities provided.

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9.18 MELANOTUS SP. (COLEOPTERA : ELATERIDAE) A PEST OF CHILLI (*CAPSICUM ANNUM* L.) IN DHARWAD

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ABSTRACT

In the preliminary observations undertaken on the pests of chilli at Regional Research Station, Dharwad, it was found that larvae of wire worms were damaging the chilli seedlings both in the nursery and after transplanting during June-July 1978. The larvae of the wire worm *Melanotus* sp. were very active in the tilled black soil and were found attacking the seedlings from within the soil and in rainfed crop, cutting the seedlings at collar, resulting in collapse of the plants. The extent of damage varied from 2 to 50 per cent in rainfed crop. The pest has not been reported earlier on chilli crop as causing damage from India. The adults were found attracted to light during May-June.

INTRODUCTION

Chilli (*Capsicum annum* L.) is widely grown in the tropics, sub-tropics and under glass in temperate regions. Over 20 species of insect pests, in addition to mites and nematodes, have been reported from India to damage the leaves, fruits and roots of chilli plants (Butani, 1976). Among them, the insects which have been reported as causing damage to roots are : *Odontotermes* sp., grubs of chaffer beetles (Singh, 1970), *Heterotermes indicola* Wasmann (Holihosur *et al.*, 1977) from India and *Melanotus* sp. on *Capsicum* sp. in addition to other crops from Bulgaria (Popov, 1971). Immature stages of *Melanotus* sp. was reported damaging vegetables (Genung, 1974). Riley *et al.* (1973) reported it from USA, on maize, sorghum and wheat. Sunflower,

tobacco, tomato and cucurbits were also damaged by this pest (Kabano, 1969) ; Kerby and Benjamin (1969) and Kabano (1969) reported *Melanotus* sp. feeding on certain larvae.

During 1977-78 in Dharwad, Bagalkot and Nargund areas, a preliminary survey was undertaken to investigate the pests that damage the rainfed chilli crop in black soils. The survey revealed a wire worm, *Melanotus* sp. which was damaging tender stems and roots of chilli in nursery and field after transplanting.

MATERIAL AND METHODS

The observations were made on Byadagi variety of chilli, sown and transplanted crops, in black soils, at the Regional Research Station, Dharwad. Ten plots of one gunta area each were selected for the survey with a plant population of 1100 hills of two seedlings each, with a spacing of 2' x 2' in rainfed condition. Observations were recorded 24 hr after transplanting and continued for a period of seven days. The number of seedlings cut by *Melanotus* larvae were counted and the pooled data for 7 days from each plot is presented in Table I. To ascertain that the damage was due to wire worms alone, the soil around the cut seedlings was dug out and the larvae were collected and enclosed in pots planted with chilli seedlings to record the nature and symptoms of damage. The larvae collected in the previous season were reared to adults and identified.

RESULTS AND DISCUSSION

Chilli seedlings, transplanted in tilled black soils under rainfed condition, were severely attacked by the wire worm, *Melanotus* sp. larvae. Different instars of the wire worms, feed on the roots and root tips. In addition, they were also found to attack the seedlings at the collar region, eating the tender stem, resulting in collapse and total kill of the seedlings. Similar damage was observed in the potted plants, where even the entire seedling within the soil was eaten up by the larvae. In the plots, where the observation on the incidence was recorded, it was found that the intensity of attack and extent of damage was more up to 3 days of planting, by which time most of the seedlings were either completely cut or killed. The extent of damage on an average was 15.75 per cent with a minimum of 2.18 and a maximum of 53.09 per cent (Table I). The cumulative per cent damage will be much more, when the extent of damage in nursery is also considered.

The larvae of *Melanotus* sp. was reported by Popov (1971) from Bulgaria, causing damage to *Capsicum* sp. The present observation clearly indicates that

TABLE I
Per cent damage to chilli seedlings due to the larvae of Melanotus sp.

Plot Number	Per cent damage
1	5.36
2	35.63
3	39.18
4	8.36
5	53.09
6	2.54
7	2.18
8	2.81
9	5.72
10	2.72
Average percentage	15.75

Melanotus sp. is a potential pest of chilli and may become serious in chilli growing areas. The pest has not been reported on chilli from India. Further, detailed work on its biology, distribution, host range and its role as a pest and predator is to be investigated.

The authors are thankful to the authorities of the British Museum (Natural History), London, for identifying the insect.

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9.19 PHOTOTROPHIC SOIL INHABITING INSECT PEST FAUNA OF DHARWAD REGION AS REVEALED BY A MERCURY BULB LIGHT-TRAP

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ABSTRACT

The phototrophic soil inhabiting insect pest fauna of Dharwad region was studied during February, 1976 to January, 1977 using a mercury bulb light-trap. The catches included nine beetle pests namely, *Oryctes rhinoceros* L., *Anomala ruficapilla* Burm., *A. dorsalis* (F.), *Rhinyptia indica* Burm., *Maladera* spp., *Aulacophora foveicollis* (Luc.), *Cylindrothorax tenuicollis* (Pallas), *C. audouini* (Haag-R) and *Psalydolytta atricollis* (P.C.) ; two orthopterous pests namely *Platygyrthus guttiventris* (Walker) and *Gryllotalpa africana* Biauvois, a termite species, *Odontotermes obesus* Rambur and a root eating ant, *Dorylus orientalis* Westw. The seasonal occurrence, effect of weather factors and moon light on the activity of these insect species are discussed.

INTRODUCTION

During the present investigation on use of light-trap for monitoring the pest population, various insect species, which include soil inhabiting ones, were caught in the light-trap. The important soil inhabiting insect pest species which were collected in large numbers are presented and discussed in this paper with reference to their seasonal occurrence and effect of weather factors and moon light on their activity.

MATERIAL AND METHODS

The studies were carried out on the Agricultural College Campus, Dharwad, Karnataka State, India.

The light-trap with mercury bulb (Philips, M.L.L., 210-240 V/160 W) was used. The trap was similar to the black tube light-trap which was designed by Hollingsworth *et al.* (1963) except that a mercury bulb was used in place of the black tube.

The trap was operated daily from dusk to dawn during February 1, 1976 to January 31, 1977. The method followed by Williams *et al.* (1956) was adopted to evaluate the effect of moonlight on light-trap catches during the present study.

RESULTS AND DISCUSSION

In all, 13 different soil inhabiting insect pest species were caught in large numbers. The catches included two orthopterous species namely, *Platygyrthus guttiventris* (wlk.) (Gryllidae) and *Gryllotalpa africana* Beauvois (Gryllotalpidae); a termite species, *Odontotermes obesus* Rambur (Termitidae) and a root eating ant *Dorylus orientalis* Westw. (Formicidae) belonging to the orders Isoptera and Hymenoptera, respectively. It also included nine beetle pests namely *Oryctes rhinoceros* L., *Anomala ruficapilla* Burm., *A. dorsalis* (F.), *Maladera* spp., and *Rhinyptia indica* Burm. all belonging to the family Scarabaeidae, *Cylindrothorax tenuicollis* (Pallas), *C. audouini* (Haag-R) and *Psalydolytta atricollis* (P.C.) belonging to the family meloidae and *Aulacophora foveicollis* (Luc.) belonging to the family Chrysomelidae.

The salient findings with reference to these insect pest species are presented below :

ORDER : ORTHOPTERA

P. guttiventris was more abundant than *G. africana* in the light-trap catches. Both the species were trapped in large numbers during February, 1976 and their activity was seen throughout the period of observation. Similar reports have been made in the past by McGregor (1929), Kundu *et al.* (1961) and South (1920) on the abundance of *Gryllus* and *Gryllotalpa* in March and April respectively, with their light-trap studies. The activity of both the species was found greatly influenced by the presence or absence of moonlight. The ratio in the case of *P. guttiventris* and *G. africana* between full moon week (FMW) and new moon week (NMW) catches was 21.4 : 53.5 and 14.6 : 29.8 respectively (Table I).

ORDER : ISOPTERA

Adults of the termite, *O. obesus* emerged four times in the year as indicated by the light-trap catches (Table I). The emergence of adults was always preceded by rains (Table II). On the contrary, the effect of moonlight was most interesting. More adults were seen in FMW than NMW catches. The ratio between FMW and NMW catches was 5.6:2.8.

ORDER : HYMENOPTERA

The root eating ant, *D. orientalis* is an important root feeder (Roonwal, 1975). This species was caught continuously throughout the period of observation with a peak catch in March, 1976 (Table I). The present observation of insect activity is in close conformity with the previous reports (Kundu *et al.* 1961 and Bowden and Church, 1973). Large number of insects were caught in all the months during NMW

TABLE I

Monthly light-trap catches and summarised log ($n+1$) catch of insects during the two phases of moon from February, 1976 to January, 1977

Months		Feb. 1976	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec 1976	Jan 1977	Full moon week (FMW)	New moon week (NMW)
Name of the insect species															
1)	<i>Oryctes rhinoceros</i> L.	—	53	63	32	17	59	63	28	138	11	—	—	4.3	4.9
2)	<i>Anomala ruficapilla</i> Burm.	—	—	163	211	189	288	22	44	199	43	12	—	20.3	20.8
3)	<i>Anomala dorsalis</i> (F.)	—	—	292	321	418	381	47	129	236	29	—	—	21.3	24.3
4)	<i>Maladera</i> spp.	—	—	—	92	499	1892	2210	3288	816	812	311	72	78.8	83.4
5)	<i>Rhinyptia indica</i> Burm.	—	—	482	162	—	—	—	112	1981	220	313	127	39.9	44.3
6)	<i>Aulacophora foveicollis</i> (Luc.)	240	—	—	—	—	186	1691	2433	4312	2313	992	221	23.8	64.9
7)	<i>Cylindrothorax tenuicollis</i> (Pallas)	—	—	—	—	—	—	44	548	1012	691	34	14	5.8	6.1
8)	<i>Cylindrothorax audouini</i> (Haag-R)	—	—	—	—	—	—	—	253	534	453	68	3	8.9	9.1
9)	<i>Psalydolytta atricollis</i> (P.C.)	—	—	—	—	—	—	—	310	691	436	27	9	6.4	6.7
10)	<i>Platygryphus guttiventris</i> (Wlk.)	643	369	412	214	153	123	83	65	72	53	68	139	21.4	53.5
11)	<i>Gryllotalpa africana</i> Beauvois	214	208	213	93	33	43	21	21	13	33	25	34	14.6	29.8
12)	<i>Odontolermes obesus</i> Rambur	—	432	623	—	127	—	—	—	—	583	—	—	5.6	2.8
13)	<i>Dorylus orientalis</i> Westw.	1049	1666	575	409	102	64	332	75	145	502	978	927	76.7	94.7

compared to FMW. The ratio between the FMW and NMW catches was 76.7 : 94.7. This observation is in agreement with the reports by Bowden and Church (1973).

ORDER : COLEOPTERA

Oryctes rhinoceros : Activity of this beetle was first observed in March which continued upto November with a peak catch in October (Table I). This species was trapped in slightly more numbers during the NMW than the FMW, but the ratio between FWM and NMW (4.3:4.9) was very negligible.

TABLE II
Monthly average of weather elements during the period of study

Month	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	0726 hr	1326 hr	
February, 1976	31.3	15.2	47	21	—
March	34.9	19.5	67	20	8.5
April	35.2	20.3	76	27	61.8
May	35.7	20.1	82	29	13.8
June	29.3	20.6	91	65	83.6
July	26.8	20.7	93	78	107.4
August	27.4	20.4	92	75	44.3
September	29.2	19.6	83	62	35.9
October	32.4	18.7	73	35	18.4
November	30.3	18.6	83	44	90.9
December	28.9	14.6	77	33	—
January, 1977	29.9	13.2	70	25	—

Anomala ruficapilla : This species was trapped from April to December with a peak catch in July. However, the species was caught in small numbers (Table I). No significant effect of moonlight on the activity of this species was noticed. The ratio between FMW and NMW catches was 20.3:20.8.

Anomala dorsalis : This species was observed from April to November with a peak catch in June (Table I). There was no significant effect of moonlight on the activity of this species. The ratio between FMW and NMW catches was 21.3:24.3.

Maladera sp. : The number of individuals of this species caught was more than of the other scarabaeids discussed earlier (Table I). Its first activity was noticed in May, 1976 through light-trap catches which continued upto January, 1977 with a peak catch in September. Interestingly more numbers were caught during NMW as compared to FMW catches. The ratio between FMW and NMW was 78.8:83.4.

Rhinyptia indica : It was first caught in the light-trap in April, continued upto May, 1976 and again in September, 1976 to January, 1977 with a peak catch during October (Table I). No significant effect of moonlight could be observed on the activity of this species as the ratio between FMW and NMW catches was 39.9:44.3.

Work on this aspect in the past is very much lacking with regard to the scarabaeid species involved in this study. However, observations made by Leefmans (1920) with reference to *O. rhinoceros* is in close conformity with the present study, who also suggested the use of light-trap for taking immediate effective control measures. The present observations with regard to *R. indica* are partially in agreement with the reports made by Pal (1976) that the attraction is from April to early October with a peak catch in June-July in Jodhpur, India. He also stated that the species was more abundant when a high relative humidity was coupled with low temperature (in June and July). But the present observation differs completely as the peak catches were noticed in October when the temperature was high and humidity was less compared to the previous months (Table 2). This may have to be attributed to the change in cropping pattern and climatic conditions between these two places.

Among the three species of Meloidae, *C. tenuicollis* was caught in large numbers. This species was caught from August, 1976 to January, 1977 with a peak catch in October. The other two species were collected in small number from September, 1976 to January, 1977 with a peak collection of both the species in October (Table I). In general, more number of these insects were caught during NMW compared to FMW,

A chrysomelid species, *A. foveicollis* was first trapped during February, 1976 and then there was a slack period of about four months, once again it was caught from July, 1976 to January, 1977 with a peak catch in October (Table I). Its abundance during the period may be due to the presence of more favourable hosts in large numbers near the light-trap. There was a significant effect of moonlight on the activity of this species and the ratio between the FMW and NMW catches was 23.8 to 64.9. This needs further confirmation.

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9.20 LIGHT TRAP STUDIES ON BLACK CUTWORM *AGROTIS IPSILON*

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ABSTRACT

Agrotis ipsilon (Hufnagel) (Lepidoptera, Noctuidae) popularly known as black cutworm or greasy cut worm, is a very destructive pest of gram, wheat, cotton, tobacco, potato and many other cultivated crops in India and abroad as well (Lefroy, 1904; Singh, 1949; Sen, 1952; Birat, 1968; Chaudhary, 1953; Thimmaiah et al., 1972; Kamel & Shoeb, 1964 and Narayanan, 1954). Its distribution is very peculiar in the sense that it appears in certain pockets only and is more destructive in areas where 'Haveli' cultivation is practiced. It has been reported to be a notorious pest of all rabi crops in tal areas of Bihar, U.P., and M.P. (Bindra et al., 1970 and Singh and Sinha, 1965).

During recent years, with an increasing emphasis on the ecological consideration in pest control, the use of light traps has gained an increasing importance in entomological studies all over the world. Much work has been done on various aspects of light trap studies in USA, USSR & Japan but in India very little systematic work has been done so far.

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To fill up this lacuna in Indian work, investigations were carried out at Jabalpur since 1974 to date. The results pertaining to *Agrotis ipsilon* are discussed in the present paper.

MATERIAL AND METHODS

One light trap unit, mechanical and gravitational type, was installed in an open field in the experimental area of J.N. Krishi Vishwa Vidyalaya, Jabalpur (M.P.). Number of cereal, oilseed and pulse crops were grown in the area in both the seasons. The light trap unit, made of 24 gauge G.I. sheet, consisted of two major components (A) trapping unit and (B) insect collection unit. The trapping unit consisted of a funnel (top diameter 60 cm, base and stem diameter 9 cm), three baffle plates (each 45 x 23 cm in size) mounted vertically on the rim of the funnel, equidistant and projecting towards the centre of the funnel, and a rain shed (90 cm diameter) over the baffles. The insect collection unit was 2 x 1 x 1 meter in size with three sides covered by a wire mesh screen (26 gauge and 16 mesh/inch).

A mercury vapour lamp of 250 watts, was used during 1974-75, 75-76 and 76-77. In 1977-78, a 125 watt lamp which was equally efficient was used. The light source was nearly 3 meters above the ground level. The trap was operated every night from sunset to sunrise.

Most of the insects were retained in the cage in live condition, resting on walls, roof and floor of the screen cage with minimum damage to body scales.

Insects were collected every morning, by hand picking and killing in cyanide bottle. When insects were large in number, a spray of dichlorvos (Nuvan) knocked down the insects. A record of per day collection was maintained. Weekly averages of per day catch were computed following the limits of International weather weeks prescribed by Meteorological Department, Poona.

The use of light trap for activity studies is based on the assumption that changes in light trap catches are mainly an expression of changes in the general activity of moths. This assumption would be fairly valid if due corrections are made to minimise the effects of activity and the efficiency of the trap is maintained uniform. The running means of weekly per day catch smoothen the catch profile and minimise the influence of weather factors considerably (Williams, 1940 and Hartstock 1973). The use of mercury vapour lamp throughout the study period maintained the efficiency of trap uniform.

The variation due to day to day change in weather factors and its short term effect on the activity of insects was averaged out in weekly means. The variation in

running means, therefore reflected population changes and the departures of the actual catch from them reflected the influence of climate.

RESULTS AND DISCUSSION

A. Seasonal Activity :

Five years data of monthly distribution of light trap catches presented in Table I, show the activity of moths in different seasons of the year and their relative distribution in different years. The major active period was November to April. The activity of moths during June, July, August, September and October remained at very low to absolute zero level with total monthly catch not exceeding 8 moths with an exception in the year 1978-79, when maximum monthly catch was 18 moths in August.

The first significant appearance of moths was noticed in the month of November. In December and January the activity of moths remained at moderate level. February to April was the period of highest activity. The highest number of moths were trapped during the month of March with a total monthly catch of 390 moths

TABLE I
*Monthly distribution of light trap catch of **Agrotis ipsilon***

Month	Total catch of a month per trap				
	1974-75	1975-76	1976-77	1977-78	1978-79
June	—	3	0	0	3
July	—	0	1	0	0
August	—	7	1	1	18
September	—	0	5	8	7
October	—	0	5	0	8
November	—	—	57	39	57
December	265	35	21	19*	
January	129	81	63	32*	
February	136	151	36	116	
March	390	102	160	256	
April	112	38	63	153	
May	7	8	12	81	
Total catch of a year	1039	425	424	705	

January '76 to February '77 data are averages of two traps.

* Light trap was not operated from 22nd December '77 to 12th January '78.

made in 1975 followed by 256, 160 and 102 moths in 1978, 1977 and 1976 respectively. In the first week of May the activity declined to very low numbers and almost disappeared by the end of May.

The population trend of weekly distribution of moths (Fig. 1) shows the presence of 3 to 4 distinct peaks in catches during the active period of the pest from November to April. The gap between the successive peaks closely coincided with one life cycle period of the pest which indicates the possibility of completion of 3 to 4 generations during this period.

Our field observations showed that during 1974-75 and 1977-78 the incidence of the cutworm was very high. Almost 100 per cent loss to wheat and gram crops was recorded in endemic areas within 10 days of sowing. Larvae were already present in the soil in second and third instar stages at the time of sowing. In 1975-76 infestation of the cutworm in December sown crop originated after 3 weeks of sowing, when the crop was well established. In 1978 the collection was nil during September and October. No observations were made in November. These observations indicate that the data of light trap catches can provide a good information about build up of larval population at the time of sowing.

Very high activity of moths in the end of April and then sudden decline of population in May with no sign of further breeding of the pest in the same area during June to September suggests the possibility of either suicidal emergence of moths or their migration to other areas at high altitudes or cooler regions where conditions are suitable for off-season breeding after harvest of the *rabi* season crops. Field observations revealed that the pest do not carry over in the form of either larvae or pupae in the same field (Vaishampayan and Veda, 1975-78). Kapur (1955) also failed to locate any stage of *Agrotis ipsilon* during summer months.

B. Sex Ratio Analysis

Two years data, presented in Table II, clearly reveal that males were always predominant in all the months. The overall sex ratio of yearly catch was quite uniform in both the years with an average ratio of 62.5 : 37.5 (F).

C. Attracting efficiency of various light sources

Tests were carried out to study the relative efficiency of various light sources available in India in attracting the flying adults of the species.

Four light traps were installed in a rectangular design 50 x 16 meter in size. Only two traps spaced 50 meters apart were operated in each test comparing two light sources at a time. Total number of insects trapped in each trap were counted

next day after overnight operation of trap. One nights' comparison was considered as one replication.

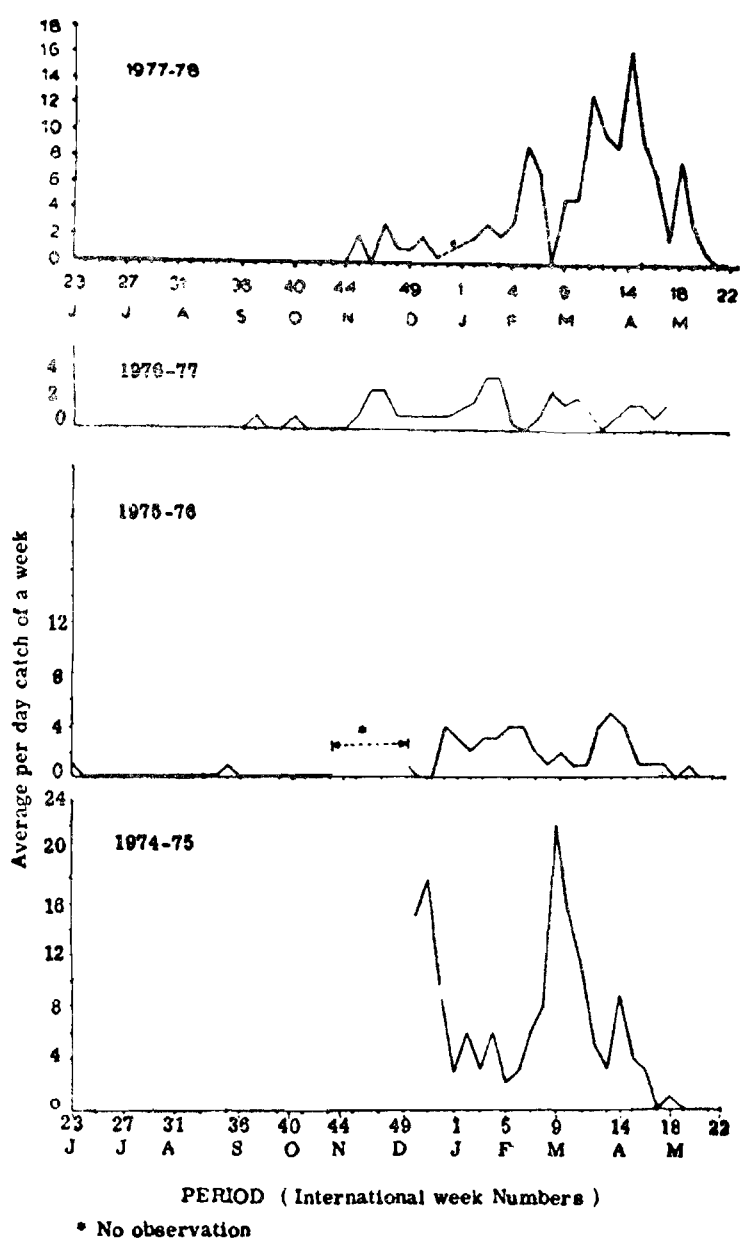


Fig.1 Weekly distribution of light trap catch of moths of Gram Cut Worm *Agrotis ipsilon*

Incandescent tungsten, 150 and 300 watt. lamp, mercury vapour 125 and 250 watt. ultra violet 15 watt, fluorescent 40 watt. daylight white and shades of blue, green and red were included in the tests. To compare the efficiency of various light sources the relative response index was calculated for each source in each paired test considering the response of mercury vapour to be equivalent to 1.00.

TABLE II
Sex ratio analysis (in per cent) of light trap catch of black cutworm
Agrotis ipsilon

Month	Sex ratio in per cent					
	1976-77			1977-77		
	Total catch	% of male	% of female	Total catch	% of male	% of female
June	0	0	0	0	0	0
July	1	100	0	0	0	0
August	1	100	0	1	100	0
September	5	40	60	8	50	50
October	5	80	20	0	0	0
November	57	61	39	39	69	31
December	21	67	33	19	58	42
January	63	56	44	32	62	38
February	36	70	30	116	59	41
March	160	63	37	256	64	36
April	63	65	35	153	58	42
May	12	83	17	81	63	37
Overall sex ratio yearwise :				1976-77	1977-78	
1.	Total catch of a year			424	705	
2.	Number of males			268	434	
3.	Number of females			156	271	
4.	Sex ratio			63 : 37	62 : 38	
				M F	M F	

Results, summarised in Table III, show that in general mercury vapour 250 and 125 watt both and ultra violet 15 watt. proved to be better light sources compared to others. Response to UV source was very typical. When tested during November, the UV lamp proved highly efficient and the best source with almost double the response of MV 250 watt source (Test 1 and 2). However, when tested during

TABLE III
*Relative efficacy of various light sources in attracting **Agrotis ipsilon***

Test No.	Light sources compared	Total No. of moths responded	Relative response index	No. of replications	Period of test
1	M.V. 250 W	40	1	14	November
	V/S U.V. 15 W	76	1.9		
1A	M.V. 250 W	202	1	21	February
	V/S U.V. 15 W	74	0.37		& March
2	M.V. 250 W	20	1	7	November
	V/S U.V. 15 W	38	1.9		
	(Unpaired test)				
3	M.V. 250 W	111	1	13	April
	V/S Fluorescent 40 W	37	0.33		
	Blue colour				
4	M.V. 125 W	40	1	12	January
	V/S U.V. 15 W	21	0.52		
5	M.V. 125 W	20	1	8	February
	V/S Incandescent				
	150 W	0	0.0		
6	M.V. 125 W	81	1	19	February
	V/S Incandescent				
	300 W	1	0.01		
7	Fluorescent 40 W				
	(different colours)				
	Blue	14	1	4	March
	V/S Green	0	0.0		
8	Blue	69	1	9	March
	V/S Red	3	0.04		
9	Blue	23	1	6	April
	V/S White	5	0.22		

January and February–March respectively (Tests No. 1A and 4) *i.e.* towards end of the cropping season the relative response to UV was drastically reduced from 1.9 to 0.52 (with 125 watt) in January and to only .37 in February–March (250 Watt) compared to 1.00 of Mercury vapour.

Comparing MV and incandescent sources, MV source attracted most of the insects. Incandescent bulb both 150 and 300 watt practically failed to attract this

species. Response to 40 watt. fluorescent blue was much better than incandescent with a relative response of 0.33 compared to MV 250 W. Results regarding comparison of response towards various coloured light sources (test No 8, 9 and 10) revealed that blue colour proved most effective and significantly better than white, red and green with a response of 0.22, 0.04 and 0.00 respectively. Blue colour characterised by short wave radiation proved better than white light which emitted much more quantum of light energy compared to blue.

The above results thus, clearly reveal that it is the spectral characteristics of the light which is more important in eliciting the response than the total intensity of light. In general, the shorter wave length elicited more response with greater trap catch compared to longer wave lengths.

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9.21 A PRELIMINARY STUDY ON THE ANT FAUNA OF BISTHENHATTI

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ABSTRACT

Eleven species of ants belonging to five sub-families were collected from different habitats of Bisthenhatti, near Dharwad. The different habitats include the open places, grass land, shrubby jungle and wood forest. Some of the ant species were found associated with Homopteran insects, few others were natural predators, pests, pollinators and one was an arboreal species. In most of the cases only foraging workers were collected and a few winged males which were attracted to light were also collected.

INTRODUCTION

Bisthenhatti is located in rich forest surroundings of North Kanara, north-west of Dharwar, Karnataka. Here live a very large number of species of ants, apparently owing to the variety of flora in and around the place and adjoining Dandeli forest. The general topography is undulating with gullies and nallas running

mostly from south to north. This is characteristically a moderate to heavy rainfall area, most of the precipitation in the tract is by south-west monsoons with heavy rains in July. Premonsoon thunder storms occasionally occur in April - May. Hot weather begins in the month of March and the temperature increases till the end of May. The type of soil varies from alluvial to loamy in the foot hills. They are sticky when wet and set hard when dry. The area is dense to sparsely wooded, with a thick understory of grasses. Low areas have moist meadows, where ground water is sometimes near the surface or are swampy.

The flora includes teak - *Tectona grandis*; nandi - *Lagerstroemia lanceolata*; kindal - *Terminalia paniculata*; honne - *Pterocarpus marsupium*; shisham - *Dalbergia latifolia*; heddi - *Adina cordifolia*; nilli - *Phyllanthus emblica*; apta - *Bauhinia racemosa*; sandal - *Santalum album*; Charcoal tree - *Trema orientalis*; matti - *Terminalia tomentosa* and other trees. The open areas being covered with lantana, *Lantana camara*, and a variety of grasses.

MATERIAL AND METHODS

The survey was undertaken for the collection of ants, during November 1977, January and March 1978. The ants were collected from different habitats with an aspirator. Brief observations were recorded about their nests, mounds, foraging and other activities. Apart from the ants collected from different habitats, during March 1978, some winged ants were also collected near light, at Bisthenhatti Railway Station.

RESULTS AND DISCUSSION

The survey has indicated that a variety of ants are distributed in different habitats of Bisthenhatti. The following eleven species of ants belonging to 5 sub-families were collected:

Dorylinae

Aenictus sp. : These are the smallest of the true army ants, which are column raiders and are generally hypogaëic. These are specialised predators of other ants especially of the immature stages (Gotwald, 1976). As early as 1892, wroughton reported his observations on the genus *Aenictus* of Asia. During the present study, males were attracted to light during March.

Dorylis labiatus Schuck ; *Dorylus orientalis* Westwood : These are an interesting group of ants, which live deep in soil causing loss to the plants, adults are

pests feeding on fruits and also predators. According to Roonwal (1975) these ants are found all over India, except in the extreme north and north-western parts of India. Further, he reports *D. orientalis* the root eating ant, as a pest on potato, groundnut, sugarcane, citrus and coconut seedlings. Menon and Srivastava (1976) reported *D. orientalis* adults feeding on ripe fruits of dwarf variety of mango in New Delhi. Mukerjee (1934) observed the workers feeding on grubs and earth worms. Gosh (1936) and Cherian and Ramachandran (1943) report this ant as attacking beehives and their broods. It is considered as a relentless enemy of the termite, *Microtermes mycophagus*, Sharma and Bohra (1968), as it gathers around the hole of the termitaria and attacks while swarming in Jodhpur region. During March 1978, only males of both the species attracted to light were collected.

Formicinae

Camponotus compressus: First described by Fabricius (1787) from the collections of South India was later reported from Burma by Wheeler (1919) and Stitr (1923) from Philippines. Ayvar (1935) has given the detailed biology and economic status of this ant from Madras. Later workers from India have reported the ant mostly as associated with other Homopteran insects for honeydew. Rawat and Modi (1969) found *C. compressus* associated with the coccid on brinjal in Madhya Pradesh. Sankhla and Kushwaha (1969) reported the association of *C. compressus* with adults and nymphs of *Tricentrus bicolor* infesting lucerne and *Trifolium* sp. from Rajasthan.

During the present survey, the nests were found in loose soil and the ants in different morphs were seen associated with aphids infesting *Trema* sp. and a species of membracid infesting *Santalum album*.

Myrmicinae

Crematogaster sp. : As early as 1863, Moscou has reported the occurrence of *Crematogaster* sp. from India. Mayr (1968) reported this from Ceylon, Sikkim and Kanara (Karnataka). Later, Forel (1902) reported the ant from different parts of India : Himalayas, Assam, Bengal, Poona and Coonor (Tamil Nadu) and further in Sri Lanka. Hingston (1925), gives an interesting account of the nesting, food pastoral activities, communication etc. Different species of *Crematogaster* have been reported from all over the world (Chapman and Capco, 1941). *Crematogaster* sp. plays a great role as a pest of cocoa in Africa (Weulersse, 1972 and Akotoye, 1977). As a pest on *Cola* sp. and *Phyllanthus* sp. (Eguawe, 1973) as a predator on pupae of *Dacus oleae* (Cavalloro and Delrio, 1975) and on *Clarasoma* sp. As a pollinator *Crematogaster* sp. plays an important role in pollinating cocoa flowers upto 23 per cent according to Mire and Mbondji (1972) in Africa.

During the present study, *Crematogaster* sp. was observed nesting on *Tectonia grandis*, *Terminalia alata*, *Dalbergia* sp. The ants were found briskly moving about on teak, predated on the teak defoliator larvae, pupae and dead adults.

Monomorium indicum Forel : These forage indoors around the year near walls and foundations of buildings and is known to attack wood work and masonry (Pruthi and Singh, 1950). Though *M. indicum* is mostly considered as a domestic pest and reports are available to indicate it as a predator (Hardy *et al.*, 1969) Srivastava *et al.* (1969) reports it as a potential pest of sown sorghum seeds from Rajasthan. According to Gadiyappanavar and Channa Basavanna (1973) it acts as a dispersal agent of ragi root aphid. Verghese and Veeresh (1976) observed it nibbling the roots of wheat inoculated with *Rhizobium*. This species of ants were observed carrying grass seeds to their colonies established in grass fields, under shrubs.

Myrmecaria sp. : The species was reported from India, Ceylon and Sumatra by Saunders during 1841. Donisthorpe (1942) reported *Myrmecaria* sp. from South India and Ayyar (1965) refers to it as a household pest. The ant was observed actively foraging in the shrubs.

Pheidologeton sp. : Jerdon (1851) reported this species from India and Malayasia. Later, Chapman and Capco (1941) reported it from other parts of the World. This ant was collected at light during March 1978.

Ponerinae

Bothroponera sp. : This is a fairly common active paleotropical ponerine ant. According to Haskins (1941), it nests in soil, decaying wet logs in deeper forest, frequently running its galleries and chambers into the wood, maintaining open communication to the earth beneath. During the present study, only males were collected at light.

Pseudomyrmicinae

Tetraponera allaboras (Walker) ; *Tetraponera rufonigra* (Jerdon) : Both the species were reported from India-Madras by Jerdon (1851), Mayr (1887) and Dutt (1912). Both the species were collected at light during March.

Further exploration of the rich fauna in Dandeli forest area is necessary to study the different species of ants, their mound building, breeding, foraging and their role in Forest Ecology. Considering the fact that they are excellent predators, work in biological control programmes must be initiated.

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9.22 THE SUB-FAMILY DORYLINAЕ (HYMENOPTERA : FORMICIDAE)-A REVIEW

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ABSTRACT

The true army ants (Subfamily Dorylinae) consists of four tribes, nine genera and about 225 species. Dorylines are characterized by their group predation which includes both group raiding and group retrieving in the process of hunting live prey. Being nomadic, they construct temporary nests called 'Bivouacs' in the hollows of trees or in a burrow in the soil. Some species of dorylines have also been observed to be serious root pests of crops.

An attempt has been made to bring together the available information regarding the origin and distribution, taxonomic position, nests, polymorphism, allometry, social behaviour, foraging habits, group raiding, nomadism and their status as injurious insects to crops.

INTRODUCTION

The subfamily Dorylinae is so named meaning 'spear' in Greek, because of their potent sting. Hyatt Verrill, a naturalist and explorer of animal life described army ants as follows : In all the world, the army ants of the tropics are the most

remarkable in many ways. Utterly blind, yet they move in vast armies across the land, overcoming every obstacle other than fire and water, maintaining perfect formation, moving with military precision and like a real army, they have their scouts, their engineering corps and their fighting soldiers (quoted by Topoff, 1972).

Although they are among the most common ants encountered in the tropical forests of old and new worlds, the dorylines have long remained among the least known. Ants of the subfamily Dorylinae are usually referred to as 'Driver ants', or 'Safari ants' or 'Legionary ants' or 'Army ants'. A few myrmecologists call them as 'true army ants' to distinguish them from the ponerines, which are also sometimes referred to as army ants (Wilson, 1978 ; Gotwald, 1977).

Origin and Distribution

There is no clear indication of the exact origin of the subfamily Dorylinae. Wheeler (1914 & 1921) suggested that the baltic amber contains a diverse ant fauna of which 50 per cent belong to the genera considered as extinct. However dorylines are not represented and according to his speculation the dorylines were either restricted to the tropics during the oligocene or were so hypogaeic in their habits as to preclude their entrapment in amber. The doryline army ants are entirely absent from fossil records (Gotwald, 1977). *Sphecomyrma freyi* is the earliest known fossil of an aculeate hymenopteran and can be assigned to the lower part of the upper cretaceous period (Wilson *et al.*, 1967). The primitive nature of *Sphecomyrma* and the diversity of the oligocene ant fauna suggest that the dorylines must have originated in the late cretaceous or possibly early tertiary period (Schneirla, 1971). Based on the available geological data Gotwald(1977) concluded that : (a) *Aenictus* arose in tropical laurasic in the early tertiary and dispersed into Africa sometime between the late pliocene; dispersal of *Aenictus* to North America was not climatically possible (b) *Dorylus* evolved in Africa in the early tertiary but did not disperse to Asia until late in the tertiary before the land connection narrowed and became arid. (c) The Ecitonini and Cheliomyrmecini arose in tropical South America

Taxonomy :

Dorylinae is divided into four tribes, Dorylini, Aenictini, Ecitonini and Cheliomyrmecini which include nine genera and about 225 species (Wheeler and Wheeler, 1972; Gotwald, 1977). Keys for the identification of Dorylines and taxonomic notes have been given by many (Bingham 1903; Wheeler, 1910, Clark, 1951; Wilson, 1964 ; Gotwald, 1971, 1976; Bolton, 1973) authors. Important among these are the ones given by Wilson (1964) for the Indo-Australian dorylines and by Bolton (1973) for the West African dorylines.

Polymorphism and Allometry :

Wilson (1964) defined polymorphism as 'the occurrence of non-isomeric relative growth, occurring over a sufficient range of size-variation within a normal mature colony to produce individuals of distinctly different proportions at the extremes of size range'. Differential rates of growth whereby the sizes of certain parts of the body increase on a constant exponential function of the size of the whole insect is called 'Allometry'.

Emery (1910) and Borgmeier (1954) described the worker caste in a doryline ant, *Cheliomyrmex morgius*, as dimorphic and separated the two types into workers and soldiers, taking the mandibles and overall size into consideration. The size variation in the workers of *Anomma nigricans* was studied from the point of view of the association between polymorphism and allometry (Huxley, 1927) and the workers were divided into four distinct morphological and functional types by Cohic (1948). In strong refutation to Cohic's conclusions, Hollingsworth (1960) observed a continuous morphological series of workers from the smallest to the largest, the largest being about 75 times the size of the smallest. However, some authors maintain that the doryline workers are only dimorphic with major and minor worker castes (Gotwald, 1971; Roonwal, 1972) and in the genus *Aenictus* the workers are not polymorphic (Topoff, 1972).

The developmental basis for polymorphism is not clear although two possibilities exist. The first is that the developmental pathways leading to adult workers differing in size and structure are determined by the amount and kind of food eaten by the larvae immediately after they hatch and the second possibility is that the eggs laid by the queen differ biochemically, hence the subsequent development of the larvae is unaffected by the quantity or quality of food consumed (Topoff, 1972).

Social Behaviour

Topoff opines that, practically all army ants are notable for four characteristics : (a) they typically have very large colonies, (b) they are nomadic, (c) they exclusively carnivorous and (d) the trait that typifies the behaviour of dorylines is their high cohesiveness (Topoff, 1975) unlike many species of ants, army ants never forage individually.

The colonies of army ants typically consists of a single queen, a brood of developing young and a large population of adult workers which may vary from a few thousands to 20 million. Table I gives the approximate number of workers in a colony of some common species of dorylines.

TABLE I
Comparison of some biological characters of the best known species of the ants of the
sub family Dorylinae (from Wilson, 1971)

No	species	number of workers per colony	nesting habits	food habit	raiding pattern	cycle	Refe- rences
1	2	3	4	5	6	7	8
1.	<i>Dorylus</i> (<i>Anomma</i>) <i>wilverthy</i>	15 million to 20 million	subterranean clus- tering with much excavation of soil	many kinds of small animals mostly arthro- pods, some vegetable matter	swarms of about 12m wide in front tapers to trunk columns in rear, raids begin any time, usually at night	emigration irregular, average one about every 20-25 days and continue day and night for 2-3 days for average of 223 m, occur when brood consists mostly of pupae	Raigner and Van Boven (1955)
2.	<i>Aenictus</i> <i>laeviceps</i>	60,000 110,000	cluster in sheltered places on the ground surface during nomadic phase, moving underground	mostly other ants, social wasps, and termites ; a few other arthropods	weak dendritic columns, mostly over the surface of the ground ; raids occur any time-day or night	the <i>Eciton</i> pattern is followed except that as many as 5 or more emigrations occur daily when larvae are most active during nomadic phase, considered a primitive condition ; nomadic phase lasts about 14 days, statary phase 28 days.	Schneirla (1955)

1	2	3	4	5	6	7	8
3.	<i>Eciton burchelli</i>	150,000 700,000	exposed clusters above surface, often arboreal; no modi- fication of bivouac site	arthropods of a wide variety, including imma- ture stages of social wasps & ants	swarm of 10-15m in front, tapers to trunk column in rear; raid begins at day break; ends at dusk	nomadic phase (11-17 days) alternates with statory phase (19-22 days); emigrations daily during nomadic phase, which begins when adults eclose from pupae	Schneirla [1957(b)]
4.	<i>Eciton hamatum</i>	100,000 500,000	exposed clusters above surface, seldom arboreal; no modification of bivouac site	immature stages of social wasps and other ants	several dendritic columns lead away from bivouac site; raid begins at day break, ends at dusk	as in <i>E. burchelli</i> , except that nomadic phase lasts 16-18 days and statory phase 17-22 days	Schneirla (1957 b) Retten- meyer (1963)
5.	<i>Eciton vagans</i>	?	mostly in prefor- med subterranean cavities such as abandoned ant nests, also in and under rolling logs; some excavation is practiced	primarily imma- ture stages of other ants and a few other arthropods	as in <i>E. lamatum</i> , except that columns are partly subterra- nean & some times nocturnal	emigrate with larvae and callow adults	Schneirla (1954) Retten- meyer (1963)

1	2	3	4	5	6	7	8
6.	<i>Chelio- myrmex</i> (<i>abides</i>) <i>predator</i>	probably over 1 million	as in <i>E. vagans</i> some excavation is practiced	arthropods of wide variety, including immature forms of other ants; some nuts & other vegetable matter	swarm of variable size & shape; front usually less than 4 m wide, at pering to trunk columns; much of the raiding is underground and occurs day & night	emigrations occur, but pattern is apparently irregular & not closely correlated with brood development	Retten- meyer (1963)
7.	<i>Nomamyrmex</i> <i>exenbuki</i>	?	subterranean bivouac sites of unknown nature	mostly brood of other ants; some other arthropods also	weak dendritic columns, mostly under objects on ground or under- ground	probably an irregular <i>Eciton</i> pattern, but evidence is incomplete	Retten- meyer (1963)
8.	<i>Neivamyrmex</i> <i>nigrescens</i>	80,000 140,000	mostly subterra- nean bivouac, sites, often under rocks & logs; also occasionally in rotting logs	primarily other ants; also a few beetles and other small arthropods	weak dendritic columns, mostly over the ground surface but partly subterranean; raid at night or on overcast days	the <i>Eciton</i> pattern is followed but less regu- larly, with emigration less than daily during the nomadic phase; nomadic phase lasts about 14 days; statary phase 19-21 days	Schneirla (1963) Retten- meyer (1963)

In the functional and behavioural patterns of dorylines four aspects have been recognised, (a) the functional cycle, (b) the brood cycle, (c) nesting condition and (d) the raiding pattern. In the activity cycle of army ants there are two phases (a) the nomadic phase, during which there will be large daily raids ending in nightly emigrations and (b) the statary phase when there will be reduced raiding and no emigration (Schneirla, 1934; 1940; 1944a; 1944b; 1953; 1956a; 1956b; 1957a; 1957b; 1958). The activity cycle of *Eciton* colonies is truly endogenous and is not linked to any known astronomical rhythm or weather event (Wilson, 1971).

Nests of Dorylines

Almost all social insects build nests of some sort. However, Sudd (1967) has described army ants as nestless ants. As these ants are nomadic for part of their life, while resting during night they merely form a 'bivouac', a cluster of worker ants surrounding the queen and the brood, the bivouac hangs down from a tree or inside the hollow of a tree or a log or in a burrow in the soil. In shape it may be cylindrical, curtain like, conical or just a pouch (Schneirla *et al.*, 1954; Sudd, 1967). Bivouacs are constructed in such places which offer some sort of protection from extremes of temperature and humidity (Jackson, 1957; Kistner, 1976).

Just before construction of a bivouac, a cluster begins to form a sort of 'confusion centre'. The ants eventually break off and start moving in a new direction in a column, whose front moves rather hesitantly, as if led from behind. The front spreads out and may be forked over trees or logs. When an ant runs over a substance, say a log, it is likely to stop on the overhanging surface with its forelegs and body dangling from the middle and hind legs. If it is left alone, it will shortly recoil and turn back. Before this happens another ant runs over it and in turn stops hanging by its hind legs from the first ant. If another ant runs over the second and yet another over this, a string of ants begin to form. In *Eciton hamatum* the strings can grow up to 28 cm and in *E. burchelli* still longer. Neighbouring strings become cross linked when ants settle between them and ropes, curtains and cylinders eventually form. When the nest is constructed in the burrows in the ground, soon after the emigration, column gets established, the ants start pouring into a hole nearby in the ground carrying their larvae. Other ants get busy depositing minute pieces of dirt, from around the roots of plants and fallen leaf. These particles are carried individually and dropped. The entire building process lasts for about 48 hours (Schneirla *et al.*, 1954; Kistner, 1976).

The nests of *Dorylus* (*Anomma*) *welverthi* are 1 to 21 meters deep, 3 meters square and compact, formed in a single cavity with higher temperature while those of *D. (A.) nigricans* are 2-4 meter deep, dispersed in numerous deep chambers and galleries with lower temperature (Schneirla, 1957a; 1957b; Wilson, 1971).

A nest of *D. (A) nigricans* was found beneath a compost heap (Hollingsworth, 1960). Nests of *Neivamyrmex nigriscens* and *N. opacithorax* were found in and around foundation walls of buildings (Smith, 1965). A colony of *Cheliomyrmex* was found under a decayed log and temporary subterranean nests of *Anomma* in cocoa fields (Gotwald, 1972; 1974a). Dorylines have found to nest even in live termitaria with fungus gardens undisturbed and termites still inside, safe (Kistner, 1976).

Group Raiding :

A noteworthy activity of army ants is their daily or more frequent raids to gather food for the colony. The foraging patterns and raiding behaviour have been studied by many authors (Schneirla, 1934; 1938; 1940; 1944a; 1949b; 1956a; 1957a; 1971; Schneirla and Piel, 1948; Schneirla and Reyes, 1966; Schneirla *et al.*, 1954; Aliberl, 1951; Strickland, 1951; Sudd, 1967; Wilson, 1971; Topoff, 1972; Gotwald, 1974a; 1974b; 1976; Gotwald and Soman, 1976; Kistner, 1976).

The group raidings are also called 'sequential swarm raidings' and the beginning of a raid is difficult to see because the time of the day when they are likely to begin cannot be predicted (Kistner, 1976). However, at the beginning of such a sequential raid there will be a general increase in nest activity. Then occurs an enormous out-pouring of ants from one of the openings of the nest. The ants leave the nest in the form of a column which will be 3-5 inches wide in the initial stages. Column movement is in a single direction with all the ants moving out from the nest. In *Eciton hamatum* there is a branching-column pattern of group raiding with small terminal groups and this species forages mainly on ground. *E. burchelli* has swarm pattern of a large advance group and a consolidation column, foraging on ground frequently in vegetation (Schneirla, 1957a). The raids of *Eciton* begin at day break and cease at dusk, and those of *Dorylus* begin at any time of the day or night and more frequently early at night. Swarm advance is fairly direct in the morning at the rate of 20m/hr. in case of *Eciton*. In case of *Dorylus* the swarm advance is variable in direction (Raigner and Van Boven, 1955; Shneirla, 1957a; Wilson *et al.*, 1967; Topoff, 1975; Kistner, 1976).

Economic Importance

The diet of Dorylines is mainly carnivorous even though they consume occasionally some vegetable material. Workers of *D. orientalis* have been observed feeding on grubs and earthworms (Lovendge, 1922), attacking beehives and their broods (Ghosh, 1936) and even gathering around openings of termitaria of *Microtermes mycophagus*, attacking them while swarming (Smith, 1859). According to Roonwal (1972) *D. orientalis* is a serious root pest on potato, groundnut, sugarcane, citrus and coconut seedlings. Raigner and Van-Boven (1955) and Gotwald (1974b)

analysed the prey carried back to the nest by army ants and found that the prey of *D. welverthi* consists mostly of roaches and spiders, although almost every order of insects were represented. Dorylines have been reported as attacking and killing extremely poisonous snakes, a dog and young chicks in a poultry (Kistneer, 1976).

Arthropods associated with Dorylines :

Many arthropods have been found associated with the colonies of army ants. Three species of Thysanurans, *Trichatellure manni* (Caudell), *T. bongmeieri* Silvestri and *Grauiella rettenmeyer* Wygodzinsky were found living with *Eciton hamatum* (Rettenmeyer, 1963b). Several species of staphylinids including, *Ecitomorpha* spp., *Ecitophyle bicolor* Reich., *Labidoglabus nevermanni* Reich., *Mineciton antennatum* Mann, *Mimanella ecitonis* Wasmann, *Paramimeciton coeci* Reich., *Probeyerie pulex* (Sanderson), *Ecitoxenia megalops* Seevers, *Ecitogasta panamensis* Seevers, *Dinocoryna akrei* Seevers, *D. tibialis* Seevers, *Ecitona biimpreua* Seevers, *Ecitodonia cetigera* Seevers, *Ecitoglossa antennalis* Seevers, *E. quadriiceps* Brogmeier, *Ecitonidia wheeleri* Wasmann, *Ecitosius grasilis* Seevers, *E. robustus* Seevers, *Ecitotone miniventris* Seevers, *Microbonie kamane* Seevers, *M. nittidiventris* (Brues), *Tetradonia marginalis* Reich., *Wasmannina isthmian* Seevers, *Ecitocleptis socie* Borgneier, *Mimaphites borgmeieri* Reich., *Synecitonides phasma* Reich. and *Philonthus* spp. were found closely associated with *Eciton*, *Labidus*, *Nomamyrmex* and *Meivamyrmex*. (Akre and Rettenmeyer, 1966; Akre and Torgerson, 1968). Millipedes belonging to three genera, *Calymmodesmus*, *Rettenmeyrie* and *Yucodesmus* were identified as myrmecophilic, associated with *Eciton*, *Neivamyrmex*, *Labidus* and *Nomamyrmex* (Rettenmeyer, 1962).

Natural enemies of Army ants

Driver ants have relatively few predators. A few birds have been found predating on army ant columns (Wheeler, 1921, 1922). In the stomach contents of large frogs safari ants were found. Flies of the genera *Bengalia* (Calliphoridae) and *Stylogaster* (Conopidae) are considered as its natural enemies (Cohic, 1948). Gotwald recorded *Oecophylla longinoda* as an important predator of *Anomma* (Gotwald, 1972).

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9.23 NESTING PATTERN OF THE ANT *CAMPONOTUS SERICEUS*

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ABSTRACT

The ant *Camponotus sericeus* Fabricius is very shy and timid, mostly found in the field unlike other species which also make nests in human habitations. Its nests are neither cognizable nor in abundance. Total number of nests per 102 meter area was observed to be 1.1 ± 0.195 .

C. sericeus normally constructs tower shaped structure at the entrance which is 0.6 to 4 cm and 0.6 to 0.8 cm in height and diameter, respectively. Invariably, the nests of this species open by a single entrance/exit hole. From the base of the entrance tower, the opening of the nest, 0.8 to 1.5 cm in diameter, was found descending down as a shaft up to the entire depth of the nest. Brood chambers necessary for the purpose of incubation of eggs, larvae and pupae, were normally observed, radiating from the main shaft of the nest in all directions. They were of two types : (i) the upper and horizontally placed ones ; (ii) the deeply located ones. The former type of brood chambers were found at a depth of 1 to 4.5 cm and some times up to the depth of 11 cm from the ground level, whereas, the deeply located ones were at a depth of 11 to 46 cm. Usually the brood chambers, it was observed, had a slope towards the main shaft of the nest. Temperature recorded in these two types of brood chambers was 24 to 28°C (24.3°C) and 22 to 25°C (22.5°C), respectively.

The deeply situated brood chambers consisted of eggs, pupae and larvae. The superficially situated brood chambers were mostly found housing the pupae and some times a few older larvae as well. This indicated that pupae need slightly higher temperature for their development.

9.24 ANTS IN THE INTEGRATED CONTROL OF CUTWORMS IN LAWNS

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ABSTRACT

Investigations were carried out at the Raman Research Institute lawn, Bangalore on the possibilities of using ants (*Solenopsis geminata* Fabr., *Tapinoma melanocephalum* Fabr. and *Camponotus sericeus* Fabr.), in the control of the cutworm, *Laphygma exigua* Hubn. Methods of attracting the ants and disseminating them are described. Comparative efficacy of insecticides and predatory ants in the control of cutworms is discussed. Use of ants in the management of cutworms was found to be very effective with no hazards to other natural enemies of the pest.

INTRODUCTION

A severe out break of the cutworm, *Laphygma exigua* Hubn , appeared during 1977-78 in the grass lawn of Raman Research Institute, Bangalore. Two attempts were made with insecticides (Carbaryl and BHC) to control this pest with no encouraging results, before taking up this experiment. Further use of insecticides in the lawn was thought to be hazardous to other fauna like rabbits, mynahs and other birds, which regularly visited this lawn. Although a large number of adult braconid parasite, *Chelonus formosanus* Sonan, were found active in the lawn, there was no check of the pest. Birds like crows and mynahs visited the lawn regularly but they could exercise no control as the cutworm population was as high as 42 larvae per 30 cm² in some places.

The lawn was being completely grazed and the pest was not allowing any green grass to sprout. In addition to the cutworm, *Laphygma exigua*, a leaf roller *Cnephalocrosis medinalis* was also causing damage, but these were in small number, because of the preferred attack of *Chelonus formosanus* on them,

A number of ant colonies were found around the Institute, but there was no activity of the same in the lawn. Although ants attacking insects, poultry and other animals have been reported in several cases. (Verghese & Veeresh, 1978). Therefore an attempt was made to utilise the predatory ant fauna found in the vicinity of the Institute for checking the pest.

MATERIAL AND METHODS

Two experiments were taken up simultaneously. One with insecticides and another with ants. In the insecticidal trial, four insecticides viz, carbaryl 25 WP, chlordane 20 EC, BHC 50 WP & phorate 10 G were applied in 2 x 2 m² plots, replicated 4 times and compared with no insecticides/check. This experiment was taken up in one corner of the lawn. The rate of application was : carbaryl at 4 g/l, chlordane 5 ml/l., BHC 5g/l., stock solution of these was poured in a rose - can at the rate of one litre per 2m². Phorate was applied at the rate of 25 kg/hectare. The granules were sprinkled uniformly and then watered, by a hose pipe, with force. Samples were taken before treatment and 3 and 8 days after treatment by forcing out the larvae with a jet of water through a hose pipe. Two samples were taken from each plot keeping a 30 cm² quadrat and the live and dead larvae were counted.

Ants were attracted to minced meat plates. One kilogram of minced meat was divided into 8 parts on separate 60 x 60 cm card board. These boards with minced meat spread on them were kept in the afternoon at several points where

the nests were noticed. In about 4 hours, the card boards were full with ants. These were then placed at several points in the lawn. This was repeated for two days. Three species of ants were involved viz., *Solenopsis geminata* Fab. (Myrmicinae), *Tapinoma melanocephalum* Fab. (Dolichoderinae) and *Camponotus sericeus* Br. (Formicinae). Sampling for the number of larvae was similar to the one explained under insecticidal trial, taken on 3rd and 8th day after the release of ants.

RESULTS AND DISCUSSION

There were on an average 22 larvae per 30 cm² in plots with no insecticides on the 3rd day after treatment, the same in carbaryl, chlordane, BHC and phorate treated plots were 12, 14, 16 and 9 respectively. Eight days after the treatment, the number of larvae were 16, 15, 12 and 14, respectively, in carbaryl, chlordane, BHC and phorate treated plots, compared to 27 in untreated plots. The number of young larvae in the untreated plots was more compared to treated plots during the 2nd observation. Although the larval population in insecticides treated plots were reduced compared to untreated plots, the reduction was not enough to protect the lawn. There was no new growth of grass even after two weeks of treatment. The thick mat of grass prevented proper percolation of the chemicals. The larvae took shelter underneath this thick mat, during day time, when the insecticides were applied and thus escaped direct contact with the chemicals. In the ant released area, on the 3rd day after release, a number of ant hills were visible. Early in the morning ants were busy bringing out earth, remains of insect body like head capsules and pupal cases. These ant hills had a number of larval head capsules of all stages and pupal cases deposited at the outer edge of the excavated soil at distances varying from 15 to 30 cm from the entrance holes. A maximum of 2005 head capsules were counted in one ant hill and 57 pupal cases in another ant hill in addition to head capsules. On an average 1.2 nests were found per 2 m² all over the lawn. The insecticide treated plots were conspicuous in not having ant hills. Perhaps, earlier application of insecticides to the lawn might have prevented early establishment of ants in the lawn. Average number of larvae per sample of 30 cm² on the 3rd and 8th day of sampling was 17 and 3.5, respectively. Ants were particularly busy in dragging the larvae in to the nests in the afternoon (Fig. 1). They could locate the larvae and pupae even under the thick mat of grass. Foraging activity of the ants was less during the morning hours when there was moisture in the lawn, they were mostly attending to cleaning of the nests during this time. As the moisture reduced with advance in the day they started carrying the food. Among the three species of ants, *Solenopsis geminata* was dominant. The other two species were more or less equal in number. There were more number of ant hills in the lawn, than realised earlier, some times as close as 50 cm apart.

This phenomenon could not be explained as to how the number of ant hills suddenly increased. Holldoblers' (1974) observation that '*Camponotus sericeus* recruits nest mates to newly discovered food sources or nest sites by the tandem running technique', may be recollected here. According to Szlep and Jacobi (1967) pilot ants are able, in the course of a few seconds, to mobilize a number of secondary foragers. As many as thirty-one queens of the tropical fire ant *Solenopsis geminata* have been reported in a single nest in the field (Adams *et al.*, 1976). This explains the quick



Fig. 1

multiplication of nests in a field where abundant food source is available as was found in the lawn during the present study. Digging the nests by *Solenopsis geminata* has been explained by Hangartner (1969) and in the present study similar behaviour was observed. Although detailed biology of *S. geminata* has not been made, yet interesting observations have been recorded by Banks *et al.* (1973), Travis (1941) and others (Anonymous, 1977).

No reports are available on the use of ants in the control of pests. However, Long *et al.* (1958) reported increase of sugarcane borers after the fire ant eradication programme in Texas. Nagi *et al.* (1930) reported all the three species of ants mentioned here, visiting lac insects for honeydew, but *S. geminata* takes particular interest on *Eublemma*, a predator of lac and kills the exposed *Eublemma* in a few seconds and carries it to its nests.

CONCLUSION

The present findings clearly establishes the usefulness of ants in the control of cutworms in lawns where it is difficult to control by other methods including insecticides. Except for a little disfiguring of lawns by their nest building activity, their presence in lawns, turfs and golf courses would keep the pest under check particularly the lepidopterous pests. There was no recurrence of the pest even after 18 months from the first establishment of ants. Use of ants in the control of cutworms in the lawn was highly satisfactory not only in quick control of the pest but also in it being least hazardous and non-polluting with almost no expense except for the cost of meat.

The authors are highly indebted to Professor Krishnan of Raman Research Institute and his colleagues for their keen interest, encouragement and assistance.

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9.25 PROBLEMS IN THE MANAGEMENT OF CUTWORMS IN COTTON

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ABSTRACT

High incidence of *Prodenia litura* in January, on leaves and growing fruits resulted in total failure of cotton crop in most of the farms in spite of high dose of insecticide application. To meet effectively such situation some sort of system or order is essential. It is suggested that, alternate methods such as chemosterilization and biological control may be evolved and employed.

9.26 ECOLOGY OF SUBTERRANEAN APHIDS (HOMOPTERA : INSECTA) IN INDIA

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ABSTRACT

Out of more than 720 species known from the Indian region only 24 species are now known to feed on roots. Most of these are distributed in an area between ca 500-2000 m altitude and major area of distribution appears to be in the N.W. Himalaya, Eastern Himalaya and Nilgiri Hills in the south. The host range of subterranean aphids includes a large number of Graminae besides a few Cyperaceae, Compositae, Rosaceae, Solanaceae and Conifers. Some of the species occur all through the year at different altitudes while others are found only towards the end of winter.

INTRODUCTION

Aphids are well known as obligatory phytophagous insects feeding on wide variety of host plants, from Bryophytes, Pteridophytes, Gymnosperms to an array of Angiospermic plants. Most aphids are known to feed on aerial parts of plants viz. foliage, stem, flowers, fruits, bark etc. but some of the species spend at least a part of their life cycle in subterranean habitat, feeding on roots of secondary hosts. It is interesting to note that a large number of root feeding aphids, are capable of producing temporary to definite galls on the aerial parts of their primary hosts. In typical heteroecious holocyclic pattern of life cycle, aphids migrate to roots and

produce apterae-viviparae which in turn produce sexuparae-alatae, the latter migrating to primary host and producing sexuales and repeating the cycle. This cycle has often been modified in warm temperate region of distribution of these insects.

Subterranean aphids are known from a wide number of genera, (about 20) belonging to Aiceoniinae, Aphidinae, Lachninae and Pemphiginae. Many members of these genera may be partly dependent on subterranean habitat while others of genera *Protrama*, *Trama*, *Forda* etc. may be wholly dependent (Curtwright, 1925). In the Indian region, a total of about 24 species belonging to 12 genera are known to occur in subterranean habitat and these represent all the four subfamilies mentioned earlier. A list of root sucking aphids of coimbatore was published by George (1924) and recently Rao and Kulkarni (1975) have compiled a list of 20 Indian root-aphids including 7 undetermined species. Pal (1975) has worked extensively on the subterranean aphids of graminaceous plants of Eastern Himalaya.

Trophobiotic relationship

Relation between aphids and ants is well-known. Ants attend to aphid colonies on aerial parts of host plants and the association may be casual to symbiotic. The subterranean aphids are mostly attended by ants and many species may be located in the ant-nests. The trophobiotic association may be (1) myrmecoxenous—when ant association is minimum as has been observed in the case of *Prociphilus* (S.) *himalayensis* Chakrabarti, infesting roots of *Pinus* or *Prociphilus taxus* A. K. Ghosh *et. al.*, infesting roots of *Taxus*; (ii) myrmecophilous—when ant association is common but degree of association may be variable; most of the species of Pemphiginae are myrmecophilous during their subterranean life and ants of *Camponotus* and *Solenopsis* are common associates. No species seems to be myrmecobiont—completely dependent on ants—as is *Paraclites cimiciformis* Heyd., on *Tetramorium caespitum* L. in Europe (Zwölfer, 1958), where species of *Lasius myrmica*, *Tetramorium*, *Solenopsis* and *Formica* are normally associated with root feeding Aiceoniinae and Pemphiginae.

Host range and Life Cycle

The host range of subterranean aphids include a large number of Graminae, viz., *Avena*, *Andropogoni*, *Capillipidium*, *Eichoncola*, *Elesuine*, *Eragrostris*, *Hordeum*, *Poa*, *Oryza*, *Polypogon*, *Triticum* etc., besides a few Cyperaceae, Compositae, Rosaceae, Solanaceae and Coniferae. During the aerial phase of life cycle a separate host-plant group may be associated in heteroecious holocyclic species or even in polyphagous anholocyclic species but in the region most of the species appear to be restricted to the same host group e.g. *Rhopalosiphum padi* L. and *R. rufiabdominalis*

(Sasaki). In some cases, the dependence on subterranean life seem to be complete except in the period when emigrant alate search for another host plant ultimately to form colonies below soil level e.g. species of *Forda*, *Geocica*, *Protrama*, *Smynthuroides*, *Tetraneura*; other species of *Rhopalosiphum*, *Eriosoma* lead a subterranean life only during winter; complete heteroecious cycle has been shown in *Schizoneurella indica* H.R.L., which forms galls on *Ulmus villosa* and feed on the roots of *Malus pumila*; discovery of sexuparae of *Prociphilus* on the roots of Coniferae (*Pinus*, *Taxus*, *Tsuga*) indicate a possible heteroecious cycle but the same species have not been recorded from primary hosts, which in this genus, are wide and numerous.

The subterranean species indicate a significant change in two aspects of life cycle viz., monoecious habit and anholocycly from heteroecious habit and holocycly. The suppression of some phase of sexual cycle may not be attributed to the possibility of absence of primary host, as primary hosts of most Pemphigids are available in the region (*Ulmus*, *Populus*, *Pistacia*). Had sexuparae been produced, it could have been assumed that the same morph migrate to some yet unknown host, but most of the root-feeding aphids do not produce sexuparae.

Distribution : Altitude, Area, Soil types

The subterranean species are mostly distributed in Eastern Himalaya, North-west Himalaya and Nilgiri Hills showing a strong co-relation with the altitude. Most of the species occur between ca. 500-2000 m except a few like *Tetraneura nigriabdominalis* (Sasaki), *Rhopalosiphum padi* Linn., *Rhopalosiphum rufiabdominalis* (Sasaki), all infesting graminiae including paddy, which are found in the plains. Almost all the species are recorded during end of winter and early summer but in some cases early winter has been noted as period of occurrence. Aphids in the temperate holarctic region normally hibernate or overwinter in the roots/soil/underbark and apterous exules produce sexuparae at the end of the unfavourable season which migrate to primary hosts and produce sexuales. But anholocycly may help to maintain a fluctuating subterranean population at different altitudes all through the years as in the case of *Tetraneura nigriabdominalis* (Sasaki); similarly, the wooly apple aphid, *Ergosoma lanigerum* (Hausman) maintains subterranean population in the winter but migrate to aerial part of the same host (Pomoidea) during other season, reproducing parthenogenetically during the entire period. The soil types of the areas, where subterranean forms are recorded, include dry sandy soil, dry to semiwet sandy loam soil, wet loam soil and clay soil, showing that these insects as a whole do not exhibit any preference to a particular soil-type. The maximum depth at which the insects are found may vary between 1 cm and 20 cm. No data is available to indicate presence of any thermophilous, xerophilous or hygrophilous biotypes.

Biomorphological changes

The continuous anholocycly associated with subterranean life has lead to some changes in biology and morphology of the species. The formation of alate, even in parthenogenetic cycle below the soil, become scarce as the stimuli associated with the triggering mechanism of alate formation become scarce except for crowding effect. The morphological changes has lead to some loss or reduction of characters like facets of eyes, antennal segment, secondary rhinaria, siphunculi, sclerotisation and number of tarsal segments. Some characters like wax glands and antennal segments are very variable in subterranean aphids, unless complete life-cycle and absence of heterocy is proved, formation of new species based only on radicolous form may lead to confusion.

Wax gland secretion by radicolous exules is common in many Pemphiginae but it can not be considered as a correlated adaptive factor for subterranean life, as Hormaphidine aphids on aerial parts of Graminae are also well known for wax secretion. The natural enemy complex of aphids on aerial parts include predators like birds, spiders and other insect larvae and insect-parasitoids but the subterranean colonies appear to be relatively free from these except for a limited extent. The increase in population density, by anholocycly and absence of natural enemies, help the subterranean forms to balance the restriction in nutritional physiology.

DISCUSSION

Extensive year round survey in the areas where primary host-plants and secondary host-plant coexist, may help to have a better understanding of subterranean aphids with regards to their ecology, biology and life-cycle. Data on soil temperature, humidity and mineral elements may indicate relationship between occurrence of aphids and extrinsic factors. Pemphigid aphids which constitute the largest group of subterranean aphids in the region should be investigated in such a way so as to have extensive data on gallicolous form and radicolous form and possible relationship between the two.

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TABLE I
BIOLOGY OF SUBTERRANEAN APHIDS IN INDIA

Aphid group	Host Plant (Subterranean phase)	Cycle	Trophobiotic association Myrmecophilous + Myrmecoxenous —	Altitude	Distribution
AICEONIINAE					
<i>Anoecia</i>	Graminae	Monoanholocyclic	+	1000 m - 2500 m	East India
LACHNINAE					
<i>Protrama</i>	Helianthus	Monoanholocyclic	+	1500 - 2500 m	North East & North West India
APHIDINAE					
<i>Rhopalosiphum</i>	Graminae	Heteroanholocyclic	±	2500 m	North East & North West India
PEMPHIGINAE					
<i>Chactogeoica</i>	Graminae	Monoanholocyclic	±	600 - 2000 m	East India
<i>Eriosoma</i>	Pomoidea	Monoanholocyclic	+	1500 - 2500 m	North East North West & South India
<i>Forda</i>	Graminae	Monoanholocyclic	+	440 - 2000 m	North East & South India
<i>Geoica</i>	Graminae	Monoanholocyclic	+	1000 - 2200 m	North East & South India
<i>Pemphigus</i>	Graminae	Monoanholocyclic	—	1500 - 2000 m	North East & North West India
<i>Prociphilus</i>	Coniferae	Heteroholocyclic (?)	—	1500 - 2000 m	North East & North West India
<i>Schizoneurella</i>	Rosaceae	Heteroholocyclic	—	1800 - 2000 m	North East & North West India
<i>Tetraneura</i>	Graminae	Monoanholocyclic	+	S.I. - 2700 m	North East & South India
<i>Smynthuroides</i>	Graminae Compositae	Monoanholocyclic	+	1000 - 2000 m	North East & South India

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9.27 RHIZOBIAL NODULE DAMAGE BY INSECT FAUNA AND THEIR CONTROL

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ABSTRACT

The ecological studies on root nodulation in pulse crops conducted in Agricultural Research Station, Gulburga and Northern Karnataka over two years led to the discovery that the nodules formed by the native Rhizobia as well as the nodules formed by the introduced Rhizobia through seeds were severely damaged by the insects on cowpea, greengram, blackgram and redgram. The insects larvae involved, damaged the fresh vigorous nodules from the 10th day of sowing the crops till maturity in kharif season. In majority of the cases the damage was caused by a dipterous maggot (unidentified) and in a few cases by the grubs of a chrysomelid and an apodus larvae of a curculionid. The damage ranged from 10 to 100 per cent in various locations and indicated the wide-spread nature of the pests. It has been established that the nodules eating insects have been the major constraint in the production of these pulses primarily from this station. The results of the field scale experiments conducted at Agricultural Research Station farm of the UAS on blackgram in 1977 kharif with the basal application of a granular insecticide i.e., aldicarb or disulfotol or carbofuran at 1 kg a.i./ha has successfully controlled these insects. The chemical used did not affect the nodulation process. While the treatment has registered a significant increase in the growth of the plant and grain yield over that of control receiving no insecticide and application of fertilizers.

Similar insecticidal experiments on cowpea, greengram, blackgram and redgram conducted in kharif 1978 have resulted in a significant grain yield increase due to protection of Rhizobium nodules. The granular insecticide application has been economically viable.

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ABSTRACT

Termites are broadly grouped as wood-inhabiting and soil-inhabiting. The wood-inhabiting species nest in living and dead portions of trees or in the converted woods and have no connection with soil at all. The soil-inhabiting species make their nests either partly in soil and partly in wood (Rhinotermitidae) or completely in soil (Hodotermitidae, Termitidae) and visit plants, trees, converted woods, structural timbers and stored articles for their food. They fall in the following four categories : (i) Partly subterranean and partly wood-inhabiting ; (ii) purely subterranean, making nests under surface of the ground ; (iii) mound building and (iv) carton-nest building.

The present contribution deals with the field observations on these termites, made by the author during several of the surveys conducted by him in various parts of the country. The distribution, nesting behaviour, nature of damage caused, swarming behaviour and ratio of soldier and worker castes of some of the species are given.

INTRODUCTION

The role of soil termites has always remained a debatable one and a very few reports of their involvement in either the beneficial or the harmful effects, with regard to the fertility of soil, are available. There are reports that some termites help in breaking up the fallen leaves and twigs and converting them into soil, that they bring up newer subsoils over the surface of the ground in the tropics as done by earthworms in the temperate parts, that the mound soils are more fertile and are mixed up in the fields for better crops and so on. At the same time there are reports that these insects cause degradation of soils. In any case it may be mentioned that these insects play an important role whether beneficial or harmful. In fact, some extensive studies and soil analyses are required to determine their exact contribution in this respect.

In this paper on the soil termites of India, distribution, nesting behaviour, nature of damage caused, swarming behaviour and the ratio of different castes, in certain important species are given and are mainly based on the author's field observations and study.

Soil Termites of India

Termites are broadly grouped into wood-inhabiting and soil-inhabiting forms. The wood-inhabiting termites nest in the living and dead portions of trees or in the

structural and converted timbers and have no connection with the soil at all. The soil-inhabiting species make their nests either partly in soil and partly in wood or completely in the soil. They, however, are come across in plants, trees, wooden structures in buildings and in godowns and store-houses where paper, textiles and wooden articles are stored, since they are feeders of cellulosic matter. There are four categories of soil termites namely (i) partly subterranean and partly wood-inhabiting, (ii) purely subterranean, (iii) mound building and (iv) carton nest-building, and they belong to the families Hodotermitidae, Rhinotermitidae and Termitidae.

Family Hodotermitidae : This family is represented in the Indian subcontinent by six species of the genus *Anacanthotermes* viz., *baluchistanicus* Akhtar, *macrocephalus* (Desneux), *peshawarensis* Akhtar, *rugifrons* Mathur & Sen-Sarma, *vagans* (Hagen) and *viarum* (Konig). These termites are known as harvester termites since they feed on grasses and store bits of them in the under-ground chambers. The species, *viarum* was collected while foraging in the open grassy scrub jungle near Tirunelveli in southern India where it makes long galleries and small, circular chambers in the ground and while making small mounds (12 cm in height and 30 cm in circumference at the base) of granular, excavated soil in the vicinity of the sea-shore at Kanya Kumari. The galleries at Kanya Kumari could not be traced due to the sandy nature of the soil. The swarming in this species has been recorded in the month of October by Roonwal (1970).

The nest of *Anacanthotermes macrocephalus*, which occurs in the North-western parts of the subcontinent, is described in detail by Roonwal (1970). The species *baluchistanicus*, *peshawarensis* and *vagans* are reported from Pakistan.

Family Rhinotermitidae : The termites belonging to this family have their main nests in soil under the surface of ground and galleries are extended into the wooden structures in houses and in trees. Twenty seven species are known from the subregion, of which the most common ones are *Coptotermes heimi* (Wasmann), *C. ceylonicus* Holmgren, *Heterotermes indicola* (Wasmann), *H. malabaricus* Snyder, and *H. ceylonicus* (Holmgren). *Coptotermes heimi* is one of the most destructive species and is distributed widely throughout the subcontinent. Its nest in the soil is of diffuse-type and in the wood it is formed of network of strands, of uneaten wood plastered with excrement and is of brownish colour. It is a pest of serious nature of agriculture, stored products, and timbers both in timber yards and in the buildings. It has been collected attacking a number of trees, timber in yards and jute goods at Salem and from paper, textiles and other articles at a number of places in northern and eastern India. At Gurgaon it was noticed infesting the wood-works of the P. W. D. rest house so severely that the authorities were planning to reconstruct the rest house. The swarming of this species, begins by middle of March and continues intermittently

till the month of June, at Calcutta. The ratio of the soldiers and workers is 1:8.3-11:1 and that of male and female imago is 1:1.6. The species *Heterotermes indicola* is another very destructive termite and has been collected from structural timbers in old buildings at Calcutta and at several places in northern India. At Karnal (Haryana) a large number of houses in Model Town, the locality which came up only after independence, were found infested with this termite. Roonwal (1955) has recorded virtual ruining of whole of the township of Sri Hargobindpur in Gurdaspur District (Punjab). It has also been found damaging stored goods of cellulosic nature including library books and office records at several places. The nest of *H. indicola*, in the wood, is made up of long, flat, longitudinal excavations which run along the fibre of the wood and are plastered with soil and faecal matter of the insects. The ratio of soldiers and workers is nearly 1:18. *Heterotermes malabaricus* is a pest of number of trees, wooden structures and stored materials and has been collected from several places in southern India and *H. ceylonicus* is a well known pest in Sri Lanka.

Family Termitidae : The termites of the family Termitidae build their nests either completely below the soil or construct large, earthen mounds of varying shapes and sizes or make carton-nests in stumps of trees or on trees, poles, etc. and in the hollows of tree trunks.

The Apicotermitinae and the Termitinae have their nests in soil under the surface of the ground and are made up of long, narrow galleries having pouches or pockets enroute and at the end of the galleries. The nests may run horizontally just under the surface of the ground and may go down into the soil to about 50 cm below the level of the ground. The galleries and chambers may or may not be coated with faecal matter. On the surface of the ground the galleries open up under stones or logs of wood or cowdung or just into the open. Sometimes small heaps (3-5 cm in height) of excavated earth may be thrown out in case of some *Speculitermes* spp. A number of nests of *Speculitermes sinhalensis* Roonwal & Sensarma were thoroughly excavated at Dharwar and Coimbatore and it was observed that the pouches or pockets were being used as store houses, containing dried up pieces of grasses. The soldiers in the *Speculitermes* are very rare and have been reported (Roonwal & Chhotani, 1960, 1966) only in *S. sinhalensis*, they are only 0.2-0.44 per cent of the whole population of the colony and were found in the months of April and September at Dharwar and in April and November at Coimbatore. The swarming in this species is reported during the months of March and April. The distribution of the species extends from central India to Sri Lanka and is quite common in southern India. The other very common species known from eastern, central and western India, making such nests and galleries in soil is *Synhamitermes quadricaps* (Wasmann). It has been observed nesting in soil and in the

mounds of *Odontotermes* species. The nests are in the form of long and narrow galleries and small chambers of 20-30 cm diameter. The royal chamber is spindle-shaped of 4 cm length, 2 cm width and 1 cm height. The queen is nearly 3 cm in length. The ratio of male and female reproductives is 1 : 1. The *Capritermes* group of genera also build similar system of galleries and are quite abundant in the Western ghats. *Dicuspitermes fletcheri* is the most common species of the group in southern India and has been observed damaging roots of Eucalyptus sapplings at Yercaud. A nest of *Pericapritermes tetraphilus* (Silvestri), encountered in a mound of *Odontotermes obesus* in Kanha National Park (M.P.), comprised thin, flat galleries and round to irregular, flat below and arched above chambers leading into a series of larger chambers arranged in a tier one above the other. All these galleries and chambers were neat, clean and coated with grayish material (Chhotani, 1977). The species of the genus *Microcerotermes* are also very common in the subcontinent, they either make nests in soil or in some pieces of wood left in the ground or make carton nests in stumps of trees. The nests of *Microcerotermes beelsoni* Snyder are of common occurrence in Balukhand Forest Range, near Puri (Orissa), where almost all the stumps of *Casuarina equisetifolia* were found infested with this termite when the author visited the area in the year 1957. In Haryana near Karnal it has been collected from a number of trees and in the Kanha National Park from jungle wood pieces lying on ground, from carton nests in stumps of wood and from soil under stones. In soil, it makes narrow galleries and in one case a queen was also found from a larger chamber in the soil. The ratios of soldiers and workers and that of males and females are approximately 1:10 and 1:1.4, respectively. Mature imagos ready for swarming were noticed during the month of June in Kanha National Park. *M. fletcheri* is quite common in southern India and has been collected from carton nests, while damaging tree branches, from soil and from stumps of coconut palms, Casuarina and some unknown trees.

The Macrotermitinae are fungus growers, they make their nests either in soil under the surface of the ground or build mounds above ground. The *Macrotermes* are grass feeders, in India they make extensive nest-systems in soil under the ground surface. *Macrotermes estherae* (Desneux) is common in southern India and has been collected as far North as Rambha in Orissa. Its underground nests are in the form of long and narrow galleries running for long distances and burrows and chambers for fungus combs. The soldiers and workers go out on long foraging expeditions in fields. *M. gilvus* has been observed making mounds in Burma, the mounds of this species are large, sprawling, dome-shaped multi-locular structures (Roonwal & Chhotani, 1961). All the *Microtermes* species are soil burrowers, the nests sometimes are also found in the mounds of *Odontotermes* species. *M. obesi* is the most common species and does extensive damage to agricultural crops such as sugarcane, wheat and maize, and to ornamental and flowering plants. It is one of the smallest

of termite species but is most notorious. The males and females are in the ratio of 1.3 : 1. The swarming of the species is during the earlier part of the monsoons. Its fungus combs are small, round, walnut-like structures. Most of the *Odontotermes* species live underground in the soil but a few such as *obesus* (Rambur), *redemanni* (Wasmann), *brunneus* (Hagan), *microdentatus* Roonwal & Sensarma and *wallonensis* (Wasmann) build large earthen mounds. The mound-building species may also make nests under the ground. A few species which generally have nests under the ground-level sometimes build mounds as well. *Odontotermes obesus* is the most common species and is distributed throughout the Indian subcontinent. Different types of mounds are attributed to this species, Chhotani (1977) considers that they probably belong to some sibling species whereas Roonwal (1977) treats it as a variation in mound structure. The male and female imagos are in the ratio of 1.1:1 and the soldiers and workers according to Gupta (1953) are in the ratio of 1:6.36 (2.8:17.8) in fungus combs and 1.6:36 (7.7:49.0) elsewhere in non-mound building months and 1:12.1 (5.5:66.5) in mound-building months. The species, *O. redemanni* is distributed in eastern and southern India. *O. brunneus* in western, southern and eastern India, *O. wallonensis* in central, western and southern India and *O. microdentatus* in central and northern India. Occasional mounds of *O. assmuthi* Holmgren and *O. feae* (Wasmann) and *O. kushwahai* Roonwal & Bose have been met with and described by various workers (Basalingappa, 1971; Roonwal & Chhotani, 1966; and Roonwal & Rathor, 1978). The species *Hypotermes obscuriceps* (Wasmann) is also reported to construct mounds in Sri Lanka. The swarming of Macrotermitinae begins with the start of monsoon. It is generally at dusk but in the case of *O. assmuthi* it is often in the afternoon.

The Nasutitermitinae, in India, is mainly represented by the genus *Nasutitermes*, the species of which build nests in dead logs of woods, and in the hollows and damaged portions of living trees. A number of species build arboreal carton nests on the tree trunks and branches or in stumps left buried in soil. *N. indicola* Holmgren is a common arboreal, carton nest-building termite in Mercara Reserve Forest, Mercara, Coorg. The author studied its nesting behaviour (Chhotani, 1971) and examined a large number of nests. The ratio of soldiers and workers was found to be 1:4.3-6.0. From the nest, these termites make galleries over tree trunks and branched and on soil below, through which they go out for foraging. The genera *Bulbitermes*, *Ceylonitermes*, *Grallatitermes*, *Hospitalitermes*, *Trinervitermes*, *Ceylonitermellus*, *Emersonitermes*, *Acicultitermes* and *Ampoulitermes* of this subfamily are also represented in the Indian subregion. *Trinervitermes biformis* is reported building mounds in southern India.

Soil termites and their role in ecosystem

Termites are voracious consumers of plant material both living and dead.

decomposing matter and humus soil rich in organic matter. Considering the huge communities of these social insects, termites play a very important role in the modification of the environments. Wood and Sands (1978) have recently reviewed the effects of their involvement in the modification of physical and chemical properties of soil, vegetation and in the distribution of organic matter.

The mound-building termites excavate immense quantity of soil under the surface of ground, which ultimately in the long run gets spread over the ground surface. The soil brought out and laid in the form of earthen sheets as a cover over the tree trunks, dead wood, etc. and in the form of earthen galleries for their protection, is similarly also of quite a large quantity and gets distributed. This affects the structure, infiltration, water holding capacity, permeability and the chemical nature of the soil.

The organic material consumed and transformed into faecal matter is mainly used in the construction of nests, in lining of galleries and in the cultivation of fungus in the Macrotermitinae. As such the faecal matter is not returned to the ecosystem until the nests are destroyed or abandoned. According to Wood and Sands (1978) the effects of the erosion of mounds, earth sheeting and galleries is negligible in comparison to the nutrients available from the decomposing plant material not attacked by termites. Some studies on the chemical analyses of the termite modified soils have been done in Australia, Africa and also in India on some mound-building termites.

In this country the most common species of the soil termites are the mound-building *Odontotermes* and the soil dwelling *Odontotermes* and *Microtermes*. The butterresed-type mounds of *Odontotermes obesus* sometimes go as high as 3 metres and the others assigned to this species also may attain huge dimensions. Similarly other *Odontotermes* spp. also build quite large structures. These termite species are so versatile in their habitation that their mounds are come across in the open land, in forests, on the road sides of agricultural fields, and so on. It has been observed that generally there is no vegetation on the mounds which is very probably due to some inhibiting factor. Very seldom grassy or scrub vegetation has, however, been noticed on dome-shaped mounds with larger surface area which probably helps in holding of some of the moisture from the rains. The mounds otherwise are hard structures as these termites mix saliva with soil in the construction work and they do not allow infiltration of water and imbedding of any wild seeds. Pathak and Lahiri (1959), Agarwal (1978) and Basalingappa *et al.* (1978) have studied the chemical and physical composition of the soils from the mounds of a few species and found the presence of certain binding elements. These elements help in holding the mounds for many years, as such the mound soils do not readily get mixed with the

surrounding soils. The soil dwelling *Odontotermes* and *Microtermes* also bring out large quantities of under ground soil and lay it in the eaten up parts of plants and logs of wood and also over the trunks of trees and fallen branches and twigs. The analysis of these soils in case of different species and that of surrounding surface soils will give us a picture of the role these termites play in the modification of different types of soils since they are found in almost all types of soils. Similarly, the role of other soil termites also needs to be examined.

However, as has been observed before, the fact that these insects bring out soil for mound-building does not necessarily mean the enriching of land due to upturning of soil, for unless the mounds decay and mix with soil there is not much scope for that advantage. Perhaps in the case of those termites where the galleries are below the soil can this be true, for there is the possibility of moisture retention and the lining of the galleries and chambers with faecal matter may help enriching the soil. So far the balance weighs down on the side of degradation of the soil due to these tiny insects rather than on the side of enrichment.

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9.29 RECENT ADVANCES IN TERMITE RESEARCH IN INDIA AND FUTURE STRATEGY*

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ABSTRACT

Detailed review has been provided regarding the work done in India on different aspects like taxonomy, morphology, embryology, biology, ecology, colony founding, termitophile associates, physiology, mass culturing, resistance of timbers to termites and control. A brief note on the future lines of research is also included.

INTRODUCTION

Termites are ubiquitous insects that live in highly organised colonies. The earliest recorded scientific observations on termites are those of Konig (1779). Beeson (1941) gave an excellent summary of the existing knowledge of termites in

* Dedicated to the memory of my teacher Prof. D. Mukerji who pioneered termite research in India in early forties.

India. The work carried out during the period 1938-50 was reviewed by Roonwal (1954). Roonwal (1958) also gave a comprehensive account of termite research in India during 1947-57. Work on the biology of several Indian termites has been presented in a review by Roonwal (1970). Our knowledge on the ecology and biogeography of Indian termites has been summarised by Sen-Sarma (1974). Chhotani (1977) has given a review of taxonomy of Indian termites. The present paper is a brief summary of recent advances in termite research in India and future strategy. While doing so, earlier work has also been mentioned in order to have a connected account. In a short paper like this, some works have not been mentioned and this omission is no reflection on the importance of those papers.

Taxonomy :

During the post-independence period, research on termite taxonomy was carried out primarily at the Forest Research Institute, Dehra Dun and Zoological Survey of India, Calcutta. A large number of publications including a number of monographs on faunistic and revisionary studies was published besides descriptions of several new taxa during this period. Most important of these publications are : (i) revision of the Oriental species of the genera *Kaloterms* and *Neoterms* (Roonwal and Sen-Sarma, 1960), *Cryptoterms* and *Glyptoterms* (Chhotani, 1970 ; 1975), revisions of Indian species of the genera *Coptoterms* (Roonwal and Chhotani, 1962b), *Microceroterms* (Prashad, Thapa and Sen-Sarma, 1967), *Styloterms* (Mathur and Chhotani, 1959), *Eremoterms* (Roonwal and Sen-Sarma, 1960), *Euryterms* (Roonwal and Chhotani, 1966b), *Hypoterms* and *Microterms* (Chatterjee and Thakur, 1963 ; 1964), Indian species of the subfamily Nasutitermitinae (Prashad and Sen-Sarma, 1959 ; 1960 and 1966a,b), *Odontoterms* (Thakur, 1979 in press) ; (ii) faunistic studies of termites of Rajasthan (Roonwal and Bose, 1964), Andaman and Nicobar Islands (Roonwal and Bose, 1970), North-Western Himalayas (Chatterjee and Thakur, 1967), Assam (Roonwal and Chhotani, 1962a), Tripura (Sen-Sarma and Thakur, 1979a) and West Bengal (Maity, 1971). A detailed account of wood destroying termites in India has been given by Sen-Sarma *et al.* (1975).

Important among these are the establishment of a new family Indotermitidae to accommodate the genus *Indoterms* from Burma (Roonwal and Sen-Sarma, 1960) and the discovery of the soldier caste (supposed to have been lost secondarily) in the genus *Speculiterms* (Roonwal and Chhotani, 1960 ; 1966a). Although the genus *Indoterms* has subsequently been placed under the subfamily Amitermitinae by Ahmad (1963) and Krishna (1965), Roonwal (1975) defended the validity of the family Indotermitidae and discussed its phylogenetic position and taxonomic status. Roonwal (1970b) has given a standardised account of measurements of termites for taxonomic purposes and urged the future workers on taxonomy to follow this.

Sen-Sarma (1968) has discussed the phylogenetic relationship of the world genera of the subfamily Nasutitermitinae. Phylogenetic relationships have also been mentioned in most of the revisionary works referred to above.

Morphology and Anatomy :

Morphology of Indian species has not received the attention that it deserves. The classical work by Imms (1919) on the morphology of primitive species of *Archotermopsis wroughtoni* is worthy of special mention. In recent years, morphology of the following few species has been described : *Anacanthotermes macrocephalus* by Gupta (1960), *Odontotermes obesus* by Kushwaha (1960) and by Vishnoi (1956). Roonwal (1956) has given a glossary of terms used for the external genitalia and related abdominal structures. Microsculpturing of wings in different termite species and its evolutionary and taxonomic significance have been discussed by Roonwal (1977a), Roonwal *et al.*, (1974) and Rathore (1977). Mukerji and Raychaudhury (1943) described the anatomy and histology of the alimentary system of *Odontotermes redemanni*.

Embryology :

Mukerji (1970) has reviewed the existing knowledge on embryology of termites, a field of profitable research that has received scant attention so far. According to Mukerji (1970), in a period of more than 64 years only twelve authors have investigated this field and the only Indian work is that by Mukerji and Chowdhuri (1962) on *Odontotermes redemanni*. This deplorable condition is rather surprising taking into consideration the easy availability of termite eggs, and the progress made in the field of insect embryology. It is hoped that future workers will direct their attention to both embryonic and post-embryonic development of Indian termites.

Biology and Ecology :

In a comprehensive review, Roonwal (1970a) has discussed the biology of Oriental termites including Indian species. Since this publication, only a few papers are available. Sen-Sarma and Thakur (1974) have given an account of biology and economic significance of some termites attacking buildings. Roonwal *et al.* (1973) described the gallery-system of *Microcerotermes raja*. Roonwal and Rathore (1973) made some observations on sex-ratios, sexual dimorphism etc. of two desert termites *Microcerotermes raja* and *Microtermes obesi*. Banerjee (1975) has investigated the growth of mounds and foraging territories in *Odontotermes redemanni*. Roonwal and Rathore (1975) made some detailed observations on the egg laying and brood-care in termites of the genus *Microtermes* from the Indian desert. They (1974) have also given some biological observations on three species of Indian desert termites, *Eremotermes*

paradoxalis, *Microcerotermes raja* and *Angulitermes jodhpurensis*. The same authors (1978) also described the mound-structure of *Odontotermes kushwahi* occurring in Pune (Maharashtra). Roonwal (1977b) has given an account of intraspecific variability in the mound construction and nesting habits in termites. Sen-Sarma *et al.* (1975) have given an account of bio-ecology of several species of wood destroying termites. Roonwal (1978) has published some aspects on bioecological observations on termites of Peninsular India.

Flight and Colony Foundation :

The timings of swarming of a species, in general, are extraordinarily precise and repeats itself year after year. Alates of *Odontotermes assmuthi* normally swarm during the day at 4.30 P.M. in the sunshine in Doon Valley (Mathur and Sen-Sarma, 1959 ; Sen-Sarma, 1962). There is only one record when it was observed to swarm at 7 A.M. during drizzling and the sky being overcast with clouds (Thakur, 1978). Swarming in *O. indicus* Thakur is crepuscular or nocturnal in Doon Valley which may continue till late in the night. *O. distans* swarms at dusk which totally stops at the advent of darkness. *Coptotermes heimi* swarms at sunset usually followed by heavy shower of rains. *Heterotermes indicola* swarms at night between 9.00 to 11.30 P.M. (Thakur and Sen-Sarma, in press).

Interesting observations on the swarming behaviour in several species of termites occurring in arid-zone in Rajasthan have been made by Roonwal *et al.* (1973; 1974; 1975). Among three species of *Microtermes*, *M. mycophagus* and *M. unicolor* swarm at night between 8 and 9 P.M. ; alates of *M. obesi* prefer bright sunshine and swarm between 10.30 A.M. and 1.30 P.M. The swarming period of some other species are as follows : *Eremotermes dehraduni* at noon or early afternoon, *E. paradoxalis* at late afternoon or early evening, *Microcerotermes raja* in the morning or early afternoon either during bright sunshine or in semi cloudy weather and *Angulitermes jodhpurensis* at early afternoon even when it is raining.

Colony foundation in termites is effected by three ways, namely, (i) primary reproductives (alates), (ii) budding or fission of an existing colony and (iii) sociotomy (Harris, 1958).

Colony foundation by swarming of alates is the principal way of colony foundation. The sequence of behavioral acts which lead to courtship, dealation, tandem behaviour and the movement of the pair to a suitable site for purpose of founding new colonies are so divergent that it is difficult to form any generalisation. These aspects have been investigated in case of only a few species of termites

(Roonwal *et al.*, 1973 in *Microcerotermes raja*; Roonwal and Rathore, 1975 in the genus *Microtermes*, and Sen-Sarma, 1962 in *Odontotermes assmuthi*).

Among Indian termites, the phenomenon of budding and development of satellite colonies have been observed in *Heterotermes indicola* (Becker, 1962; Sen-Sarma and Chatterjee, 1965), *Microcerotermes beesoni* (Vishnoi, 1964; Sen-Sarma and Mishra, 1972), *M. fletcheri* (Joseph, 1964), *Speculitermes cyclops* (Thakur, 1973), *Nasutitermes dunensis* (Mishra, 1976) and *Euhamitermes lighti* (Verma and Thakur, 1978).

Sociotomy which was first recorded in *Anoplotermes* and *Trinervitermes* in West Africa (Grasse and Noirot, 1957) has not been observed so far in India.

From the above account, it will be seen that our knowledge on swarming and colony foundation is far from satisfactory and deserves more attention than had been given hitherto. This knowledge is also of practical value for adopting control measures in case of drywood termites *Cryptotermes* spp. where new infestation of wood can be prevented by switching off the lights in buildings and houses during swarming of alates.

Ecology

The ecology of the termites in India is largely determined by the geological history, monsoon rainfall pattern, atmospheric temperature and relative humidity, vegetation, altitude, soil type, etc. (Sen-Sarma, 1974). Although the influence of vegetation type on the distributional pattern is generally recognised, very little is known about the precise relations of different species to these factors. Because of complex nature of ecology of termites, only some aspects of ecology are described here. Field ecology and ecobiogeography of Rajasthan termites have been presented by Roonwal (1976).

Termites and Soil

A great many species of termites are subterranean insects. The effects of the additives of subterranean termites on the soil present a number of interesting features but in India, practically very little is known of the changes brought about by the termites in the soil. The role played by humivorous termites is not known at all. These termites are active in the top soil which are, therefore, depleted of organic matter that can be a serious economic problem in areas deficient in humus (Sen-Sarma, 1974). Recent review on termites and soil by Lee and Wood (1971) presents the world situation on the subject. Roonwal (1976) has discussed the adaptation to various soil types by Rajasthan termites. Notwithstanding these lacunae, fairly good deal of work has been carried out on the physico-chemical characteristics of the soil of mounds built by different species of termites. Shrikande and Pathak

(1951) observed that earthen galleries made by *Odontotermes* spp. in Kanpur showed higher nutrient levels than those of adjacent soil. Pathak and Lahiri (1959) found that the soil of termitaria built by *Odontotermes* sp. had a higher percentage of lime, magnesia and phosphorus. Similarly, on the basis of study of *Odontotermes microdentatus* at Dehra Dun, Agarwal (1978c) has observed almost similar levels of organic content in mound soil and the adjacent subsoil which denotes the origin of the mound soil from the subsoil. On the other hand, Banerjee and Mohan (1976) concluded, on the basis of similar levels of organic carbon in mound soil of *O. obesus* and adjacent top soil, that the mound soil was derived from the top-soil. Basalingappa *et al.* (1978) studied the chemical components of soil of mound and the royal chamber in *O. assmuthi* in Dharwar. The mounds of *Trinervitermes biformis* have, however, entirely different relations with the surrounding soil. High lignin content and fair quantity of undigested cellulose are characteristics of these mounds (Sen-Sarma and Mathur, 1961). Detailed analyses are, however, called for.

Termites and vegetation

The close association of termites with living plants, especially crops, horticultural and forest trees, coconut, coffee and tea plantations, grass, etc. has attracted considerable attention, primarily because of heavy damage caused. Sen-Sarma (1974) has reviewed the existing knowledge of this subject. The crops commonly damaged by termites are wheat, millets, pulses, cotton, spices, vegetables, etc. The common species of termites causing serious damage to these crops include *Coptotermes heimi*, *Odontotermes obesus*, *Microtermes obesi* and *Trinervitermes biformis*. The sugarcane crop is primarily damaged by *Microtermes obesi*. The other species that are known to damage sugarcane crop in India are *Coptotermes heimi*, *Eremotermes paradoxalis*, *Odontotermes assmuthi*, *O. obesus*, *O. wallonensis*, *Trinervitermes biformis* and *T. heimi* (Aggarwal, 1970). In forest nurseries and plantations, roots of seedlings are damaged by different species of termites, particularly when the plants are about 1-3 years old. The valuable and fast-growing *Eucalyptus* is perhaps the worst sufferer.

Temperature and humidity relation

Atmospheric temperature and humidity are two dominant environmental factors that influence termites profoundly (Sen-Sarma, 1974). Temperature and relative humidity inside the mound have been recorded through the year by Aggarwal (1979) in *Odontotermes obesus* and by Agarwal and Sen-Sarma (1979) in *Odontotermes microdentatus*. No diurnal fluctuations of temperature and relative humidity inside the mounds have been observed and the fluctuations through the year are within a narrow range. However, a sudden fall in temperature was observed during emer-

gence of alates, Cheema *et al.* (1962) have observed that the temperature in areas where fungus combs are lodged is always higher than in the surrounding parts of the mound. Under laboratory conditions, *Neotermes bosei* prefers a temperature of 28°C (Sen-Sarma and Chatterjee, 1965b), while optimum temperature requirements of *Heterotermes indicola* seem to lie between 30° and 32°C ($\pm 1^\circ\text{C}$) (Becker, 1962). Preferred temperature for *Microcerotermes beasoni* is $29^\circ\text{C} \pm 1^\circ\text{C}$ (Sen-Sarma and Chatterjee, 1968).

Comparatively more information on the water relations and humidity tolerance of Indian termites is available than in case of temperature. *Neotermes* requires as high a relative humidity as 98 per cent but *Bifiditermes beasoni* and *Cryptotermes bengalensis* survive best at 92 percent R.H. (Sen-Sarma, 1974). Survival time under different percentages of relative humidity differ not only in different species but even within the same species it varies from caste to caste (Sen-Sarma and Chatterjee, 1966a; Sen-Sarma, 1969; Sen-Sarma and Mishra, 1977; Mishra and Singh, 1978). In general survival time is greater in grouped termites than in isolated and single individuals. Further, the intensity of response to humidity fluctuations among termites is influenced by the conditions of humidity to which they had previously been subjected (Sen-Sarma and Chatterjee, 1966b).

Gravity response and vertical distribution

For subterranean species gravity must be considered as one of the most important environmental factors. While the subterranean termites live in soil, the drywood species inhabit trees, rafters, etc. without maintaining soil connection. Sen-Sarma and Gupta (1968) observed that workers of subterranean *Microcerotermes beasoni* show negative geotactic response and pseudoworkers of the drywood termite, *Neotermes bosei*, show positive geotactic response.

The depth to which subterranean termites penetrate has an important bearing on preventive measures by soil poisoning. Except for the work by Hoon (1962), no extensive study has, however, been made on this problem. Hoon observed that the termite could penetrate as deep as 300 cm in areas of deep alluvial deposit.

Population ecology

Mukerji and Mitra (1949) were the first to report the ratio of soldiers-workers-nymphs in the fungus combs of *Odontotermes redemanni* but did not count the total number of individuals in the mound which was done by Gupta (1953) in case of *Odontotermes obesus*. Sen-Sarma and Mishra (1969) were the first to study the seasonal fluctuations in the nest population *Microcerotermes beasoni* and the relationship between the weight of the nests and number of workers.

Seasonal fluctuations of proportions of different castes as found in the fungus combs of *Odontotermes obesus* and *O. microdentatus* were studied by Agarwal (1978b). Sen-Sarma and Mishra (1969, 1977) have investigated the seasonal fluctuations of colony composition and nest population in *Neotermes bosei*, *Microcerotermes beelsoni* and *Nasutitermes dunensis*. Banerjee (1966) made a statistical study of the population of the building termite *Odontotermes redemanni*. In a subsequent paper, on the basis of some theoretical consideration, Banerjee (1971) discussed about the dynamics of termite populations. All these studies demonstrate that the polymorphic populations of termites are not only qualitative but also quantitative. Each neuter caste represents a rather constant proportion of the total population. This proportion is, however, greatly influenced by the longevity of various individuals, as well as differential mortality while foraging. The proportion, however, tends to be readjusted by factors determining the differentiation of castes. Each species seems to possess its characteristic constants of composition. Seasonal fluctuations are, however, governed by nutritional status on account of foraging which in turn is regulated by the climatic conditions.

Termites and fungi

The association of termites and different fungi, though extensively investigated elsewhere, has been neglected in India. The primitive species *Archotermopsis wroughtoni* always attacks and builds nests in partially decayed stumps and fallen logs (Imms, 1919). Similar is the case of termites belonging to Termopsidae, Rhinotermitidae and Termitidae.

Sponge-like fungus gardens of Macrotermitinae have attracted the attention since the time of Konig (1779). Fungi cultivated on the fungus combs of various species of *Odontotermes* have been investigated by Bakshi (1951), Das *et al.* (1962) and Batra and Batra (1966). *Termitomyces albiminosa* occurs on fungus combs of most of the *Odontotermes* spp. in India except that *T. eurhiza* grows in the termitaria of *O. gurdaspurensis* (Batra and Batra, 1966). According to earlier workers re-inoculation in a newly founded nest takes place through the workers that gather the discharged basidiospores from the surface of the soil. Batra and Batra (1966), however, claim to have observed conidia in the gut and in crevices of the integument of swarming alates. On the contrary, when a termite mound is deserted or exposed fruit bodies of another fungus *Xylaria nigripes* appear and this fungus brings about the death of workers. The problem of how the *Xylaria* is prevented from growing in an active mound does not seem to be satisfactorily solved. According to Batra and Batra (1966), salivary secretion of soldiers and workers exerts a strong fungi-static effect on the growth of fungi other than *Termitomyces*. However, high CO_2 content inside the mound might inhibit the growth of *Xylaria* and foreign fungi.

that may have been carried inside the mound as contaminants by foraging workers (Batra and Batra, 1966; Sen-Sarma, 1962; in discussion of paper of Das *et al.*, 1962). Agarwal (1978a) has analysed the chemical composition of fungus combs.

Some genera of fungi are pathogenic to termites. *Termitaria* sp. has been reported by Snyder (1933) as pathogenic to *Nasutitermes fletcheri*. *Aspergillus flavus* has been observed to parasitise royal pairs of *O. obesus* in South India which is associated with melanosis of the cuticle (Sannasi, 1969a,b).

Termitophile associates

The most important termitophilous insects in India are the Staphylinidae (Coleoptera) and Phoridae (Diptera). The distribution and phylogeny of the termitophiles are mirror images of those of the termites (Seevers, 1957). The major specialization associated with termitophily, are physogastry, lamuloid body outline and presence of exudatory appendages of the termitophile insects, which in turn obtain shelter and food from the termites. Collembola are also found as termitophile associates. Notwithstanding the importance of termitophile associates of termites, practically no work has been done in India.

Natural enemies

Mathur (1962) was the first to give an extensive list of the natural enemies of termites. The ants are perhaps the most implacable enemies of termites of India. Dragon flies, robber flies and muscoid flies prey upon swarming alates of various species of termites. Among the vertebrates, frogs, toads, lizards, insectivorous birds, scaly-anteater (*Manis crassicaudata*), insectivorous bats and sloth-bear (*Melurus ursinus*) take heavy toll of termites. This aspect also deserves more attention.

Physiology and biochemistry

Notwithstanding the considerable progress made on the physiological and biochemical investigations on termites elsewhere in the world, this field of research has been comparatively neglected in India. Misra and Ranganathan (1954) and Misra and Vijayraghavan (1956) were the first to investigate the digestive physiology of *Odontotermes obesus*. Subsequently, Krishnamoorthy (1960), Rao (1962) and Singh (1975, 1976) have investigated certain non-cellulases and proteinases in *Heterotermes indicola* and *O. obesus*. However, recently Mishra (1979) has investigated systematically various aspects of the digestive physiology in *Neotermes bosei*, *O. distans* and *Speculitermes cyclops*. The former two are wood-consumers and the last is a humus feeder.

Mishra (1979) analysed the chemical composition of food of termites including the gut contents. In addition to wood particles, considerable quantity of micro-

organisms and fungal hyphae were observed in the contents of foregut. Mishra and Sen-Sarma (1979b) have studied the influence of temperature and relative humidity on consumption and digestibility of wood in *Neotermes bosei*.

The hydrogen ion concentration and transit of food material in the digestive tract have so far been studied by Singh (1975) and Mishra (1979). Mishra (1979) has made detailed study on the various digestive enzymes and has concluded that major portion of cellulase is produced by the termites themselves. The salivary glands also secrete considerable quantity of cellulase in addition to certain other enzymes. The gut symbionts play an important role in the digestion of hemicelluloses. Gut symbionts, however, do not secrete the enzyme lignase extracellularly (Mishra and Sen-Sarma, 1979c). Mishra and Sen-Sarma (1979a) have contributed to the knowledge of chemical composition of faecal matter, nest material and fungus combs in relation to digestive physiology. Further, formation of humic substances in the digestive tract of termites has been reported by Mishra and Sen-Sarma (1979d).

Among the biochemical aspects, only the fat content in different castes has been investigated by Basalingappa (1970) in *O. assmuthi* and Mishra and Sen-Sarma (1979e) in *N. bosei*, *Microcerotermes beelsoni* and *Nasutitermes dunensis*. The latter authors have concluded that lipid is also synthesised in the body of termites irrespective of their food.

Mass culturing of termites in laboratory

Although culturing of termites *en masse* under laboratory conditions was done in Australia for the first time in the world in 1930, laboratory culture methods were developed in India only in sixties. So far, four species of termites namely, *Neotermes bosei*, *Heterotermes indicola*, *Coptotermes heimi* and *Microcerotermes beelsoni* have been cultured at the Forest Research Institute, Dehra Dun (for details, see Sen-Sarma *et al.*, 1975). Outside India, mass cultures of *Heterotermes indicola* are maintained in Bundesanstalt für Materialprüfung, West Berlin (Becker, 1962).

Laboratory testing of termite resistance of timber and other material

Heartwood of certain timbers is known to possess inherent quality to resist termite attack. This quality is attributed to the physical and chemical properties of timber of which the chemical extractives appear to play the most vital role. In India, as in many other countries, natural termite resistance of timber is generally ascertained from the so called 'Grave Yard Tests'. These field tests are necessarily elaborate, takes a long time to get the result and are meant only against subterranean termites. Advantages of laboratory tests with small test pieces are : (i) Uniformity of testing conditions, (ii) easy reproducibility of results, (iii) feasibility to increase

and control the intensity of attack, (iv) quantitative assessment of results and finally (v) the shorter duration of the test period (10-90 days).

However, in spite of the advantages given above, laboratory tests do not always predict the service life of a given material for which field trials may have to remain the standard practice. But often the service-life of an unknown wood can be predicted to a great degree of accuracy by comparing its performance in laboratory tests with that of a timber whose service life is known.

The following factors are required to be taken into consideration while designing a laboratory test : (i) choice of test termite, (ii) group-size of the test termite, (iii) proper sampling of test timber, (iv) methods of culturing the test termites, (v) duration of the test depending upon the purpose of the test and end use of the test material, and finally (vi) assessment of results which may be both qualitative and quantitative.

Laboratory tests of several Indian timbers have been carried out by Sen-Sarma (1963 a, b, c, 1972), Sen-Sarma and Chatterjee (1972b, 1968), Sen-Sarma *et al.* (1975), and Sen-Sarma(1972). In all, eighty four timber species have been tested so far (Sen-Sarma *et al.*, 1975). Sen-Sarma (1970) has given an exhaustive account of various methods of laboratory evaluation of termite resistance of wood and wood products.

Life of a material in service is greatly influenced by abiotic factors such as temperature, relative humidity, rainfall, solar radiation and biotic associates like fungi and other micro-organisms. Techniques for accelerated climatic treatment is known (Sen-Sarma 1963c). But the natural biotic associates of field conditions could not be incorporated in laboratory test techniques so far and further research is needed in this direction.

Termite resistance of heartwood of teak exhibited wide range of variation and Sen-Sarma and Thakur (1979) are of the opinion that this quality is perhaps genetically controlled. Gupta and Sen-Sarma (1978) have investigated the antitermite properties of some Anthraquinone derivatives of teak.

Control

Next to the taxonomic study of termites, termite control engaged the attention of a large number of investigators of the agricultural crop, investigations to control termites affecting sugarcane having received the maximum attention. The horticultural and fruit trees also received adequate attention. In so far as termite control in building is concerned, recommendations of pre-construction and post construction methods of control by means of soil poisoning by soil insecticides have been

published by the Indian Standard Institution. Basic principles in all these control methods are the incorporation of insecticides such as aldrin, lindane, heptachlor or chlordane in the soil in suitable dosages.

Roonwal (1979) and Agarwala (1964) have summarised the knowledge regarding methods of termite control in agricultural and horticultural crops, archives and libraries, timber and other building contents, etc. Spear (1970) has enunciated the principles of termite control in buildings, etc.

Future Strategy

Notwithstanding the rapid advances in termite research made in India during the last two decades, there are areas where our knowledge is extremely inadequate. More systematic surveys are necessary particularly in areas which are *terra incognita* from termite point of view in order to augment taxonomic research of Indian termites. Except the primitive termite *Archotermopsis wroughtoni*, complete biology is not known for any other species of Indian termites. Termite ecology needs extensive research particularly with regard to spatial and vertical distribution of termites. Certain wood infecting fungi act either as attractant or repellent to termites; this is a rewarding line of research from practical point of view (Allen *et al.*, 1964; Esenther *et al.*, 1961; Becker, 1965). Promising results to control termites have been reported from U.S.A. by using attractant insecticide (mirex) bait (Esenther and Beal, 1974). This method is particularly useful in the control of harvesting termites. It has been successfully tried in Canada for eradicating termites infestation in buildings (Ostaff and Gray, 1975). Juvenoids are reported to cause excess production of soldier caste (a dependent caste for food) in laboratory experiments (French, 1974; Hardy, 1974). This is another promising line of research.

Certain basic aspects like morphology, anatomy, embryology and physiology etc. of termites, had remained so far neglected. These lines of research are not encouraged in applied research institutes in India and the universities should come forward to investigate these aspects.

Causes of natural durability of Indian timbers are not known adequately. Such knowledge can assist in developing non-hazardous wood-preservatives. This requires a multi-disciplinary approach with collaborative work between Chemists, Entomologists and Pathologists.

Biochemical studies on termites have made rapid advances in many developed countries (for a review see Moore, 1969). However, this aspect has not at all been investigated in India.

In conclusion, it may be emphasised that in view of the enormous economic importance of termites and utterly inadequate knowledge in several aspects of termite research, it is high time that a separate Termite Research Centre, be opened in the country with adequate staff and equipment in order to deal with the problem more effectively.

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9.30 TERMITES OF AGRICULTURAL IMPORTANCE IN INDIA AND THEIR CONTROL

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ABSTRACT

The principal termites which damage agricultural and plantation crops, fruit trees and forest and avenue trees in the Indian region, are listed and their damage described for each of the major crops and control measures are given for each crop. Out of about 270 termite species known in the Region, about 40 damage crops. Other aspects including control of mound-building termites, protection of fence-posts, mud huts and other buildings are also briefly discussed.

INTRODUCTION

Termites (Isoptera) are social insects which live in small to large colonies, the largest ones containing well over a million individuals. Their destructive capacity lies in their numbers. They are polymorphic and possess various "castes" e.g., soldiers, workers and reproductives (functional males and females).

The castes most commonly available in the field are workers (or pseudo-workers) and soldiers; the latter, however, constitute only a small proportion of a colony population. In addition, royal or reproductive pair (a king and a queen) are generally present, and can be collected with some effort from a nest or mound. Imagoes (winged reproductives or alates) are produced in a colony only once or twice a year, when they swarm out of the nest to start fresh colonies. For identification, the soldier caste is essential although soldiers are either very rare or absent in a few genera, like *Speculitermes*, *Anoplotermes*, etc.

Termites should be preserved in glass or plastic vials in rectified spirit (90 per cent ethyl alcohol); in its absence, strong methylated spirit may be used temporarily as a preservative, but not formalin or kerosine oil. The label should contain the exact locality, date of collection and the crop attacked.

Termites feed largely on cellulosic material, soil and humus and have a tendency to attack all kinds of cellulosic plant material, both alive and dead, as well as such materials as textiles, paper, books, wood, bamboos, etc. They live mostly underground but come up for foraging; some species habitually live above ground in dead or living wood and in mounds, carton nests, etc.

The young plants (saplings) are ordinarily first attacked at the roots which are eaten up, causing die-back and dislodgement of the plant. Later, the termites extend their activity to the stem which is hollowed out. In sugarcane, the eye-buds of the seed setts are attacked at sowing, the attack later extending to the stem. In older trees, the trunk (bark and later the cambium) are attacked, death occurring in severe cases of cambium attack.

Though precise estimates are wanting, the damage caused by termites to agriculture and its products runs into millions of rupees per year. The extent of crop damage is discussed below under each crop.

Control of termites is largely accomplished by the use of chemicals (insecticides and other toxicants), though occasionally biological methods (use of ants) have been successful, as in plant nurseries. There is a considerable amount of published literature on agricultural termites and their control in the Indian Region.

CLASSIFICATION OF TERMITES

A detailed classification cannot be discussed here, and there is some diversity of opinion among authorities as regards the number of families. We consider the recognition of the following nine living families as adequate : 1) Mastotermitidae (exclusively Australian), 2) Kalotermitidae, 3) Termopsidae, 4) Hodotermitidae, 5) Rhinotermitidae, 6) Stylotermitidae, 7) Serritermitidae (exclusively Brazilian), 8) Termitidae and 9) Indotermitidae.

Of these, the following five contain species of agricultural and forestry importance in India : Kalotermitidae, Hodotermitidae, Rhinotermitidae, Stylotermitidae and Termitidae.

Out of about 270 species of termites known from the Indian Region (the world figure is about 1900 species), only some 40 species, as listed below, have been found to damage agricultural and forest plants.

Termites injurious to agricultural and plantation crops and fruit and forest trees in the Indian Region

Family I. Kalotermitidae

1. *Postelectrotermes militaris* (Desneux). Ceylon only.
2. *Neotermes bosei* (Snyder) [= *N. gardneri* (Snyder)]
3. *N. greeni* (Desneux). Ceylon only.
4. *Glyptotermes ceylonicus* (Holmgren). Ceylon only.
5. *G. dilatatus* (Bugnion & Popoff)
6. *Bifiditermes beesoni* (Gardner)

Family II. Hodotermitidae

7. *Anacanthotermes macrocephalus* (Desneux)
8. *A. viarum* (Koenig) [= *Hodotermes koenigi* Holmgren & Holmgren and *A. rugifrons* Mathur & Sen-Sarma]

Family III. Rhinotermitidae

9. *Heterotermes indicola* (Wasmann)
10. *Coptotermes ceylonicus* Holmgren
11. *C. heimi* (Wasmann) [= *C. parvulus* Holmgren]

Family IV. *Stylotermitidae*

12. *Stylotermites bengalensis* Mathur & Chhotani
13. *S. fletcheri* Holmgren & Holmgren.

Family V. *Termitidae*

14. *Eremotermes dehraduni* Roonwal & Sen-Sarma
15. *E. paradoxalis* Holmgren
16. *Microcerotermes beesoni* Snyder
17. *M. minor* [= *M. heimi* from *minor* Holmgren]
18. *M. tenuignathus* Holmgren
19. *Dicuspitermes fletcheri* (Holmgren & Holmgren)
20. *D. incola* (Wasmann)
21. *Odontotermes assmuthi* Holmgren
22. *O. feae* (Wasmann)
23. *O. horni* (Wasmann)
24. *O. malabaricus* Holmgren & Holmgren
25. *O. obesus* (Rambur) [= *O. assamensis* Holmgren ; *O. bengalensis* Holmgren ; *O. flavomaculatus* Holmgren & Holmgren ; and *O. obesus* var. *oculatus* Silvestri]
26. *O. parvidens* Holmgren & Holmgren
27. *O. redemanni* (Wasmann)
28. *O. taprobanes* (Walker) [taxonomic status doubtful]
29. *O. wallonensis* (Wasmann)
30. *Hypotermes obscuriceps* (Wasmann)
31. *Microtermes mycophagus* (Desneux)
32. *M. obesi* Holmgren [= *M. anandi* Holmgren]
33. *Grallatotermes grallatoriformis* Holmgren & Holmgren
34. *Nasutitermes indicola* Holmgren & Holmgren
35. *Trinervitermes biformis* (Wasmann) [= *T. heimi* (Wasmann) and *T. longinotus* (Snyder)]
36. *T. indicus* (Snyder)
37. (?) *T. ravidus* (Hagen) [North Indian records in Indian publications are probably a misidentification for *T. biformis* (Wasmann)]

TERMITES AFFECTING INDIVIDUAL CROPS AND THEIR CONTROL

1. Wheat

The most important species attacking wheat are *Microtermes obesi* and *Odontotermes obesus*. In addition, *Trinervitermes biformis* has been recorded from Gujarat and *Nasutitermes* sp. from Madhya Pradesh. The attack occurs mostly in the seedling stage when the roots are eaten up, resulting in the yellowing of leaves and dislodgement, and finally death of the plant. Attacks in the earhead stage result in loss in grain production. Losses may go up to 25 per cent of the crop, and damage occurs both in irrigated and unirrigated conditions.

Control : Three methods have been found to be successful : (i) *Seed-dressing* : Soaking in 5 per cent *pp* D.D.T. emulsion (water dilution); or dusting with 0.5 per cent gamma B.H.C. ; or aldrin emulsion. (Narayanan and Rattanlal, 1952; R.M. Patel, 1962; Sahni and Butani, 1966; Chahal *et al.*, 1976; Verma *et al.*, 1978). (ii) *Soil treatment* : Treatment of soil, either before or soon after sowing, with 1.25 per cent D.D.T. emulsion (320 gal./acre); or 5 per cent aldrin (20 lbs/acre); or technical aldrin (10 lbs/acre) (Narayanan and Rattanlal, 1952 ; Krishnamoorthy and Ramasubbiah, 1962; Chatterji *et al.*, 1958, 1960). (iii) *Treatment of plants* : with 5 per cent aldrin dust (25 lbs/acre) or 0.625 per cent aldrin 30 E.C. (one litre/ha) (Srivastava *et al.* 1962; Sandhu and Sohi, 1977).

2. Other cereals and pulses

Barley and maize are injured by *Odontotermes obesus* and *Microtermes obesi*, the plants being attacked at the ground-level. Effective control in maize is obtained by mixing aldrin (0.2 lb./acre) or dieldrin (0.25 lb./acre) of actual toxicant strength in the top 15 cm. layer of soil not more than 24 hours before sowing. Bajra is injured, sometimes seriously by *Microtermes obesi* and jowar by *Odontotermes obesus*. Paddy is reported to be attacked by termites in West Bengal (species not known) and Delhi (by *Microcerotermes* sp.).

Various pulses (gram, etc.) are known to be attacked by termites.

3. Sugarcane

Sugarcane is a favourite plant for attack by termites, and following eight species have so far been recorded on this crop : *Coptotermes heimi*, *Eremotermes paradoxalis*, *Microcerotermes beelsoni*, *Odontotermes assmuthi*, *O. obesus*, *O. wallonensis*, *Microtermes obesi* and *Trinervitermes biformis*.

The attack occurs in two growth stages, *viz.*, in the (i) pre-monsoon period when the seed-sets are sown; and (ii) post monsoon period when the cane is

growing actively. Termites enter the setts either through the injured eye-buds or through the two cut ends of the sett and then completely eat up the soft, nutritious pith. The result is either poor germination or complete death of buds, and the crop yield suffers in either case. Young germinating shoots as well as mature cane are also subjected to attack, and in severe cases the leaves and the crown die. Loss to buds may be up to 60 per cent (deaths). In cases of severe attack up to three-fourths of the total cane may be seriously damaged within a short period of 6 to 8 weeks; damage is more serious under conditions of drought.

Control : (i) Dusting furrows before sowing with 5 per cent B.H.C. or 5 per cent chlordane or 2.5 per cent aldrin dust (20 kg/ha); active dieldrin or telodrin (0.5-1 kg/ha); active heptachlor (3 kg/ha). (ii) Where necessary, standing cane may be dusted or sprayed with the insecticides mentioned above [(Agarwala *et al.*, (1954); Agarwala (1955); Khanna *et al.* (1956); Rao and Agrawal (1957); Gupta (1959) and Roonwal (1958, 1979).]

4. Cotton

Three species are known to attack cotton, viz., *Odontotermes obesus*, *Microtermes obesi* and *Trinervitermes biformis*. They attack the roots and later on tunnel the stem near ground-level, as a result the plants wilt and die.

Control : For unirrigated (*barani*) cotton, presowing soil treatment with technical sevin or technical heptachlor (10-15 lbs/acre); and for irrigated cotton, soil treatment by drilling 5 per cent (0.675 per cent gamma isomer) BHC (56 lbs/acre) gave effective protection. (Bhatnagar, 1962 ; Patel, 1962; Agarwala, 1964; Peswani and Katiyar, 1972).

5. Groundnut

Groundnut plants are attacked by *Odontotermes obesus* and *Trinervitermes biformis*. The plants, both at and below ground-level, as well as the buried nut are attacked, and the loss is sometimes heavy. In Madhya Pradesh, Rawat *et al.* (1970) obtained effective control against *O. obesus* by treating planting furrows with 6 per cent heptachlor dust (25 kg/ha).

6. Vegetables and spices

Several vegetables, e.g., chillies, potatoes, cabbages, cauliflower, etc., as well as spices such as cumin and aromatic plants such as Japanese mint, are subject to termite attack. The species incriminated are : *Coptotermes* sp., *Eremotermes* sp., *Dicuspiditermes incola*, *Odontotermes obesus* and *Microtermes obesi*.

For control, soil treatment with insecticides mentioned above for sugarcane

and cotton is found effective but for tuber chemicals which may produce odour (e.g., B.H.C.) should be avoided.

7. Grasses

In north-western India, *Anacanthotermes macrocephalus* damages grasses which are cut up and carried to underground chambers. The corresponding species in southern India is *A. viarum*. No observations on control have been made, but baiting with insecticides and other toxicants may be helpful.

8. Tea

The following eight species attack tea : *Postelectrotermes militaris* in Ceylon, *Neotermes greeni* in Ceylon, *Glyptotermes dilatatus* in Ceylon, *Coptotermes ceylonicus* in Ceylon and S. India, *Microcerotermes* sp. in E.India, *Odontotermes obesus* in N.E. India, *O. parvidens* in N. E. India and *Microtermes obesi* in N.E. India and S. India.

Some of these (*Microcerotermes*) are primary pests and attack the living plant, while others are secondary pests and generally attack only dead or dying wood. The combined damage may result in loss up to 50 or even 100 per cent of the bushes (Das, 1962).

Control : A combined method of the use of 'prophylactic' measures (removal of debris, etc.) and soil treatment around the bushes with aldrin or dieldrin (2.3kg a.i/ha) provides effective control (Das, 1962). Fumigation of galleries inside the tea bushes with phostoxin is also effective (Danthanarayana and Fernando, 1970 and Roonwal, 1979).

9. Coffee and Cocoa

Coffee is attacked in Ceylon by *Glyptotermes dilatatus* and in South India by *Dicuspitermes fletcheri*, *Grallatotermes grallatoriformis* and *Nasutitermes indicola*. Cocoa is attacked in Ceylon by *Glyptotermes ceylonicus* and *G. dilatatus*. Control measures are as for tea.

10. Coconut palm

Coconut palm is injured, both as seedling and as growing palm, by *Odontotermes obesus*, the damage to seedlings being about 20 per cent, rising to 40 per in years of drought. For control, dusting the soil with 10 per cent B.H.C. dust (100 lbs/acre) is effective. (Nirula *et al.*, 1953; Nirula and Menon, 1960; Krishnamoorthy and Ramasubbiah, 1962; Nair, 1964).

11. Jute and sunnhemp

Jute plants are subject to sporadic attack by the termite *Microtermes obesi*.

The insect enters through the tap roots and then hollows out the stem, thus reducing the fibre-yield; in severe attacks, the plant dies. Effective control is achieved by treating the top 15 cm layer of soil in the vicinity of plants with 0.4 per cent aldrin solution (35 gal/acre) (Dutt, 1962).

Sunnhemp is attacked by *Odontotermes obesus*, the damage being similar to that in jute by *M. obesi* (Tripathi, 1972) ; control measures have not been worked out.

12. Rubber

The two most important species which attack rubber plants in South India and Ceylon are *Glyptotermes dilatatus* and *Coptotermes ceylonicus*. In addition, three other species attack rubber in Ceylon, viz., *Postelectrotermes militaris*, *Neotermes greeni* and *Glyptotermes ceylonicus*. Termites on rubber trees can be controlled as in fruit trees (vide infra) ; in addition, prophylactic and insecticidal treatments as for tea are used for control.

13. Fruit trees

Several fruit trees, e.g., mango, guava, pomegranate, orange, chiku, etc., are subject to termite attack, the common termite species concerned being *Odontotermes obesus*, *Microtermes obesi* and *Trinervitermes biformis*. For control in saplings, treat the soil with chlorinated hydrocarbons (D.D.T., B.H.C., aldrin, etc.) as water suspensions, emulsions and dusts, as for the agricultural crops. In older trees the trunk should be painted, up to a height of about two meters, with the same insecticides after scraping the earthen encrustations made by termites.

14. Forest and avenue trees

Eucalyptus saplings in nurseries are particularly subjected to termite attack, the species being *Postelectrotermes militaris* (Ceylon), *Anacanthotermes macrocephalus*, *Microcero- termes minor*, *Odontotermes feae*, *O. horni*, *O. microdentatus*, *O. obesus* and *O. parvidens*, (Chatterjee, 1972 ; Roonwal, 1979). Control is achieved as in the case of fruit trees (Roonwal, 1979). Other trees recorded as being damaged by termites are : Kusum, mahua, neem, palas, sal and a few others.

SOME OTHER ASPECTS OF TERMITE CONTROL

1. Control of mound-building termites

Termites build large earthen mounds which sometimes rise up to a height of 2 or 3 m above ground ; they form a common feature of the countryside in the wetter zones of India. These mounds often cover fields as well as fallow ground and forests, and their removal becomes necessary both for cultivation and for preventing

these population foci from spreading out. Most of the species concerned belong to the genus *Odontotermes*.

Quick and complete extermination of the mound-colonies at low cost can be achieved by treating the mounds, by pouring in through a funnel, water suspensions of the following insecticides in two or three holes made in the mound, at the minimum rate of 9,000 cc. of liquid per 10 cu. ft. (2.8 cu. m.) of mound-volume, both the concentration of the insecticide and the total quantity of liquid being important in achieving good results (Roonwal, 1951, 1958; Roonwal and Chatterjee, 1961, 1962) : 0.05 per cent gamma B.H.C., or 0.04 per cent D.D.T., or 0.025 per cent aldrin or dieldrin. For subcylindrical mounds, as in *Odontotermes obesus*, the following height-liquid ratio may be followed :

Height of mound	Dosages of liquid insecticide
3 ft (<i>ca</i> 91 cm)	1 gal (4.5 litres)
4 ft (<i>ca</i> 122 cm)	5 gal (23 litres)
5 ft (<i>ca</i> 152 cm)	10 gal (45 litres)
6 ft (<i>ca</i> 183 cm)	18 gal (82 litres)

In the absence of these insecticides, fumigate mounds by pouring in petrol through small holes and then plug the holes with wet earth.

2. Protection of stored products

Stored grain : Inspect storage structures frequently; use resistant or treated wood; destroy nearby mound-colonies; ensure that the walls and floor of storage bins are without cracks.

Storage of wood, etc. : Prevention of attack can be achieved as follows :—
(i) Soak the ground soil with a 1:1 mixture of coal-tar creosote and fuel oil (used oil will serve the purpose), or with an emulsion of 5 per cent D.D.T. or 0.5 per cent B.H.C. or 0.1 per cent aldrin in fuel oil. (ii) Use about 45 cm high skids.

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9.31 FAUNAL ZONES AND BIOECOLOGICAL NOTES ON THE SOIL INHABITING TERMITES (ISOPTERA) OF WEST BENGAL, INDIA

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ABSTRACT

The dispersal of termites is usually influenced by many a ecological factors of which the vegetation and soil type are considered most important. In order to understand the influence of such factors on the distribution pattern and survival potential of termites in West Bengal, about 19 species of soil inhabiting ones have been studied and the results achieved have been discussed in the present paper. Considering the distribution pattern and relative abundance of these insects, the State can be divided into three faunal zones (Himalayan and Sub-Himalayan, Gangetic alluvial and lateritic), which broadly correspond to the natural physiographic units of the State. It is interesting to note that the fungus growing species, *Odontotermes horni*, *O. redemanni* and *Microtermes obesi* are widely distributed in all the zones, while the species, *Synhamitermes quadricaps* and *O. feae* are found only in the lateritic and Gangetic zones. Further, some five species (*Eurytermes*-1, *Speculitermes*-1, *Angulitermes*-1, *Dicuspitermes*-1 and *Odontotermes*-1) are solely restricted in the lateritic zone. Still more concentration of endemic species (*Euhamitermes*-1, *Pericapritermes*-3, *Macrotermes*-3, *Odontotermes*-1, *Indotermes*-1 and *Hypotermes*-1) is found in the soil rich in humus content at the Himalayan and Sub-Himalayan zone.

The probable cause of richness or paucity of termites in each zone along with their bioecological criteria has been discussed in the light of major environmental differences.

ARCHITECTURE OF THE MOUND OF *ODONTOTERMES MICRODENTATUS*

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ABSTRACT

The mounds of *Odontotermes microdentatus* can be divided into three parts: **exoecie** (portion above the ground), the **periecie** (portion in between the **exoecie** and **endoecie**) and the **endoecie** (where royal chamber, central fungus garden etc. are located). The external appearance of the mounds in **exoecie** was some what dome-shaped, without buttresses, low, solid uneven heaps of earth and of multilocular type. The average height and circumference of the mounds was 0.80 m and 3.80 m, respectively. The **exoecie** had a series of domed structures which were hollow inside and had no aperture or opening outside. The inner surface of **exoecie** had a few round pits. The **periecie** which goes deep had a series of irregularly arranged vaults interconnected with each other by a labyrinth of tunnels. The **endoecie** had an excentric royal chamber with single royal pair and large central fungus comb which serves as egg depository and nursery. No separate egg depository was found. The central fungus comb also harboured a large population of workers, soldiers and immature stages.

INTRODUCTION

The termites build a variety of nests. The simplest type, normally built by primitive termites, are in the form of excavations in the wood or in the ground. In higer termites the nest system becomes more complex, culminating in nests within which microclimate is controlled with great accuracy and food is stored (Harris, 1961). The nest also provides a large measures of protection against natural enemies, particularly the arthropod predators. The nest system may be completely or partially under the ground or completely above the ground (arboreal). The variety of nests, constructed by different groups of termites, throughout the tropical world, has been reviewed at length by Emerson (1938), Grasse (1949) and Noirot (1970). In the Indian subcontinent, earthen mounds built by various species of *Odontotermes* have been described by Escherich (1911), Annandale (1923, 1924); Beeson (1941); Mukerji & Mitra (1949); Roonwal (1962); Mathur & Sen-Sarma (1962) and Roonwal (1973). Roonwal (1962) gave a detailed account of the mound structure, nest and moisture content of fungus comb in *O. obesus*. Agarwal (1978) gave a detailed account of the physical and chemical constituents of fungus combs of *O. microdentatus* and *O. obesus*. However, no work has been done on the architecture of the mounds of *O. microdentatus*. In this paper, an attempt has been made to fill the gap.

MATERIAL AND METHODS

The present investigations were carried out in Dehra Dun and its environs. The mound shape and size were studied in New Forest, Jhajhra Forest and Lacchiwala Forest of Dehra Dun Forest Division. The forest of Lacchiwala and Jajhra were dominated by Sal (*Shorea robusta*). The internal structure of the mound was studied by its vertical dissections. Height and girth values are based on the measurement of 50 mounds.

RESULTS

a) *Shape*: The mounds comprised of several dome shaped structures attached together without buttresses. From a distance, the mounds appear like an uneven heap of earth (Fig. 1). At the sides the outer surface was rough, highly undulated with wide depressions existing in between the domed portions. The mounds were short in height with a very wide base. The above ground portion (=mound as per Roonwal, 1962, *exoecie* as per Grasse, 1949) was much smaller than the underground portion, and no external apertures were usually seen over the mound.

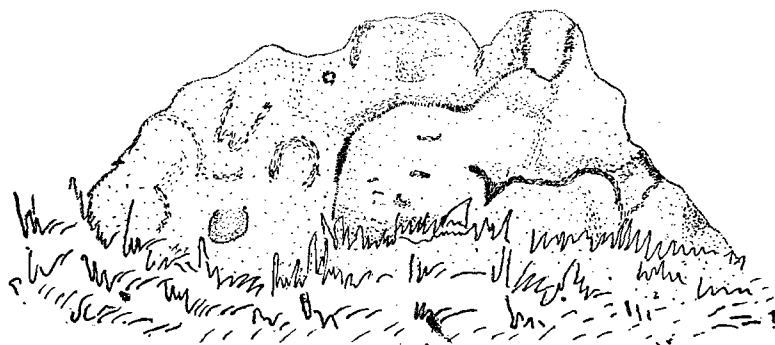


Fig. 1. Diagram of the mound of *Odontotermes microdentatus*

b) *Size*: The height and circumference of the mounds ranged from 0.50 to 0.90 meters and 2.40 to 4.05 meters, the average being 0.80 meters and 3.80 meters, respectively.

c) *Internal Structure*: Following the nomenclature of Grasse (1949), the mounds can be divided into three distinct portions namely (i) *exoecie* (portion above the ground) (ii) *perieecie* (portion in between the *exoecie* and *endoecie*) and (iii) *endoecie* (where royal chamber, central fungus combs etc. are located) (Fig. 2).

The *exoecie* comprised of series of domeshaped structures which did not open outside. These domed structures contained somewhat horse shoe shaped hollow parts inside, these were connected with the galleries in the *periecie* of the mounds. The area separating two domes comprised of solid earth without any openings. On the inner surface few pits were found.

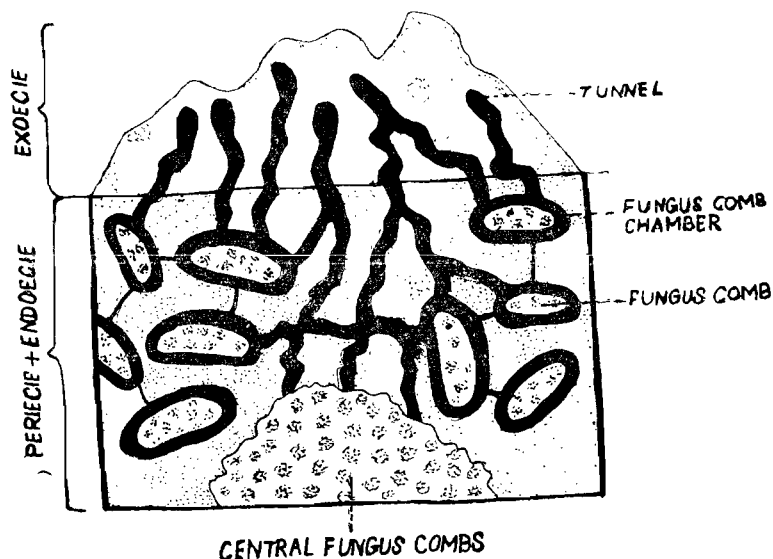


Fig. 2. Schematic diagram of the internal structure of the mound of *Odontotermes microdentatus*

The *periecie* was deep inside the soil and had a labyrinth of irregularly arranged hollow vaults with fungus combs inside. The size of these oblong vaults varied according to the size of the fungus combs. These vaults were connected with the hollow parts of the dome by means of tunnels. There were numerous fungus combs, the smaller ones being excentric and larger ones incetric. Normally, fungus combs were found below the ground level but in few cases, these were present in *exoecie*, 4 to 6 cm above the ground level. However, these fungus combs harboured only a small population of termites comprising of workers and soldiers mainly.

The *endoecie* was situated at a depth of ca 30-90 cm. An incetric royal chamber was situated at a depth of 30 to 60 c below the ground level. No specific meridional direction of royal cell or royal pair was observed. The royal chamber was dark grey in colour, made up of soil, spindle shaped in longitudinal section – somewhat like the cavity created by putting two saucer plates over each other. Small round holes, large enough for the movement of soldiers and workers to attend to royal pair; connected the royal chamber with other parts of *endoecie*. A large

number of soldiers and workers were found near the royal pair (workers 50 to 70, soldiers 15 to 35 per cent). When a royal chamber was opened, the king was found running about actively but the queen, on account of her body weight, was hardly able to move. A regular peristaltic movement of the abdomen of the queen starting from the anterior end and ending at the posterior region was observed. By this peristaltic movement the queen extruded at regular intervals liquid droplets containing eggs. A large central fungus comb with a large number of eggs and nymphs at all stages of development was found near the royal chamber. This comb, therefore seems to serve as an egg depository or nursery. Eggs were not found in other locations including empty cavities or vaults. In addition, the central fungus comb also harboured a small population of workers and soldiers.

DISCUSSION

The external appearance of *O. microdentatus* mounds in *exoecie* was dome shaped and without buttresses which differs from the other mounds of *Odontotermes* sp. found in Indian region. In Indian region, the earthen mounds are reported to be built by the following species *Odontotermes assmuthi*, *O. brunneus*, *O. feae*, *O. gurdaspurensis*, *O. microdentatus*, *O. obesus*, *O. redemanni* and *O. wallonensis* (Roonwal, 1970). The mounds of *O. brunneus* are about a meter or more in height, and are crowned by a number of rounded domes with rugose surface (Beeson, 1941; Roonwal, 1973). The mounds of *O. gurdaspurensis* are conical in shape and attain a height similar to *O. obesus*, of which it was considered a subspecies for a long time (Roonwal, 1962). The mounds of *O. redemanni* are tall and conical with non-buttressed walls (Escherich, 1911; Beeson, 1941; Mukerji & Mitra, 1949). The mounds of *O. wallonensis* which are short and irregular in shape are characterised by the existence of large open mouthed chimneys coming out above the ground level (Assmuth, 1913; Beeson, 1941; Roonwal, 1970). The domed structure of *O. microdentatus* somewhat resembles the domed structure of *O. brunneus* as given by Beeson (1941) and Roonwal (1973). Like *O. wallonensis* mounds of *O. microdentatus* are also short, above the ground. Annandale (1923, 1924) classified termite mounds into two categories, unilocular type and multilocular type based on the number of cavities or vaults inside the nest. Unilocular type are once with a single cavity while multilocular type are those with number of cavities inside the nest. Mounds of *O. microdentatus* can belong to the multilocular type.

The *exoecie* in *O. microdentatus* was different from the *exoecie* of *O. obesus*, *O. redemanni*, and *O. wallonensis* in having a series of domed structures which were hollow inside. These obviously serve as ventilation shafts. In contrast, *O. obesus*, and *O. redemanni* had a central wide hollow shafts in addition to a few lateral shafts in order to facilitate

ventilation. The *exoecie* of these mounds do not have apertures or opening outside as found in *O. wallonensis* (Mathur & Sen-Sarma, 1962). However, Mathur & Sen-Sarma recorded the existence of one or two external openings leading deep inside the nest in older mounds.

The *periecie* was deep in the ground and the *exoecie* was not equal to the *periecie*+*endoecie*. Roonwal (1962) observed similar height and depth of *exoecie* and *periecie* in *O. obesus*. In the *periecie*, a series of irregularly arranged cavities inter-connected with each other by a labyrinth of tunnels somewhat resembled those reported in *O. redemanni* by Mukerji and Mitra (1949). Unlike in other species of *Odontotermes*, the cavities or vaults of *O. microdentatus* had one fungus comb in one vault. During the present studies only one queen and king inside the royal chamber could be recorded. It is worthy to note that occurrence of two queens and two kings inside the chamber has been reported by Roonwal and Gupta (1951) in *O. obesus*, and occurrence of three queens in *O. wallonensis* by Mathur and Chhotani (1960). No specific meridional direction of royal cell or royal pair as reported by Deoras (1944) and Vishnoi (1955) in *Odontotermes* sp. was observed. Gupta also could not confirm the observations of the above authors in *O. obesus*. Roonwal (1962) in *O. obesus* and Mukerji and Raychaudhari (1943) in *O. redemanni* opined separate egg depository in *endoecie*. No separate egg depository was noted in *O. microdentatus*, but eggs were deposited in the central fungus comb and were also found in smaller numbers in other adjacent fungus combs. This phenomenon had also been observed by Mukerji and Mitra (1949) in *O. redemanni*. It appears, eggs are first deposited in the central fungus comb (egg depository) from where the eggs are transferred to the neighbouring combs.

I am highly indebted to Dr. P. K. Sen-Sarma, Forest Entomologist, Forest Research Institute and Colleges, Dehra Dun for his invaluable guidance. I am also grateful to Dr. B. S. Lamba, Deputy Director, Northern Regional Station, Zoological Survey of India, Dehra Dun for his valuable suggestions.

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9.33 SOME OBSERVATIONS ON SWARMING, PAIRING AND ESTABLISHMENT OF NEW COLONY IN *TRINERVITERMES BIFORMIS*

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ABSTRACT

Trinervitermes biformis (Wasm.) is a common grass cutting termite found in India. It is a sub-terranean species, building low dome shaped mounds. The swarming seasons, wing shedding by alates, tandem behaviour and the manner in which a new colony is formed have not been studied in this species. Though Roonwal and Sen-Sarma (1955) reported about the swarming behaviour in **Neotermes gardneri** (Snyder). Swarming behaviour in **O. assmuthi** was described by Sen-Sarma (1965) from Dehra Dun and Basalingappa (1974) from Dharwad.

Observations on swarming and related behaviour on **Trinervitermes biformis** were made during 1977, 1978. Alates were collected by light trapping and other observations were made in the laboratory. Swarming flight was observed on 13th June 1978, 16th July 1978. On both the occasions the flight took place during the night time, always after a heavy shower of rain, extending from 1-3 hours when the temperature was reduced from 31.5 to 25.5°C and humidity increased from 74 to 98 per cent. The ratio of male to female sexes was 1 : 3.

Small exit holes were formed on the mound to facilitate swarming, which were guarded by soldiers and workers. After swarming workers sealed the exit holes. Alates were kept in large petridishes for observations. They shed their wings after meeting the opposite sex. After pairing they exhibited tandem behaviour, the male was always following the female.

When the male was lost during wandering, the female remained stationary and exhibited calling attitude, without searching for the lost male. When moist soil and grasses were added to the petridish the female exhibited digging behaviour, where a small tunnel was made. Later the pair entered into the tunnel and closed the mouth of the tunnel. 2 eggs were seen on the second day and 7 eggs on the third day. Hence, it is presumed that they copulate immediately after sealing the mouth of the tunnel.

9.34 FORAGING BEHAVIOUR OF THE TERMITE *ODONTOTERMES WALLONENSIS* (ISOPTERA : TERMITIDAE)

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ABSTRACT

Amongst several of the destructive termite species *Odontotermes wallonensis* (Wasmann) is the one which infests during its forage several trees such as eucalyptus, mango, neem, casuarina, terminalia, teak etc. Attempts are made to observe some aspects of its foraging behaviour and estimate the damage caused mainly on eucalyptus trees.

The foraging workers were found making their galleries at a depth of 10 to 30 cm below the ground level. The diameter of such galleries was 2 to 3 cm. The foraging workers of this species were found attacking the bark of standing eucalyptus trees, making earthen covered runways up to a height of 6.5 meters. Population study of foraging termites made from different trees has shown that population density in each 10 cm² area was 31.11 ± 6.08 individuals. Total population of termites per tree ranged 229 to 6167. Total percentage of workers and soldiers from the entire area on the tree was 92.8 and 7.2 respectively. Normally, the workers of *O. wallonensis* were observed foraging when the temperature was 27°C and below and when the relative humidity was 58% and above. While foraging, the temperature inside the foraging galleries was 24 to 27°C ($26 \pm 1^\circ\text{C}$). Other details are discussed in the paper.

9.35 POPULATION ECOLOGY OF THE MOUND BUILDING TERMITE
ODONTOTERMES WALLONENSIS (ISOPTERA : TERMITIDAE)

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ABSTRACT

The population ecology of the mound building termite *Odontotermes wallonensis* (Wasmann) has been studied. A suitable population extraction method from fungus comb has been evolved. Three methods were adopted for extracting population from fungus combs, viz., (1) Berlese funnel technique (2) Hand sorting method (3) Flotation method. Among these, flotation method proved to be better for extracting entire population from the fungus combs.

The estimation of population was made on whole mound basis by direct counting of 50 g samples. The population density of mounds varied depending on the size of the mound and fungus comb weight. A relationship was obtained when the size of the sampled mounds was measured as sum of two arcs at right angles, indicating that mound size was a good index to total number of termites in the mound.

Seasonal fluctuations of population revealed the presence of all the stages of termites in the mound throughout the year. The total population fluctuated considerably. The mean population per 50 g fungus comb sample being 1040 ± 62 . The total population was lower during January-March and again in June as compared to other months. Nymphal population was greater during July to November. The nymphs of alate forms were found only during September to March in the colony. Slight variation was observed in worker population. Soldier population did not vary much compared to other castes.

9.36 TERMITES AS PESTS OF GROUNDNUTS*

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ABSTRACT

Different kinds of damage to groundnuts from termites are described. In addition to causing significant losses in yield by direct attack termites may also cause damage that predisposes pods to invasion by toxigenic fungi. Control measures are briefly indicated.

*Approved as ICRISAT Conference paper no. CP-19

INTRODUCTION

Though termites have been recognized as serious pests of groundnuts in the tropics, very little attention has been given to the losses caused by them. Termites can attack planted seeds, seedlings, stems, and pods of developing and mature plants, harvested plants drying in the field, and pods and seeds in storage. In addition to direct physical loss of yield, there may also be considerable loss of quality. Harris (1969) listed 17 species of termites known to damage groundnuts in the moderate to low rainfall areas of Africa and Asia. In this paper the various kinds of damage caused by termites to groundnuts and measures for controlling them are reviewed.

TABLE I

List of species of termites known to cause damage to groundnuts (From: Harris, 1969)

Termite species	Country
<i>Coptotermes formosanus</i>	China
<i>Amitermes evuncifer</i>	Nigeria
<i>Eremotermes nanus</i>	Sudan
<i>Microcerotermes</i> sp.	Gambia
<i>Macrotermes bellicosus</i>	Sudan
<i>Odontotermes badius</i>	South Africa
<i>Odontotermes latericius</i>	South Africa
<i>Odontotermes obesus</i>	India
<i>Odontotermes nilensis</i>	Sudan
<i>Odontotermes vulgaris</i>	Senegal
<i>Odontotermes</i> spp.	Tanzania
<i>Ancistrotermes crucifer</i>	Gambia
<i>Ancistrotermes latinotus</i>	Congo
<i>Microtermes thoralis</i>	Sudan
<i>Microtermes</i> sp.	Nigeria
<i>Trinervitermes biformis</i>	India
<i>Trinervitermes ebenerianus</i>	Senegal

Preemergence damage

Groundnut yields in India and in other parts of the semi-arid tropics are low, seldom exceeding 700 kg/ha, and this is in part due to suboptimal plant populations resulting from poor seedling emergence. Application of seed protectant chemicals reduces preemergence loss. Most seed dressings used on groundnuts contain both fungicides and insecticides, and while it is generally agreed that the fungicide com-

ponent plays a more important part in preventing preemergence damage and losses, there is evidence that the insecticide component can also be important (Clinton, 1962*b*; McDonald and Keay, 1974).

Clinton(1962*a*) in the Sudan estimated that some 15 per cent of preemergence seed loss was due to insect attack and most of this was attributed to termites (probably *Microtermes* spp.). Even slight damage to the seed could facilitate attack by soil fungi, with subsequent rotting of seed or developing seedling.

Postemergence damage

Seedlings, growing plants, and mature plants may all be attacked by termites (Sands, 1960; Clinton, 1962*a*; Kaushal and Deshpande, 1967; Harris, 1969; Rawat *et al.*, 1970; Feakin, 1973). There is a tendency for severity of termite attack to increase as the crop matures.

Loss of seedlings rarely exceeds 2 per cent, but much higher levels have been recorded. In young plants the termites bore into the main stem at or just below ground level. They then tunnel down into the root and up into the main stem and branches. Plants so attacked may die immediately but in most cases they survive with little apparent symptoms of damage until the water supply becomes limiting because of drought or with the end of the rains when they wilt and die. Sands (1960) has observed crop losses of up to 10 per cent from this kind of attack in Nigeria, the problem being most serious in high yielding up-right cultivars. In India, severe attack by *Odontotermes obesus* on groundnuts has been reported from Madhya Pradesh (Rawat *et al.*, 1970), resulting in plant mortality of up to 35 per cent and severe damage to pods and seeds.

A number of species, of which *Microtermes*, *Odontotermes* and *Amitermes* are most important, attack both developing and mature pods causing scarification and often penetration of shells. This damage increases rapidly if pods are left in the ground beyond maturity (McDonald and Harkness, 1967). Direct pod losses of over 25 per cent have been reported from India (Kaushal and Deshpande, 1967). Termite damage to pegs can lead to their breaking at harvest and pods being left in the ground. Combined heavy attack on pegs and pods can lead to total crop loss (Clinton, 1962*a*). In recent surveys of the groundnut crop in northern Nigeria it was found that the average crop loss from all forms of termite attack was around 10 per cent (Johnson, 1978; Johnson *et al.*, 1978).

Defoliation of plants by *Trinervitermes* spp. has been recorded, but this kind of damage is relatively unimportant (Feakin, 1973).

Use of seed dressings containing insecticides such as aldrin and lindane may reduce termite damage to seedlings. As a short term control measure where termite attack is serious chlorinated hydrocarbons can be applied in drills at sowing (Clinton, 1962b; Rawat *et al.*, 1970). Feakin (1973) recommends use of lindane at 1 to 5 kg/ha, and aldrin or dieldrin at 500 g/ha. Some of the persistent soil insecticides such as dieldrin have been banned in many countries including India. It should be noted that residues of chlorinated hydrocarbon sprays applied to groundnuts or other field crops to control other pests may enter the soil and depress termite populations rendering specific control measures unnecessary.

Repeated mechanical cultivations reduce termite populations but the cultivations carried out by small-scale farmers are unlikely to be effective in this way. Harvesting the groundnuts as soon as they are mature and early removal of produce from the field will reduce the chances of termite damage.

A longer term and more acceptable control measure would be to grow cultivars resistant to termite attack. At ICRISAT in the 1978 rainy season, a large number of cultivars and lines were grown in a replicated field trial and it was observed that they varied in respect to percentages of pods with shell scarification from 0 to 85 per cent. Cultivars NC Acc. 17587, NC Acc. 2560, NC Acc. 2279, NC Acc. 17127 and NC Acc. 17090 all had less than 5 per cent of pods scarified, while pods of NC Acc. 2738 were entirely free from scarification. Elements of choice and escape may have been present, and obviously further work is required to determine if genuine resistance is available.

Post-harvest damage

Damage to pods on plants sun-drying in the field has been reported but is not normally important. Stored groundnuts in pyramids and in sheds have been attacked and this damage can be prevented by incorporating aldrin or dieldrin into the foundations of the stacking plinths or storage shed floors.

Reduction of quality

Damage to pods can reduce seed quality both for planting and for human and animal consumption. Direct damage to the seed renders it liable to invasion by various soil fungi after sowing. Damaged seeds also have a higher rate of buildup of free fatty acids when in storage.

Scarification and penetration of shells of developing pods render them more susceptible to invasion by soil fungi that can attack the seeds. Such seeds may be rotted, or if they are less severely damaged, may be incorporated in the yield and raise levels of free fatty acids and possibly introduce mycotoxins. Seeds from termite

damaged pods have been shown to be more likely to contain aflatoxins than seeds from undamaged pods (McDonald and Harkness, 1967).

Premature death of plants from termite damage to stems and roots can cause their pods to dry out slowly in the soil before harvest (Perry, 1967). Seeds of pods are very liable to be invaded by the toxigenic *Aspergillus flavus* and be contaminated by aflatoxins (McDonald and Harkness, 1967; McDonald, 1970).

General comments

From the limited information available, it would appear that termites are important pests of groundnuts in Africa and Asia. Absence of reports of damage from other parts of the world may reflect less importance being attached to the pests, or possibly more mechanical cultivations and more common use of pesticides limits termite populations in those areas.

Reduction in seed quality from termites attack could be even more important than direct damage, particularly in relation to possible mycotoxin contamination.

More research is required into population ecology, crop loss assessment, cultural and chemical control measures, and genetic resistance.

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9.37 INCIDENCE OF TERMITES ON PULSES IN PUNJAB— A SURVEY REPORT

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ABSTRACT

Field surveys were conducted during 1978-79 to record the incidence of termites, *Odontotermes* sp. on pulses viz., chickpea—*Cicer arietinum* L., lentil—*Lens culinaris* M., blackgram—*Vigna mungo* L. and greengram—*Vigna radiata* W. in the main pulse growing tracts of the Punjab State. The surveys revealed that these crops had comparatively higher damage caused by the termites in the sandy soil than in the heavy soils. The damage was more prominent in the districts of Bhatinda, Faridkot, Ferozepur and Sangrur. The intensity of damage was up to 12.0 per cent in these districts.

INTRODUCTION

In the Punjab State pulse crops are grown every year on about 385 thousand hectares of land. The major pulse crop of the State is chickpea, *Cicer arietinum* L., which is grown on more than 90 per cent of the total area under pulses. Next comes the *Vigna* group occupying about 5.7 per cent of the total area under pulse crops. Lentil, *Lens culinaris* M. is grown in about 3.4 per cent and pigeonpea, *Cajanus cajan* (L.) M. occupies about 0.5 per cent. All these crops are attacked by more than 250 insect pest species. However, about a dozen of them are important major pests including a termite, *Odontotermes* sp. This pest being polyphagous attacks almost all crop plants including pulses. Its activity is slow or vigorous according to the soil type. It was therefore, considered necessary to record the incidence of termites in the pulse growing tracts of the State, at various stages of crop growth.

MATERIAL AND METHODS

Since chickpea is the major crop of the state, surveys to assess the damage done by termites to this crop were conducted during the cropping season of 1978-79. For recording the incidence of termites, pulse growing regions of the

State were surveyed, first at the active vegetative growth period in January and then just before the maturity of crop. For conducting the survey, all the fields of gram and lentil falling after every 15-20 KM along the route were surveyed. To record the damage, observations were taken from five spots (each 1 m²) in the field. Total plant population in each spot and mortality of plants due to termites were recorded. Like-wise observations were taken from all the five spots and average termite attack in per cent for the field has been worked out. Similarly, average plant population per sq. m. for the field has been calculated. While taking the observations for termites mortality, soil type was also recorded. In all, 27 fields in the main pulse growing tracts of the State have been surveyed covering the districts : Ludhiana, Faridkot, Ferozepur, Bhatinda, Sangrur, Jullundur, Amritsar and Gurdaspur. Complete data have been presented in Table I.

A second survey was conducted during second half of March. It was observed that attack of termites on matured crop plants was almost negligible.

RESULTS AND DISCUSSION

From the data presented in Table I, it is evident that the incidence of termites in the different districts varied from 0.0 to 12.0 per cent. The districts which have light soil (sandy) had the highest termite attack. However, This diminishes with the heaviness of the soil. Hence, there seems to be a direct correlation between the incidence of termites and soil type or texture.

TABLE I
Details of the survey

Village	District	Soil type	Crop sown	Average plant population per sq.m.	Per cent termites attacked plants	Average of the district
1	2	3	4	5	6	7
Ajitwal	Ludhiana	Loam	Gram	18	1.0	2.50%
Malerkotla	Ludhiana	Loam	Gram	25	1.0	
Morjagrina	Ludhiana	Loam	Gram	20	5.0	4.30%
Chadak	Ludhiana	Loam	Gram	17	1.0	
Reg.Res. St. Faridkot	Faridkot	Loam	Gram/ Lentil	23	1.0	
Khara	Faridkot	Sandy Loam	Gram	27	6.0	
Wada	Faridkot	Sandy Loam	Gram	35	6.0	

1	2	3	4	5	6	7
Bodiwala	Ferozepur	Sandy Loam	Gram	22	5.0	4.30%
Balvana	Ferozepur	Sandy	Gram	20	6.0	
Malout	Ferozepur	Sandy Loam	Gram	38	2.0	
Khumkheda	Ferozepur	Sandy	Gram	22	3.0	
Ropana	Ferozepur	Sandy	Gram	28	9.0	
Reg.Res. St.						
Abohar	Ferozepur	Sandy	Gram	28	1.0	
Gidarbaha	Bhatinda	Sandy	Gram	17	10.0	8.75%
Bhucho Mandi	Bhatinda	Sandy	Gram	16	8.0	
Kachi Bhucho	Bhatinda	Sandy	Gram	19	12.0	
Rampur	Bhatinda	Sandy	Gram	18	5.0	
Tapa	Bhatinda	Sandy	Gram	30	3.0	
Dhanecha	Sangrur	Sandy	Gram	26	8.0	10.0%
Bahadarpur	Sangrur	Sandy	Gram	26	12.0	
Beas	Jullundur	Loam	Lentil	—	0.0	0.0%
Alkade	Amritsar	Loam	Gram/ Lentil	—	0.0	0.0%
Umra Nangal	Amritsar	Loam	Gram/ Lentil	—	0.0	
Gill	Gurdaspur	Loam	Gram	—	0.0	1.25%
Jayantipur	Gurdaspur	Loam	Gram/ Lentil	—	5.0	
Padde	Gurdaspur	Loam	Gram/ Lentil	—	0.0	
Mehta	Gurdaspur	Loam	Lentil	—	0.0	

CONCLUSION

In the districts of Bhatinda, Sangrur, Ferozepur and Faridkot, which predominantly have sandy soil, attack of termites is as high as 12.0 per cent, with an average of 4.30 to 10.00 per cent. In the districts of Ludhiana, Jullundur, Amritsar and Gurdaspur which have mostly loam soil, incidence of termites fluctuated between 0.0 and 5.0 per cent with an average 0.0 to 2.50 per cent. This indicates that soil type plays an important role in the incidence and attack of termites.

9.38 EFFECT OF VARIOUS SEED RATES OF ALDRIN-TREATED AND UNTREATED WHEAT ON TERMITE DAMAGE AND GRAIN YIELD OF THE CROP

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ABSTRACT

During 1974-75 and 1975-76, wheat crop was raised from aldrin-treated (400 ml aldrin 30 EC per quintal seeds) and untreated seeds used at rates varying from 60 to 90 kg per hectare. The differences in attack by the termite *Microtermes obesi* to tillers and grain yield of the crop raised from different seed rates, during both the years, were non-significant. Such differences for the number of effective tillers at harvest were either non-significant or lacked any trend. Use of aldrin-treated seeds, when compared with the untreated ones, resulted in lesser termite damage, more effective tillers at harvest and higher grain yield. Aldrin-treated seeds gave much better performance under limited than under more irrigation conditions.

INTRODUCTION

For checking termite damage in wheat crop, seed treatment with aldrin emulsion has been found to be both very effective and economical (Verma *et al.*, 1978). Studies were initiated to investigate the differences in damage by *Microtermes obesi* Holmgren to wheat crop raised from varying quantities of aldrin-treated and untreated seeds.

MATERIAL AND METHODS

The experiments were conducted at Haryana Agricultural University, Hissar. The seed rates, for both aldrin-treated and untreated seeds, were 90, 85, 80 and 75 kg per hectare during 1974-75 and 90, 75 and 60 kg per hectare during 1975-76. A dose of 400 ml aldrin 30 EC per quintal seeds was used for preparing the aldrin-treated seeds (Verma *et al.*, 1975). The treatments were compared in a randomised block design with three replications and plot size of 10x5 metres. Between the plots 50 cm wide buffer area was provided.

The crop (variety C-306) was sown on 19th and 17th November during the years 1974 and 1975, respectively. Fertilizers applied were 30 kg N and 15 kg P₂O₅ per hectare. The crop was irrigated twice during 1974-75 and only once during 1975-76. Termite damaged tillers were collected and counted from each plot at intervals of 20 days. At harvest, the number of effective tillers in each plot were determined by counting the tillers in 5 out of the 20 rows in each plot. For

grain yield, the crop in each plot was harvested and threshed separately. The data were subjected to analysis of variance and the differences were compared at the 5 per cent level of significance.

RESULTS AND DISCUSSION

The data on termite damage, number of effective tillers at harvest and grain yield are given in Table I.

Observations on seed germination in different treatments were not recorded, first because it has already been established (Verma *et al.*, 1975) that wheat seed treatment with aldrin emulsion, at a dose used in the current studies, neither impairs nor improves its germination and secondly the varying seed rates used in these studies are bound to give comparable variations in germination counts.

Termite damage : During both the years, there was no difference in the number of termite attacked tillers in plots sown with different seed rates though the termite damage was lesser in the crop raised from aldrin-treated than from untreated seeds. Use of aldrin-treated seeds resulted in 99.6 and 99.4 per cent reduction in termite damaged tillers during 1974-75 and 1975-76, respectively.

The extent of termite damage was relatively more (an overall of 527.4 out of 6660.5 tillers per plot) during 1975-76 than during 1974-75 (an overall of 156.9 out of 14258.8 tillers per plot). This difference may largely be attributed to the number of irrigations during the two years, these being lesser during 1975-76 than during 1974-75.

Effective tillers: During 1975-76, the differences in the number of effective tillers per plot, with the seed rates of 60, 75 and 90 kg per hectare, were non-significant. Though such differences with the seed rates of 75, 80, 85 and 90 kg per hectare, during 1974-75, were significant the results lacked any specific trend. Both overall, as with the aldrin treated seeds the number of tillers with 80 kg, though at par with 85 and 90 kg, were more than with 75 kg seed rate. Such differences between 75 and 85 as also among 80, 85 and 90 kg seed rates were also non-significant.

The number of effective tillers per plot was more during 1974-75 than during 1975-76. This again may be ascribed to more number of irrigations during the former than the latter year.

The number of tillers per plot was more in case of aldrin-treated than with

TABLE I

Effect of different seed rates of aldrin-treated and untreated seeds on termite damage, effective tillers at harvest and grain yield of wheat crop

Seed rate kg/ha	1974-75			1975-76		
	Aldrin treated*	Untreated	Mean	Aldrin treated	Untreated	Mean
1	2	3	4	5	6	7
a. Mean number of termite damaged tillers per plot.**						
60				7.0 (2.26)	1173.8 (30.94)	590.4 (16.60)
75	0.0 (1.00)\$	173.3 (12.42)	86.6 (6.71)	10.3 (3.08)	564.0 (23.49)	287.2 (13.28)
80	0.0 (1.00)	370.0 (19.26)	185.0 (10.13)	—	—	—
85	3.7 (2.02)	203.7 (13.76)	106.2 (7.89)	—	—	—
90	1.0 (1.33)	498.3 (21.47)	249.6 (11.40)	2.3 (1.75)	1407.0 (34.65)	704.7 (18.20)
Mean	1.2 (1.34)	312.6 (16.73)	156.9 (9.03)	6.5 (2.36)	1018.3 (29.69)	527.4 (16.03)
G.D. at 5%	(3.28)			(7.99)		
b. Mean number of effective tillers per plot** at harvest						
60				7403.8 (85.98)	5171.3 (71.16)	6387.6 (78.57)
75	13736.7 (117.20)θ	13468.3 (116.04)	13602.5 (116.62)	7336.3 (85.48)	6607.5 (81.21)	6971.9 (83.35)
80	15425.0 (124.18)	13943.3 (118.05)	14684.2 (121.12)	—	—	—
85	14786.7 (121.57)	13500.0 (116.19)	14143.4 (118.88)	—	—	—
90	15121.7 (122.97)	14088.3 (118.69)	14605.0 (120.83)	8193.8 (89.93)	5250.0 (72.07)	6721.9 (81.00)
C.D. at 5%	(3.70)		(2.63)			
Mean	14767.5 (121.48)	13750.0 (117.24)	14258.8 (119.36)	7644.6 (87.13)	5676.3 (74.81)	6660.5 (80.97)
C.D. at 5%	(1.84)			(6.48)		

	1	2	3	4	5	6	7
c. Mean grain yield (kg) per plot**							
60	—	—	—	—	9.84	6.57	8.21
75	18.42	18.19	18.30	18.30	9.86	7.62	8.74
80	18.77	17.77	18.27	18.27	—	—	—
85	19.41	16.52	17.96	17.96	—	—	—
90	19.73	18.07	18.90	18.90	10.03	5.73	7.88
Mean	19.08	17.64	18.36	18.36	9.91	6.64	8.28
C.D. at 5%		1.05			1.49		

*Seeds treated with aldrin 30 EC @ 400 ml per qtl

**50 sq m

$\sqrt[n+1]{S}$ transformation

$\sqrt[n]{\theta}$ transformation

untreated seeds. Treatment of wheat seeds with aldrin resulted in 7.4 and 34.6 per cent (overall) more effective tillers during 1974-75 and 1975-76, respectively.

Grain yield: There were no differences in grain yield of the crop raised from seed rates varying from 60 to 90 kg per hectare. The crop yield during 1974-75 was higher than during 1975-76 and this is considered primarily to be due to more number of irrigations during the former than the latter year.

During both the years, grain yield was higher in the plots sown with aldrin-treated than with untreated seeds. On an average, the seed treatment with aldrin resulted in 8.2 and 49.4 per cent enhanced crop yield during 1974-75 and 1975-76, respectively.

It was quite interesting to observe that response of aldrin-treated seeds in terms of reduction in termite damage and increase in number of effective tillers as well as grain yield was decidedly better under limited than under optimum irrigation conditions.

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9.39 EFFECT OF DIFFERENT LEVELS OF IRRIGATIONS AND FERTILIZERS ON TERMITE DAMAGE AND YIELD OF WHEAT CROP

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ABSTRACT

Damage by the termite *Microtermes obesi* to wheat was observed to be less when the crop received 2 or 3 as against 0 or 1 irrigations. A positive correlation between irrigation level and crop yield was evident. Difference in termite damage in plots receiving the recommended (60 kg N + 30 kg P₂O₅ per hectare) and half the recommended (30 kg N + 15 kg P₂O₅ per hectare) doses

of fertilizers was non-significant. However, on percentage basis, this difference was significant. Higher fertilization gave higher yield. As compared to untreated seeds, seed treatment with aldrin emulsion (400 ml aldrin 30EC per quintal seed) resulted both in reduced termite damage and higher wheat yield.

INTRODUCTION

In preliminary studies conducted earlier, the termite damage during the earing stage of wheat crop was found to be negatively correlated with the frequency of irrigation (Verma, 1975a) and the level of application of nitrogenous fertilizer (Verma, 1975b). It was considered necessary to investigate the effect of both irrigation and fertilization on the termite *Microtermes obesi* Holmgren in damaging the plant and reducing grain yield of wheat crop. with a view to assess the avoidable losses due to termites, aldrin-treated and untreated seeds were used.

MATERIAL AND METHODS

The experiment was conducted during 1975-76 at the research area of the Department of Soils, Haryana Agricultural University, Hissar. The levels of post-sowing irrigations were: 0, 1 (22 days after sowing), 2 (22 and 85 days after sowing) and 3 (22, 65 and 105 days after sowing) and those of the fertilizers were the recommended (60 kg N + 30 kg P_2O_5) and half the recommended (30 kg N + 15 kg P_2O_5) doses of nitrogen and phosphorus. Where there was no post-sowing irrigation full N and P_2O_5 were drilled at sowing. However if the plots were to receive post-sowing irrigations half N and full P_2O_5 were drilled at sowing and the remaining N was applied at the time of the first irrigation. For each combination of irrigation and fertilizer two types of seeds (aldrin-treated and untreated) were used. A dose of 400 ml aldrin 30EC per quintal seeds was used for preparing aldrin-treated seeds (Verma *et al*, 1975). There were thus 16 treatments and these were compared by a split plot design (irrigation being the main effect) with three replications in plots of size 40 sq. metre (12.5 x 3.2 m) Between any two irrigation blocks, one metre wide buffer area was provided.

Wheat (variety C-306) was sown by *kera* method on 13th of November, 1975 with a seed rate of 90 kg per hectare. There were 12 crop rows in each plot. Termite damaged tillers were collected and counted from each plot at about 15-days intervals. At harvest, the number of effective tillers in each plot were determined by counting the tillers in 4 out of the 12 rows in each plot. While compiling the data, the number of termite damaged tillers for any plot were added to the number of effective tillers at harvest for that plot. The crop was harvested on 20th April, 1976 and the grain yield was recorded.

RESULTS AND DISCUSSION

The data on termite damage, number of effective tillers at harvest and grain yield are given in Table I.

Termite damage : A negative correlation between frequency of irrigation and termite damage was evident. Lesser damage was noted when the crop received 2 or 3 as against 0 or 1 irrigations. Considering the number of termite damaged tillers as well as their percentage, the difference in the damage between 3 and 2 irrigation schedules was non-significant. These two parameters however, varied differently when 0 and 1 irrigation schedules were compared. When considered on the basis of number of termite damage tillers per plot, there was no difference between these two irrigation levels but when the damage was expressed on percentage basis, the value was more (5.84 per cent) in 0 than in 1 irrigation (4.00 per cent) schedule. This may be ascribed to the fact that there were relatively more number of termite damaged tillers but lesser number of total tillers per plot in case of 0 than in 1 irrigation schedule, resulting thereby in higher percentage damage in the former than the latter.

The difference in the number of termite damaged tillers in plots receiving recommended (60 kg N + 30 kg P₂ O₅ per hectare) and half the recommended (30 kg N + 15 kg P₂ O₅ per hectare) doses of fertilizers was non-significant. However, when the damage was expressed as percentage tillers damaged, this difference was found to be significant, there being more damage (3.24 per cent) with lower and lesser damage (2.57 per cent) with the higher level of fertilization. This could be explained by relatively higher number of termite damaged tillers but lesser number of total tillers per plot in case of lower than with the higher level of fertilizer application.

As compared to the untreated seeds, seed treatment with aldrin emulsion resulted in reduced termite damage when considered both on number as well as percentage basis. The overall percentage of the termite damaged tillers in case of untreated and the aldrin-treated seeds was 5.71 and 0.11, respectively. The superiority of aldrin-treated seeds was observed irrespective of the irrigation schedules.

Effective tillers at harvest : A positive correlation between irrigation levels and the total number of effective tillers per plot at harvest was observed. Their number was the lowest (5231 per plot) with 0 and the highest (8440) with 3 irrigations. The difference in their number in case of 1 or 2 irrigations was, however, non-significant. The number of effective tillers per plot was also influenced by the level of fertilization. In this case also the relationship was positive these being more (7296 per plot) with the recommended than with half-the-recommended (6384)

TABLE I
Termite damage, effective tillers at harvest and grain yield of wheat crop when aldrin-treated and untreated seed was sown in plots receiving different levels of irrigations and fertilizers

Number of irrigations	Fertilizers applied (per ha)			Type of seeds used			Mean
	30kg N+15 kg P ₂ O ₅	60 kg N+30 kg P ₂ O ₅	kg P ₂ O ₅	Aldrin treated*	Untreated		
1	2	3	4	5	6		
a. Mean number of termite damaged tillers per plot**							
0	282.5 (13.05)***	366.4 (14.73)	10.6 (3.26)	638.3 (24.52)	324.4 (13.89)		
1	367.5 (14.22)	139.3 (9.15)	9.3 (3.10)	497.5 (20.28)	253.4 (11.69)		
2	81.7 (7.06)	26.8 (3.84)	2.3 (1.60)	106.2 (9.30)	54.2 (5.45)		
3	78.0 (6.88)	80.5 (7.00)	2.5 (1.71)	156.0 (12.17)	79.2 (6.94)		
C.D. at 5%			(5.41)		(3.84)		
Mean	202.4 (10.30)	153.2 (8.68)	6.2 (2.42)	349.5 (16.57)	177.8 (8.49)		
C.D. at 5%			(3.57)				
b. Mean number of effective tillers per plot** at harvest							
0	4992.0 (70.55)***	5479.0 (73.86)	5583.0 (74.65)	4878.0 (69.76)	5230.5 (72.20)		
1	6282.5 (78.89)	7183.0 (84.51)	7031.5 (83.35)	6434.0 (80.05)	6732.7 (81.70)		
2	6139.0 (78.19)	7771.5 (88.10)	7321.0 (85.31)	6589.5 (80.98)	6955.2 (83.14)		
3	8121.0 (89.95)	8760.0 (93.52)	8157.0 (90.21)	8724.0 (93.26)	8440.5 (91.73)		
C.D. at 5%					(3.66)		
Mean	6383.6 (79.39)	7295.9 (85.00)	7023.1 (83.38)	6656.4 (81.01)	6839.7 (82.19)		
C.D. at 5%		(2.59)					

1	2	3	4	5	6
c. Mean per cent tillers damaged by termites					
0	5.41 (10.45)***	6.28 (11.10)	0.24 (2.23)	11.45 (19.32)	5.84 (10.77)
1	5.23 (10.01)	2.78 (4.62)	0.15 (1.72)	7.86 (12.90)	4.00 (7.31)
2	1.37 (4.97)	0.36 (2.08)	0.04 (0.51)	1.70 (6.54)	0.87 (3.52)
3	0.96 (4.13)	0.88 (3.94)	0.03 (0.59)	1.81 (7.47)	0.92 (4.03)
C.D. at 5%			(3.78)		(2.68)
Mean	3.24 (7.39)	2.57 (5.43)	0.11 (1.26)	5.71 (11.56)	2.91 (6.41)
C.D. at 5%	(1.89)		(1.89)		
d. Mean grain yield (kg) per plot**					
0	6.98	8.67	8.33	7.32	7.82
1	9.05	10.74	10.68	9.10	9.89
2	9.83	12.10	11.66	10.27	10.96
3	10.09	11.29	11.16	10.22	10.69
C.D. at 5%					0.90
Mean	8.99	10.70	10.46	9.23	9.84
C.D. at 5%	0.63		0.63		

*Seeds treated with aldrin 30EC @ 400 ml per qul.

**12.5 x 3.2 m (40 sq. m)

*** $\sqrt{n + 1}$ transformations

**** Angular transformed values

doses of N and P_2O_5 . Seed treatment with aldrin emulsion had no influence on the number of effective tillers per plot at harvest.

Grain yield : The grain yield was influenced by all the three parameters, viz., irrigation, fertilization and seed treatment with aldrin. With no irrigation the grain yield, as expected, was the lowest. It was also lower in case of 1 than with 2 irrigations. All other differences in the crop yield as influenced by irrigation schedules were non-significant. Higher grain yield (10.70 kg per plot) was recorded with the recommended than with half-the recommended (8.99 kg) doses of N and P_2O_5 . The yield was also higher (10.46 kg) in plots sown with aldrin-treated than with the untreated (9.23 kg) seeds. The overall enhancement in crop yield due to seed treatment with aldrin emulsion was 13.3 per cent.

The present studies, depicting a negative relationship between irrigation schedules and termite damage, are in conformity with the results of Verma (1975a). This may be explained from the observations of Harris (1961) who reported that the plant-feeding termites are encouraged by reduction in the vigour of the host plant during periods of drought. With other insect pests such as thrips (Shoeib and Hosny, 1973) and the nymphs as well as adults of the mirid, *Lygus hesperius* Knight (Leigh *et al.*, 1970) infesting cotton, the populations have been found to be positively correlated with the frequency of irrigations.

In these studies, the percentage of termite damaged tillers was negatively correlated with the level of application of N + P_2O_5 fertilizer. These findings support the earlier observation by Verma (1975b) who also recorded such a relationship between nitrogen application and termites damage during earing stage of wheat crop. Perusal of available literature reveals that with most other insects this relationship has been found to be just the reverse. For example, the level of infestation by the aphid, *Macrosiphum avenae* (F.) (Baran, 1972; Manolache *et al.*, 1976); the thrip, *Haplothrips tritici* Kurd (Manolache *et al.*, 1976) and the stemfly, *Atherigona bituberculata* Malloch (Rawat and Sahu, 1969) in wheat crop and that of the stem borer, *Tryporyza incertulas* (Wlk.) in paddy (Saha and Saharia, 1970) have been found to increase with the application of nitrogen. The only plausible explanation for this type of relationship is that fertilizer application improves the vigour of the plants and this increased vigour discourages the activity of the plant feeding termites (Harris, 1961).

The observed superiority of aldrin-treated seeds (as compared to the untreated seeds) in checking termite damage and enhancing wheat yield is in line with the earlier findings of Verma *et al.* (1978).

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9.40 EFFECT OF CROP ROTATION ON TERMITE DAMAGE AND YIELD OF WHEAT CROP

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ABSTRACT

In trials conducted for three years ending 1975-76, damage by the termite *Microtermes obesi* to wheat crop, sown in rotation with various **kharif** crops, was studied. Data of the three years revealed maximum termite damage in the crop sown after **guar** (*Cyamopsis tetragonoloba*)

and minimum in the one sown after bajra (*Pennisetum typhoides*). There was no difference in termite damage when wheat followed either jowar (*Sorghum vulgare*) or mung (*Phaseolus aureus*).

The crop sown after mung yielded more than the one sown after jowar. The differences in wheat yield when the crop followed mung, guar or bajra were generally non significant.

INTRODUCTION

In rainfed arid areas, termites cause considerable damage to wheat crop. In these situations it is quite common to sow wheat in the fields vacated from crops like bajra (*Pennisetum typhoides*), jowar (*Sorghum vulgare*), guar (*Cyamopsis tetragonoloba*) and mung (*Phaseolus aureus*). The present studies were aimed to find out if the crop preceding to wheat affects the damage by the termite *Microtermes obesi* Holmgren to plants and yield of this crop.

MATERIAL AND METHODS

The experiments were conducted in the research area of the Department of Entomology, Haryana Agricultural University, Hissar during the period 1973-74 to 1975-76. There were four crop rotations, viz., wheat sown after harvesting of bajra, jowar, guar or mung. The lay-out was of randomised block design with six replications, in plots of 8 x 6.5 metres. Between any two plots one metre wide buffer area was provided. The same field was used throughout, and the crop rotation in each plot was always the same.

All the four *kharif* crops, during any year, were sown in the middle of July. These crops were harvested towards end of October. The field was thereafter irrigated, ploughed and all the stubbles removed.

Wheat (variety C-306) was sown during third week of November with a seed rate of 90 kg per hectare. Fertilizers applied were: 60 kg N+30 kg P₂O₅ per hectare during 1973-74 and 1974-75 and 30 kg N+15 kg P₂O₅ per hectare during 1975-76. The crop was irrigated twice (22 and 85 days after sowing) during the first two years and only once (22 days after sowing) during 1975-76. Termite-attacked tillers per plot were collected and counted at 3-weeks intervals. The crop was harvested around middle of April and grain yield was recorded on plot basis. The field was irrigated, ploughed and prepared for sowing the *kharif* crops during first week of July.

The data on termite damage and yield of wheat crop obtained for each year as also the pooled data (the pooling was done replication-wise) were subjected to

analysis of variance and the results were compared at the 5 per cent level of significance.

RESULTS AND DISCUSSION

The termite damage in wheat crop was generally the lowest when it was sown after bajra and highest when sown after *guar*. The differences in termite damage in the crop sown after either bajra or mung during 1974-75 or after bajra, mung or jowar during 1975-76 were, however, non-significant. Similarly, in the pooled data and also the data obtained during 1975-76 the termite damage was the highest in the crop following *guar*, but the differences in such damage when wheat followed either *guar* or jowar (1974-75) and *guar*, jowar or bajra (1973-74) were non-significant (Table I).

In 1973-74, the differences in the yield of wheat crop sown after any of the four *kharif* crops, were non-significant. During the remaining two years, as also in the pooled data, the crop when sown after mung always yielded more than the one sown after jowar. The differences in the wheat yield when the crop followed mung or *guar* (1974-75) and mung, *guar* or bajra (1975-76 and the pooled data) were, however, non-significant.

Atwal (1976) also observed that from entomological point of view the *guar*-wheat rotation is unsound. According to him, any delay in the burial of *guar* attracts termites and may thus jeopardise the chances of growing a successful wheat crop.

Relatively higher grain yields when wheat crop followed *mung*, and in some cases even *guar*, may be ascribed to the enrichment of soil by the nitrogen fixing bacteria present in the root nodules of these leguminous crops. It is however, rather difficult to reason out the differential termite damage in wheat crop sown after different *kharif* crops.

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TABLE I
Termite damage and grain yield of wheat crop sown after various kharif crops

Crop rotation	Mean No. of termite damaged tillers per plot			Mean grain yield (kg) per plot*			Pooled data
	1973-74	1974-75	1975-76	1973-74	1974-75	1975-76	
Wheat after bajra	165.7(10.11)**	107.3 (09.80)	208.6 (10.67)	140.5 (11.84)	7.86 7.51	12.24	9.18
Wheat after jowar	286.3 (16.88)	217.2 (14.65)	356.4 (14.25)	286.6 (18.44)	6.68 6.06	11.00	7.71
Wheat after guar	518.0 (22.22)	183.0 (13.51)	974.3 (23.50)	558.4 (23.59)	7.53 8.96	12.54	9.56
Wheat after mung	451.3 (21.20)	118.5 (10.66)	241.4 (10.23)	270.4 (16.41)	8.38 9.41	15.15	10.98
C.D. at 5 per cent	(5.85)	(2.65)	(7.04)	(2.49)	N S 1.34	2.42	1.76

* 8 x 6.5 metres

** Means of $\sqrt{n+1}$ transformed values in the six replications

9.41 LOSSES TO EUCALYPTUS SEEDLINGS DUE TO TERMITES AND THEIR CONTROL

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ABSTRACT

One kilogram of heptachlor (6 per cent dust) or 0.75 kg of either DDT (50 per cent WP) or chlordane (20 EC) for one cmt. of potting soil were found to protect eucalyptus seedlings, raised in polythene bags, up to two years after planting in the field.

INTRODUCTION

Termites are known to attack many field crops, fruit crops and wood work of buildings. The influence of these on tropical forestry is well known as their attack in nurseries and to young plants is usually more evident limiting the establishment of new forests. The species known to be destructive to eucalyptus in India are *Odontotermes feae* (Wasmann), *O. redemanni* (Wasmann), *O. assmuthi* Holmgren and *Microcerotermes minor* (Cachan) (Beeson, 1941 ; Chatterjee, 1970).

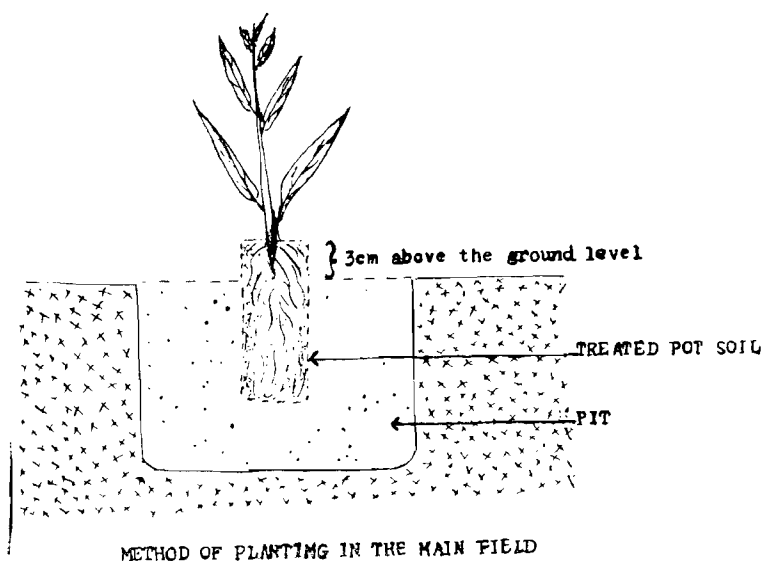
Eucalyptus, a highly favoured exotic tree for afforestation in India, is the main sufferer from termite attack. In Karnataka, eucalyptus is being grown over an area of 300,000 ha out of a total of 2,900,000 ha. Every year about 10,000 ha of eucalyptus are being added.

There is no published literature available on the assessment of losses to eucalyptus seedlings due to termites in the natural forests of India although there are records of 64 to 92 per cent loss in natural forests to *Eucalyptus* sp., in Brazil (Fonseca, 1950), Australia (Greaves *et al.*, 1967) and Queensland and Southwales (Harris, 1971). Therefore, this study was undertaken to find out the loss of plants due to termites attack and also to find out an effective method of protecting the seedlings in the first year of planting when the attack is usually severe.

MATERIAL AND METHODS

An experiment was laid out at Forest Plantation, Madally, Mysore district during 1976-77 to assess the loss and to study the efficacy of insecticides when mixed in the pot soil in protecting the seedlings up to two years after planting under

natural ecosystem. Four insecticides viz., DDT 50 W.P., chlordane 20 EC, heptachlor 6 per cent dust and BHC 10 per cent dust, replicated 4 times, were compared with no insecticide. Each treatment had 25 plants in the main field. The insecticides were mixed with soil thoroughly with the help of a spade. One cubic metre of treated soil was enough to fill 900–1000 polythene bags of size 10 x 20 cm. Seedlings were transplanted into the polythene bags filled with insecticide treated soil. After one month of its establishment in the polythene bags under shade, the seedlings were planted in the main field along with the treated soil, leaving 3 cm treated soil (Fig. 1) above the ground surface undisturbed. Incidence of termites was recorded at two months interval up to one year. The number of healthy and dead plants due to termite attack was recorded and the loss was assessed based on the number of dead plants under each treatment.



Per cent mortality of the plants due to termite infestation was analysed by using angular transformation as per Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

The number of plants killed by termites in each treatment and their percentage of loss is presented in Table I. The plants were damaged by four species of termites viz., *Odontotermes wallonensis* (Wasmann), *O. obesus* (Rambur), *O. bruneus* (Hagen) and *Microtermes obesi* Holmgren. Eucalyptus plants were subjected to the attack at three stages ; in the nursery, after planting and early establishment up to two years. In

the nursery and after planting the termite attack was confined to the roots. But during its early establishment, it was found damaging the collar region of plants, eating the bark completely, resulting in yellowing, wilting and drying of plants. Plants beyond two years did not suffer much due to termites although at all stages the trees were subjected to the attack and earthen sheathing could be seen even beyond half the height of the trunk from the base. Mostly they fed on the dry bark of the tree but their activity hastened the process of drying of the bark.

TABLE I
Effect of different insecticides as reflected in the percentage mortality of eucalyptus plants by termites

Treatment	dosage/cmt of of potting soil	no. of dead plants/rep- lication	per cent mortality
B H C 10%	1.0 kg	8.75	32.0 (34.28)*
D D T 50% W.P.	0.75 kg	2.50	10.0 (16.64)
Chlordane 20 EC	0.75 litre	3.00	12.0 (20.14)
Heptachlor 6%	1.0 kg	1.50	6.0 (12.33)
Check (untreated)	—	9.00	36.0 (36.81)
F Test			(**)
SEm $\pm$			(5.20)
C. D (P=0.05)			(11.33)
C. V. %			(30.6)

* Figures in parentheses are in angular transformed units.

From the table, it can be seen that heptachlor 6 per cent dust (12.3 per cent), DDT 50 W.P. (16.6 per cent) and chlordane 20 EC (20.1 per cent) were superior in that order and have significantly protected the plants as compared to BHC 10 per cent dust (34.3 per cent) which was on par with untreated check (36.8 per cent). There was no further attack of termites to these protected plants up to two years beyond which no further observations were taken.

The practice of using BHC 10 per cent dust against termites in forest plantation is not effective in checking the menace of termites according to the present findings. To get the desired results from effective chemicals against termites it is very essential to mix the insecticide in the pot soil thoroughly and also the method of planting as described here should be borne in mind. Care should be taken to see that no water is poured from the top to dislodge the treated soil above ground if watering is done after planting. Therefore it can be concluded that highly

satisfactory establishment of eucalyptus seedlings, even in the termite endemic areas of forest plantation can be obtained by following the methods adopted in this experiment.

The authors are grateful to Mr. G. V. Narayan, Divisional Forest Officer, Mysore and his staff for all the facilities provided to carry out this experiment.

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9.42 TERMITE DAMAGE IN EUCALYPTUS PLANTATIONS AND THEIR CONTROL

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ABSTRACT

Eucalyptus is a highly favoured exotic for afforestation schemes in India and elsewhere. Such plantations suffer from inherent limiting factors - one such problem is damage due to termites.

The role and nature of termite influence on eucalyptus plantations and forests (in endemic and exotic environments) have been described along with field observations on recognised and potential eucalyptus destructive termites of South India.

Results of effective control methods are reported. Measures for acquiring more reliable field data of basic importance under south Indian conditions in relation to acclimatization, resistance and control of termites on various species of **Eucalyptus** are indicated.

10. PESTICIDES

10.1 A COMPARATIVE ASSESSMENT OF THE EFFECT OF SOME HERBICIDES ON THE MICROARTHROPODS OF CULTIVATED SOILS

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ABSTRACT

The herbicides caused changes in the abundance of microarthropods as well as its important groups viz. Acari and Collembola in treated plots by either decreasing or increasing the population densities. An assessment of the overall impact of these herbicides upon soil microarthropods show that only TOK, E-25 significantly decreased the number of total microarthropods ($P < 0.05$) and Collembola ($P < 0.01$) in paddy field and of Mesostigmata ($P < 0.05$) in wheat field, whereas, STAM, F-34 reduced the number of Collembola ($P < 0.01$) and Mesostigmata ($P < 0.02$) significantly in paddy field. On the other hand Banvel-D, 2,4-D amine and 2,4-D sodium appeared to be relatively safe since these caused insignificant variation in the number of nontarget organisms of soil.

INTRODUCTION

Many of the chemical compounds nowadays being administered by the agricultural chemical industry as herbicides very widely in their properties. Majority of these chemicals are applied principally to the soil, and remain relatively 'free' in the soil, for their uptake by plant roots for considerable periods. Deleterious effects of these compounds, either temporary or permanent, on the non-target soil organisms in agro-ecosystems have been reviewed by Edwards (1970) and Eijsackers and van der Drift (1976), which show that several of the herbicides can affect the density and diversity of soil microarthropods, which depend directly or indirectly upon plants for their food.

In India, though the use of herbicides as a substitute for farm machinery and labour is gaining popularity, research on the effect of herbicides on the non-target organisms is quite scanty. To date the only reference in this line are of Sen (1957) to assess the effect of 2, 4-D on the aquatic fauna, Deshmukh and Srikhande (1974) who studied the effect of some herbicides like 2, 4-D; NaTA; Simazine etc., in different doses on the soil protozoa, and of Bhattacharya and Joy (1977 a & b,

1980) and Joy and Bhattacharya (1977) to evaluate the effect of Banvel-D ; Tok, E-25; Stam, F-34; 2,4-D-amine and 2,4-D sodium upon the soil microarthropods. The present paper which deals with the overall effect of different herbicides in their normal agricultural doses on the soil microarthropods as a whole and on its major groups, sums up the work which has been carried out by the present investigators from 1973 to 1978.

MATERIAL AND METHODS

In all, six field experiments were conducted using five herbicides in their usual agricultural doses on paddy and wheat crops. Details regarding the agricultural manipulations, herbicide applications, soil sampling for extraction of microarthropods are given elsewhere (Bhattacharya and Joy ; 1977 a and b, 1980 ; Joy and Bhattacharya, 1977). In paddy crop Tok, E-25 (Nitrofen) and Banvel-D (Dicamba) were used as pre-emergence herbicides and Stam, F-34 (Propanil) was used as post-emergence herbicide. In wheat crop Tok, E-25 (Nitrofen) was used for pre-emergence weed control while 2,4-D amine (Bladex-G) and 2,4-D sodium (Fernozone) were applied for post-emergence weed control.

Dry cultivable highland variety of paddy 'Pusa-2-21' and 'Janak' variety of wheat were raised as crops. Dry farmyard manure was applied at the rate of 2-3 Kg/m² in all the cases. In order to study the overall effect of herbicides on the microarthropod as a whole and on the different groups, abundance of these in the untreated plot was compared with the abundance in the treated plot, after the use of herbicides. The data obtained were statistically analysed for the test of significance using 'tw test' (Lord, 1947).

RESULTS

The main findings are summarized in Table I and Fig. 1 & 2. Tok, E-25 caused reductions in the abundance of total microarthropods and its major groups in general in both paddy and wheat fields. The effect of the chemical was particularly prominent in the case of microarthropods as a whole ($P < 0.05$) and Collembola ($P < 0.01$) in paddy field and Mesostigmata ($P < 0.05$) in wheat field. Banvel-D did not cause any significant reduction in the abundance of total microarthropods or any of its groups.

The post-emergence herbicides like Stam, F-34 ; 2,4-D amine and 2,4-D sodium, though did not affect the microarthropods as a whole, reduced the number of Mesostigmata ($P < 0.02$) and Collembola ($P < 0.01$), significantly.

TABLE I

Density of different groups in treated and untreated plots

PADDY CROP					WHEAT CROP				
Herbicide	Groups	Density	tw-test	P	Herbicide	Groups	Density	tw-test	P
		U	T				U	T	
Tok, E-25 (Pre-emergence)	Microarthropods	98	71	0.553	Tok, E-25 (Pre-emergence)	Microarthropods	78	57	0.246
	Acari	61	50	0.273		Acari	67	45	0.257
	Prostigmata	19	15	0.300		Prostigmata	24	14	0.255
	Cryptostigmata	24	21	0.096		Cryptostigmata	4	4	0.114
	Mesostigmata	7	4	0.427		Mesostigmata	7	2	0.553
Stam F-34 (Post-emergence)	Collembola	17	6	0.727	Tok, E-25 (Pre-emergence)	Collembola	8	9	0.091
	Microarthropods	102	103	0.016		Microarthropods	106	103	0.064
	Acari	62	68	0.093		Acari	84	83	0.004
	Prostigmata	20	20	0.013		Prostigmata	36	37	0.025
	Cryptostigmata	24	28	0.123		Cryptostigmata	25	28	0.112
Banvel D (Pre-emergence)	Mesostigmata	7	3	0.633	Tok, E-25 (Pre-emergence)	Mesostigmata	10	14	0.389
	Collembola	17	7	0.889		Collembola	17	15	0.189
	Microarthropods	11	10	0.215		Microarthropods	17	18	0.036
	Acari	9	7	0.243		Acari	14	16	0.090
	Prostigmata	3	3	0.086		Prostigmata	8	5	0.375
	Cryptostigmata	1	1	0.018	Tok, E-25 (Pre-emergence)	Cryptostigmata	0.4	3	0.406
	Mesostigmata	-	-	-		Mesostigmata	2	5	0.186
	Collembola	1	1	0.333		Collembola	3	1	0.333

U - Untreated Plot T - Treated Plot

DISCUSSION

In the case of Tok, E-25 (Nitrofen), sprayed as pre-emergence herbicide in paddy field, Joy and Bhattacharya (1977) found that the microarthropods as a whole as well as total Acari in the 0-5 cms of soil decreased significantly in number 45 days

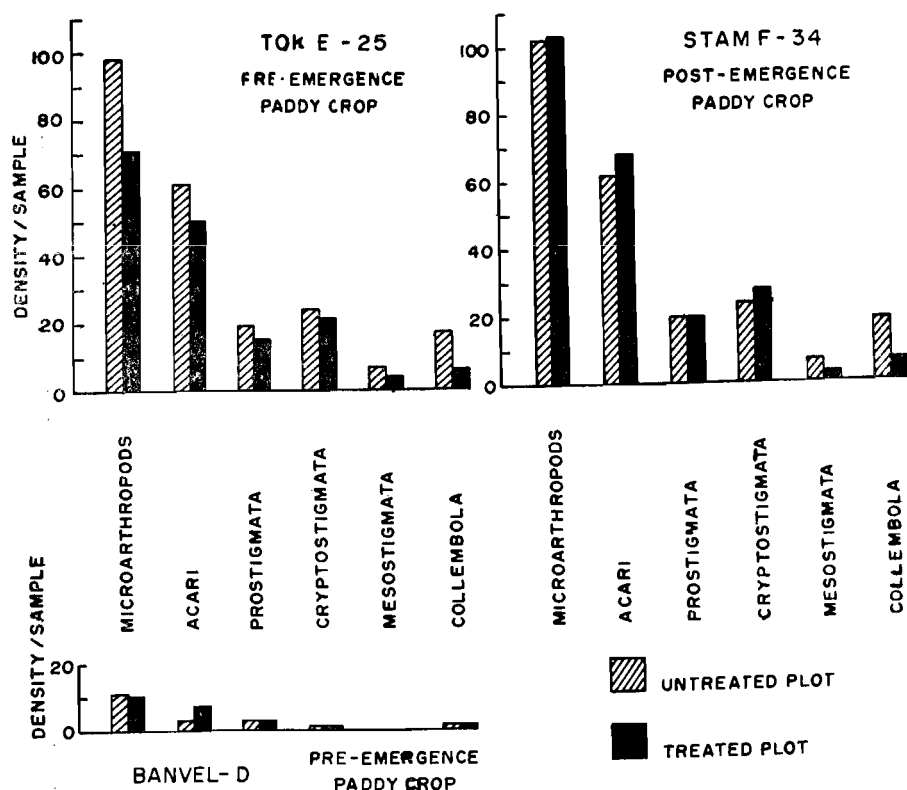


Fig. 1 Density of different groups in untreated and herbicide treated plots in paddy field

after the application, further analysis showed that among Acari, Mesostigmata and Prostigmata were the most affected groups and Cryptostigmata was the least affected group. However, 2 species of Cryptostigmata namely, *Daemeobelba* sp. and *Cosmochthonius emmae* were significantly reduced as a result of Tok, E-25 application (Bhattacharya and Joy, 1980). The present study also proves that Tok, E-25 has a serious ill effect on the microarthropods as a whole as well as on Collembola in the paddy field and on Mesostigmata in wheat field.

Banvel-D, another pre-emergence herbicide in paddy field, appeared to have no serious and lasting deleterious effect upon the microarthropods as a whole or any

of its groups (Bhattacharya and Joy, 1977a). The present inferences are also in agreement with the earlier one, proving that, Banvel-D as a pre-emergence herbicide has less serious ill effect compared to herbicides like Tok, E-25, upon the soil fauna.

Stam, F-34 (Propanil) used as a post-emergence herbicide in paddy crop has only a temporary repelling action on the microarthropods as a whole (Joy and Bhattacharya, 1977). Detail studies of the data proves that this chemical has no adverse effect on Acari as a whole, Prostigmata and Cryptostigmata. The only

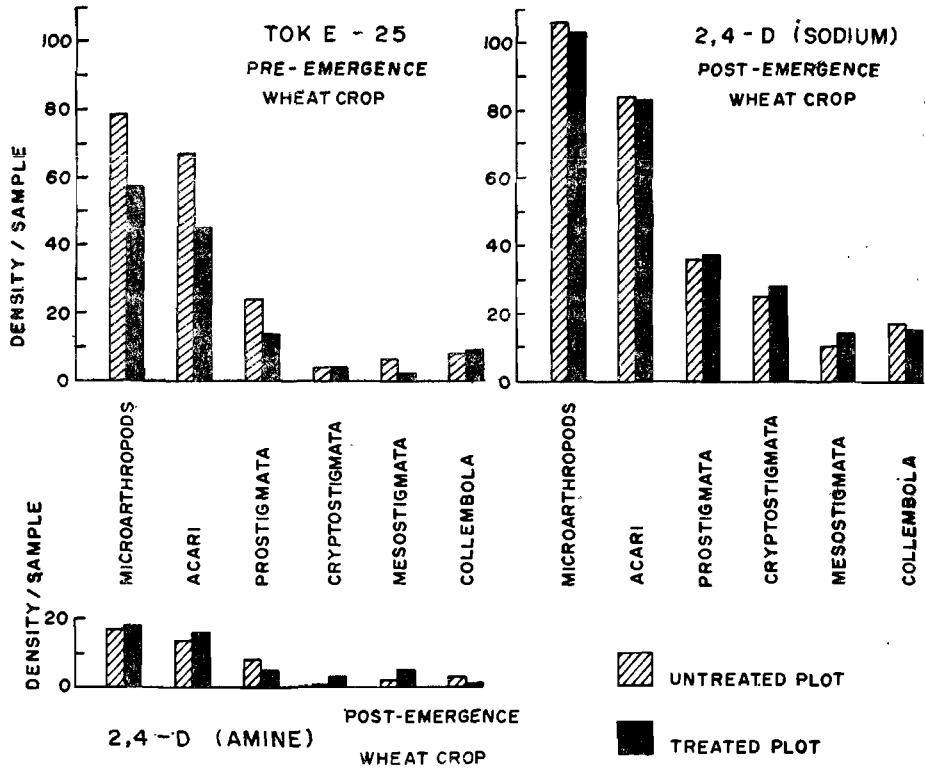


Fig. 2. Density of different groups in untreated and herbicide treated plots in wheat field.

affected group was Mesostigmata. Cryptostigmata increased in density during the period, mainly due to the increase in number of *Archegozetes longisetosus*, *Oppia* sp. and *Schelorbates albialatus* (Bhattacharya and Joy, 1980). The present analysis, however, shows that Stam, F-34 has an overall reducing effect on density of Mesostigmata and Collembola. The reason for the depletion in densities of these groups is a matter of further investigation.

The amine form of 2, 4-D applied as post-emergence in wheat field seems to have little adverse effect on the microarthropods as a whole and on its main groups except for Prostigmata, which decreased significantly during the period (Bhattacharya and Joy, 1977 b). The present study proves beyond doubt that both the amine and sodium forms of 2, 4-D has no significant ill effect upon the soil microarthropods and that these chemicals are relatively safer from the soil ecological point of view. Prasse (1975) has also showed that 2, 4-D does not have any serious effect on the soil invertebrates as a whole.

The herbicides under consideration in this communication except for Nitrofen does not pose any serious alarm to the non-target soil arthropod fauna and can be safely used for the control of weeds in the lowest, recommended agricultural doses. Further studies are however, needed for the assesment of the harmful effect of Nitrofen particularly at higher doses and repeated applications.

The authors are grateful to Prof. A. B. Das, Head, Department of Zoology and Prof. S. K. Mukhopadhyay, Principal, Agricultural College, Visva-Bharati for facilities. Thanks are also due to the CSIR for granting fellowship to VCJ.

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10.2 EFFECT OF ORGANIC AMENDMENTS ON THE DEGRADATION OF CARBOFURAN AND CHANGES IN SOIL MICROFLORA

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ABSTRACT

Persistence of insecticides in soil is influenced by various factors like temperature, moisture, organic matter, nutritional status of the soil etc. In a study on the influence of organic amendments like cattle manure, pig manure and poultry manure on the persistence and degradation of carbofuran and changes in soil microflora, it was found that although the rate of degradation was slow during the first two weeks, a rapid degradation was recorded at later stages. Almost all the quantity of insecticide applied got dissipated after 7th week. Rate of degradation was more in soil applied with pig manure (0.1 and 0.2 per cent).

The results on the changes in soil microflora revealed that there was an increase in bacterial, actinomycete and fungal populations in soils where cattle and pig manure were applied. However, in soils where poultry manure was applied an increase in bacterial and actinomycete population was observed only after second week of application and fungal population after fourth week.

10.3 EFFECT OF PESTICIDES ON NON-TARGET SOIL MICROORGANISMS

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ABSTRACT

The effect of several soil applied insecticides and herbicides on the metabolic activities of non-target soil bacteria viz., *Azotobacter chroococcum*, *Rhizobium* spp. and *Pseudomonas solanacearum*, were studied both under soil and *in vitro* conditions. The results indicate that, in general, the recommended and the higher levels of the pesticides adversely affected the growth, respiration, carbon and phosphorus metabolism of these bacteria. Some of the pesticides tested were also found to affect their beneficial/harmful functions adversely.

10.4 EVALUATION OF NEEM SEED CAKE AS A PROTECTANT AGAINST
SUBTERRANEAN TERMITES ATTACKING *EUCALYPTUS* SAPPLINGS

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ABSTRACT

Although neem seed cake is known to possess repellent effect against several insects, when mixed with soil it did not protect *Eucalyptus* saplings against termites attacking the roots.

10.5 STUDIES ON CHEMICAL CONTROL OF BLACK CUTWORM
AGROTIS IPSILON A SERIOUS PEST OF WHEAT AND GRAM
AROUND JABALPUR

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ABSTRACT

Field experiments on the chemical control of black cutworm *Agrotis ipsilon* were carried out at Kathonda (Dist. Jabalpur) during 1974-75, 1975-76, 1976-77 and 1977-78.

Aldrin, DDT and endosulfan dusts gave promising results in preliminary trials of 1974-75. In 1975-76, when infestation appeared late, 5 per cent dusts of aldrin, heptachlor and DDT and 4 per cent dust of endosulfan applied to soil at 40 kg/ha at sowing proved more effective. In 1976-77 suspension spray of DDT at 3 kg a.i./ha gave the best results. Granules of BHC 6 per cent, carbaryl 4 per cent, lindane 6 per cent and trichlorfon 5 per cent completely failed to protect the crop. In 1977-78 trials, emulsion spray of endrin and endosulfan at 1 kg ai/ha applied in soil in split doses, 1/2 kg 5 days before sowing and 1/2 kg at the time of sowing, proved highly effective and economical and afforded very good protection to the crop. Grain yield was significantly higher in both the treatments compared to control, BHC and phosphamidon.

BHC, phosphamidon and phosalone gave very poor results and failed to control the pest. Early sown crop suffered less damage compared to late sown crop. In most years the infestation of black cutworm originated in bare soil much before sowing which lead to serious damage to germinating crop.

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INTRODUCTION

Agrotis ipsilon (Hufnagel) (Lepidoptera : Noctuidae) popularly known as black cutworm or greasy cutworm, is a very destructive pest of gram, wheat, cotton, tobacco, potato and many other cultivated crops in India and abroad as well (Lefroy, 1904; Singh, 1949; Sen, 1952; Birat, 1968; Chaudhary, 1953; Thimmaiah *et al.*, 1972; Kamel & Shoeb, 1964 and Narayanan, 1954). Its distribution is peculiar, it appears in certain pockets only and is more destructive in areas where 'Haveli' cultivation is practiced. It has been reported to be a notorious pest of all *rabi* crops in tal areas of Bihar, U.P. and M.P. (Bindra *et al.*, 1970 and Singh and Sinha, 1965).

Singh and Gurnam (1961) observed aldrin emulsion spray to be the most effective and economical. Shrivastava and Khan (1962) reported better control of cutworms with soil and foliar applications of endrin, heptachlor and DDT than soil application alone. Nirula and Kumar (1963) found aldrin and heptachlor to be quite effective. Aldrin and heptachlor applied in split doses in potato crop, once at the sowing time and then 45 days after sowing gave significant protection to tubers from damage and proved more effective than DDT and chlordane (Abraham *et al.*, 1972). Dieldrin spray is reported to give good protection to cotton seedlings (Kamel & Shoeb, 1964).

The pest was observed to appear in large number in the same field year after year in the village Kathonda and other areas around Jabalpur (M.P.) causing extensive damage to gram and wheat during the seedling stages. In such endemic areas, cultivators reported failure of all methods, chemical or otherwise, to control this pest. Field studies were, therefore, undertaken in the village Kathonda during the years 1974-75 (preliminary), 1975-76, 1976-77 and 1977-78 to study the activity of the pest, and evaluate suitable methods to control the pest successfully.

MATERIAL AND METHODS

Experiments were laid out in a randomized block design with 3 replications in 1975-76 and 4 replications in 1976-77 and 1977-78 trials. In 1975-76, experiment was conducted with 8 treatments (Table I) in both wheat (variety - sarbati) and gram (deshi) crops. Both the crops were sown in each treatment plot 5m x 5m in size separately, dividing the area in two equal halves 5m x 2½m in size. Sowing was done on 12.12.75. Insecticides were applied at 40 kg/ha commercial formulation in furrows at the time of sowing. Observations were recorded 4 weeks after sowing because the pest appeared in the field much late. Sample size was ½ meter row length. Population counts of live larvae and healthy and damaged plants to

compute the percentage damage, were recorded from 8 random samples, four in wheat and four in gram, from each treatment plot.

Trials conducted during 1976-77 included 5 treatments (Table II) in wheat (variety-sarbati). Plot size was 10m x 3m and sowing was done on 30.11.76. Infestation started in the test plots much earlier, even before sowing and hence observations on pest incidence were recorded only one week after sowing. Immediately after first observation application of DDT suspension spray at 3 kg ai/ha was given uniformly in all the insecticidal treatment plots except control. Population of live as well as dead larvae was counted from four random samples per plot.

A separate field experiment was conducted to test the efficacy of soil application of granular insecticides. Experiment included four insecticidal treatments and four replications. Granules at 1 kg ai/ha were mixed with the required quantity of seed and applied at the time of sowing on 1.12.76.

In 1977-78 the experiment on wheat crop included 6 treatments (Table III). Plot size was 5m x 5m. Insecticides were applied in two stages, half dose applied 5 days before sowing and half applied at the time of sowing in furrows following the sowing on 3.1.77. Population of live larvae was recorded 2 weeks after sowing and plant population was observed 2 months after sowing from 4 random samples per replication. Sample size was $\frac{1}{2}$ meter row length for larval count and $\frac{1}{4}$ sq. meter ($\frac{1}{2}$ m x $\frac{1}{2}$ m) crop area for plant counts. Yield data were recorded at harvest time from the entire treatment plot of 25 sq. meter area per replication.

RESULTS

In preliminary trials of 1974-75 the dusts of methyl parathion (2 per cent) + DDT (7.5 per cent), aldrin (5 per cent) and endosulfan (4 per cent) applied at 25 to 30 kg/ha at the time of sowing gave very promising results. These results were not considered very reliable because of delayed observation, problem of migration of larvae etc., hence the details are not discussed here.

1975-76 trials

The analysis of data of both the crops viz., wheat and gram (Table I) show that aldrin, heptachlor, DDT, combination product of DDT + methyl parathion and endosulfan all proved much superior to control with significant reduction in both the larval population as well as percentage of plant damage in treated plots. All these insecticides proved equally effective with no significant difference among them. Ethyl parathion (2% dust) and phosalone (4% dust) were the least effective

insecticides with no significant difference between them and the control plots. During this trial the initial infestation started much late, about 4 weeks after sowing, and hence the damage was much less in experimental plots including control, contrary to the previous year.

TABLE I
Relative efficacy of various insecticides against black cutworm 1975-76

Treatments (@ 40 kg/ha. (all dust formulation)	Mean number of larvae per sample * (transformed $X + 0.5$)		Mean percentage of plants damaged (transformed-angular)	
	wheat	gram	wheat	gram
Aldrin 5%	0.70 a	0.87 a	2.64 a	19.61 ab
Heptachlor 5%	0.87 a	0.87 a	5.69 a	11.06 a
DDT 5%	0.99 ab	0.87 a	8.63 a	11.47 a
Combination of methyl parathion 1.5% + DDT 7.5%	0.87 a	1.09 a	4.60 a	24.32 ab
Endosulfan 4%	1.16 abc	0.87 a	4.99 a	10.84 a
Ethyl parathion 2%	1.55 bc	2.20 b	22.36 b	34.73 bc
Phosalone 4%	1.67 c	2.15 b	21.45 b	32.33 bc
Control (no treatment)	2.44 d	2.83 c	28.77 b	42.66 c
CD (P = 0.05)	0.60	0.62	10.98	15.45

* Means not followed by the same letter are significantly different at 5% level.

1976-77 trials

Results of first observations recorded one week after sowing as well as after application of insecticides (Table II) show that the plots treated with DDT (5 per cent dust) suspension spray and DDT spray alone had much less infestation compared to DDT (5 per cent dust) and aldrin although the differences were statistically non-significant. In the second observation made after one week of application of DDT spray, all the insecticidal treatments proved significantly better than control with no differences among themselves. Based on actual count of live as well as dead larvae, DDT suspension spray at 3 kg ai/ha proved most effective and economical. Grain yield in this treatment was 3.371 kg/plot compared to only 1.472 kg/plot in the control although the differences were non-significant at 5 per cent level.

Results of the experiment testing efficacy of granular insecticides showed that all the granular insecticides *viz.*, BHC (6 per cent), carbaryl (4 per cent), lindane

TABLE II
Relative efficacy of various insecticides against black cutworm—1976-77

Treatments with dose ai/ha	mean number of larvae per sample (transformed $\sqrt{X + 0.5}$)			mean yield in kg/plot (30 sq. meter)
	one week after I application	one week after II application		
		live larvae	dead larvae	
DDT 5% dust +				
DDT (WP) spray 1.5 kg each	5.75	2.00 a	1.90 a	3.935
DDT (WP) spray 3 kg	6.75	2.50 a	2.00 a	3.371
Aldrin 5% dust 1.5 kg	10.25	3.75 a	1.45 a	2.904
DDT 5% dust 1.5 kg	11.25	3.50 a	1.40 a	1.992
Control	11.75	8.75 b	0.70 b	1.472
CD (P = 0.05)	NS	3.31	0.63	NS

NS = Not significant

(6 per cent) and trichlorfon (5 per cent) completely failed to protect the crop. The incidence of pest was very high and uniform and the damage was 100 per cent in germinating crop 2 weeks after sowing in all the treatments including control.

1977-78 trials

Presowing application of insecticides 5 days before sowing yielded excellent results. Analysis of data (Table III) shows that during this trial in spite of presence of larvae in the field before sowing, the infestation in insecticidal treated plots was much low and the plant population was very high compared to that of 1976-77. Comparing relative toxicity of insecticides and existing plant population, endrin as well as endosulfan applied in furrows at 1 kg ai/ha split in two doses, $\frac{1}{2}$ kg 5 days before sowing and $\frac{1}{2}$ kg at the time of sowing, proved highly effective. Grain yield was significantly higher in both the treatments being 916 kg and 796 kg per hectare, respectively, compared to 160 kg/ha in control and 284 and 334 kg/ha in BHC and phosphamidon treated plots. Besides controlling the pest both these insecticides enhanced the crop growth and reduced the maturity period by 35 days. Crop in plots treated with endrin and endosulfan was harvested 35 days earlier compared to other treatments including control. DDT, which proved most effective in previous trials, failed to control the pest during this trial. This unexpected result raised a doubt about the purity of DDT (50 per cent W.P.) used for experiment. The chemical analysis proved the adulteration of the product. Phosphamidon and BHC (W.P.) both proved least effective insecticides and totally failed to protect the crop,

TABLE III

Relative efficacy of various insecticides against black cutworm—1977-78

Treatments with dose ai/ha** (all in spray form)	mean number of larvae/ sample (trans- formed $\sqrt{X + 0.5}$)	mean number of plants/ sq. meter (transformed $\sqrt{X + 1}$)	mean yield in kg per plot (25 sq.m)	yield kg/ha (computed)
Endrin 1 kg	1.13 a	20.97 a	2.29 a	916
Endosulfan 1 kg	1.92 ab	16.56 a	1.992 a	796
BHC (W.P.) 4 kg	2.85 bc	8.56 bc	0.718 bc	284
Phosphamidon 1 kg	3.38 c	6.43 bc	0.963 bc	384
DDT* 4 kg	3.88 c	6.24 bc	1.073 b	428
Control	3.87 c	4.31 c	0.401 c	160
CD (P=0.05)	1.08	3.55	0.6	—

Note : * DDT was found to be adulterated.

** Split in two doses ; half applied 5 days before sowing and the other half at the time of sowing.

DISCUSSION

The over all results of three years trials indicated that DDT, aldrin, heptachlor, endrin and endosulfan proved equally and highly effective insecticides against cutworm larvae. Superiority of aldrin, DDT and endosulfan over other insecticides was proved repeatedly in all the years of study. Spray formulations proved more effective than dusts. Aldrin and heptachlor have been found to be the most effective insecticides in potato crop by other workers also (Abraham *et al.*, 1972 ; Thimmaiah *et al.*, 1972 ; Nirula & Kumar, 1973). Soil and foliar application of endrin, DDT and heptachlor were recommended by Shrivastava and Khan (1962) on potato crop and by Popov (1965) on cotton.

BHC, phosphamidon, methyl parathion and phosalone proved useless and completely failed to control cutworm population and its damage to germinating crops of wheat and gram. Failure of BHC in reducing cutworm damage to potato crop has been reported earlier by Nirula (1961) also.

Considering the cost, persistence of insecticides in the environment and mammalian toxicity, endosulfan appears to be the best followed by DDT, aldrin and heptachlor. Endrin is highly effective insecticide but has a very high mammalian toxicity. Although DDT is highly persistent, its use could be recommended in

smaller areas where pest problem is chronic and acute. To avoid the problem of development of insecticidal resistance it is desirable to use endosulfan, DDT, heptachlor or aldrin in rotation.

For successful control of the pest the time of sowing and application of insecticides are most important. Our field observation in infested area made during last 5 years revealed that under 'Haveli' cultivation, in most of the years the infestation originated in the field before sowing as soon as the flood water receded and fields were ready for *rabi* sowing. Second and third instar larvae were seen in bare soil where absolutely no green vegetation was available. They grew just on organic matter of the soil only. Successful rearing of few of the larvae in the laboratory, fed only on organic matter collected from field, confirmed this behavior. When sowing was done in late November or December the hungry larvae, already present in the soil, started feeding on the most favoured germinating sprouts of the seed and damaged extensively the germinating crop. Damage was near absolute in the experimental plots in the years 1973-74, 74-75 and 76-77 when sowing was done relatively late. Early sown crop suffered less damage compared to late sown crop in the same area.

In 1975-76 the infestation originated in the field nearly 3 weeks after germination and hence the crop in treated as well as untreated control plots escaped much of the damage. The crop stand was very good. Taking a note of this behaviour, for successful control of the pest and protection of crop, the presowing treatment of soil after ploughing, was considered essential. In 1977-78 trials, the insecticide doses were split in two, half dose applied in soil 5 days before sowing and remaining half applied at the time of sowing in furrows. This yielded excellent results. The larval population was very low and the plant stand was very good in the best treatment plots compared to 1976-77 and 1974-75 trials.

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10.6

TURMERIC POWDER AS AN ANT REPELLENT

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ABSTRACT

In order to study an effective method to tackle the ant problems in dwellings, a preliminary study was undertaken at Dharwad, with different forms of turmeric as a repellent to the ants in dwelling houses. Freshly ground turmeric powder was found to be very effective in repelling the domestic ants.

INTRODUCTION

Ants infesting the houses affect man adversely by feeding on foods, causing structural damage by their nesting activities, killing young poultry birds etc. The species of ants encountered in dwelling houses, especially in the kitchen, during the present studies were *Monomorium* sp. *Solenopsis geminata* (F.), *Tapinoma* sp. and occasionally *Camponotus compressus* Fabr. *S. geminata* was the most persistent and annoying of these found nesting within the vicinity of dwelling houses and nearby trees.

Turmeric (*Curcuma longa* L.) has characteristic pepper like odour and is slightly aromatic, because of its characteristic odour it possesses the repellent action. It consists of monocyclic, hydro-aromatic ketone. Pillai and Desai (1978) used turmeric and its extracts for the control of root knot nematodes. In the present study turmeric in different forms was used as an ant repellent in dwelling houses and the findings are presented in this paper.

MATERIAL AND METHODS

Five houses in Saptapar and two houses at Narayanpur of Dharwad were selected. The ant problem was serious during January - February 1979. The surroundings of these houses consisted of open places, gardens planted with rose, croton, bougenvillea, jasmine, grass, sapota, coconut and tamarind. In some, plants like papaya, citrus and some ornamental succulents were also grown. The ant species predominantly encountered in the houses were *Camponotus compressus* Fabr., *Monomorium* sp., *Solenopsis geminata* (Fabr.) and *Tapinoma* sp.

The distribution of the ant species in the surroundings was more or less uniform, except for the presence of *Camponotus* in Narayanpur area.

The repellent, turmeric was used in three forms : (1) fine turmeric powder from freshly dried, powdered roots (2) commercially available packed turmeric powder and (3) the turmeric cream, which is sold as 'Viccoturmeric Vanishing Cream'. The products one and two were applied as powder each day, near the entry holes of dwelling houses where the ant species were found gaining entry into houses. Daily observations were made to know whether the ants involved had crossed the band and whether they were repelled from the site of application of the products. Observations were recorded continuously for one week, every morning.

RESULTS AND DISCUSSION

The observations revealed that the freshly powdered turmeric powder was more effective in repelling the ants at the site of application, followed by the commercial packed powder. The trails of the ants were disturbed in the first instance upto two hours after application, later the ants started their trail formation. In the case of cream, even after the application as a band, the ants were observed to form the trail. The average observed data for 7 days is presented in the Table I. All forms of turmeric were not effective on *Camponotus compressus*. Freshly powdered turmeric, was quite effective in repelling the *Monomorium* sp. *S. geminata* and *Tapinoma* sp. The trails were completely absent immediately after the application of the

TABLE I
Effect of different forms of turmeric as ant repellents

Ant species	Forms of turmeric		
	Freshly powdered turmeric	Commercial packed powder	Cream
<i>Camponotus compressus</i>	0	0	0
<i>Monomorium</i> sp.	**	§	*
<i>Solenopsis geminata</i>	**	§	*
<i>Tapinoma</i> sp.	**	§	*

0 In this case only foraging workers in small numbers were observed to move freely, without any effect of the turmeric repellent.

§ Trails were formed two hours after application.

* Trails were formed immediately.

** The trails were completely absent, immediately after the application of turmeric repellent and the same effect was maintained for 12 hours.

repellent and up to 12 hours. In case of commercial powder, initially it was effective and the trails were formed two hours after the application of the powder. Further, the effect of single application of the different forms of turmeric could not be observed for more days, as the powder did not last for more than a day due to many factors. The trials need further confirmation.

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10.7 CHEMICAL CONTROL OF BANANA RHIZOME WEEVIL *COSMOPOLITES SORDIDUS* USING GRANULAR SOIL INSECTICIDES*

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ABSTRACT

An experiment was carried out to evaluate four granular soil insecticides for their efficacy in the control of banana rhizome weevil, *Cosmopolites sordidus*. The insecticides, carbofuran, disulfoton, phorate and quinalphos were tried at 1 gm a.i. per plant. Phorate was superior followed by carbofuran, disulfoton and quinalphos in controlling immature stages. Phorate was effective even in controlling adults, this was followed by carbofuran, quinalphos and disulfoton.

INTRODUCTION

Banana (*Musa paradisiaca* Linn.) is an important fruit crop of tropical and subtropical regions. Of the several insects reported on this crop, the rhizome weevil, *Cosmopolites sordidus* (Germar) is a cosmopolitan and destructive pest inflicting damage every year.

Extensive information is available on the chemical control of this pest using insecticides. Roberts (1958) reported that an aerial application of granular dieldrin gave some control. Bullock and Evers (1962) tested 10 per cent granules of aldrin, dieldrin and heptachlor at the rate of 2 lb. a.i. per acre (1.12 oz per mat) and noticed that dieldrin was superior to the other two insecticides. Wolfenberger (1965) reported the superiority of granular formulations viz., aldrin, dieldrin and heptachlor over emulsions of the same in the control of the banana rhizome weevil. Terracur P 10 per cent granules at the rate of 30 g per plant on clean soil controlled banana borer effectively (Anonymous, 1969).

Gaud *et al.* (1975) tested keepone 5D, diazinon 14 G, dieldrin 15 EC, dasanite 15 Gr, disulfoton 10G, Iannate 90S, carbaryl (sevin 30 WP, 80 WP), parathion 15 WP, carbofuran 10G and found that dieldrin 15 EC at 5 ml, carbofuran 10 G at 10 gm, dasanite 15 G at 14 gm and kepone 5 D at 2 oz per plant were most effective.

*Part of the Ph.D. thesis submitted by the first author to the University of Agricultural Sciences, Bangalore.

MATERIAL AND METHODS

All the insecticides (Phorate 10G, furadon 3G, disulfoton 5G, quinalphos 5G) were tested with a single dose. A completely randomized design with five treatments and six replications was followed for this experiment. Banana suckers (cv. Budubale, group AAB) were planted in cement cisterns. Twenty five adult weevils were released to each cistern, at the time of planting. All agronomic practices were uniform for all cisterns.

The granular insecticides were applied one month after planting around the base of the plant and mixed with soil followed by watering. One month after the application of the insecticides, the plants were uprooted and the number of surviving grubs, pupae and adults were recorded in addition to the visual symptoms like marginal drying of leaves, dead hearts etc.

RESULTS AND DISCUSSION

Among the insecticidal treatments phorate showed significantly less number (3.33) of immature stages as compared to disulfoton (7.83) at 5 per cent level of significance and quinalphos (11.33) at both the levels of significance. Carbofuran (4.33) showed significantly less number of immature stages as compared to quinalphos at both levels of significance. There was no significant difference between phorate and carbofuran, carbofuran and disulfoton and disulfoton and quinalphos. All these were significantly less than check (23.50) (Table I, Fig. 1)

TABLE I

Number of immature stages and adults recovered in different insecticidal treatments after 30 days

Treatment	Dosage a.i./plant (g)	Amount of insecticide per plant (g)	Mean no. of immature stages recovered	Mean no. of adults recovered
Carbofuron (Furadon 3G)	1.0	33.00	4.33	2.67
Disulfoton (Disyston 5G)	1.0	20.00	7.83	15.33
Phorate (Thimet 10G)	1.0	10.00	3.33	1.83
Quinalphos (Ekalux 5G)	1.0	20.00	11.33	3.33
No treatment (Check)	—	—	23.50	20.67
S.E.	—	—	0.239	0.985
C.D. at 5%	—	—	0.56	2.05
C.D. at 1%	—	—	0.74	2.80

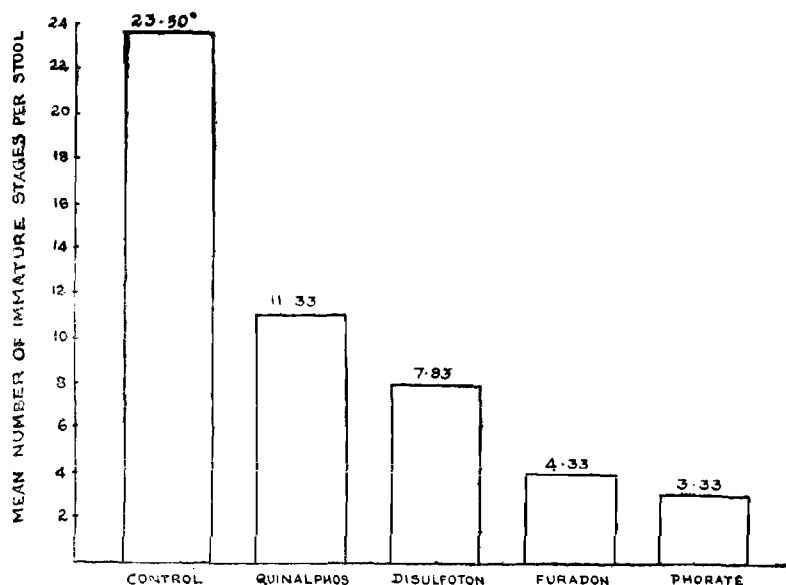


Fig. 1. Effect of granular insecticides on the immature stages of *Cosmopolites sordidus*

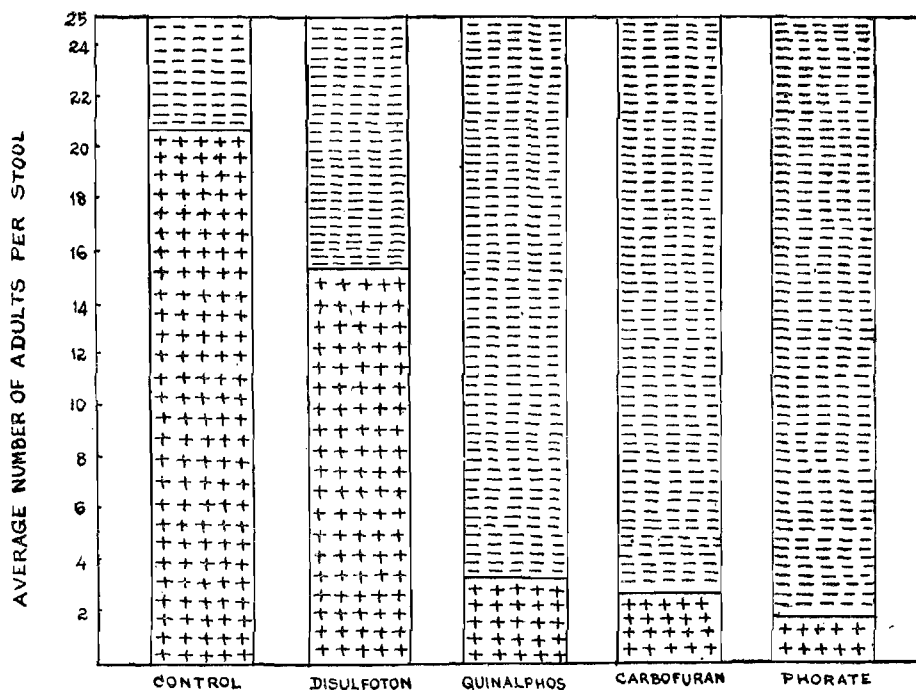


Fig. 2. Effect of granular soil insecticides on adults of *Cosmopolites sordidus*

The number of adults recovered in all the insecticidal treatments were significantly less as compared to untreated control (20.67). The number of adults recovered from plants treated with phorate (1.83) ; carbofuran (2.67) ; and quinalphos (3.33) were significantly less as compared to that of the plants treated with disulfoton (15.33), there being no significant difference among them (Table I, Fig. 2).

The effectiveness of carbofuran 10 G (10 gm/plant) and disulfoton 10 G (14 gm/plant) have been studied along with the other insecticides by Gaud *et al.*, (1975), who reported the superiority of carbofuran over other insecticides, which is confirmed in the present studies also but being superceded by phorate. Incidentally phorate and quinalphos have been tested for the first time in the present investigations against banana rhizome weevil.

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EVALUATION OF INSECTICIDES AGAINST WHITE GRUB, *HOLOTRICHIA SERRATA* IN SUGARCANE

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ABSTRACT

In all, nine granules at different doses and three dusts were applied at planting. The germination count after planting was found to be maximum (62.62 per cent) in fensulfothion G. at 3 kg a.i./ha at 6 weeks and 64.92 per cent in carbofuran G. at 3 kg a.i./ha at 8 weeks. All the treated plots showed higher germination than the untreated (control) plot. The treatment with disulfoton G. and carbofuran G. at 3 kg a.i./ha and quinalphos G. at 2 kg a.i./ha had no dead canes due to white grub attack at 8 and 12 weeks after planting while untreated plot had 32.65 per cent and 54.36 per cent dead canes in the respective weeks. At harvest, more millable canes per hectare were obtained in quinalphos G. at 2 kg a.i./ha (85802), disulfoton G. at 3 kg a.i./ha (84321) and fensulfothion G. at 3 kg a.i./ha (76266) as against 25308 in untreated control. The treatments with quinalphos G. at 2 kg a.i./ha and fensulfothion 4.3 kg a.i./ha gave higher yields of 88.63 and 82.53 MT/ha, respectively, as against 16.91 MT/ha in untreated control.

INTRODUCTION

Sugarcane crop is affected by a number of pests throughout the growth period, causing notable damage, resulting in loss of sugarcane and sugar yield (Hapase, 1978). The white grub *Holotrichia serrata* F. attacks sugarcane severely and complete loss of fields has been observed in some endemic pockets of Maharashtra State. During the months of July to October, activity of the pest is predominant and thus the *adsali* planted canes are more susceptible than those of *suru* planted. An attempt was made to test the efficacy of some newer insecticides and the presently recommended (Anonymous, 1977) and widely used BHC dust against the white grub in Maharashtra State.

MATERIAL AND METHODS

The field experiment with twelve insecticides (Table I) replicated three times in R.B.D., was laid out at Sugarcane Research Station, Padegaon on Co. 740 variety of sugarcane planted in *adsali* season of 1977-79. The insecticides were directly applied only once, in furrows, at the time of planting and thoroughly mixed with soil. The plot size was 9 x 5 m with row spacing of 100 cm. All the recommended agronomical practices were followed.

The known number of setts with three eye buds were planted in all the treatments. The observations on germination and dead canes at 6 and 8 weeks, grub population by digging soil of one meter row length at 8 weeks after planting and number of millable canes and yield at harvest were recorded. The data were analysed statistically.

RESULTS AND DISCUSSION

All the insecticidal treatments had a boosting effect on germination (Table I) and all were significantly superior over the control. Six and eight weeks after

TABLE I
Mean per cent germination, per cent dead canes and grub population

Sl. No.	Treatment	Dose in kg ai/ha	Weeks after planting				
			6	8	8	12	8
1.	Fensulfothion (5 G)	3	62.62	63.35	1.56	0.42	1.66
2.	Fensulfothion (5 G)	2	50.79	54.76	3.78	0.96	2.00
3.	Disulfoton (5 G)	3	51.43	54.76	0.00	0.00	2.00
4.	Disulfoton (5 G)	2	51.42	54.13	3.23	1.13	4.00
5.	Carbofuran (3 G)	3	61.11	64.92	0.14	0.24	2.00
6.	Carbofuran (3 G)	2	53.33	57.30	0.00	0.00	3.66
7.	Aldicarb (10 G)	3	50.63	56.03	2.76	3.35	4.33
8.	Aldicarb (10 G)	2	45.24	49.68	9.32	11.39	3.00
9.	Quinalphos (5 G)	3	53.97	58.41	0.44	0.00	1.66
10.	Quinalphos (5 G)	2	56.82	60.00	0.35	0.00	1.00
11.	Phorate (10 G)	3	58.57	62.06	0.37	0.00	0.00
12.	Phorate (10 G)	2	56.03	60.16	0.92	0.00	0.33
13.	Lindane (6 G)	3	47.78	51.43	7.37	12.67	4.33
14.	Lindane (6 G)	2	56.44	58.41	1.42	0.00	4.66
15.	Phenthoate (5 G)	2	50.95	55.23	1.54	1.64	1.33
16.	Cytrolane (5 G)	2	55.55	59.68	0.51	0.00	1.00
17.	B H C (10 % dust)	12.5	54.28	53.09	4.50	1.13	2.66
18.	Heptachlor (5 % dust)	6.25	46.19	49.04	5.48	2.73	3.33
19.	Carbaryl (10 % dust)	12.5	51.27	53.65	0.24	0.81	3.66
20.	Untreated (Control)		34.76	20.00	32.65	54.36	7.33
S. E. $\pm$				2.06*	1.39*	1.54*	4.47*
C. D. at 5%				5.88	3.98	4.41	12.78
							3.42

* Statistical analysis based on transformed values.

planting the treatments with fensulfothion and carbofuran at 3 kg a.i./ha gave the maximum germination while the lowest was recorded in untreated plot. These findings are in conformity with those of Patil *et al.*, (1977, 1978) and Moholkar *et al.*, (1977).

The numbers of dead canes recorded 8 and 12 weeks after planting in all the insecticide treated plots were significantly less than in untreated control. Less than 1 per cent dead canes were noticed in the treatments with carbofuran at 3 kg ; quinalphos and phorate at 2 and 3 kg ; cytolane at 2 kg and carbaryl at 12.5 kg a.i./ha at 8 weeks and fensulfothion at 2 and 3 kg; carbofuran at 3 kg and carbaryl at 12.5 kg a.i./ha at 12 weeks after planting. Maximum of 32.65 per cent and 54.36 per cent dead canes were recorded in the untreated plot at 8 and 12 weeks after planting, respectively.

The maximum (7.33) grub population per m² was recorded in untreated plot as against (0) number of grubs in the treatment with phorate at 3 kg a.i./ha. All the insecticidal treatments except disulfoton at 2 kg, aldicarb at 3 kg and lindane at 3 kg and 2 kg a.i./ha were significantly superior in keeping the grub population at low level. David and Ananthanarayana (1975) ; Veeresh *et al.* (1976) and Veeresh (1977) also observed the reduction in grub population in the plots treated with fensulfothion and quinalphos at 5 kg a.i./ha and phorate, quinalphos and carbofuran at 1 kg a.i./acre.

As regards millable canes (Table II) at harvest all the treatments were significantly superior to untreated control except the treatment with aldicarb 2 kg and lindane at 3 kg a.i./ha. The treatment with quinalphos at 2 kg a.i./ha yielded the highest number (85802) of millable canes/ha followed by disulfoton at 3 kg a.i./ha (84321) and cytolane 2 kg a.i./ha (82222) as against the minimum number (25308) recorded in untreated plot.

The markedly higher yield of sugarcane obtained in plots treated with systemic insecticides, during the present investigation, is in conformity with reports of David and Ananthanarayana (1975), David *et al.* (1976), Patil *et al.* (1978) and Hapase (1978).

In respect of Insecticidal Cost Benefit Ratio (Table II) it was observed that BHC 10 per cent dust accrued maximum (11.17) return per rupee invested on insecticides followed by lindane (10.85), quinalphos (10.20) and phorate (9.90) at 2 kg and heptachlor 5 per cent dust (8.87) at 6 25 kg a.i./ha. It is also clear that though most of the granular insecticides controlled the grub satisfactorily resulting in more yield and more profit, the amount required to be invested in purchase of these insecticides was high.

TABLE II

Millable canes and yield at harvest with economics of the insecticidal trial

Treat- ment	Total millable canes/ha	Yield MT/ha	Additional yield over control MT/ha	Additional Income Rs/ha	Cost of insect- icide Rs/ha	ICBR **	
						Profit Rs. (5·6)	Return per rupee invested
		At harvest					
1.	76266	82.58	65.67	6567	1608	4959	3.08
2.	60741	49.74	32.83	3283	1072	2211	2.06
3.	84321	76.66	59.75	5975	810	5165	6.38
4.	73951	51.97	35.06	3506	540	2966	5.49
5.	69383	71.35	54.44	5444	1600	3844	2.40
6.	74321	71.35	54.44	5444	1067	4378	4.02
7.	56173	55.42	38.51	3851	870	2981	3.42
8.	48889	37.52	20.61	2061	580	1481	2.55
9.	77531	73.20	56.29	5629	960	4669	4.86
10.	85802	88.63	71.72	7172	640	6532	10.20
11.	74444	64.93	48.02	4802	615	4187	6.80
12.	73704	61.60	44.69	4469	410	4059	9.90
13.	33704	31.84	14.93	1493	450	1043	2.31
14.	74815	52.46	35.55	3555	300	3255	10.85
15.	74321	56.91	40.00	4000	N.A.	—	—
16.	82222	71.47	54.56	5456	N.A.	—	—
17.	66296	33.70	16.79	1679	138	1542	11.17
18.	65803	65.30	48.39	4839	500	4439	8.87
19.	62716	47.86	30.95	3095	475	2620	5.31
20.	25308	16.91	—	—	—	—	—
S. E. $\pm$	9221	10.35					
C.D. at 5%	26350	29.59					

* Price of cane Rs.100/- per ton.

** ICBR – Insecticidal Cost Benefit Ratio.

N. A. – Not available.

Note : The yields are low due to very light soil with low fertility.

ticides was much more than that of BHC 10 per cent dust. Besides, the returns per rupee invested on granular insecticides were much less as compared to BHC dust, the presently recommended insecticide against white grubs in Maharashtra State.

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10.9

SOIL FAUNA AND INSECTICIDE INTERACTIONS

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ABSTRACT

The soil environment is a medium of complex interactions between its physical/chemical components and its biomass. The introduction of pesticides initiate a series of interactions which may be divided into two groups - (i) effects of pesticides on the soil fauna and (ii) fate of pesticides in soil. The soil fauna plays an important role in making dead plants available for further fungal and bacterial breakdown. In general, the organochlorines have an adverse effect on carabids, staphylinids, millipedes and to some extent nematodes. On the other hand microarthropods and earthworms are not affected by compounds like DDT. Organophosphates and carbamates affect beetle, millipede, earthworm and nematode population. The net influence of insecticides on soil biota is linked with their persistence in soil, which in turn is dependent on a number of important physical, chemical and biological factors. The interactions between insecticides and the living organisms involve many interlinked steps like penetration, metabolism, attack on target site, storage and excretion.

We are living in an age of technological advancement, with its associated shares of boons and horrors. There is a growing concern about potential health hazards facing the general population centered around the ever increasing use of chemicals for controlling pests in agriculture and public health. Today the subject of pesticide ecology encompasses the study on the side effects of pesticides on the three environmental components (*viz.*, air, land and soil) for in many cases, populations of organisms performing important basic ecological processes are at risk.

When used for normal crop protection purposes, pesticides are likely to contaminate soil, either during application or indirectly through incorporation of sprayed vegetation when crop debris is ploughed in. Here the contaminant may disturb important soil processes (necessary to continued soil fertility such as nutrient cycling and nitrogen fixation). These processes are carried out by a complex assemblage of microorganisms and animal populations, the equilibrium of which can be easily disturbed by the pesticides.

Under normal cropping practice, after settling on the crop and loss to the atmosphere by volatilization following pesticide application quite a good percentage of the pesticide reaches the soil. The resulting complex interactions, for convenience may be grouped as effect of pesticides on the soil fauna and fate of pesticides in soil.

The soil fauna is represented by micro and macroarthropods, nematodes, molluscs and annelids. These also include some of the important soil pests which are responsible for extensive losses to a wide variety of field crops, forest timber, buildings, stores, textiles, paper and leather. Important examples of soil insect pests are – termites, cutworms, cockchafers, wireworms; root, root-knot, stem and bulb and leaf and bud nematodes. Some of the widely used and effective soil insecticides include BHC (correctly renamed as HCH), DDT, chlordane, dieldrin, aldrin, parathion, methyl-parathion, fenitrothion, thionazin, diazinon, trichlorfon, systox, nematicur, disulfoton, phorate (Brown, 1978).

Going back to the problem of total effect of pesticides on various ecosystems we drew up a long-range programme. In the first phase emphasis was laid on a few selected biochemical effects of widely used representative organochlorines (OC), organophosphates (OP) and carbamates on insects and invertebrates on one hand, birds and mammals on the other. We have started the second phase of our programme on the effects of a few selected insecticides on the soil fauna which includes earthworms, millipedes, centipedes, coleopterans (carabids, staphylinids and white grubs), ants and nematodes.

We have initiated the laboratory studies on acute toxicity to earthworms, millipedes and crickets. The insecticides chosen are - DDT, *r*HCH, fenitrothion, quinalphos and carbaryl. Dose administration is made *via* topical application and preoral intubation. After single exposure, readings are taken at 24 hrs. From our preliminary experiments it appears that earthworms are less susceptible to DDT and *r*HCH than to quinalphos or carbaryl. As for crickets we have worked with quinalphos and on the basis of results obtained so far, crickets have been found to be far more susceptible than millipedes. However we are continuing work on these aspects and it will take quite some time before we can draw some meaningful correlations or inferences. We have also drawn up a plan of work to correlate the effect of insecticides on earthworms in the laboratory and in grassland.

The future field experimental design is intended to compare pesticide free soil with soil that has been contaminated with insecticide in the same manner as in normal agricultural practice. To provide the basis for these comparisons the following treatments are maintained :

1) Fallow land	3) Cultivated and treated with insecticides, each growing season
2) Cultivated and untreated with insecticides.	4) Cultivated and treated in alternate growing season to provide contaminated situation in the unsprayed season.

Although the microflora is responsible for about 90 per cent of the biological respiration activity in the soil, the microarthropods in conjunction with earthworms, play an important part in breaking down dead plant material and making it more available for bacterial and fungal breakdown (Phillipson, 1966). The principal predators in the soil are the carabid beetles, whereas, staphylinids are also important carnivores. Ants and cicindellid tiger beetles also play a part in predation in soil.

The overall effect of organochlorines (OC) applied to cropland is a net reduction in the carabid and staphylinid population and a change in species composition. Some of the organophosphate (OP) and carbamate compounds like parathion, phorate, disulfoton and carbaryl reduce beetle population. Populations of soil collembola and mites in general are not reduced by DDT, until the application rate is high (Hartenstein, 1960). Cyclodienes which are widely employed against wireworms, root worms and root maggots, in contrast to DDT reduce collembola and predaceous mites (Edwards, 1969; Fox, 1967). Non-persistent soil insecticides such as OP and carbamate compounds slow the rate of litter breakdown through their suppressive effect on collembola and saprophagous mites (Way and Scope, 1968; Barlet, 1968). Among other soil arthropods the millipedes are the most abundant of the myriapods in damp soil and constitute an important element of the

invertebrate biomass in soils. Repeated application of OCs like DDT, aldrin, dieldrin reduce the millipede population (Edwards, 1965) OPs like parathion and diazinon have been found to be toxic but others like fenitrothion, thionazin are harmless (Edwards and Gunn, 1961). Carbaryl has been found to cause almost 75 per cent reduction in millipede numbers (Voronova, 1968). In general earthworms are not adversely affected by OCs like DDT, lindane, aldrin (except chlordane). Thus they accumulate large quantities of OCs in their tissues (like gizzard and crop) (Brown, 1978). OPs now available as soil insecticides have little lasting effect on earthworm populations, although a few e.g. phorate and fensulfothion cause heavy initial kills. These compounds are not concentrated in earthworm tissues (Brown, 1978), carbamates on the other hand are quite toxic to earthworms (Voronova, 1968). Nematodes are susceptible only to certain OCs (e.g. lindane). In general OPs and carbamates decrease nematode population (Brown, 1978).

The spectrum of sensitivity/tolerance of various groups of animals to insecticides is quite complicated. Several steps can be distinguished, uptake (penetration into organism), translocation, activation, inactivation (activative and degradative metabolism), penetration to target site, storage and excretion (Sen Gupta and Mukherjee, 1978). The eventual effect exerted by a certain quantity of a toxic compounds depends on the intrinsic reactivity at the target site and on its concentration as a function of time at the target site. All these form parts of a dynamic system where some steps are consecutive and some simultaneous e.g. some OPs like the thiophosphates have to be activated before they can reach the target. Thus insects having efficient activating enzymes will be comparatively less susceptible to a particular compound by virtue of gaining more time for the degrading enzymes to interact.

Finally, the influence of insecticides on the soil fauna is linked with their persistence characteristics. As anticipated, the OCs are the most persistent followed by various groups of herbicides. In contrast OPs and carbamates do not persist for long in most soils. The persistence of a pesticide in soil is determined by a number of processes which can be grouped under three sub-divisions physical, biological and chemical (Kearney and Helling, 1969).

So we can visualise the complexity of soil fauna and insecticide interactions which are governed by intrinsic and extrinsic factors. These eventually go a long way to make an insecticidal compound effective against target species as well as safe for the environment.

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Original not seen.

10 10 TOXICITY OF CERTAIN GRANULAR INSECTICIDES TO EARTHWORMS

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ABSTRACT

Earthworms constitute one of the important macroforms of life in cultivated soil. They are often subjected to the harmful effects of pesticides especially when these chemicals are applied direct into the soil. Present study deals with the effect of certain granular insecticidal formulations, both systemic and non-systemic, on the toxicity to these worms when applied at their recommended dosages. Experiments are also aimed at estimating the pick up of these pesticides by the worms at various periods of time and moisture levels. Results indicate carbofuran to be the most toxic compound to the worms.

10.11 EFFECT OF SEVIN (CARBARYL) ON ACTIVITIES OF EARTHWORM *PONTOSCOLEX CORETHRURUS*

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ABSTRACT

Carbamates in recent years have found their place as general insecticides for their toxicity towards insects, and for being non-toxic to various other animals, especially to higher vertebrates. However, the literature indicates the possible toxicity produced by carbaryl and carbofuran on earthworm populations. In the present set up, earthworms, *Pontoscolex corethrurus*, were exposed to different concentrations of Sevin in culture pots for a period of 4 weeks to observe the response rendered by the worms for this insecticide. As such *Pontoscolex corethrurus* has greater degree of tolerance when compared to other worms discussed in earlier findings.

The Sevin concentrations in soils used for experimentation ranged from 0-375 ppm. The pesticide concentration in soil manifested reduction in number of worms, the loss of weight in surviving ones. The relationship established a curvilinear function. The concentration of Sevin up to 75 ppm favoured the worms to gain some weight. The amount of worm casts, the number of cocoons recovered in the jars with 37-75 ppm Sevin were more than those of the control. The increase in weight of the worms, feeding rate of worms and higher rate of fecundity observed at lower concentration indicated that the pesticide in these concentration ranges favoured earthworm populations. Over 100 ppm the worms lost mobility, reduced the feeding rate resulting in loss of weight, and ceased cocoon laying. This indicates that chronic contact with the pesticide, perhaps by repeated applications may bring forth irreversible changes in the worm populations in the soil.

10.12 CHEMICAL CONTROL OF BANANA NEMATODES

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ABSTRACT

An attempt is made here to evaluate the efficiency of different nematicides for the control of banana nematodes. The nematicides tried were the following: Dasanit, Temik, Furadan, Thimet, Nema-cur and neemcake, at 2 grams of a.i./plant. Before planting soil samples were taken from each treatment to assess the population. First application of nematicides was done at the time of planting, the second was repeated 4 months after planting. Before second application, the soil and root samples were collected and the nematode population was assessed. Final

nematode assay was done four months after the second application. The efficiency of different nematicides was evaluated by the population of nematodes and bunch weight in various treatments. From the counts of the nematode population in the root samples of various treatments, it was revealed that there was significant difference between the population in treated plots and control plots. The bunch weight of the treated plots were significantly superior to control. Maximum bunch weight was obtained in the plots treated with Nemacur followed by Temik and Dasanit.

INTRODUCTION

The plant parasitic nematodes have now assumed importance as a pest of banana. The nematodes feed by puncturing individual root cells with the stylet, injecting a digestive secretion from the oesophageal glands and sucking out the liquified cell contents. The first visible symptom of the attack is a small dark spot on the root. Later, these lesions enlarge and spread through the cortex. As a result of the attack, the number of fruits in the bunch gets reduced and individual fruits often become smaller in size. Affected plants fail to give expected response to fertilizers, irrigation and other cultural practices. Nair *et al.*, (1966) recorded the presence of parasitic nematodes in banana plants and soils of Kerala. The present study was undertaken with a view to evaluate the efficiency of different nematicides for the control of banana nematodes.

MATERIAL AND METHODS

A field experiment was conducted during 1976-77 at the Banana Research Station, Kannara, Trichur for evaluating the nematocidal efficiency of different materials and assessing their effect on banana yield. There were altogether seven treatments laid out in RBD with four replications. The variety used in the trial was Nendran. The treatments were as follows :

1. Dasanit (fensulphotion)	- 2 g of a.i./plant
2. Temik (aldicarb)	- 2 g of a.i./plant
3. Furadan-3 (carbofuran)	- 2 g of a.i./plant
4. Thimet (phorate)	- 2 g of a.i./plant
5. Nemacur (phenamiphos)	- 2 g of a.i./plant
6. Neemcake	- 400 g/plant
7. Control	- Untreated

Before planting, soil samples were taken from each plot to assess the initial population of nematodes. First application of nematicides was done at the time of planting. A second application was done 4 months after planting the banana

suckers. Prior to the second application and 4 months after it, soil and root samples were collected for assessing the nematode population. Decrease in the nematode counts and increase in yield following the nematicide application were considered for evaluating the efficiency of the treatments.

The total as well as species-wise population of nematodes on banana roots at different stages of plant growth are presented in Table I. *Radopholus similis* appeared to be the most predominant nematode attacking banana roots. Nearly 65 to 70 per cent of the total nematode population on roots of the untreated plants was constituted by this species. Following the nematicidal treatment, drastic reduction occurred in the population of nematodes. Depending on the type of nematicides population of nematodes on roots decreased on an average from 129 counts in control to 27 counts in nemacur treated plants. According to Guerout (1972),

TABLE I
*Effect of different nematicides on the population of nematodes
on banana roots*

Treatments	Months after planting	<i>Radopholus similis</i>	<i>Pratylenchus sp.</i>	<i>Helicoty- lenchus</i> sp.	Total
Dasanit	4	25	8	—	33
	8	20	4	—	24
Temik	4	28	7	2	37
	8	25	8	—	33
Furadan	4	30	10	5	45
	8	28	5	8	41
Thimet	4	26	8	7	41
	8	21	9	2	32
Neemcake	4	40	21	8	69
	8	35	22	4	51
Nemacur	4	18	6	3	27
	8	15	8	4	27
Control	4	78	24	9	111
	8	97	32	17	146

critical pathogenic level of nematodes is 100 counts per 10 g of roots. Based on this, the population of nematodes exceeded the pathogenic level in untreated plots. Eventhough the population was sufficiently lower than the critical level in plants

receiving nematicides, nemacur proved to be the most efficient in suppressing the nematodes. A similar trend was observed in the case of soil nematodes also (Table II).

TABLE II

Population of nematodes in soil at different intervals of plant growth

Treatment	Months after planting	Soil population (Counts/200 cc)				Total
		<i>Rado-pholus</i> sp	<i>Praty-lenchus</i> sp	<i>Helicoty-lenchus</i> sp.	Others	
Dasanit	Before planting	59.5	69.7	13.5	19.2	162.0
	4	32.0	24.0	4.0	8.0	76.0
	8	28.0	20.0	8.0	3.0	59.0
Temik	Before planting	59.7	53.5	14.7	19.7	167.7
	4	31.0	21.0	8.0	9.0	69.0
	8	25.0	18.0	8.0	7.0	58.0
Furadan	Before planting	60.5	65.5	19.5	20.2	165.5
	4	35.0	28.0	9.0	8.0	80.0
	8	30.0	23.0	7.0	5.0	65.0
Thimet	Before planting	63.2	66.0	20.0	14.7	164.0
	4	31.0	23.0	6.0	11.0	76.0
	8	30.0	22.0	10.0	16.0	78.0
Neem cake	Before planting	57.7	69.2	21.0	14.5	162.5
	4	40.0	39.0	10.0	8.0	97.0
	8	48.0	37.0	12.0	4.0	101.0
Nemacur	Before planting	63.5	66.0	16.5	16.7	164.5
	4	27.0	18.0	5.0	7.0	57.0
	8	21.0	12.0	6.0	5.0	44.0
Control	Before planting	69.2	62.7	17.7	19.0	158.7
	4	49.0	38.0	32.0	41.0	160.0
	8	70.0	69.0	40.0	27.0	206.0

Yield data in terms of bunch weight per plant, as influenced by various nematicides, are given in Table III. The data revealed that the plants from nemacur and Temik treated plots gave significantly higher yields than that of control. The findings agrees well with the report of Vilardebo (1971) and Roman *et al.* (1976).

TABLE III
Yield of banana as influenced by nematicides application

Treatment	Yield (kg/plant)
Dasanit	10.3
Temik	11.0
Furadan	9.9
Thimet	10.0
Neem cake	9.2
Nemacur	11.3
Control	8.7
C. D. at 0.05 level	9.16

The results of this study indicate that the yield losses in banana due to nematode attack can be effectively reduced by the application of nematicides and that nemacur is the most effective of all the nematicides tested.

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11. SOIL CLIMATOLOGY

11.1 FEATURES OF SOIL MOISTURE AND SOIL TEMPERATURE IN RELATION TO SOIL FAUNA IN THE ARID ZONE OF INDIA

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ABSTRACT

Soil climate of the arid zone is characterised by large extremes. Hence the same considerably influences the movement and type of living of soil fauna.

The soil thermal regime in the arid zone of India exhibits two distinct patterns viz., summer and winter patterns. Features of these patterns and the diurnal variation of soil temperature are discussed. Harmonic analysis of weekly means of soil temperatures in the arid zone of India indicates special features due to the occurrence of south-west monsoon. Soil heat fluxes indicate large oscillations during monsoon season which may be partly due to transfer of heat with mass movement of water.

Observations on comparative soil moisture regime under different land use conditions indicate that the residual moisture storage after the growing season is maximum in a fallow land followed by cropped land and then in the native grass land. Results of water balance analysis of native grass land in the arid zone of India are also presented.

Some possible influence of these features on soil fauna are indicated.

INTRODUCTION

Soil climate of the arid zone is characterised by large extremes. Soil temperatures reach very high values up to 70-75°C on individual days in the sand dunes and sandy plains of the arid zone of India during extremely hot months of May and June. Similarly they reach below freezing temperatures in mid winter month due to high nocturnal cooling that takes place in these sandy soils, aided by prevailing large atmospheric dryness. Evapotranspiration in the sandy to loamy sand soil of the arid zone of India in periods other than monsoon months is extremely low. In fact the rainless season is marked by alternate occurrence of condensation and low evaporation (Krishnan *et al.*, 1968). The above special features of soil temperature and soil moisture regimes in the arid zone considerably influence

the movement and type of living of soil fauna. To a large extent, the fertility of a soil is directly related to the development of microorganisms. The processes involved are largely the result of bacterial activity. Bacteria are also responsible for the bulk of the nitrogen which becomes available for crop utilisation. But the development and activity of these microflora react very markedly to temperature variations and generally proceed at an optimum rate when temperatures are between 25 to 32°C. Similarly germination of crops and natural vegetation is also rapid in optimum soil temperature/soil moisture ranges. The ecology and movement of rodents and soil fauna like termites, white grubs, earthworms etc., also depend on the distribution of soil temperature and moisture with depth. Extremes are avoided by vertical movement as well as by construction of suitable burrows. In view of the same, a study on special features of soil temperature and soil moisture regime in the arid zone of India is important and the same has been presented in this paper. An instance of the manner in which the Indian desert gerbil, *Meriones hurrianae*, avoids the extreme desert climate by making suitable burrows has also been presented in this paper.

I. Soil temperature regime in the arid zone of India

(1) Summer and winter patterns

Figs. 1 and 2 show the mean weekly patterns of soil temperatures from surface to 120 cm depth based on the data for the period 1967-1976.

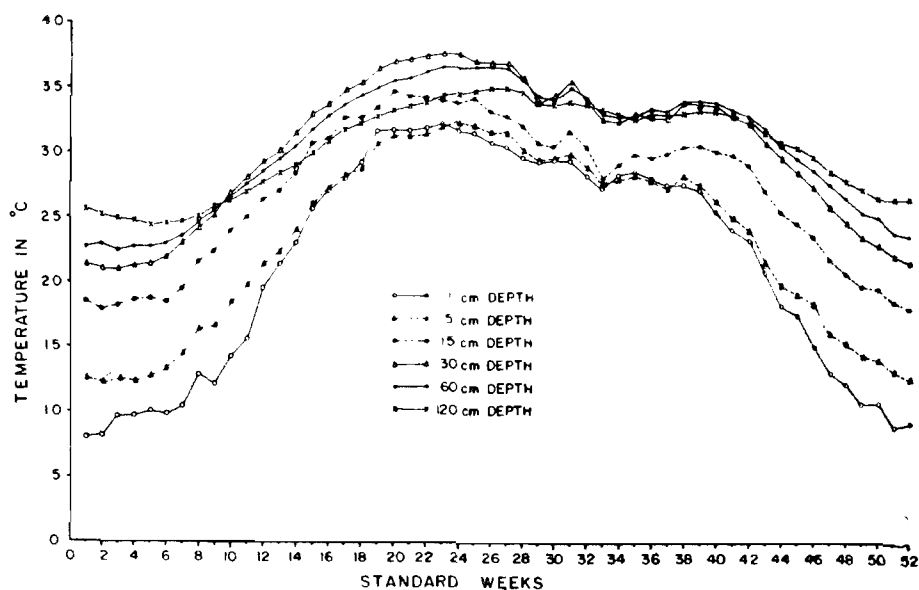


Fig. 1. Mean weekly pattern of soil temperature

From the figures, it is seen that during the minimum temperature epoch (0735 hrs IST) the soil temperature steadily increases from 1 cm to 120 cm depth from 1st to 9th week as well as from 42nd to 52nd week and during the rest of the year, the temperatures increase from 1 cm to 30 cm depth and decrease thereafter. Thus the temperature inversion conditions from surface to 30 cm layer of the soil is well marked in all the weekly means throughout the year during 0735 hrs I.S.T. observations.

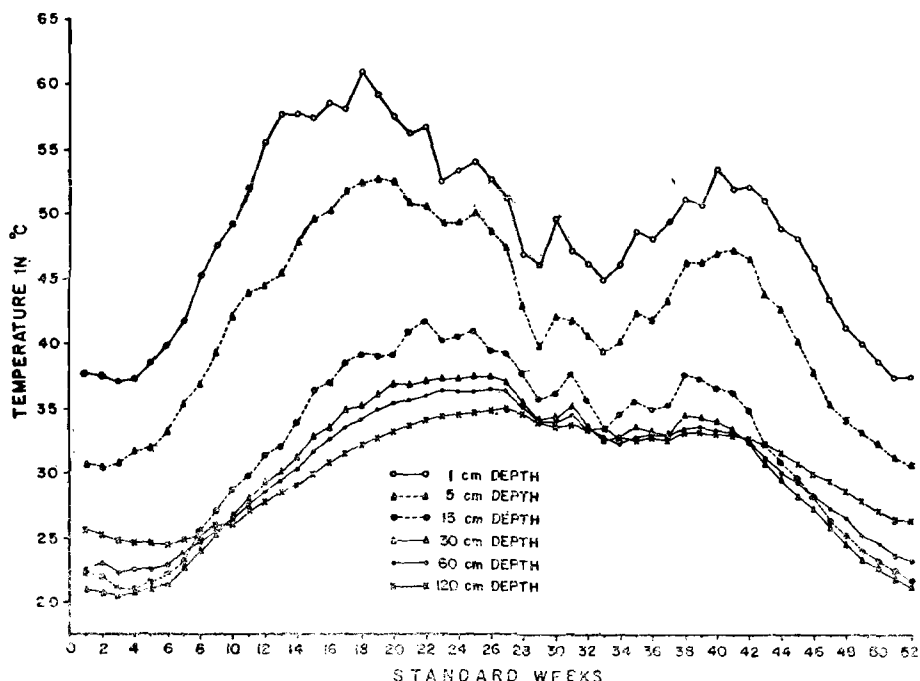


Fig. 2. Mean weekly pattern of soil temperature

For 1435 hrs I.S.T. observations representing the maximum temperature epoch, there is difference in pattern for the above periods. During 1st to 10th week and 42nd to 52nd week, the soil temperatures decrease from 1 cm to 30 cm depth and increase thereafter. For the rest of the year the soil temperature decreases continuously from 1 cm to 120 cm depth. During the monsoon season, which at Jodhpur normally lasts from 27th to 37th week (2nd July to 16th September) the tendency is towards the winter pattern of soil temperature regime, both with regard to maximum and minimum temperature epochs

Thus we can define for the sandy to loamy sand soil of Jodhpur, two types of soil temperature regime patterns *viz.* (1) summer pattern when soil temperature decreases from surface to 120 cm depth during maximum temperature epoch and

increases up to 30 cm depth with a decrease thereafter for minimum temperature epoch and (2) winter pattern when soil temperature during maximum temperature epoch decreases only up to 30 cm depth with an increase thereafter and during minimum temperature epoch, temperature increases continuously from 1 cm to 120 cm depth (Krishnan and Rao, 1979). The former pattern lasts from the second week of March to middle of October with a few breaks during rain spells in monsoon season when due to increased cloudiness and higher moisture content in soil, the winter pattern is brought in. The winter pattern lasts from the middle of October of a year to middle of March of next year.

The diurnal variation of temperature is present only up to 30 cm depth. It ranges from 16° to 30°C at surface, from 3° to 21°C at 5 cm depth, from 4° to 6°C at 15 cm depth and from 0.1° to 0.4°C at 30 cm depth and beyond. The diurnal variation observed in summer and winter is considerably reduced during monsoon season.

It would be seen from the figures that the thermal pattern suitable for upward movement of moisture in vapour phase occurs during the morning hours and for downward movement of moisture in afternoon hours throughout the year. During the period, mid-March to end of October, gradients are stronger. During the monsoon season, vapour pressure gradient favourable for upward movement of moisture in morning hours is only slightly less than that of other months, whereas the downward gradient in the afternoon is much lower than the same in other months. Further, the duration of occurrence of conditions favourable for upward movement of moisture is longer during each day of the monsoon season. For the layer 30 cm to 60 cm, the diurnal variation is small. In this layer, the conditions favourable for upward movement of moisture in vapour phase at minimum temperature epoch occurs during July to mid-March and at maximum temperature epoch from mid-October to mid-March. For 60 to 120 cm layer, there is no diurnal variation. The condition favourable for upward movement of moisture in vapour phase occurs in this layer from mid-October to mid-March. Thus the change-over from summer pattern to winter pattern in 30-60 cm layer takes place with the onset of monsoon, whereas at 60-120 cm layer this change over takes place only in mid-October. In a few weeks of active monsoon, winter pattern is actually realised.

(2) *Harmonic representation of annual soil temperature cycle*

The exchange of radiation at soil surface causes daily and yearly variations in soil temperature. In addition to regular annual and diurnal cycles of solar radiation, irregular cycles due to fluctuations of soil temperatures on account of cloudiness, rain, warm and cold spells etc., are also superimposed. Therefore, the temperature of the soil can be expressed as a sum of a number of superposed harmonics. It can be accounted for by a finite number of sine and cosine terms in

a Fourier (harmonic) analysis which reduces the soil temperature vs time curve into a Fourier series. The coefficients in this series give an objective description of the variation with the depth of the amplitude of temperature wave and time of temperature extremes. These coefficients also provide information about the heat transfer processes operating and about the thermal properties of the soil.

At many regions in the northern hemisphere, scientists have shown that the annual temperature cycle is well represented by the first harmonic alone, showing a symmetrical pattern with maximum around mid-July at the top layers with a progressive lag towards the lower depths. But the actual observed soil temperature variations at different depths in Jodhpur representing the arid zone of India indicates that the pattern is not symmetrical. Considerable anharmonicity is produced by the fall of temperature with the monsoon which lasts from the beginning of July to mid-September and later rise during post monsoon season. This causes time series of soil temperature in Jodhpur to be bimodal and does not allow the first harmonic alone to explain the complete cycle.

In order to specify the annual soil temperature cycle, the soil temperature data recorded at 1 cm, 5 cm, 10 cm, 15 cm, 30 cm, 60 cm and 120 cm depths in Jodhpur have been represented by the following Fourier series

$$T = \bar{T} + \sum_{n=1}^{N/2} C_n \sin \left(\frac{360}{P} nx + \theta_n \right) \quad \dots (1)$$

where $\bar{T}$ is the mean of 52 weekly averages of soil temperature at the concerned depth, P is the period of the fundamental cycle, x is the time factor varying from 0 to 51, C_n is the amplitude of the n th harmonic given by $\sqrt{A_n^2 + B_n^2}$ and θ_n is the phase angle given by $\tan^{-1} A_n/B_n$ where A_n and B_n are given by the following equation

$$T = \bar{T} + \sum_{n=1}^{N/2} \left(A_n \cos \frac{360}{P} nx + B_n \sin \frac{360}{P} nx \right) \quad \dots (2)$$

The above harmonic equation fitted to weekly mean soil temperature data of Jodhpur indicates that the first harmonic explains only 69–85 percent of the total variance at different depths while the second and third harmonics represent 8–22 per cent and 0.6 to 4 per cent of total variance, respectively. The contribution of fourth harmonic is very low being generally between 0.1 and 0.2 per cent. So fitting of further harmonics was not attempted. According to Carson (1963), the first harmonic alone explains more than 96 per cent of the total variance of soil temperature at Argonne, USA. But the bimodal nature of the time series of soil temperature due to occurrence of monsoon season does not allow a simple sine curve to explain

the complete annual cycle. Values of the soil temperatures were computed for each of the standard weeks considering the first two as well as all the three harmonics and curves were drawn to represent the mean annual cycles at different depths. Figs. 3 to 5 represent the same for 5 cm, 30 cm and 120 cm depths.

It is seen from the figures that the change in pattern due to monsoon is well reflected especially in the upper layers, if the third harmonic is superposed. Addi-

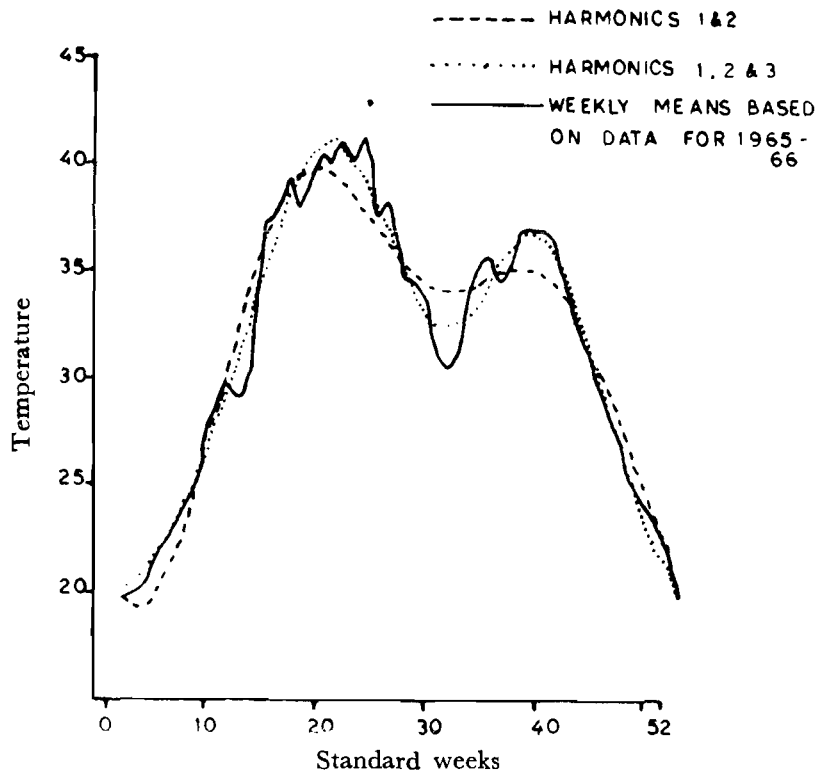


Fig. 3 Weekly mean observed soil temperature at 5 cm depth and those predicted by first two and first three harmonics

tion of third harmonic to the first two in the equation also makes the fit between observed and estimated values better during the other seasons.

3. Amplitude and phase angles of soil temperature at different depths

Table I shows the amplitudes and phase angles in respect of first four harmonics fitted to the weekly mean soil temperature. Mean temperatures for the year appropriate to the depths have also been indicated.

The largest value of amplitude is recorded at 1 cm depth for the first harmonic and third harmonic while it is at 5 cm depth for the second and 30 cm depth for

TABLE I
*Amplitude (A in C°) and phase angles (P in degrees) of soil temperature
at different depths in Jodhpur*

Number of Harmonic		Depth below ground level						
		1 cm	5 cm	10 cm	15 cm	30 cm	60 cm	120 cm
1	A	9.09	7.77	7.95	8.03	6.96	6.19	4.82
	P	277°	272°	269°	267°	262°	259°	245°
2	A	4.06	4.40	3.03	3.32	2.51	2.13	1.49
	P	233°	234°	231°	238°	217°	220°	202°
3	A	2.07	1.72	1.07	1.20	0.62	0.78	0.50
	P	180°	8°	164°	167°	143°	147°	124°
4	A	0.34	0.37	0.28	0.43	0.64	0.21	0.12
	P	322°	355°	197°	336°	197°	345°	331°
Mean temperature of the year (°C)		34.5	31.6	30.9	29.4	30.4	30.6	30.7

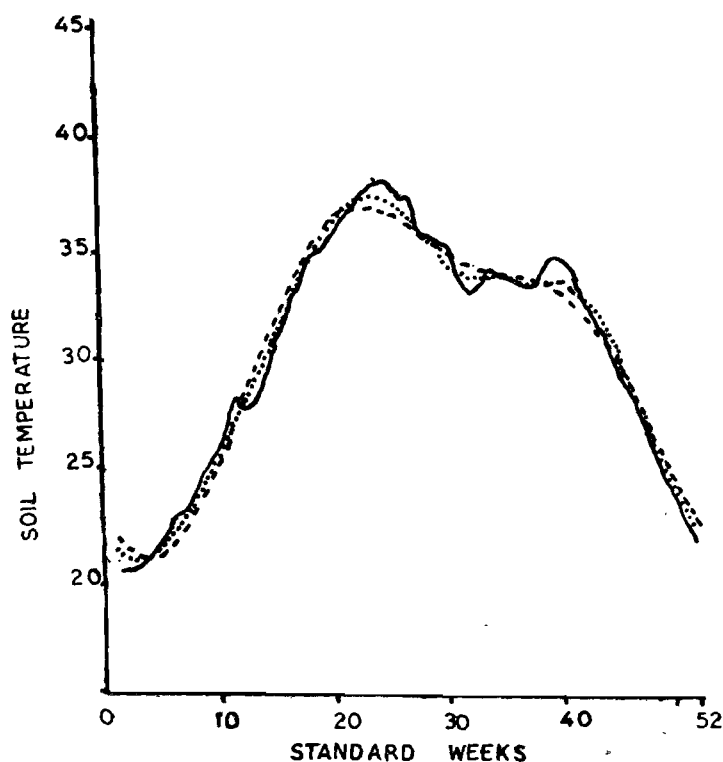


Fig. 4 Weekly mean observed soil temperature at 30 cm depth and those predicted by first two and first three harmonics

fourth. The range of variation of the amplitude of first harmonic is from 4.82 to 9.09°C. The amplitude sharply decreases upto 15 cm depth and increases thereafter.

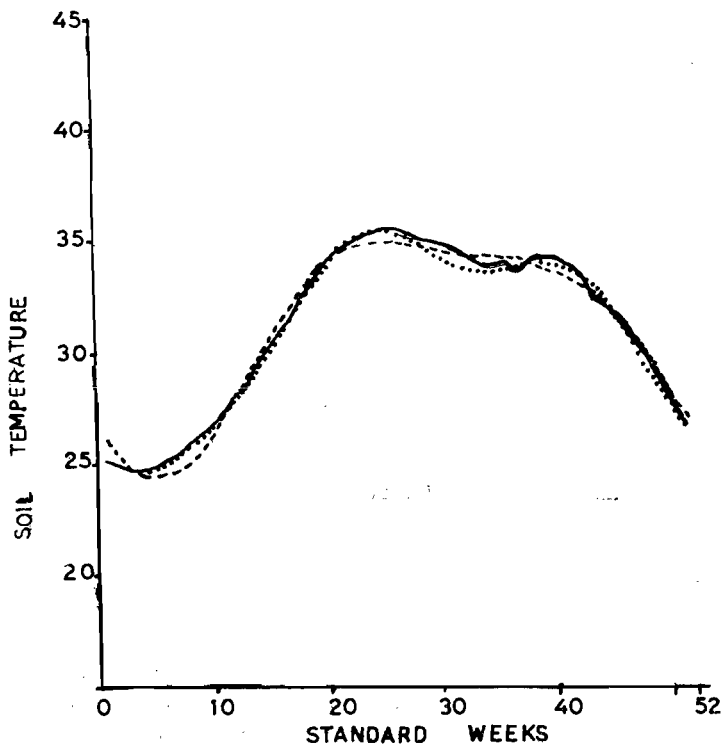


Fig. 5 Weekly mean observed soil temperature at 120cm depth and those predicted by first two and first three harmonics

The maximum value of n th harmonic occurs when $\frac{360}{P}nx + \phi n = 90^\circ$. Thus the angular values corresponding to the maximum of the first harmonic representing soil temperatures at different depths in Jodhpur have been found. By converting these angles into a time factor, actual dates of maximum at different depths have been completed. These are as follows :

	Depth						
	1 cm	5 cm	10 cm	15 cm	30 cm	60 cm	120 cm
Date of maximum	28	2	5	7	12	15	29
soil temperature	Jun	Jul	Jul	Jul	Jul	Jul	Jul

Thus the warmest soil temperature is recorded on 28th June while at 120 cm depth, the temperature maximum is delayed by a month. Carson (1963) reported that the time of maximum in respect of Argonne, USA, is 20th July at 1-20 cm depth, whereas, the same is 15th August for 100 cm depth. Thus the lag between the depths is similar in the two cases. However, at Jodhpur, in view of south-west monsoon and associated rainfall and cloudy conditions at Jodhpur, the time of maximum is much earlier than in USA and other countries where there is no monsoon activity during summer (Krishnan and Kushwaha, 1972).

(4) *Seasonal variation of soil heat fluxes*

The amount of heat energy stored (or lost) in an unit area of soil during a given time interval can be calculated if the temperature distribution within the soil at the beginning and end of the period and the heat capacity of the soil as a function of depth and time are known. The heat stored ΔQ in unit area of soil upto depth z is given by equation (3)

$$\Delta Q = \int_0^z C. \Delta T. dz \quad \dots (3)$$

Where ΔT is the temperature change during the time interval and z increases with depth.

The above mentioned integration can be performed by weighing of the temperature change readings for different depths with a depth range or interval of which the particular depth is representative. These intervals have been selected after studying the nature of the typical soil temperature profiles at Jodhpur. By working out soil temperature changes during each week from its earlier week and by computing weekly mean heat capacity values from the values of soil moisture content, soil mineral and organic matter content etc., mean weekly soil heat fluxes have been computed by the above method for a few years. Fig. 6 depicts the mean soil heat flux in the layer from surface to 120cm depth during 1965.

The most important feature noticed is the high variability from week to week in the soil heat flux values even by working out the same on weekly mean basis. During the period 1st to 22nd standard week (January to May), on the average ± 25 calories/sq. cm heat flux occurred. But there are weeks having positive heat flux of 60 calories/sq. cm on account of heat spells and those with high negative heat fluxes in association with cold spells. Another important feature is the occurrence of large oscillations, of very much higher order than those in other seasons, from 26th week which is the normal time of onset to 37th week which is the normal time of withdrawal of south-west monsoon at Jodhpur. The range of fluctuation during 1965 was +84 to -116 calories/sq. cm in the layer surface to 120 cm depth.

The weeks of rainfall had usually negative heat fluxes while the intervening dry spells between the two rainy weeks had large positive fluxes. Fluctuations of high order are also noticed during monsoon season in the individual sub-layers. For instance, the ranges covered 80 calories/sq cm week in the layer surface to 30 cm depth, 60 calories/sq cm week in the layer 30 cm to 60 cm depth and 80 calories/sq cm week in the layer 60 to 120 cm depth. These huge flux values during the rainy season may be partly due to the fact that bodily movement of water through the loamy sand soil of Jodhpur with large pores can transfer appreciable quanti-

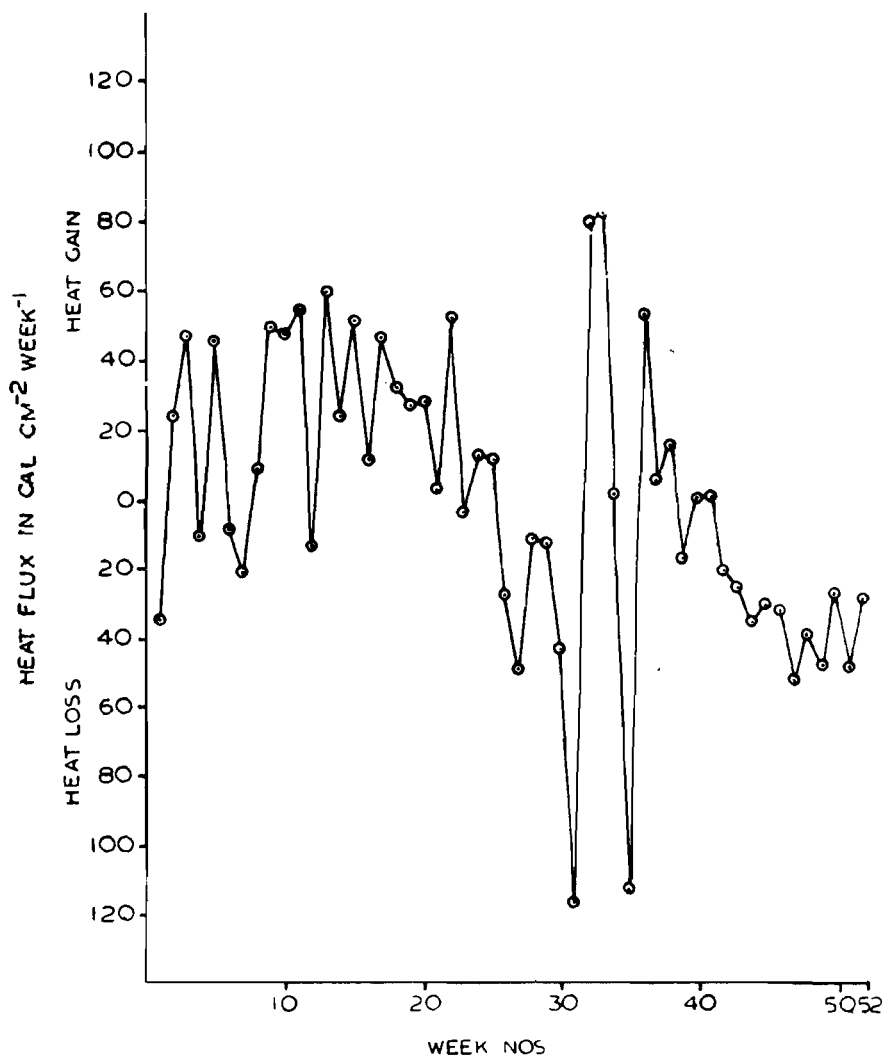


Fig. 6 Annual cycle of soil heat flux in surface to 120 cm layer during 1965 based on weekly changes in heat storage at Jodhpur

ties of heat with it. Further, during the dry spells in between the rainy weeks, moisture can move in vapour phase under the vapour pressure gradient set up by temperature gradient invalidating the applicability of the theory of heat transfer by thermal conduction alone. All these factors along with large rise in the heat capacity of various soil layers are probably responsible for the sudden heat gain and loss of large magnitude noticed during the monsoon season. The period October to December is one of continuous decrease of heat storage with the least fluctuations (Krishnan and Kushwaha, 1974).

The maximum accumulated heat flux for the year 1965 and 1966 was 557 calories computed on weekly average basis for the layers from surface to 120 cm depth. The maximum occurred on 25th week (18th June to 24th June) in case of 1965 and 22nd week (28th May to 3rd June) in case of 1966. On the whole, there was net increase in heat storage of 28 calories from 1-1-1965 to 1-1-1966 but there was a net decrease of 65 calories from 1-1-1966 to 1-1-1967.

Soil-moisture regime and water-balance pattern

Sand-dunes : In the unstabilised sand-dunes, a sharp discontinuity in moisture content in the layer 1.5 to 2 metres below the soil surface has been observed. Below this layer, the soil moisture reached more than 5 per cent by weight (*i.e.* the field-capacity value) throughout the year. However, in the stabilised sand-dunes, this feature was not observed and the moisture content was generally found to be less than 1.5 per cent up to a depth of 3 metres with the values increasing as the depth increased. The patterns below this layer were complicated owing to the differential extraction patterns of trees, shrubs and grasses over the stabilised sand-dunes. This feature explains the surer establishment of, and a better growth in the trees planted on unstabilised dunes.

Sandy plains : A comprehensive experiment on the water balance of the typical native vegetation of the arid zone of north-western India was conducted at the Central Research Farm of the Central Arid-Zone Research Institute, Jodhpur, from 1963 to 1967. Apart from the trees of *Prosopis cineraria* several important species of grasses, *e.g.*, *Dactyloctenium aegyptium*, *Eleusine indica*, *Cenchrus ciliaris*, *Cenchrus setigerus*, *Panicum antidotale*, *Aristida adscensionis* and *Cyperus rotundus* were included in the experiment. The soil at the experimental site is sand up to 15 cm depth (6 per cent clay content) and sand to loamy sand downwards up to a depth of 200 cm (average clay content 8 per cent). Below this depth there is a kankar pan. The soil texture is quite uniform and unaggregated, with constant bulk density of 1.5 g/cm³. During 1963, 1964 and 1965, the rainfall amounted to 156.9, 536.2 and 234.6 mm (the normal annual rainfall at Jodhpur is 366 mm). The monsoon commenced very late

in 1963, i.e., on 30th July ; very early in June, in 1964 and very close to the normal date in 1965, i.e., on 4 July.

The water-balance analysis indicates that the period 30th July to 27th September (60 days) accounted for 156 mm of evapotranspiration during the deficient-rainfall year of 1963, whereas the period 10th May to 6th October (150 days) accounted for an evapotranspiration of 321.9 mm and a deep drainage of 34.9 mm during the surplus-rainfall year of 1964. The measured runoff losses were 0.7 mm (0.4 per cent) for 1963 and 125.9 mm (23 per cent) for 1964. The very high runoff loss during 1964 was due to the very high intensity of rainfall between 8th July and 18th August, together with a good antecedent moisture conditions in the soil due to well-distributed rainfall in the season. During the medium rainfall year of 1965, the period 29th June to 7th October (100 days) had an evapotranspiration loss of 219.5 mm and a runoff loss of 5 per cent. Thus there was a high variability from year to year in the available growth period for the native vegetation. From the transpiration measurements made during the experiment it was inferred that the trees of *Prosopis cineraria* extracted moisture not only from large area, but also through the kankar zone (Krishnan *et al.*, 1968).

An evapotranspiration model applicable to the native vegetation was evolved from this experiment for predicting the storage of soil moisture under native vegetation during the growing season of the vegetation (Krishnan and Kushwaha, 1970). The agreement between the values predicted on the basis of the model and the actually measured values was quite close.

Comparative soil moisture regimes in native vegetation plot, cropped land and fallow land

The soil moisture observations of the year 1965 to 1967 in respect of (a) fallow land (free from weeds), (b) cropped land with bajra crop and (c) land with the native vegetation community were analysed. In the years 1965 and 1966 the monsoon started by about 4th July while it started on 18th June in 1967 and the effective rainfall (*viz.*, rainfall *minus* run-off) amounts during 1965, 1966 and 1967 were 223, 231 and 415 mm. The total soil moisture contents in mm in first 120 cm of soil were as follows (Table II).

It is seen that the residual moisture status is maximum in bare plot followed by cropped land and then by grasslands. The last one has moisture much below the wilting percentage value (*viz.* 36 mm.). Though the wilting point value was not reached in bare plot and cropped land even up to December, the moisture content in native vegetation plot reached the wilting percentage value by 19th September during 1965, by 10th September during 1966 and by 9th November during 1967.

It is seen that the native vegetation in arid zone extract moisture even below wilting percentage and is more extravagant in water use than the bajra crop. Further it can be observed that conservation of moisture in fallow land is not high (Figs. 6 to 9).

TABLE II
Moisture content (mm) in bare land (a), cropped land (b) and native vegetation plot (c)
in first 120 cm of soil

	1964			1966			1967		
	A	B	C	A	B	C	A	B	C
Prior to onset of monsoon	46	33	22	55	27	17	63	37	21
Moisture status on 15th December	66	44	24	55	40	23	73	52	32

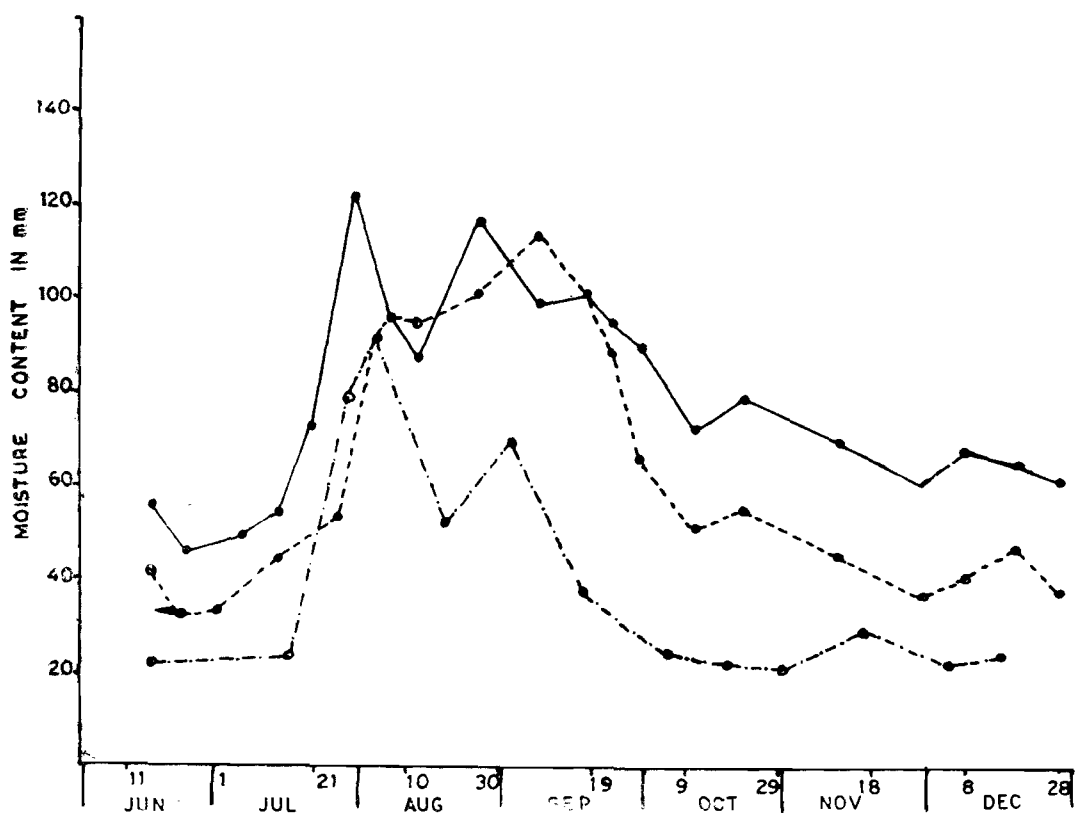


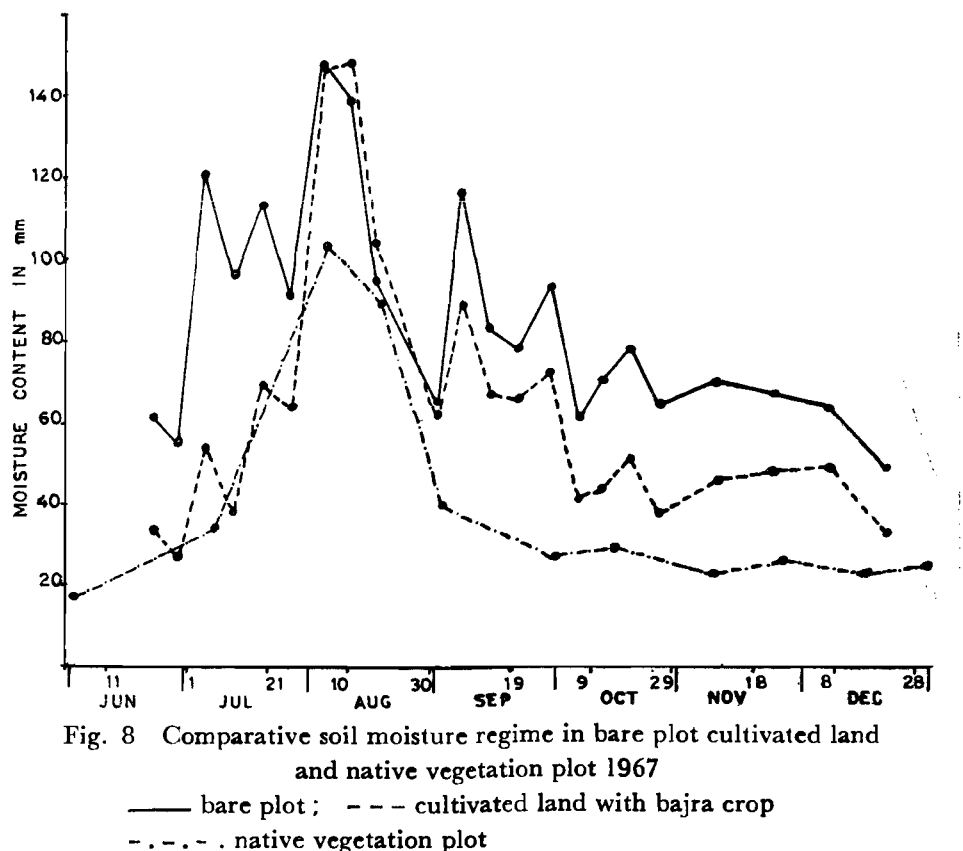
Fig. 7. Comparative soil moisture regime bare plot, cultivated land and native vegetation plot 1965

— Bare plot ; --- Cultivated land with bajra crop ; - . - - Native veg. plot

Adjustment of desert fauna to extremes of arid zone climates

As a case study, the adjustment of desert gerbilla to avoid extremes of soil temperature regime in the arid zone of India has been presented in this section.

Being diurnal, the Indian desert gerbilla, *Meriones hurrianae* (Jerdon) is more exposed to vagaries of temperature than the nocturnal Indian Gerbille, *Tatera indica indica* (Hardwicke). In the Rajasthan desert, as already stated, the soil surface



temperature rises to 60°C or more whereas for gerbilles, the lethal temperature is 41-42°C. Moreover gerbilles are unable to tolerate warm summer afternoon winds for more than 8 to 12 minutes. The desert gerbilla avoids exposure to heat and consequent desiccation of its body by leading a fossorial life and by making burrows extremely suitable for such extreme conditions. The author along with Dr. Ishwar Prakash and Shri Kumbakarni conducted a year long experiment on the determination of burrow temperatures of *Meriones hurrianae* during different seasons of the year (Ishwar Prakash *et al.*, 1965). The Philips Rod Thermistors type 100-092 and

suitable wheatstone type bridge were used for burrow temperature measurements. Temperatures outside the burrow, soil surface temperature and burrow temperatures observed during this experiment are discussed below.

Temperature outside burrow

a. *Average air temperature* : Average hourly air temperatures indicate a well-defined peak corresponding to 4 p.m. during winter, between 4 and 5 p.m.

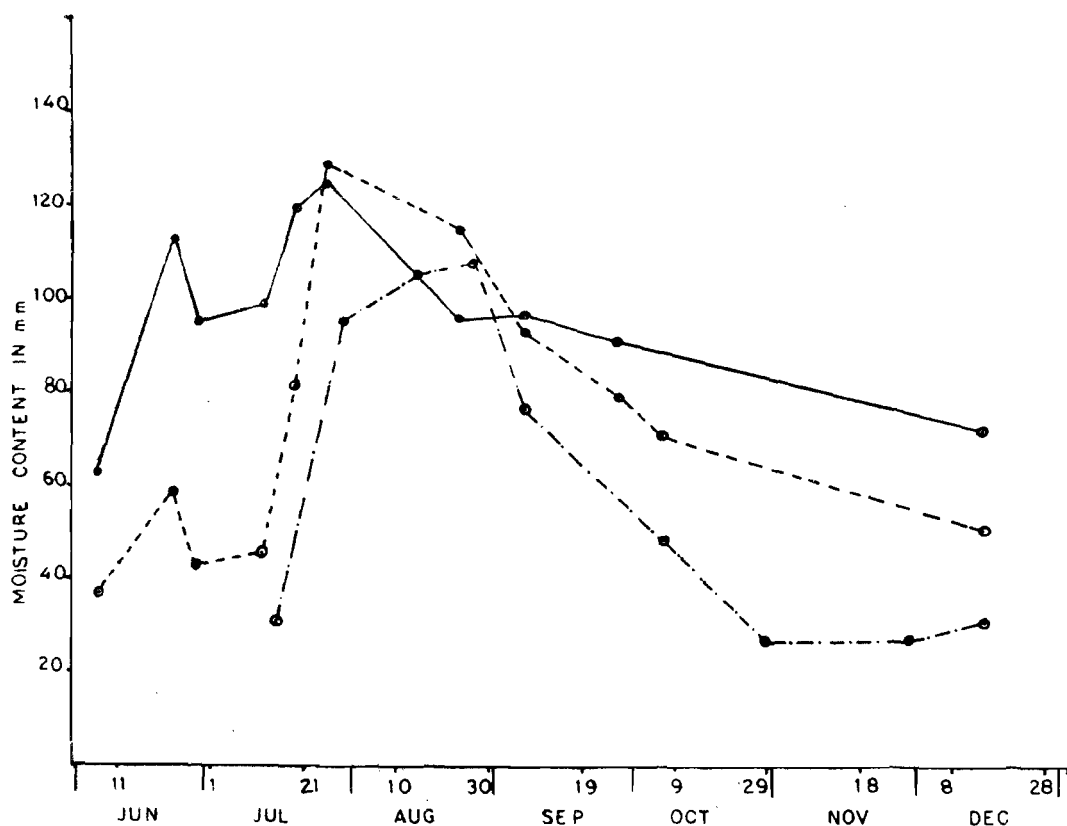


Fig 9 Comparative soil moisture regime in bare plot land and native vegetation plot 1967

— bare plot ; - - - cultivated land with bajra crop
 - . - . - native vegetative plot 1967

during the hot weather, between 3 and 4 p.m. during monsoon, and at 3 p.m. during post-monsoon season. The average range of day temperatures during the various seasons is as follows :

		Range (°C)	Actual variation (°C)
Winter	—	13.1 to 23.8	11.7
Hot weather	—	28.1 to 39.3	11.2
Monsoon	—	26.8 to 33.4	6.6
Post-monsoon	—	19.6 to 32.7	13.1

b. *Soil surface temperature* : The seasonal and hourly variation are the highest at soil surface. There is a well-defined peak of maximum temperature during all seasons. This occurs at 2 p.m. during winter and hot weather, at 1 p.m. during monsoon, and between 12 noon and 1 p.m. during post-monsoon season; thereby showing that the maximum temperature epoch for soil is generally two to three hours ahead of the maximum temperature epoch of air. The range of soil surface temperatures from 7 a.m. to 7 p.m. recorded during various seasons is as follows :

		Range (°C)	Actual variation (°C)
Winter	—	11.9 to 39.0	27.1
Hot weather	—	26.7 to 55.5	28.8
Monsoon	—	31.5 to 45.8	14.3
Post-monsoon	—	22.7 to 49.3	26.6

Burrow temperature

In contrast to the air and soil surface temperatures, there is very little hour-to-hour variation of temperatures inside the burrows during the various seasons. The variation of temperature from season to season is also considerably less at all depths. There is no well-defined peak of maximum temperature inside the burrows except in the monsoon and post-monsoon seasons, when a peak is noticed at 50 cm depth and corresponding to 1 p.m. Generally the burrow temperatures tend to increase during the late afternoon, after 5 p.m. In winter the burrow temperatures are not only higher during the late afternoon but also at 7 a.m., thereby indicating that the burrow is probably uniformly warmer during the night when air and surface temperatures fall considerably, and the gerbille has not to encounter the chilly cold winter night. It is further observed that in winter, the burrow temperatures averaged over all depths are warmer than the normal air temperature from 7 a.m. to 10 a.m. by 2.0 to 7.1°C. and warmer than soil surface by 1.1 to 7.6°C from 7 a.m. to 9 a.m. and by 3.7°C at 7 p.m. In the hot weather, the burrow temperatures are in the range of 33.6 to 37.6 considering all depths, whereas the soil surface temperatures reach as high as 55.5°C. These features indicate clearly that the burrows serve the gerbilles as air-conditioned chambers to avoid the high extremes of temperatures noticed in the arid region. Very little variation with respect to depth is noticed in the burrow temperatures. This is, however, a slight indication

of temperature with depth during decrease winter and hot weather periods and of increase with depth during the other seasons. The range of the day temperatures at various depths in the burrows is given below for various seasons :

Slant depth	Winter °C	Hot weather °C	Monsoon °C	Post-monsoon °C
50 cm	19.9 to 21.1 (1.2)	35.2 to 37.6 (2.4)	28.5 to 34.3 (5.8)	24.6 to 25.7 (1.1)
100 cm	19.1 to 20.5 (1.4)	33.6 to 35.2 (1.6)	27.6 to 35.3 (7.7)	27.9 to 28.7 (0.8)
150 cm	19.2 to 20.7 (1.5)	33.9 to 35.4 (1.5)	32.9 to 35.8 (2.9)	30.4 to 31.3 (0.9)
200 cm	19.1 to 20.6 (1.5)	34.2 to 35.3 (1.1)	— —	29.1 to 29.9 (0.8)

It is interesting to note that the burrow temperatures which have generally a small range, varying from 1 to 2°C., show a considerable increase in range during the monsoon when the air and soil temperatures have the minimum range. The increase in range inside the burrows during this season may be attributed to the occasional flooding of the burrows with rain water. Table III gives the normal air

TABLE III

The air and burrow temperatures at the maximum temperature epoch of the soil surface during different seasons

	Winter 2 p.m. °C	Hot weather 2 p.m. °C	Monsoon 1 p.m. °C	Post-monsoon 12 & 1 p.m. °C
Soil surface	39.0	55.5	45.8	49.3
Normal air	24.1	38.6	32.4	31.6
Burrow temperature averaged for the four depths	19.8	34.7	34.4	28.4
Difference between soil surface and average burrow temperature	19.2	20.8	11.4	20.9
Difference between soil surface and normal air temperature	14.9	16.9	13.4	17.7

temperatures and the burrow temperature averaged for the four depths at the time of maximum temperature epoch of the soil surface temperatures recorded during various seasons.

Table III shows that, at the time of maximum temperature epoch of the soil surface temperatures, burrows are cooler than the soil surface by 19.2° to 20.9°C in various seasons except in the monsoon when the difference is 11.4°C, whereas the air temperatures are less than the soil surface temperatures by 13.4° during monsoon and from 14.9° to 17.°C during other season. This also indicates that the burrows help the gerbilles in avoiding the extreme temperatures of the desert.

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