

**STUDIES ON THE TERMITE SPECIES OCCURRING
AT THE MAIN RESEARCH STATION, HEBBAL,
BANGALORE AND SOME ECOLOGICAL
ASPECTS OF *Microtermes obesi* Holmgren
(ISOPTERA : TERMITIDAE)**

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**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE
1987**

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in

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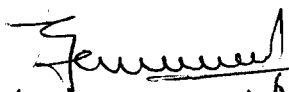
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Smt. Lakshmidevi Sharanappa
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BANGALORE

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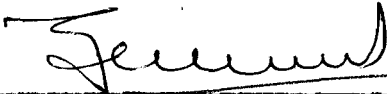
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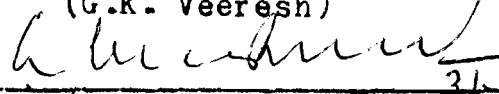

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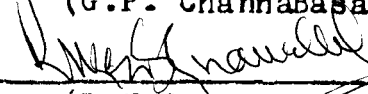
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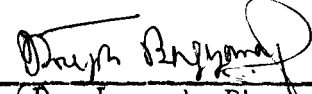
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INTRODUCTION

I. INTRODUCTION

Termites are social insects living in communities like ants, bees and social wasps. They are abundant in the tropics and subtropics and may be grouped into two types, namely, wood dwelling and soil dwelling termites. The former confine themselves to wood and within this group are included the dry wood termites and the damp wood termites. The damp wood termites are associated with decaying wood. The soil dwelling termites are also of two major types - the mound building termites and the subterranean termites. By far, the most important from the economic point of view are the subterranean termites which maintain their colonies in the soil (below the ground level) by constructing underground galleries to attack roots of plants.

Termites are voracious consumers of plant material both living (cellulose material) and dead decomposing matter and humus soil rich in organic matter. They generally attack plants that are weak due to some internal growth factors or due to some environmental causes such as drought or poor soil (Roonwal, 1979). They damage a variety of crops throughout the tropics. They attack seed, seedling, sett or mature plant and in the latter instance the attack may be directed to the part of the plant to be harvested or some other part.

Crop-loss due to termites in India is estimated to vary from Rs. 230 million (Mehtha and Varma, 1968) to Rs. 280 million annually (Fletcher, 1912). A loss of 6 to 25 per cent of wheat crop (Hussain, 1935), 88 per cent of sugarcane setts (Agarwal, 1964), and 15 per cent in the case of tea in North-East India (Das, 1962) have been reported. Kaushal and Deshpande (1967) claimed 5-50 per cent mortality of groundnut crop in Madhya Pradesh in addition to 35 per cent damage to pods and seeds (Rawat et al., 1970).

Out of nearly 2000 species termites reported from all over the world, a little over 300 are known from the Indian region (Chhotani, 1980). The termites are polyphagous, and about 40 species have been recorded so far causing damage to economically important plants including agricultural, horticultural crops, forest plants and stored products; the principal species among them being Microtermes obesi Holmgren and Odontotermes obesus Rambur attacking large number of host plants (Roonwal, 1979).

In India, a great deal of work has been done on faunistic and systematic study of termites (Roonwal and Bose, 1964, 1970; Chhotani, 1970, 1975). The ecology of termites in India largely concerns the geological history, influence of monsoon rain fall pattern, atmospheric temperature and relative humidity, vegetation, altitude and

soil type on termites (Sen-Sarma, 1974); very little is known about the precise relations between different species of termites including Microtermes obesi, and these factors.

Data on precise estimates in loss due to termites are lacking on the crops like bajra, barley, jowar, maize, setaria, wheat, gram, pigeon pea, groundnut, niger, sunflower and cotton. These are the main rainfed crops constituting 36 per cent of the net sown area of 47 million hectares spread over in 84 districts (Bindra, 1961).

Among the cereals, wheat is the most suffered crop due to subterranean termite, Microtermes obesi; it attacks the crop from seedling till harvest. Some scanty information is available on chemical control and crop losses; besides, the information on cost-benefit ratios are very little for many dry land agricultural crops.

With a view to generate information on the above lacunae the present study was undertaken with the following objectives:

- 1) To know the different species of termites and their relative abundance at the Main Research Station, Hebbal, Bangalore-560024.

- 2) To study some aspects of ecology of the subterranean termite, M.obesi Holmgren.
- 3) To understand the host preference and losses caused by termites; and
- 4) To estimate the loss to wheat by M.obesi and its management.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Since the present study is confined to some aspects of termite abundance, ecology, host preference and losses caused by M.obesi on wheat under differential irrigation and insecticidal application, the review of literature is confined mostly to these aspects on other related species of termites.

2.1. Abundance and distribution

From India, so far nearly 300 species of termites have been reported (Chhotani, 1980). Members belonging to 15 genera in 5 families are reported to be injurious to agricultural crops, fruits, plantations and other trees, (Roonwal, 1979). The major species of agricultural importance reported from India belong to the genera Odontotermes Holmgren and Microtermes Wasmann.

The genus Odontotermes is believed to have originated in Ethiopian region and dispersed to India and rest of the Indo-Malayan region through West Asia in the early Miocene period (Emerson, 1955; Krishna, 1970; Sen Sarma, 1972 and Thakur, 1976). Out of 195 species known, 107 species occur in Ethiopian region and the remaining 88 species have been recorded from the Indo-Malayan region (Thakur, 1981). Some of the important species under this genus reported from Indo-Malayan region are:

<u>Species</u>	<u>Distribution</u>	<u>Author</u>
<u>Odontotermes bellahunisensis</u> (Holmgren & Holmgren)	Peninsular India, Eastern India Himalayan region	Thakur (1981)
<u>O. ceylonicus</u> (Wasmann)	Peninsular India Ceylon and Burma	-do-
<u>O. horni</u> (Wasmann)	Eastern India, Himalayan region & Nepal	-do-
<u>O. obesus</u> Rambur	Peninsular India, Central India, Eastern India, Himalayan region, Western India, Pakistan & Burma	Weidner (1970)
<u>O. redemanni</u> (Wasmann)	Ceylon, Peninsular India, Central India, Himalayan region, Western India and Pakistan	Thakur (1981)
<u>O. wallonensis</u> (Wasmann)	Peninsular India, Arid Zone, Eastern India	Weidner (1970)
<u>Microtermes</u> Holmgren		

Chatterjee and Thakur (1964), while studying with Indian Microtermes, stated that "the generic name Microtermes was first introduced by Wasmann (1902), who included only one species, Microtermes globicola from Ceylon. This genus includes 58 species of small sized termites of which 13 species are Oriental (Roonwal, 1970).

Some of the important species under the genus reported from India are:

<u>Species</u>	<u>Distribution</u>	<u>Author</u>
<u>Microtermes obesi</u> Holmgren (= <u>M. anandi</u> Holmgren)	South East Asia, Pakistan, India, Sri Lanka, Bangla- desh and Burma	Roonwal & Bose (1964)
<u>M. globicola</u> Wasmann	Karnataka, Tamil Nadu, Kerala and Ceylon	Bose (1984)
<u>M. mycophagus</u> Desneux	Western India and Pakistan	Ahmad (1955)
<u>M. unicolor</u> Snyder	Pakistan, India and Bangla Desh	Chhotani and Bose (1973)

Trinervitermes Holmgren

This genus comprises 64 species and subspecies of which seven are oriental. T. biformis (Wasmann) has been reported from different parts of India.

<u>Species</u>	<u>Distribution</u>	<u>Author</u>
<u>Trinervitermes</u> <u>biformis</u> (Wasmann)	U.P. & Maharastra Karnataka, Andhra- Pradesh, Tamil Nadu- Kerala, Madhya - Pradesh, Sri Lanka	Patel (1962) Sankran (1962) Butani (1967) Agarwal (1972) Sudhakar (1983)

Speculitermes Wasmann

The genus comprises 14 known species distributed in Neotropical and Oriental region, of which Oriental region accounted for the distribution of 10 species. Roonwal (1970) reported the occurrence of S. sinhalensis Roonwal & Sen-Sarma in Tamil Nadu & Karnataka.

2.1.1. Abundance of mounds/nests

The estimates made by different workers on the abundance of nests relating to species studied here are presented here under :

Mound density in different species of termites

<u>Species</u>	<u>No. of mounds per ha</u>	<u>Habitat</u>	<u>Locality</u>	<u>Source</u>
1. <u>Amitermes laurensis</u> Mjoberg	217	Savannah Woodland	Australia	Wood & Lee (1971)
2. <u>A. vitiosus</u> (Hill)	330	Low Wood- land	"	"
3. <u>Anacanthotermes</u> <u>ahngerianus</u> (Jacobson)	570	Savannah & dense forest	Central Asia	Kozlova (1951)
4. <u>Coptotermes</u> <u>lacteus</u> Froggot	1.9	Schlerophyll forest	Australia	Wood & Lee (1971)
5. <u>Cubitermes</u> <u>exiguus</u> Mutho	0.652	Steppe, Savannah	Congo	Bouillon & Mathot (1964)
6. <u>C. fungifaber</u> (Siostest)	875	Tropical rain Forest	Congo	Maldague (1964)
7. <u>Dicuspiditermes</u> <u>nemorosus</u> (Haviland)	60-110	Equatorial rain forest	West Malaysia	Matsumoto (1976)
8. <u>Macrotermes</u> sp.	3-4	Savannah	East Africa	Hesse (1955)
9. <u>M. bellicosus</u> (Smeathman)	2-3 1-4	" Valley Bottom	Congo Uganda	Bouillon & Kidieri (1964) Pomeroy (1976)

<u>Species</u>	<u>No.of Mounds/ ha</u>	<u>Habitat</u>	<u>Locality</u>	<u>Source</u>
10. <u>M.carbonarius</u> (Hagen)	15-41	Equatorial rain forest	West Malaysia	Mutsumoto (1976)
11. <u>Microtermes</u>	Domi- nant	Cultivated land	Northern Nigeria	Wood et al. (1977)
12. <u>Nasutitermes</u> <u>exitiosus</u> (Hill)	6.6	Dry schlero- phyll forest	Australia	Wood & Lee (1971)
13. <u>N.triodae</u> (Froggott)	1.7	Savannah	"	"
14. <u>N.magnus</u> (Froggott)	38	Pasture	"	"
15. <u>Odontotermes</u> sp.	5-7	Savannah	Kenya	Glover et al.(1964)
16. <u>O.assmuthi</u> Holmgren	62	Uncultivated tract	Karnataka India	Basalin- gappa (1968)
17. <u>O.obesus</u> Ramber	5	Tropical decidious	Varanasi	Singh (1982)
18. <u>O.redemanni</u> Wasmann	4	"	"	"
19. <u>O.wallonensis</u> (Wasmann)	3.00 8.20 15.50 19.00	Barren land Cultivated land Grass land Forest	)) Karna-) taka)	Rajgopal (1979)

Nature of damage

Out of nearly 300 species known from Indian region (Chhotani, 1980) hardly 40 species have so far been found to be injurious to economically important plants (Roonwal, 1978a; 1979).

Microtermes obesi

According to Wood et al. (1980), the root system of maize was attacked by many of the litter feeding macrotermitinae in Nigeria. Smaller termites such as Microtermes entered and consumed the larger roots and continued their excavations into the stem which was packed with soil to heights varying from 1-2 cm. Above ground symptoms of these subterranean attacks were broken prop roots and lodging. Attack on the roots began 10-12 weeks after planting and intensified as the plant matured. Similar damage has been reported on barley and maize (Roonwal, 1981) and sorghum (Gahukar and Jotwani, 1980).

Wheat seems to be the worst sufferer due to the attack of Microtermes obesi, both seedlings and grown up crops are subjected to the attack of this termite (Hussain, 1935; Broad, 1966; Varma and Kashyap, 1980; Deol et al., 1981; Roonwal, 1981).

Next to wheat perhaps the sugarcane is the most suffered crop both by Microtermes and Odontotermes. Damage starts with the planting of setts. Termites enter the sugarcane setts either through the injured buds or through the two cut ends of the sett and then completely devour the soft, nutritious pith, resulting in either poor germination of shoots or complete death of shoots. In severe cases the leaves and the crown die (Gupta, 1959; Nayar et al., 1976; Roonwal, 1981).

The pods of groundnut are vulnerable to the attack of Microtermes sp. during periods of drought. It enters the growing pod through a slit made near the free end and pierces the terminal seed, with the result the seeds fail to develop (Massibot, 1946). The plant at and below ground level, as well as the buried nuts are attacked (Beeson, 1940; Sharma, 1967; Sudhakar, 1983).

Even cotton plant is not free from the attack of Microtermes. The damage starts from the root and then tunnels the stem near ground level. Such plants wilt and die in severe cases (Butani, 1973). There are reports of severe damage of eucalyptus (Nair and Varma, 1985). Damage to wooden support by Microtermes is also reported (Reddy, 1984).

There are a number of reports of damage to maize crop by Odontotermes obesus. The attack is at the ground level and the damage occurs throughout the growing season from germination onward (Beeson, 1940; Srivastava, 1959; Kushwaha, 1960; Wood et al., 1980). Often the termites consumed larger roots and continued their excavations into the stem packing with soil to heights varying from 1-2 cm to 1 m in severe attack (Wood et al., 1980).

Other crops subjected to the attack of Odontotermes spp. include upland paddy (Verma and Kashyap, 1980), sorghum

(Gahukar and Jotwani, 1980) and wheat. Termite attacked wheat resulted in Chaffy earheads with little or no grain (Verma and Kashyap, 1980). In addition it

the field (Reddy, 1984).

Odontotermes obesus is known to attack groundnut foliage, seeds, seedlings, stems, pods of developing and matured plants, harvested plants, pods and seeds in storage. The attacked pods are filled with fine soil (Beeson, 1940; Sharma, 1967; Kaushal and Deshpande, 1967; Rawat et al., 1970; Johnson et al., 1981; Amin and McDonald, 1981; Sudhakar, 1983).

One of the symptoms of damage to pods is, the scarification of pods, which weaken the shells and make them liable to shatter or crack during harvest resulting in loss of kernels especially with mechanical harvesting but cracking is more serious in the presence of moisture because it facilitates the entry of and growth of the toxic fungus Aspergillus flavus. The scarification of pods is accentuated by late harvesting or irregular ripening of the crop. The extent of damage vary with season and area (Feakin, 1973). and dry wood.

O.obesus is also known to attack the roots and collar region of cotton, eucalyptus and of chilli (Beeson, 1940; Butani, 1973; Nair and Varma, 1985; Reddy and Puttaswamy, 1985).

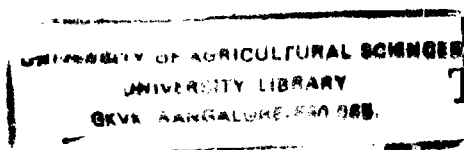
O. bellahunisensi is reported to attack the roots and collar region of eucalyptus and coconut, make earthen sheathing on plants and feed inside. In addition it also feeds on the wood and dung in the field (Reddy, 1983; Sudhakar, 1983; Roonwal and Rathore, 1984).

O. ceylonicus - in addition to causing considerable damage to wood work (Roonwal, 1970); it also attacks the crops like maize, ragi, castor, grasses and roots of diseased or drying plants and trees (Margabandhu, 1934; Sudhakar, 1983).

O. horni is mostly found feeding on fallen wood and bark of the living trees. It also make earthen sheathing while feeding (Roonwal, 1970; 1978b; Sudhakar, 1983). Eucalyptus, coconut and tea are subjected to damage by O. redemanni. It constructed the earthen sheathing on the plants (Jepson, 1931; Harris, 1969; Chatterjee, 1970; Roonwal and Rathore, 1984).

O. wallonensis is reported from Karnataka damaging standing crops like groundnut, sunflower, niger, ragi, maize, eucalyptus and dry wood. The infested plants wilted and lodged and earthen sheathing was visible at the site of attack (Rajgopal, 1979 and Sudhakar, 1983).

The damage of harvester termite (Trinervitermes) is indicated by a few pieces of stem and leaves left lying



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around, when foraging stopped at day light (Sands, 1973).

In India, it has been found to damage cotton, sugarcane, groundnut, wheat and forest plantation (Roonwal, 1970).

List of economically important hosts of termite species reported in the present study.

<u>Species</u> (1)	<u>Hosts</u> (2)	<u>Locality</u> (3)	<u>Nature of damage</u> (4)	<u>Source</u> (5)
1. <u>Micro-termes obesi</u> Holmgren	Sugarcane maize Jute <u>Crotolaria juncea</u>	Bihar Bihar West-Bengal U.P.	Setts & Canes Roots & Stalks Root & Stem	Fletcher (1912) Agarwal (1955) Agarwal and Sharma (1954) Dutt (1962) Tripathi (1967, 1972)
	Maize, Wheat & Sugarcane Poplars	India North-Eastern region	Roots & Straw	Reddy (1962) Chhotani (1981)
	Sisoo (<u>Acacia arabia</u>)	Karachi	Wood	Joshi <u>et al.</u> (1984) Ahmad and Chaudhary (1977)
	Red gram	U.P., Haryana	Stalk	Lal <u>et al.</u> (1980)
	Aak	Rajasthan	Root and Stem	Parihar (1981b)
	Cassava	Kerala	Roots	Lal and Pillai (1981)
	Chrysanthemum & Rose	New Delhi	Roots & stem	Butani & Dadlani (1983)
	Wheat, Groundnut, Chilli, Sugarcane, Mango, Grape, Bajra, Castor, Pulses, Barley, Jowar, Cotton, Guar, Tea, Vegetables, Gram, Jute, Coffee, Rubber, Coconut, Fruit trees, Plantation trees, Eucalyptus, Mango, Guava.	Through-out India	-do-	Roonwal & Bose (1978) Kushwaha <u>et al.</u> (1980) Parihar (1981a) Kushwaha (1983) Roonwal (1983) Kashyap <u>et al.</u> (1984)

(1)	(2)	(3)	(4)	(5)
2. <u>O.obesus</u> Rambur	Coconut, Wheat, Barley, Bajra, Maize, Jowar, Groundnut, Cotton Sugarcane, Tea, Vegetables, Pulses, Jute, Castor, Rubber, Mango, Guava, Citrus, Grape, Pome- granate, Chilli, Eucalyptus.	Through out India	Seed- lings, roots and stems	Nirula <u>et al.</u> (1953) Kapur (1958) Krishnamurthy and Rama- subbaiah (1962) Kushwaha (1983) Agarwal (1972) Nath (1972) Roonwal and Bose (1978) Kushwaha <u>et al.</u> (1980) Parihar (1981a) Nair and Verma (1981) Roonwal (1983) Reddy and Puttaswamy (1985) Dutt (1962)
	<u>Crotalaria</u> <u>junea</u>	U.P.	-	
3. <u>O.wallo-</u> <u>nensis</u> (Wasmann)	Casurina, Mango, Silver oak, Groundnut, Maize, Eucalyptus Nizer, Maize, Ragi, Castor, Redgram, Coconut, Jack, Cashew, Grass	India Karna- taka	Roots and Collar region and Stubble	Roonwal (1970) Rajgopal (1979, and 1982) Sudhakar (1983)
4. <u>O.redemanni</u> (Wasmann)	Eucalyptus Coconut Tea	Kerala Sri- Lanka "	Roots & Collar region Collar region Roots	Chatterjee (1970) Nair and Verma (1981) Jepson (1931) Harris (1969)
5. <u>O.horni</u> (Wasmann)	Maize, Ragi, Castor, Euca- lyptus, Tamarind, Cashew, Silver oak, and Jack tree.	Karna- taka	Roots & Stem	Roonwal (1978b) Sudhakar (1983)

(1)	(2)	(3)	(4)	(5)
6. <u>O. ceylo-</u> <u>nicus</u> (Wasmann)	Maize, Ragi Subabul, Grass Eucalyptus	Karna- taka Kerala	Roots & Stem Roots & Collar region	Sudhakar (1983) Nair & Verma (1981)
7. <u>O. bella-</u> <u>hunisensis</u> (Holmgren & Holmgren)	Eucalyptus Coconut	Tamil- Nadu Orissa	-do- -do-	Roonwal and Rathore (1984) Reddy (1983)
8. <u>Trinervi-</u> <u>termes</u> <u>biformis</u> (Wasmann)	Cotton, Wheat Groundnut, Brinjal, Guava, Mango, Citrus, Pome- granate and Sapota Grasses, Ragi	Uttar- Pradesh Maharashtra Karna- taka	 - Stalks	Patel (1962) Agarwal (1972) Butani (1973) Sudhakar (1983)

2.2. Bio-ecology of termites

There have not been much information on the biology of termites, except some observations made during the course of study of some species on other behaviours (Mukerji and Mitra, 1949a; 1949b; Roonwal, 1958; 1960; Lee and Wood, 1971).

2.2.1. Swarming

According to Snyder (1948), Swarming or "Colonizing flight" occurs for the purpose of establishing new colonies. Swarming behaviour of Indian species have been described by Konig (1779); Roonwal (1970), Roonwal and Rathore (1975).

Swarming in termites is common to all species at all places. The reproductive alates take to wings during a particular part of the year, varying from species to species and place to place. Swarming behaviour of some of the species occurring in India is listed here under :

Species (1)	Time (2)	Season & Locality (3)	Authority (4)
1. <u>Heterotermes indicola</u> (Wasmann)	Morning Night	Monsoon-Bombay Mid-July-August East Punjab and Dehradun	Assumuth (1913) Arora and Gilotra (1960)
2. <u>Microtermes</u> sp.	- Night	2nd & 3rd week of July, Delhi 3rd week of June to 2nd week of August - Delhi	Pruthi (1939) Vishnoi (1959)
3. <u>Microtermes mycophagus</u> (Desneux)	Night (8-9 PM)	24th June to 24th August Jodhpur	Roonwal and Rathore (1975)
4. <u>M. obesi</u> Holmgren	Day (10.30- 1.30) Evening (18.50- 19.00)	23rd June to 17th August Jodhpur May-Chintamani (Karnataka)	Roonwal and Rathore (1975) Sudhakar (1983)
5. <u>M. unicolor</u> Snyder	Night (8-9 PM)	5th July to 20th August Jodhpur	Roonwal and Rathore (1975)
6. <u>Odontotermes</u> sp.	-	2nd week of July - Delhi	Pruthi (1939)
7. <u>O. assmuthi</u> Holmgren	Afternoon Dusk (Night)	June - July North India April-December Karnataka	Roonwal (1970) Basalingappa (1968, 1974)

1	2	3	4
8. <u>O.obesus</u> (Rambur)	Night Day (9.30- 10.30 AM)	June North India June-July Karnataka	Roonwal (1970) Sudhakar (1983)
9. <u>O.horni</u> (Wasmann)	Evening	October, Manipur) Dec.-Jan. Ceylon)	Roonwal (1970)
10. <u>O.redemanni</u> (Wasmann)	- evening	September East India Nov.-Dec. Sri Lanka	Mukerjee and Mittra (1949a) Banerjee (1966) Escherich (1911) Bugnion (1915) John (1925)
11. <u>O.wallonensis</u>	Evening Morning	April-May Karnataka May - Karnataka	Rajgopal (1979) Sudhakar (1983)
12. <u>Speculitermes</u> <u>sinhalensis</u> Roonwal and Sen-sarma	-	March-April	Roonwala and Chhotani (1966)
13. <u>Speculitermes</u> sp.	Noon	May	Sudhakar (1983)
14. <u>Trinervitermes</u> <u>biformis</u> (Wasmann)	Night Night	Middle of June to Middle of July Andhra Pradesh Karnataka	Peter and Radhakrishna (1981) Sudhakar (1983)

2.2.2. Foraging

Termites must forage to get the food. Food supplies for the termite colony are collected by the workers who besides themselves, feed the dependent castes: nymphs,

soldiers and primary and secondary reproductives in the colony. All termites construct a system of galleries or runways either covered or uncovered, along which they travel in search of requisites such as food, moisture and soil particles. The foraging galleries or runways lead from the central nest system to sources of food and often they are very extensive (Wood, 1978). Andrews (1911) reports that the odour trails are connected with foraging in Nasutitermes. In this genus the origin of odour and the trail lies in the sternal gland (Stuart, 1963). In the Ivorycoast, Trinervitermes trinervium (Rambur) forages throughout the year, although the intensity of foraging is related to the seasonal weather, the maximum being during September-October after heavy rains and the minimum in dry seasons during December-May (Bodot, 1967).

and food

According to Wood et al. (1977), Trinervitermes geminatus Wasmann forages either early morning, late evening or some times at both the periods on any particular day. For foraging several hundred individuals emerge from their subterranean galleries via holes at the soil surface. They climb up standing grass tussocks and cut the grass into pieces of 2-20 mm in length. Some of the cut grasses is left on the ground but most is transported back to the surface foraging holes via the subterranean galleries to the

mounds. T.geminatus forage in the open for upto 2 m from their foraging holes. Sands (1961b) observed foraging parties of T.geminatus spreading out over areas upto 3 m² and climbing tall grass upto heights of 1 m, whereas the sympatric species, T.oeconomus (Tragardh), mainly foraged near its mounds, often emerging directly from the mound.

Wood and Ohiagu (1976) reported that a colony of Macrotermes subhyalinus (Rambur) appeared to forage over an area of 0.31 hectare at Mokwa (Nigeria). This species forages on the surface for short distances from its foraging holes and consequently, in areas of the territory where foraging is active there are many foraging holes (upto 30 per m² but more often 10-15 per m²). Nel (1968) estimated 0.08-0.56 of foraging holes per m² for Hodotermes mossambicus (Hagen) and Ohiagu and Wood (1976) estimated 0.015-0.133 of foraging holes per m² for T.geminatus. Active foraging of this species occurred during September-October and May-April in Northern Nigeria (Sands, 1965 and Bodot, 1967).

Coaton (1958) reported H.mossambicus foraging during day in open air, but never at night during colder months. Foraging was observed if the days were clear and windless between 10.00 -16.00 hours and in summer the foraging took place in the cooler hours, late in the evening and early morning.

The foraging activity of some termites is nocturnal but can also be active during the day if the sky is cloudy and the weather humid, as in Trinervitermes spp. (Sands, 1961a) and in Macrotermes natalensis (Haviland) (Grasse and Noirot, 1961).

Trinervitermes geminatus forage during the months of December to June between 06-9.30 hours in the morning and from 16.30 to 18.30 hours in the early evening. Foraging occurs largely during day light and the last half hour of the morning period and first half hour of the evening period is carried in bright sunlight. Low temperature early in the morning restrict foraging to the evening period (Ohiagu and Wood, 1976).

O.wallonensis make their galleries at 10-30 cm below the ground level. The diameter of such galleries range from 2 to 3 cm. The foraging workers are found attacking the bark of standing eucalyptus trees making sheath to a height of 6-7 m. Normally foraging occurs at temperature of 27°C and below (Veeranna and Basalingappa, 1981).

Rajgopal and Veeresh (1981) reported that only workers of O.wallonensis took part in foraging while soldiers guarded them. They always foraged under the earthen sheathing or galleries measuring 6-9 mm in diameter and running 3 to 30 cm

from the mound and they came to the surface to forage on the ground or climbed the trunks of trees. Foraging was mainly carried out in the cool early morning or late evening and it also occurred during the day when the sky was overcast. Two peak foraging periods occurred one from April to June and the other from October-December. Higher temperature and more sunshine hours reduced the foraging activity.

The Adult workers, soldiers and sometimes immature workers of O.redemanni make covered runways and forage several meter distance from the mound (Mukerji and Mitra, 1949a).

Roonwal (1970) reported that in T.biformis foraging workers set out at sunset in thousands. Workers marched in the column and on either side, soldiers took positions to protect the columns. When alarmed, workers quitely returned to the nest but soldiers remained on guard until every worker was in.

Foraging habits of Microtermes sp., Coptotermes, Allodotermes and Odontotermes sp. in Southern Nigeria, showed that under normal conditions these termites rarely foraged more than 7-8 cm above soil unless in continous contact with cellulose material (Kay and Macnutt, 1968).

Surface foraging activity of Microtermes was stimulated after heavy rain and shortly declined at the end of wet season under Nigerian conditions (Johnson et al., 1981).

2.2.3. Natural enemies

The available information on the natural enemies of subterranean termites is very little. Maxwell-Lefroy and Howlett (1909) mentioned that at certain seasons, immense number of winged males and females emerged and were at once attacked by innumerable birds and other enemies. Birds, frogs, toads, scorpions, lizards, ants, mantids, crickets, beetles, wasps, cockroaches devoured the winged termites as they emerged from the nest (Fletcher, 1914; Snyder, 1948; Harris, 1964; Nutting, 1969; Hickin, 1971; Rajgopal, 1979 and Maiti, 1983).

Among the invertebrates, ants (Formicidae) are the most important predators of termites at the time of swarming and foraging. Some species of ants attack termites in the colony. Mathur (1962), reported the following species of ants as enemies of termites. Acantholepis frauenfeldi Mayr (Formicinae), Camponotus compressus Fab. (Formicinae), Crematogaster sp. (Myrmicinae), Lobopelta diminuta (Ponerinae), Monomorium destructor Jerdon & M. indicum Fonel (Myrmicinae). Leptogenys processionalis (Jerdon) was also reported as an active predator of termites by Negi (1934), Rajgopal and Ali (1984) and Shivashankar and Veeresh (1986); other insect predators include the dragonfly, Pantala flavescens Fabr., the rober

flies, Machimus rufipes Ricardo and Promachus duvaucelii (Macquart), the callophorid fly, Bengalia jejuna (F.) which all prey on swarming alates (Green, 1906 ; Maxwell-Lefroy and Howlett, 1909; Mathur, 1962). A reduviid bug, Acanthaspis sulcipes Signoret is also reported to feed on termites (Anwar, 1970; Rajgopal, 1979).

Mathur (1962) listed the following vertebrate predators, frogs, toads (Rana tigrina Daud and Bufo melanastictus Schneider) and birds (Carvus splendens Vieillot, C. macro-rhynchos Wagler, Dicrurus macroceyus Vieillet. Molpastes cafer Linn., Acridotherus tristis Linn., A. ginginianus Latham, Upupa epops Linn., Gallus bankiya murghi (Robinson and Kloss), G. sonneratti Temminck, Coturnix coturnix Linn., Francolinus sp., F. pictus (Jardine and Selby), F. pondicerianus Gmelin; Turdoides somervillei syxes, Gallus gallus Linn., Saxicolaidea fulicata Linn., Uroloncha punctulata Linn. and Athene brama (Temminck).

Among the mammals, the scaly ant eater (Manis crassicaudata Gray), the sloth bear (Melursus ursinus Shaw) are the most important and feed on adults, nymphs and eggs (Mathur, 1962).

2.2.4. Fungal association and composition of fungus comb

The association of termites with fungi is not clearly understood. Konig (1779) was the first to report the sponge

like fungus garden of Macrotermitinae, built from vegetable residues and supporting a mycelium, with white nodules of conidia and conidiophores. He believed that the conidia might be used as food for the termites. The fungus combs in the nests of macrotermitinae was a possible source of food for the termites (Annandale, 1923, 1924; and Das et al., 1962). Grasse (1949), Luscher (1951) and Das et al., (1962), however observed, that the conidia were occasionally eaten by termites in small quantity as a source of vitamins. The fungus combs are believed to serve as "egg depositories" and "nursery" for termites (Mukerji and Mitra, 1949a). Kalshoven (1936) reported that the fungus combs of Macrotermes, Odontotermes and Microtermes were eaten away from bottom by the termites, when the combs attained a certain size. Sen-sarma (1974) also made similar observations. On the other hand Luscher (1951) and Geyer (1951) claimed that the fungus comb might generate heat as a result of fermentative process and thus assist in the maintenance of constant temperature inside the mound.

2.2.4.1. Moisture content

Cheema et al. (1962) measured the relative abundance in the air around the fungus gardens of O.obesus and it varied between 85 and 95 per cent. The moisture content in the fungus garden was 51.63 per cent (Roonwal, 1960). Mishra

and Sen-sarma (1979) reported that the moisture content in the fungus comb indicated to conserved moisture of ejected excess water. Hesse (1957) also considered the fungus gardens to function primarily to control humidity by taking up excess of moisture in African termite species.

2.2.4.1. Chemical composition

Termites belonging to the family Macrotermitinae construct the fungal combs. According to Grasse (1949) the fungus combs were constructed by a paste of finely divided wood, chewed for a long time by the workers and shaped into small balls, by rolling in the mouth parts then built up into combs. But Sands (1969) and Wood (1976) reported that the combs were constructed from faecal pellets or excreta.

The available information on the chemical composition of the fungal comb, which is very scanty, indicate that, they consist of mainly lignin and cellulose. Bachelier (1963), Joachim and Kandaiah (1940), Hesse (1957), Becker and Seifert (1962) analysed fungus combs constructed by several East African species of Macrotermes and Indian species Odontotermes. The ash content varied from 10.7 to 23.9 per cent (Hesse, 1957; Becker and Seifert, 1962), the lignin:cellulose ratio from 0.20 to 0.55 (Becker and

Seifert, 1962), the pH of the fungal comb was 4.3 to 4.5 (Hesse, 1957), the nitrogen content from 1.1 to 2.0 per cent (Joachim and Kandaiah, 1940; Hesse, 1957) and the C:N ratio was from 25.5 to 28.3 (Matsumoto, 1976).

Mishra and Sen-sarma (1979) reported the ash content, soluble sugars of the fungal comb to be higher and lignin content lower.

Rajgopal (1979) made a detailed study on the constituents of the fungal comb of O.wallonensis. According to him, the cellulose content varied from 22 to 26 per cent lignin from 12 to 21 per cent carbon content from 33 to 36 per cent nitrogen from 0.690 to 1.330 per cent, C:N ratio between 24.81 to 49.25, crude fat content from 2 to 5 per cent and the ash content from 21.5 to 24.0 per cent.

2.2.5. Communication, alarm and defense

Communication is one of the important aspects of social behaviour in termites by which they are able to perform different biological activities like foraging, tending the eggs and young ones inside the nest, feeding and cleaning individuals of other castes, construction and repairing of the nest.

Krishna (1969) reported that termites produced sound by convulsive movements, jerking and tapping their heads against the ground. According to Emerson (1929) the sounds produced by the soldiers served as means of communication of warning to other termites probably by creating substratum vibrations. The soldiers of Macrotermes sp., Microtermes sp. and Odontotermes release a defensive fluid and adhesive material from their large labial glands when fighting (Maschnitz and Tho, 1974).

2.3. Host preference and losses caused by the termites among the agricultural crops

Very little information is known regarding the food preference of termites and it is poorly understood either in field or laboratory conditions (McMahan, 1966).

Nel et al. (1970) claimed that the laboratory colonies of Hodotermes mossambicus preferred dry to green plant material, Further, grasses were preferred over shrubs with exceptions; such as green Aster muricatus (compositae) which was eaten in preference to many dry grasses and also green Eragrostics superba (graminae) which ranked below a number of grasses.

Sands (1965) conducted a laboratory study on T.geminatus Wasmann and showed that many different species of grasses were accepted although smaller, fine leaved

species were preferred to larger, coarse leaved species.

In living plants, decrease in vigour due to drought and disease are the predisposing factors for the susceptibility of plants to termite attack in over 47 million hectares of land distributed in 84 districts comprising 36 per cent of the net area sown in India (Peswani and Katiyar, 1972).

Termites damage a variety of crops throughout the tropics (Harris, 1969). In all tropical and subtropical countries the annual losses caused by termite depredations run into millions of dollars. As early as 1912, Fletcher estimated the loss to crop due to termites alone to account to 280 million rupees in India. The loss in terms of rupee vary from time to time (Roonwal, 1970).

Agarwal and Sharma (1954) reported that the average losses by termites to maize plant stand was 22 per cent from India; 27 per cent from Tanzania (Bigger, 1966) and 29 per cent from Nigeria (Sands, 1977).

Yield losses due to Microtermes on recently cultivated fields (1-3 years) varied from 0.1 to 3.0 per cent and on long cultivated fields (10-27 years) from 3.9 to 9.5 per cent; commencing from 10-12 weeks after sowing in maize (Wood et al., 1980). Damage and loss in yield were

linearly correlated with abundance of Microtermes and years of cultivation and crop losses as high as 70 per cent in Northern Africa have been reported (Johnson and Wood, 1979).

Drought, natural and physiological factors were the predisposing cause of termite attack on growing plants (Hickin, 1971). Thus, only in low rainfall areas, damage to groundnut was serious (Feakin, 1973).

The foliage of groundnut was attacked by Odontotermes with the result loss in yield was less than 5 per cent in Sudan and Nigeria. Further there was linear relationship between the percentage of stands with taproots invaded by Microtermes and loss in yield; damage varied from year to year, yield losses upto 40 per cent were recorded (Johnson et al., 1981).

In India, Rawat et al. (1970) reported the groundnut plant mortality of 35.2 per cent in untreated plots. Kaushal and Deshpande (1967) reported 25 per cent pod loss in groundnut in untreated plot and yield improvement of 112 per cent in Heptachlor treated plots. Termites attacked all the stages of the groundnut in the field, seed storage causing physical loss and loss of quality (Amin and McDonald, 1981).

Microtermes sp. attacked the roots and kernels of groundnut

causing severe damage in Somalia (Farah, 1974). Lamb (1979) recorded 40 per cent loss of yield in groundnut in Nizerian condition. The roots of bajra were attacked by Microtermes sp. and Odontotermes sp., and recorded 10 per cent infestation in Nigeria (Ajayi, 1980).

Mean per cent infestation of termites was maximum in maize (38.48) followed by ragi (14.01) niger (12.08) and groundnut (8.21) and no infestation was recorded in sunflower (Sudhakar, 1983). Further, he reported that the avoidable loss due to termites was 50.25 to 51.19 per cent in groundnut, 35.29 to 36.14 per cent in ragi, 31.31 to 37.83 per cent in niger and 13.10 to 21.78 per cent in maize.

A gradual increase in the intensity of attack by termites from the month of November when the rains ceased was observed. The per cent infestation was 15.84 during the beginning of November and the same doubled (30.15 per cent) by the end of the month in maize (Veeresh, 1983). Further, he made similar observations in niger, where the per cent infestation increased from 6.99 to 55.28 and the per cent loss was 57.20. Sunflower recorded the infestation of 23.20 under dry condition (Anonymous, 1985).

In sugarcane belt of North India, 30 to 60 per cent of freshly planted setts have been destroyed by the termites (Agarwal, 1955; Avasthy, 1967; Gupta, 1959; Nayar, et al., 1976). The eye bud damage ranged from 7.2 to 81.8 per cent (Singh and Sandhu, 1966; Teotia et al., 1963; Thakur et al., 1957).

Losses to setts due to termite attack also ranged from 1.54 per cent to 100 per cent according to various workers (Agarwal, 1972; Gupta, 1959; Kadirvelu and Venugopal, 1965; Karla and Kumar, 1971; Krishnamurthy and Ramasubbaiah, 1962; Narayanan and Lal, 1952; Rao and Agarwal, 1957; Singh and Sandu, 1966).

2.4. Losses caused by the subterranean termite, *Microtermes obesi* Holmgren in wheat and its management

Among cereals, wheat is one of the most susceptible cultivated crop to termite attack at all stages of its growth. *Microtermes obesi* and *Odontotermes obesus* have been reported to be the most important termite species damaging wheat (Hussain, 1935; Beeson, 1940; Parihar, 1978 and Vevai, 1972).

The average annual losses of wheat in India at different places were estimated to vary from 6 to 40 per cent (Hussain, 1935; Sharma, 1959; Sood et al., 1970; Srivastava

and Lal, 1973; Nair, 1975) and 40 per cent from Nigeria (Johnson, 1981).

Ghose (1964) reported that the dusts of 5 per cent aldrin at 60, 40 and 30 lbs/acre as a presowing treatments controlled the M.obesi on wheat effectively. Application of aldrin 5 per cent dust at 25 kg/ha before sowing recommended for the control of M.obesi and O.obesi in wheat crop (Sood et al., 1970; Batra, 1976; Huque, 1977).

Kishen et al. (1972) observed the incidence of M.obesi on wheat and it varied from fortnight to fortnight. The incidence reached maximum during the second fortnight after sowing and caused 2.08 per cent damage to clumps.

Verma et al. (1976) studied the effectiveness of B.H.C. at 2.5, 1.875 and 1.25 kg/ha and 1.875, 1.25 and 0.625 kg aldrin/ha applied as a presowing soil treatment or with the first irrigation water. In all the 3 doses of B.H.C. and the lower dose of aldrin applied with irrigation water, the termite damage during the growth stage was as high as that of in control. However, all the insecticidal treatments reduced the crop damage during the ear formation stage and led to increase in crop yield. The most profitable treatments yielding 47, 46.6 and 46.5 per cent net gain over control were aldrin

1.875 kg ai with irrigation water, aldrin 1.875 kg ai and B.H.C. 2.5 kg ai presowing treatments respectively.

Investigations of Verma et al. (1978), revealed that, irrespective of wheat variety, termite damaged tillers during the earing stage resulting in 91.4 per cent loss in grain yield. Similarly Singh et al., (1970) estimated 0.8 per cent yield loss for every one per cent increase in termite infestation.

Aldrin 30 EC was found to be more effective when broadcasted although it gave good control when applied via the irrigation water, according to the findings of Sandhu and Sohi (1977).

Verma (1980) found the number of damaged tillers by termites in wheat crop to be highest in plots irrigated once and lowest in the plots irrigated 3 or 4 times. Further, as compared to untreated seeds, seed treatment with aldrin 30 EC (40 ml aldrin 30 EC/Q seed) resulted both in reduced termite damage and higher wheat yield.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The present study was undertaken during the years 1979-80, 1982-83 to 1985-86 at the Main Research Station, Hebbal (altitude 899 m) and during 1982-83 at the Agricultural Research Station, Chintamani (altitude 869.90 m). Studies were conducted at M.R.S. Bangalore on both cultivated and uncultivated lands and at Chintamani only on cultivated land.

3.1. Species of termites and their relative abundance at Main Research Station, Hebbal

Wheat, ragi and maize straw were used as baits (for scouting termites) to know the relative abundance of different species of termites. The baits were placed alternatively ragi, wheat and maize at 5 meter apart along the bunds in cultivated field. Fortnightly observations were made from September 1985 to August 1986 on the infestation and the species involved in different baits.

In addition to collection made from the baits placed as above, termites were also collected from the mounds, sheathings, infested tree-bark, dung, grasses, leaf litter and dead wood by using an aspirator. They were then transferred into small glass vials of 5 x 1 cm containing 70 per cent alcohol, and stoppered tightly and labelled in pencil,

placed inside, stating location, habitat and date of collection. Observations were made on the

Alates were collected as and when emerged during the course of study. Species were identified using the key of Bose (1984) by preparing the slides and mounting the head capsule by standard method. Diagrams were made using the camera lucida.

Distribution of nests/mounds in the study area (40 ha) were located and mapped (Fig.11). The subterranean nests were located at the time of alate emergence. See noted.

3.2. Studies on some ecological aspects of the subterranean termite, *Microtermes obesi* Holmgren

This study was undertaken during the years 1983 to 1985 at the Main Research Station, Hebbal.

3.2.1. Swarming

Swarming flights in respect of four nests were observed for two years 1983 to 1985. The time, place, duration of emergence and number of exit holes were noted as occurred on the nest surface (Table 5). Atmospheric temperature, per cent relative humidity and average rainfall of the week were also recorded.

3.2.2. Foraging activity

Observations were made on the foraging activity and the runways or galleries made in the soil by the workers. The depth and distribution of subterranean runways were studied by making 'L' shaped trenches at two sides of each nest. The trenches were dug to 2.4 M long, 0.9 m wide and 1.2 m depth on both the sides of the nest at a distance of 1.2 m away from its base. The observations on the location and number of runways at different depths were recorded on the two vertical trenches in all the three nests. Foraging activity in different seasons of the year was also noted.

3.2.3. Natural enemies

Observations were also made on the incidence of natural enemies during swarming flight near the nest and also near the light, and the data is presented in Appendix 1.

3.2.4. Moisture content and Chemical composition of fungus comb

The moisture content of the fungus combs were determined by removing the fresh fungus combs from the nest during three seasons in a year; Summer (April-May), rainy season (July-August) and Winter (November-December) 1983. Three to four fungal combs from a nest were dug up and immediately transferred to 0.5 mm thick polythene bags. Wet weight was determined in a monopan balance soon after collection along with the

termite; then the combs were broken into small pieces, anaesthetized with chloroform to separate the termites and weight of termites was recorded separately. The combs were dried in a hot air oven at 105°C for 24 hrs and weighed to calculate the per cent moisture of the fungal combs.

Chemical analysis for cellulose was made following the method of Lossin (1971), weighed samples were treated with glacial acetic acid and concentrated nitric acid and further treated with benzene to remove benzene soluble material. The sample was filtered through a Gooch crucible. The residue in the crucible was treated with ether and washed with acetone and then washed with successive 100 ml portions of hot benzene, hot methanol and ether before being oven dried, cooled in the desiccator and weighed. The dried material was ignited at 625°C in muffle furnace for one hour, cooled and weighed. The cellulose percentage was calculated by using the formula -

$$\text{Cellulose per cent} = \frac{\text{Loss after ignition} \times 100}{\text{Initial sample weight}}$$

The lignin content of the fungus comb was estimated by following the procedure of Allen et al. (1974). A weighed sample of the fungal comb was treated with diethyl ether for overnight to remove the fat. The residue was dried and then

treated with 10 per cent sulphuric acid for one hour and filtered through linen cloth. The residue was further treated with 72 per cent sulphuric acid and heated on a water bath having boiling water for two hours, filtered through linen cloth and then residue washed with hot water till it was free from acid. Later it was dried at 105°C for three hours and weighed as corrected lignin residue. The lignin content was calculated by using the formula -

$$\text{Lignin per cent} = \frac{\text{Corrected lignin weight (g)} \times \text{Total ether extracted sample} \times 10^2}{\text{Weight taken for water extraction (g)} \times \text{Sample weight (g)}}$$

Total carbon and total nitrogen from fungus combs were determined by adopting the procedure of Jackson (1967).

To determine fat percentage of fungal combs. Allen et al.'s (1974) procedure was adopted. A weighed quantity of the fungal comb was treated with diethyl ether over night and dried at 105°C for 30 minutes and then weighed. The loss in weight taken as crude fat percentage.

Ash was estimated as explained by Jackson (1967). The weighed samples were ignited at 600°C for 2 hours. The remaining ash was weighed after cooling it in a desiccator.

3.3. Host preference and estimation of avoidable losses

During Kharif season of 1983-84, an experiment was conducted at the Main Research Station, Hebbal, and Agricultural Research Station, Chintamani, to determine the host preference of termites among the agricultural crops. At both the locations the experiment was laid out in the split plot design with two main treatments, namely the protected (treated) and unprotected (untreated) with eight agricultural crops as subtreatments. The experiment was replicated three times. The size of the experimental plot was 3 x 3 m. The subtreatments (Agricultural crops) included (1) Ragi (Indaf-5), (2) Wheat (UP-301), (3) Setaria (RS-118), (4) Bajra (BJ-104), (5) Groundnut (Spanish improved), (6) Sunflower (Modern), (7) Niger (Variety No.71), and (8) Maize (Deccan). The insecticide used in the main treatment was aldrin 5 per cent dust (D) at 25 kg/ha. The insecticidal dust was thoroughly mixed with the soil in the entire plot before sowing. The recommended package of practices (Anonymous, 1986) were adopted for cultivation except the plant protection measures. Sowing was taken up during the month of July and August 1983 at Main Research Station, Hebbal, and Agricultural Research Station, Chintamani, respectively.

Fortnightly observations on termite infestation were taken and the data was subjected to statistical analysis. The grain yield of each plot was converted to quintals/ha and analysed statistically and the results have been discussed at the probability level of 5 per cent. Subsequently, to assess the crop-loss, the per cent increase in yield over control and per cent avoidable loss were computed by using the formulae -

$$1) \text{ Per cent increase over control} = \frac{\text{Yield in the treatment to be assessed} - \text{Yield in the untreated check}}{\text{Yield in untreated check}} \times 100$$

$$2) \text{ Per cent avoidable loss} = \frac{\text{Yield in the treatment to be assessed} - \text{Yield in check}}{\text{Yield in the treatment to be assessed}} \times 100$$

Further, the cost benefit ratio was also worked out for each crops by the following formula:

$$\text{Cost benefit ratio} = \frac{\text{Value of Added yield (total value of the produce)}}{\text{Cost incurred towards the treatment}}$$

$$\text{Where, Added yield (Q/ha)} = \text{Yield from the treated plots} - \text{Yield from the untreated plots}$$

3.4. To estimate the loss in wheat by *Microtermes obesi* Holmgren and its management

During rabi season of the year 1979-80 and 1982-83 experiments were conducted at the Main Research Station, Hebbal, to assess the crop-loss in wheat due to the subterranean termite, *Microtermes obesi*. This experiment was laid out in the split plot design with three main treatments, consisting of (1) No irrigation, (M_1), (2) Frequent irrigation (M_2), and (3) Normal irrigation (M_3), and with six sub treatments including -

- (1) Aldrin 5 per cent dust (D) at 25 kg/ha
Broad-casting (B.C.);
- (2) Aldrin 5 per cent dust (D) at 37.50 kg/ha
Broad-casting (B.C.);
- (3) Aldrin 5 per cent dust (D) at 25 kg/ha Row
application (R.A.);
- (4) Aldrin 5 per cent dust (D) at 37.50 kg/ha
Row application (R.A.);
- (5) Aldrex 30 EC 0.3 per cent (Soil drenching
to the row); and
- (6) Control (No insecticide).

Under frequent irrigation condition the crop was irrigated once in 5 days whereas under normal irrigated once in 10 days.

All the insecticides were applied at the time of sowing. The dusts broadcasted and mixed into the soil in the entire plot, whereas in row application the insecticidal

dust was applied into the row only and mixed with the help of a stick. Stock solution of Aldrex 30 EC, at 0.3 per cent concentration was made and applied to rows at 1 litre per plot, immediately after sowing. Other methods followed for cultivation is as per the package of practices (Anonymous, 1986) excepting plant protection measures. Sowing was taken up during the months of October 1979 and 1982 at Main Research Station. Wheat variety CC-464 was used in the experiment.

Weekly observations for infestation based on the drying up of seedlings or plants was recorded. The per cent infestation of plants due to termite was calculated and the data was analysed statistically and the results have been discussed at the probability level of 5 per cent.

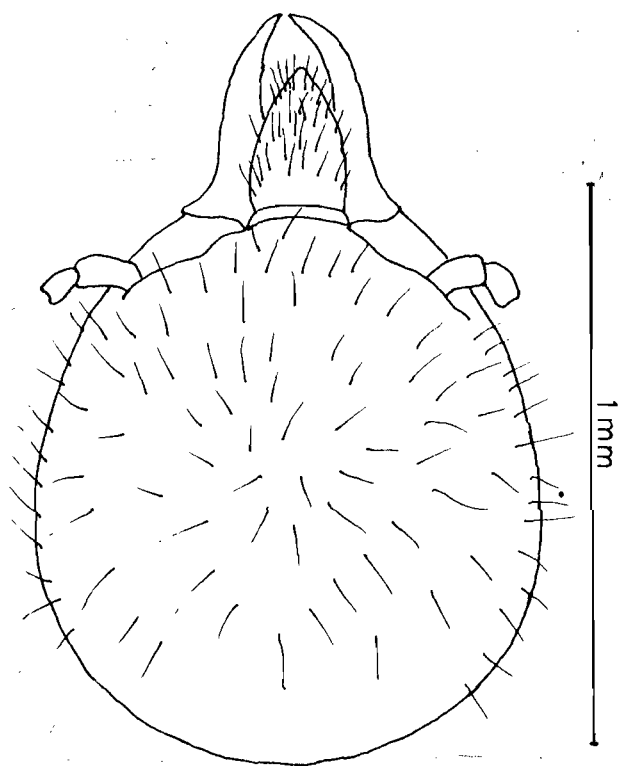
Grain and straw yields recorded per plot were converted to Q/ha and the data was statistically analysed. Subsequently, to assess the crop-loss, the per cent increase in yield over control, per cent loss over best treatment and the per cent avoidable loss were computed by using the formulae -

$$1) \text{ Per cent increase over control} = \frac{\text{Yield in the treatment to be assessed} - \text{Yield in the untreated check}}{\text{Yield in untreated check}} \times 100$$

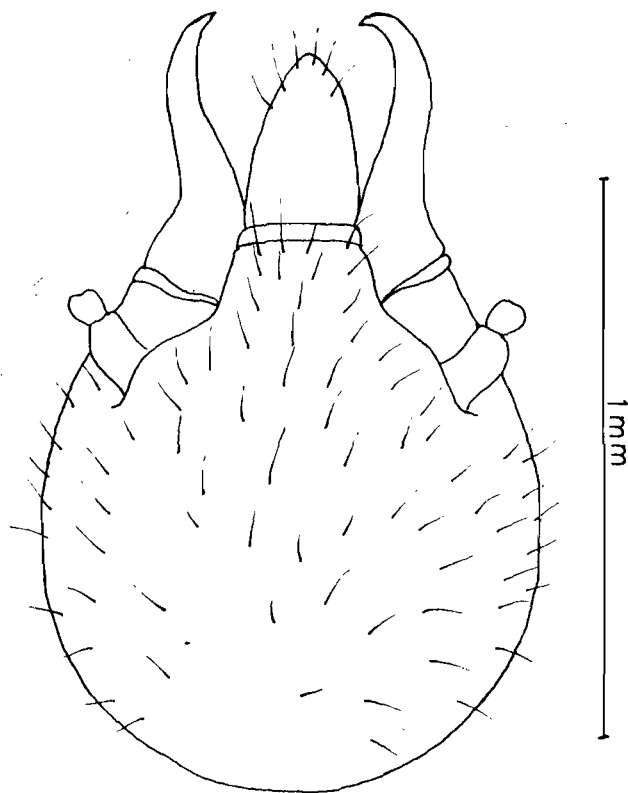
$$2) \text{ Per cent loss over best treatment} = \frac{\text{Yield in best treatment} - \text{Yield in the treatment to be assessed}}{\text{Yield in best treatment}} \times 100$$

$$3) \text{ Per cent avoidable loss} = \frac{\text{Yield in the treatment to be assessed} - \text{Yield in check}}{\text{Yield in the treatment to be assessed}} \times 100$$

EXPERIMENTAL RESULTS

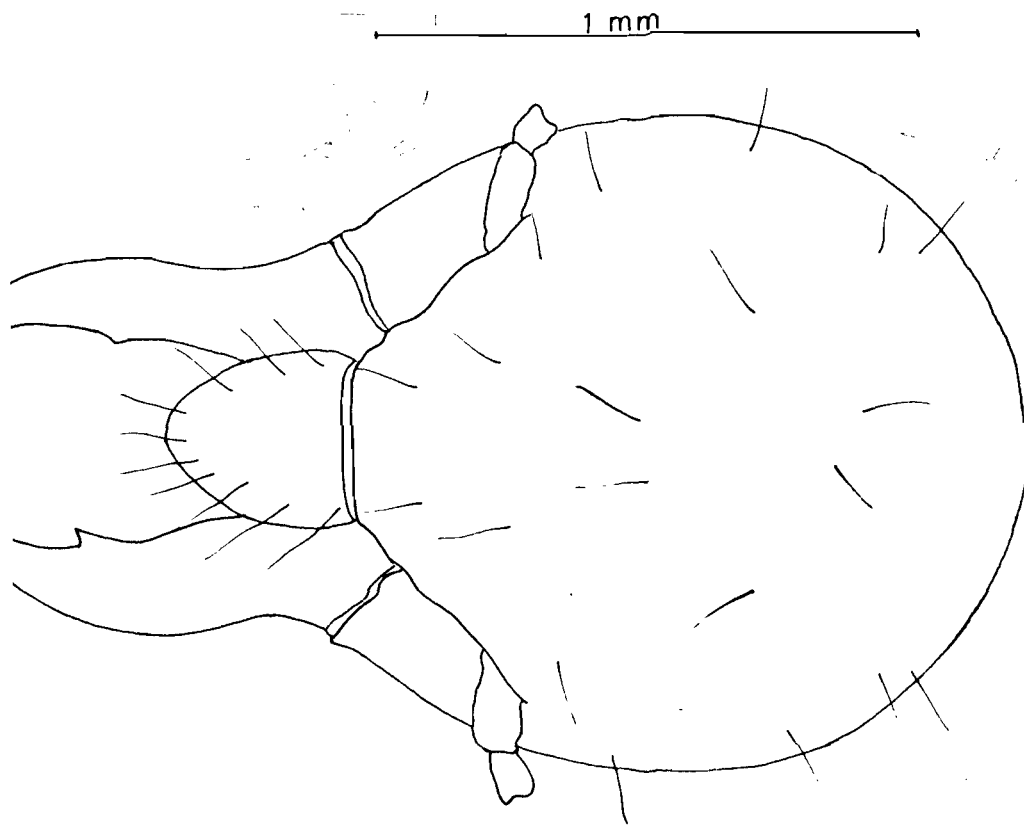


Microtermes globicola

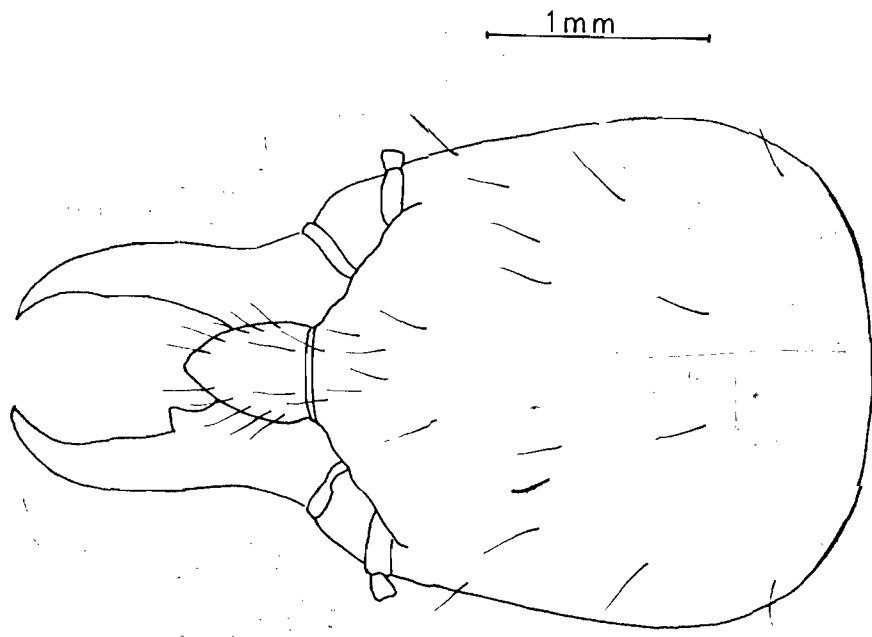


Microtermes obesi

FIG.1: DIAGRAMS DISTINGUISHING Microtermes spp. (ENCOUNTERED IN THE PRESENT STUDY) BASED ON SHAPE OF THE HEAD AND MANDIBLES.

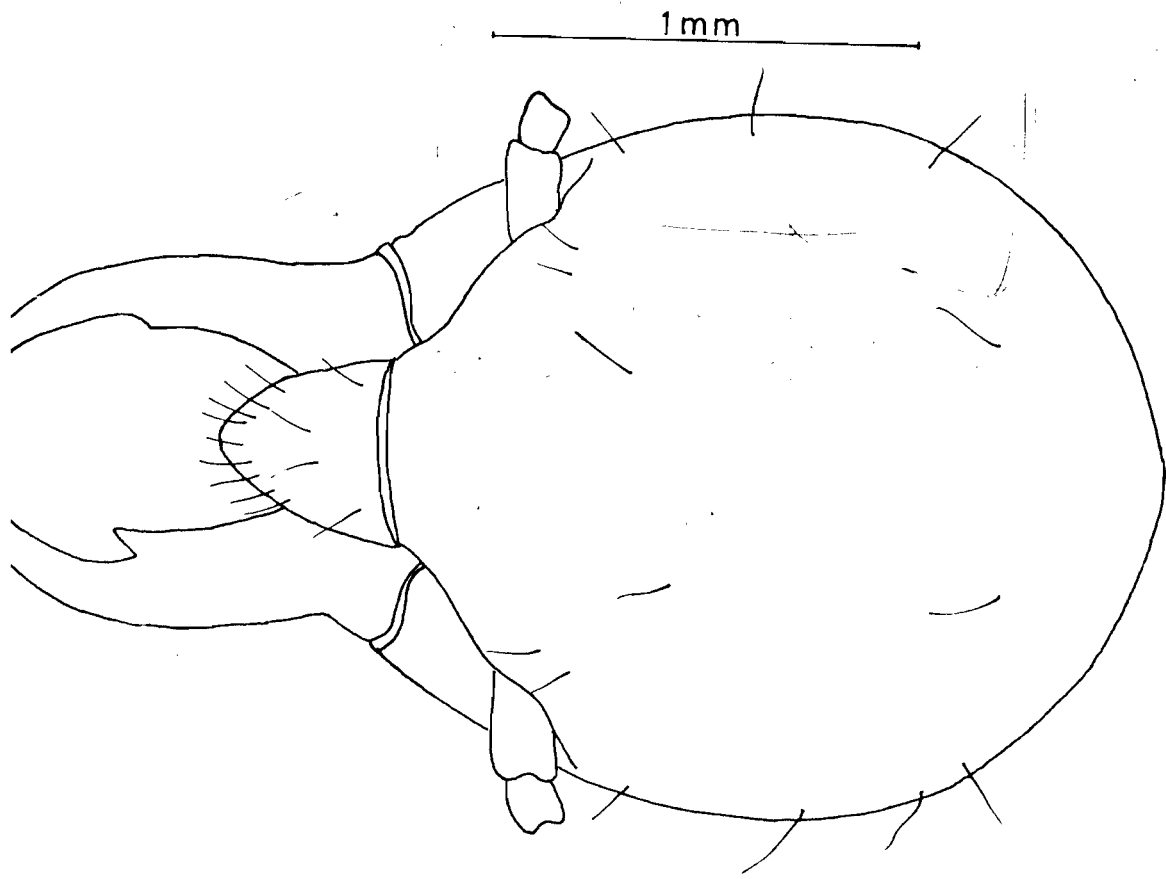


Odontotermes redemanni

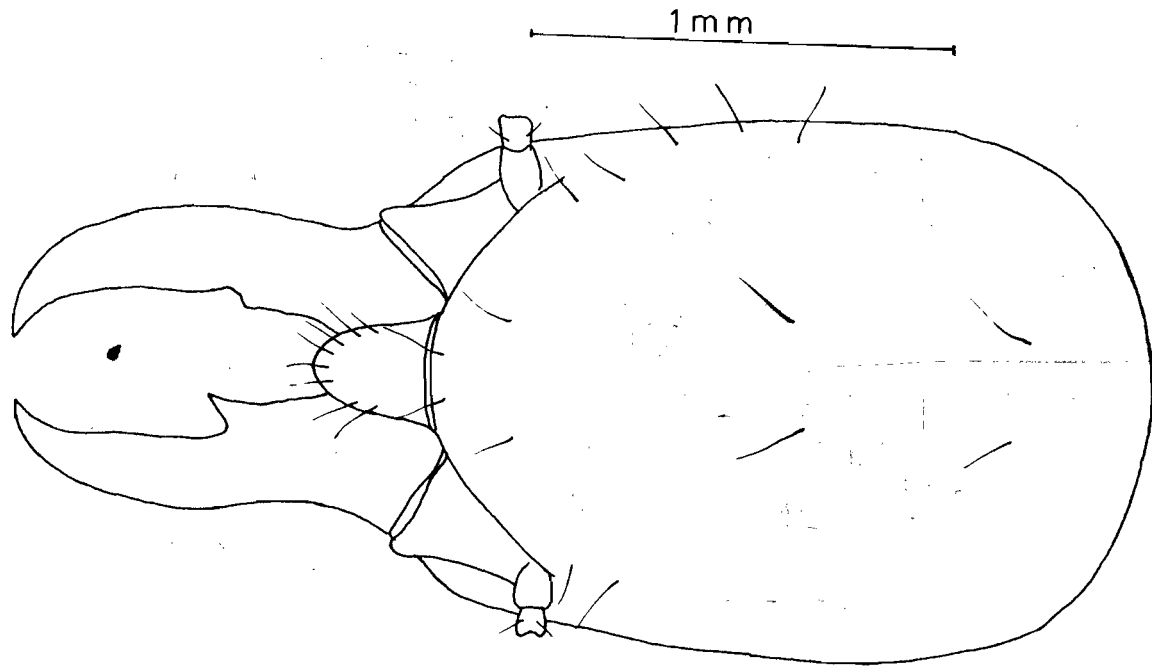


Odontotermes horni

FIG.2 : DIAGRAMS DISTINGUISHING Odontotermes spp.(ENCOUNTERED
IN THE PRESENT STUDY) BASED ON SHAPE OF THE HEAD AND
MANDIBLES.

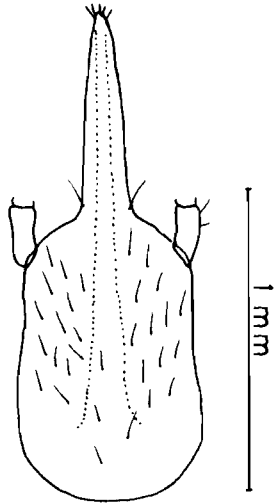


Odontotermes obesus

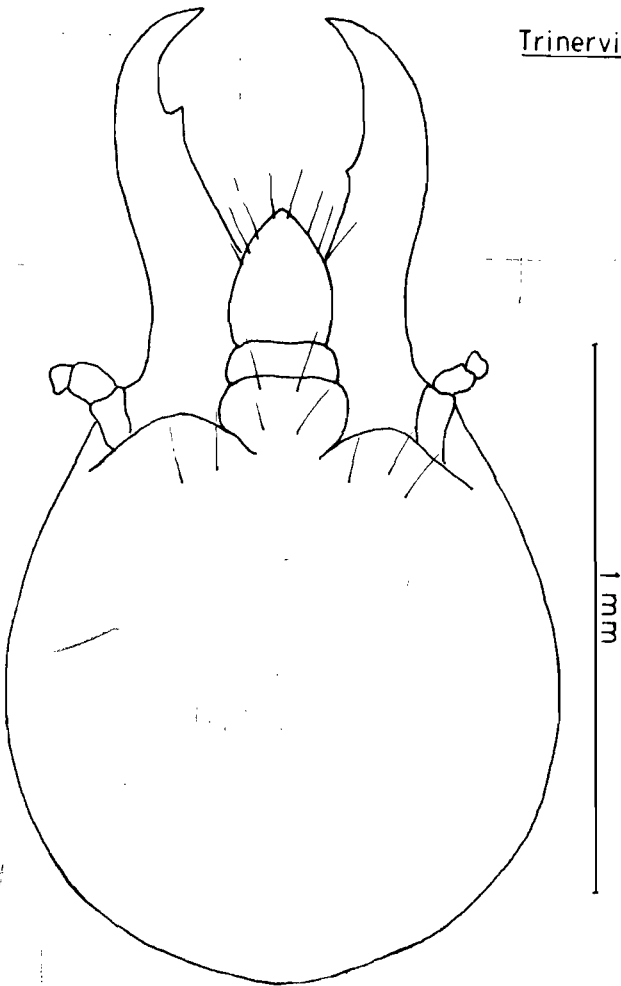


Odontotermes wallonensis

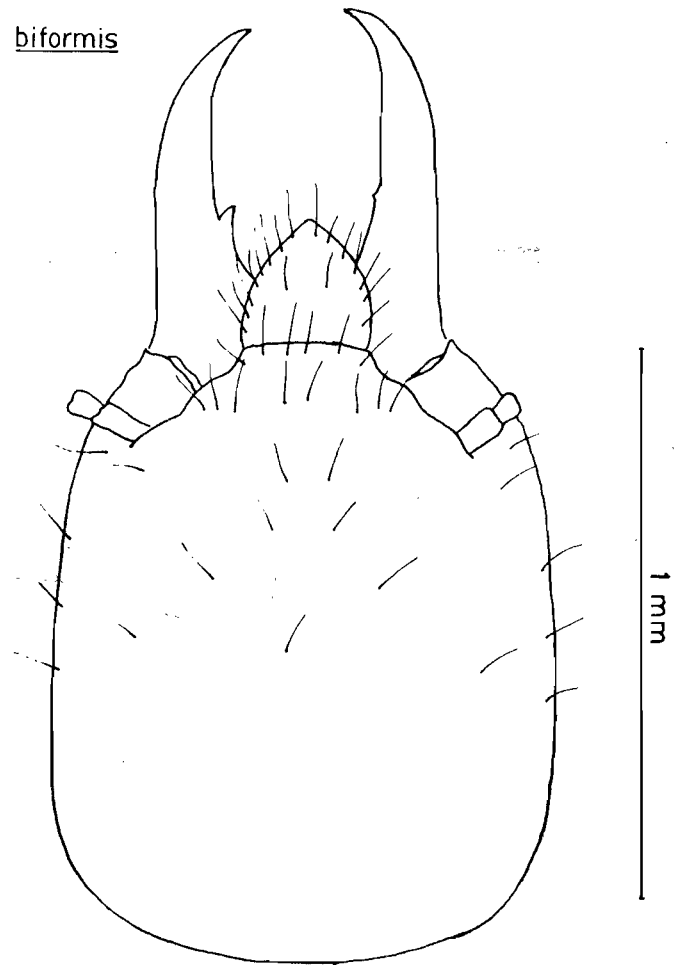
FIG.3: DIAGRAMS DISTINGUISHING Odontotermes spp. (ENCOUNTERED IN THE PRESENT STUDY) BASED ON SHAPE OF THE HEAD AND MANDIBLES.



Trinervitermes biformis



Odontotermes bellahunisensis



Odontotermes ceylonicus

DIAGRAMS DISTINGUISHING Trinervitermes biformis WASMANN AND Odontotermes spp. ENCOUNTERED IN THE PRESENT STUDY) BASED ON SHAPE OF THE HEAD AND MANDIBLES

- 3) Odontotermes bellahunisensis (Holmgren & Holmgren)
- 4) Odontotermes ceylonicus (Wasmann)
- 5) Odontotermes horni (Wasmann)
- 6) Odontotermes obesus Rambur
- 7) Odontotermes redemanni (Wasmann)
- 8) Odontotermes wallonensis (Wasmann)

Sub-family: Apicotermitinae

- 9) Speculitermes sp.

Sub-family: Nasutitermitinae

- 10) Trinervitermes biformis (Wasmann)

Among the ten species found in the study area, four were dominant, viz., Microtermes obesi, Odontotermes obesus, O.wallonensis, and O.horni found throughout the study period.

The per cent incidence of termites on baits (Wheat, Ragi and Maize straw) was maximum during the months of September to November 1985 and May to August 1986. The termite activity was comparatively low during the months of December 1985 to April 1986 (Table 1 and Fig.5).

There was not much difference in their preference among wheat, ragi and maize straw during different months. However the data revealed that the incidence of M.obesi on wheat was maximum followed by O.obesus, O.wallonensis,

Table 1: Per cent incidence of termite attack on baits (wheat, ragi and maize straw) in the field during different months of 1985-86 at M.R.S. Hebbal.

Months	Wheat straw			Ragi straw			Maize straw		
	No.		Per-cent	No.		Per-cent	No.		Per-cent
	placed	attacked		placed	attacked		placed	attacked	
September 1985	25	17	68.00	25	16	64.00	25	15	60.00
October	25	15	60.00	25	14	56.00	25	14	56.00
November	25	11	44.00	25	12	48.00	25	14	56.00
December	35	6	17.14	35	7	20.00	35	6	17.14
January 1986	35	9	25.71	35	9	25.71	35	10	28.57
February	35	9	25.71	35	10	28.57	35	11	31.42
March	45	11	24.44	45	12	26.66	45	10	22.22
April	45	13	28.88	45	13	28.88	45	11	24.44
May	45	32	71.11	45	33	73.33	45	34	75.55
June	60	44	73.33	60	43	71.66	60	46	76.66
July	60	45	75.00	60	45	75.00	60	45	75.00
August	60	47	78.33	60	46	76.66	60	48	80.00
		259			260			264	

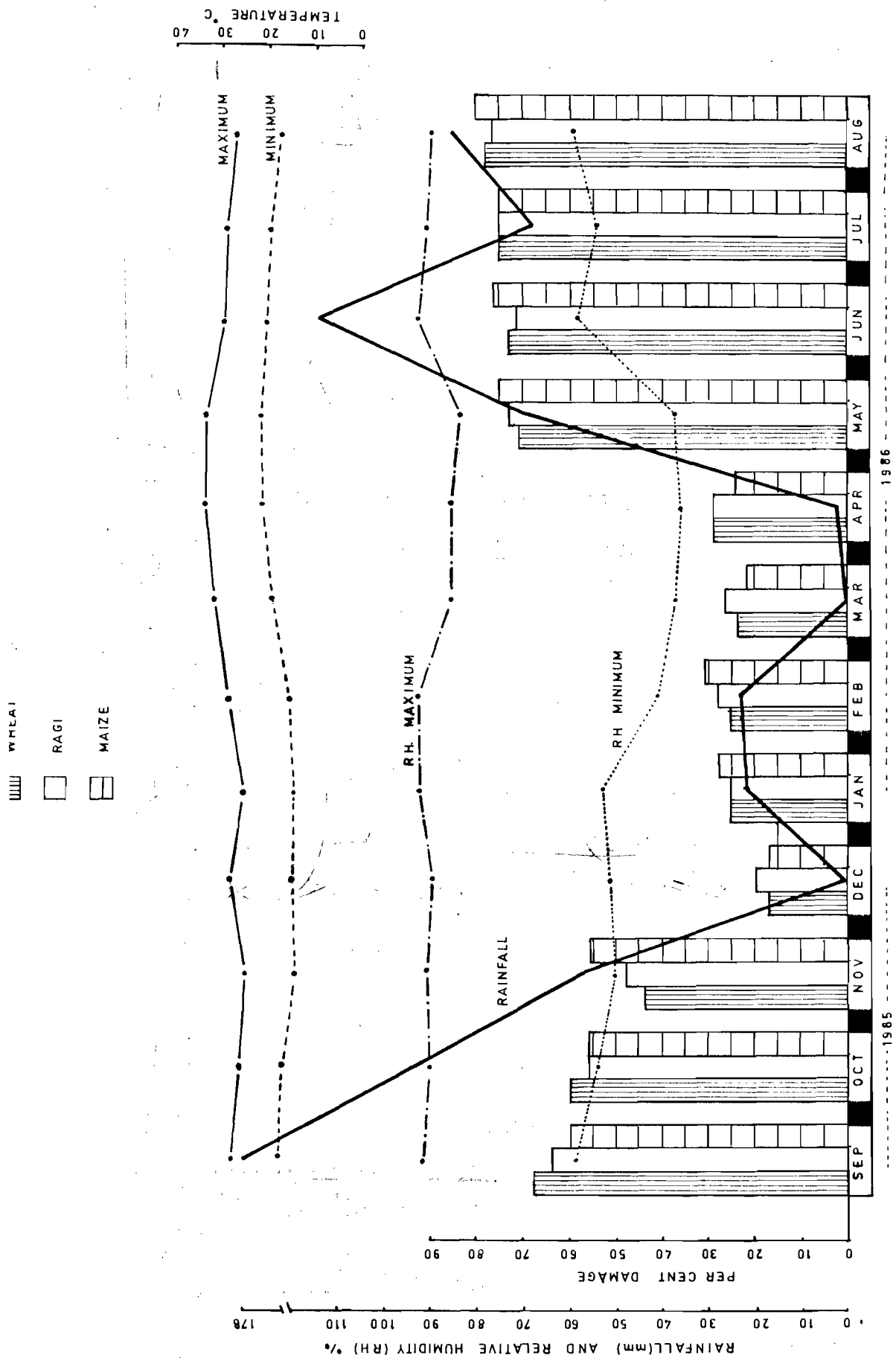


FIG.5: PER CENT INCIDENCE OF TERMITE ATTACK ON BAITS (WHEAT, RAGI AND MAIZE STRAW) IN THE FIELD DURING DIFFERENT MONTHS OF 1985-86 AT MRS. HEBBAL.

O.horni and other species (Appendix 2; Fig. 6). Similarly the incidence of O.obesus was maximum followed by M.obesi, O.wallonensis, O.horni and other species both on ragi and maize (Appendix 3 and 4; Fig.7 & 8).

Microtermes obesi, Odontotermes obesus, O.wallonensis and O.horni were found throughout the study period. Out of 495 baits each of wheat, ragi and maize straw baits placed, 259, 260 and 264 baits were attacked respectively (Table 2).

Out of 259 wheat straw baits attacked, maximum attack was by M.obesi (116) followed by O.obesus (88), O.wallonensis (23), O.horni (13), M.globicola (9), O.redemanni (7) T.biformis (2), and O.ceylonicus (1) (Table 2).

The situation in ragi was different, the maximum being O.obesus (125) followed by M.obesi (54), O.wallonensis (29), O.horni (25), O.redemanni (14), O.ceylonicus (6), T.biformis (5), M.globicola (1), and O.bellahunisensis (1).

Similarly in maize, O.obesus (141) accounted for the maximum number of baits attacked followed by M.obesi (41), O.wallonensis (32), O.horni (26), O.redemanni (15), O.ceylonicus (7), T.biformis (2) and O.bellahunisensis (1).

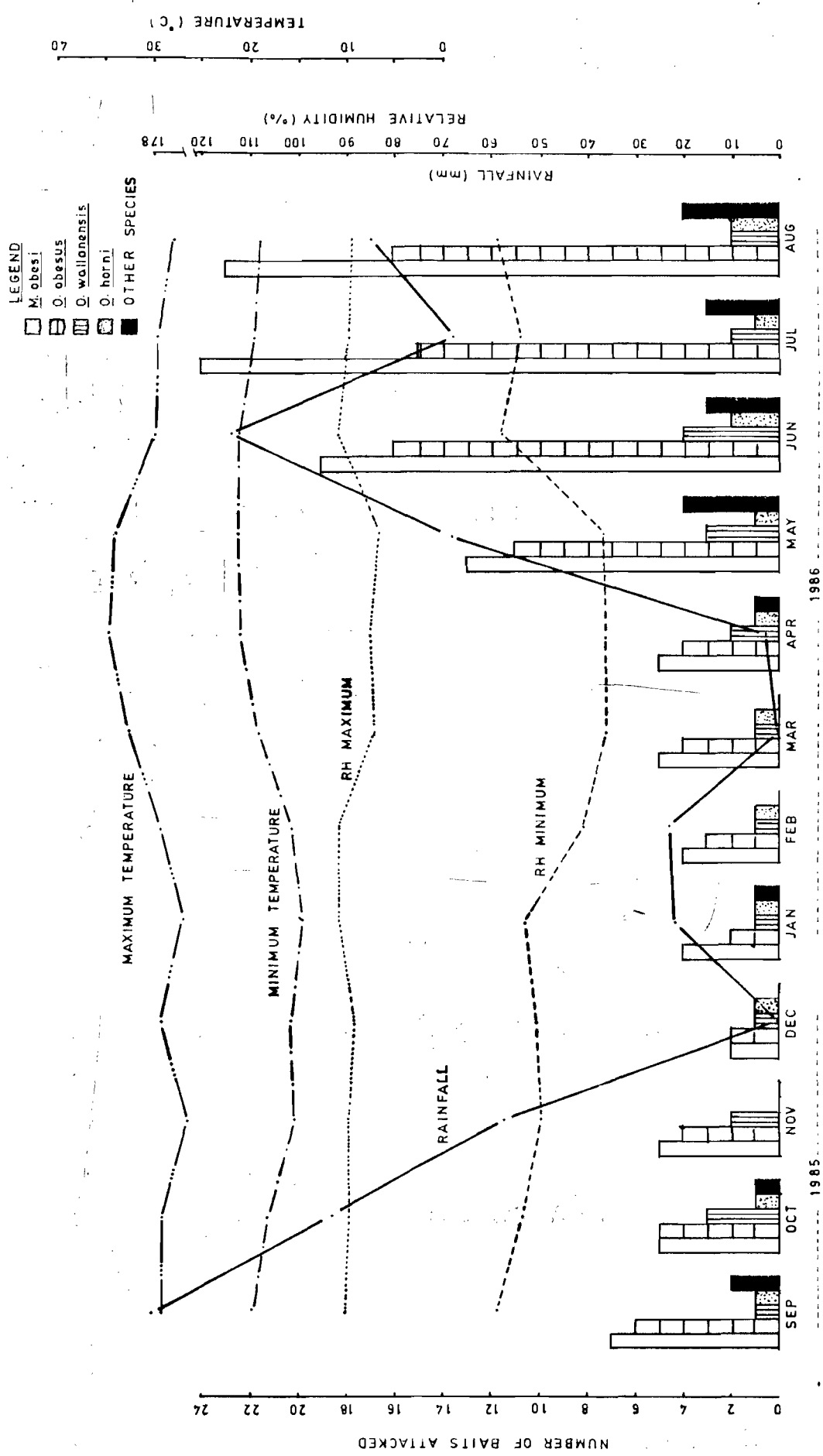


FIG. 6: RELATIVE PREFERENCE OF WHEAT STRAW BY DIFFERENT SPECIES OF TERMITES IN THE FIELD.

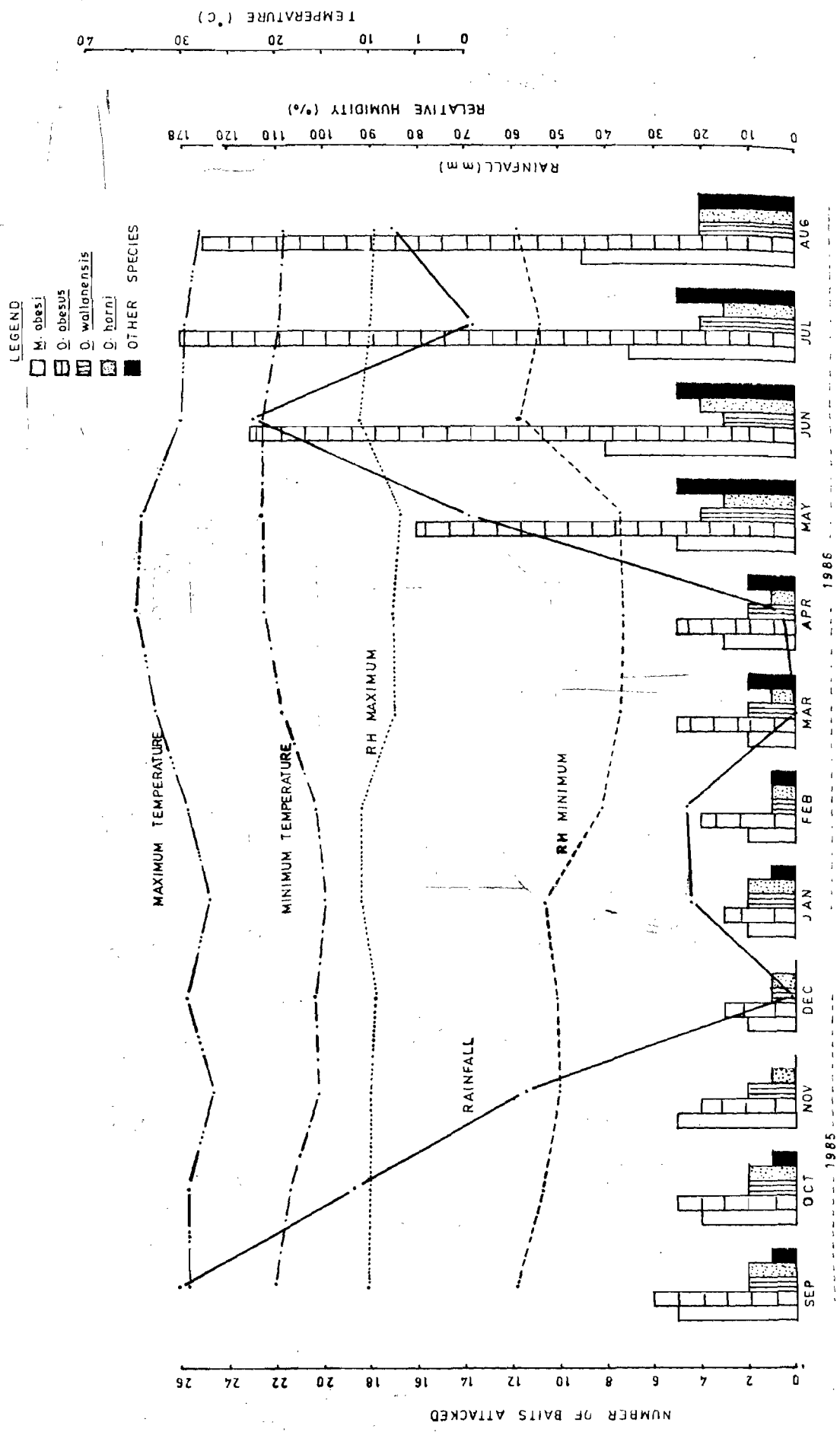


FIG. 7: RELATIVE PREFERENCE OF RAGI STRAW BY DIFFERENT SPECIES OF TERMITES IN THE FIELD.

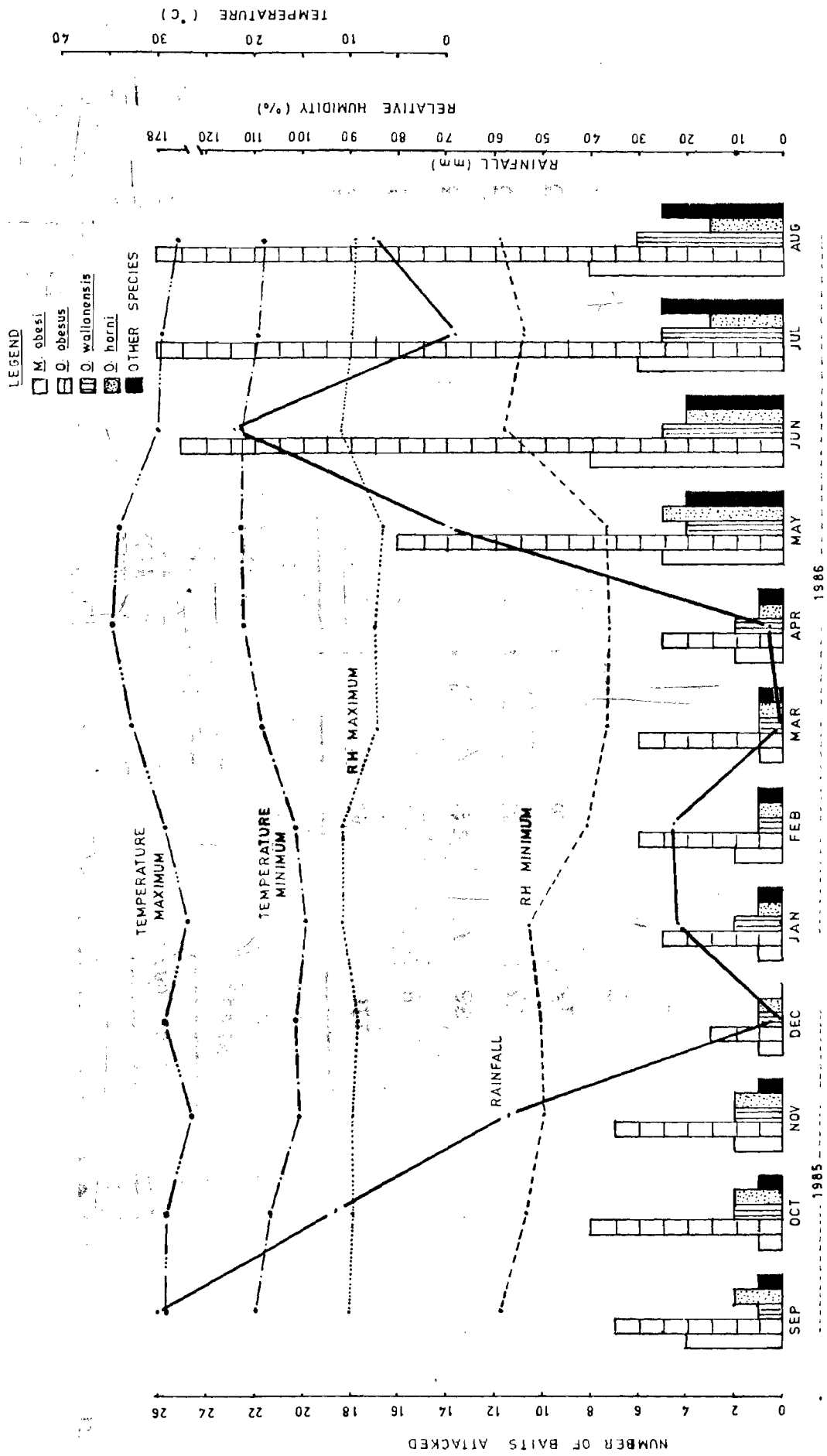


FIG. 8 : RELATIVE PREFERENCE OF MAIZE STRAW BY DIFFERENT SPECIES OF TERMITES
IN THE FIELD.

Table 2: Relative abundance of different species of termites at M.R.S. Hebbal

Species	No. of baits attacked			Total	Relative abundance (per cent) of termite species(out of 783)	Per cent incidence on individual baits		
	Wheat	Ragi	Maize			Wheat	Ragi	Maize
1. <u>Microtermes obesi</u>	116	54	41	211	26.94	54.97	25.59	19.43
2. <u>Microtermes globicola</u>	9	1	-	10	1.27	90.00	10.00	-
3. <u>Odontotermes obesus</u>	88	125	140	353	45.08	24.92	35.41	39.66
4. <u>Odontotermes wallonensis</u>	23	29	32	84	10.72	27.38	34.52	38.09
5. <u>Odontotermes horni</u>	13	25	26	64	8.17	20.31	39.06	40.62
6. <u>Odontotermes redemanni</u>	7	14	15	36	4.59	19.14	38.88	41.06
7. <u>Odontotermes ceylonicus</u>	-	6	7	13	1.66	-	46.15	53.84
8. <u>Odontotermes bellahunensis</u>	1	1	1	3	0.38	33.33	33.33	33.33
9. <u>Trinervitermis biformis</u>	2	5	2	9	1.14	22.22	55.55	22.22
Total:	259	260	264	783				

Out of total 783 baits found infested by the termite, 353 baits were attacked by O.obesus accounting 45.08 per cent of the total incidence; followed by M.obesi (211 baits and 26.94 per cent), O.wallonensis (84 and 10.72 per cent), O.horni (64 and 8.17 per cent), O.redemanni (36 and 4.59 per cent), O.ceylonicus (13 and 1.66 per cent), T.biformis (9 and 1.14 per cent) and O.bellahunisensis (3 and 0.38 per cent) (Table 2 and Fig.9).

Among the three baits offered, wheat was more attractive to M.obesi with 54.97 per cent incidence followed by 25.59 and 19.43 per cent incidence on ragi and maize respectively. Whereas, ragi and maize were more preferred to wheat by O.obesus with 39.66 35.4 and 24.92 per cent incidence on maize, ragi and wheat, respectively. Odontotermes wallonensis, which was the third dominant species almost had equal preference for maize (38.09 per cent) and ragi (34.52 per cent) and less preference for wheat (27.38 per cent). Similarly the other two important species namely O.horni and O.redemanni also had equal preference for maize and ragi over wheat. Odontotermes ceylonicus did not prefer straw; whereas, M.globicola preferred only wheat straw except on one occasion on ragi out of ten incidence. Odontotermes bellahunisensis had equal preference for all three baits (Table 2 and Fig.10).

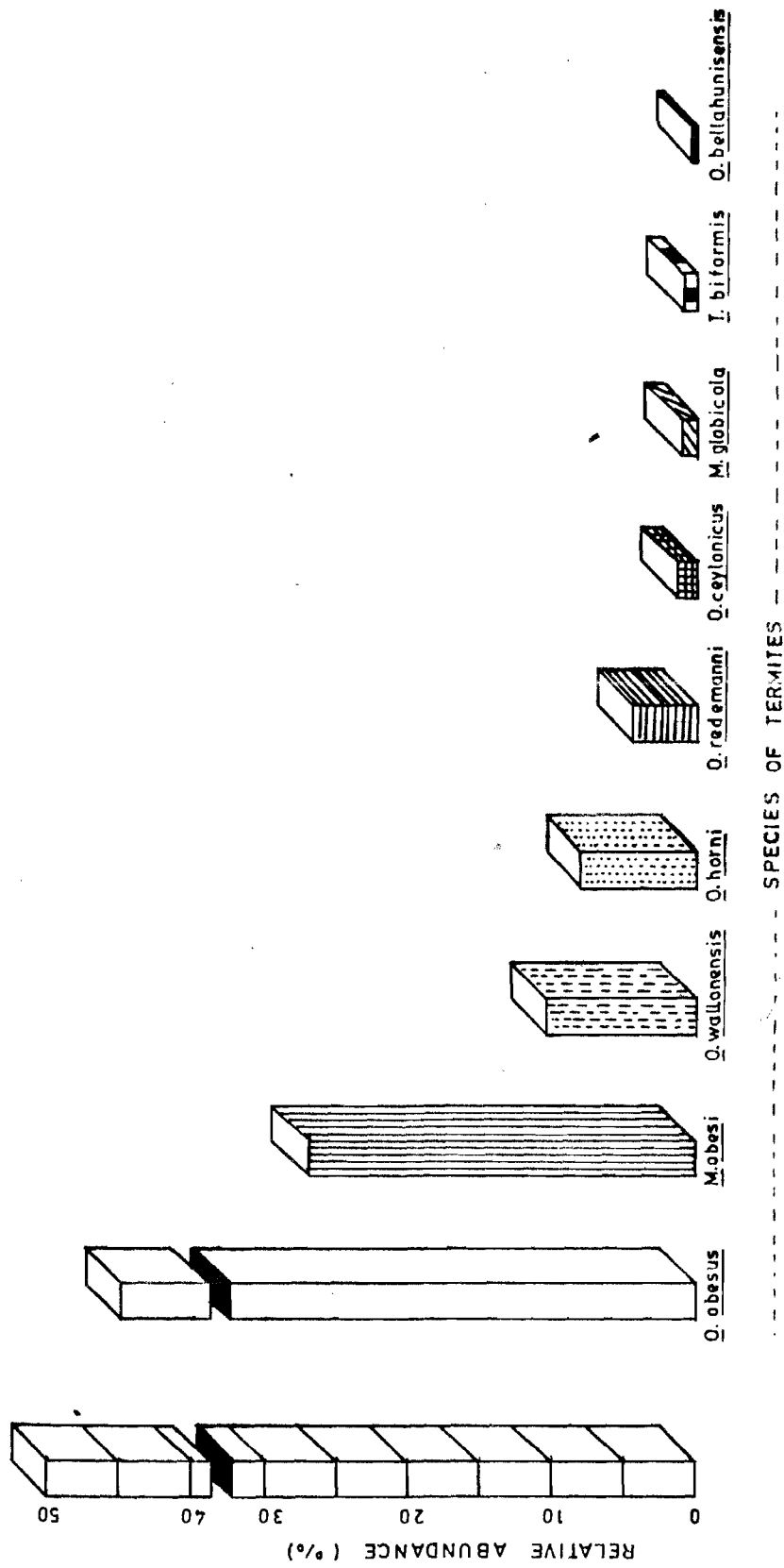


FIG. 9 : RELATIVE ABUNDANCE OF DIFFERENT SPECIES OF TERMITES DURING
1985_86 AT MRS. HEBBAL

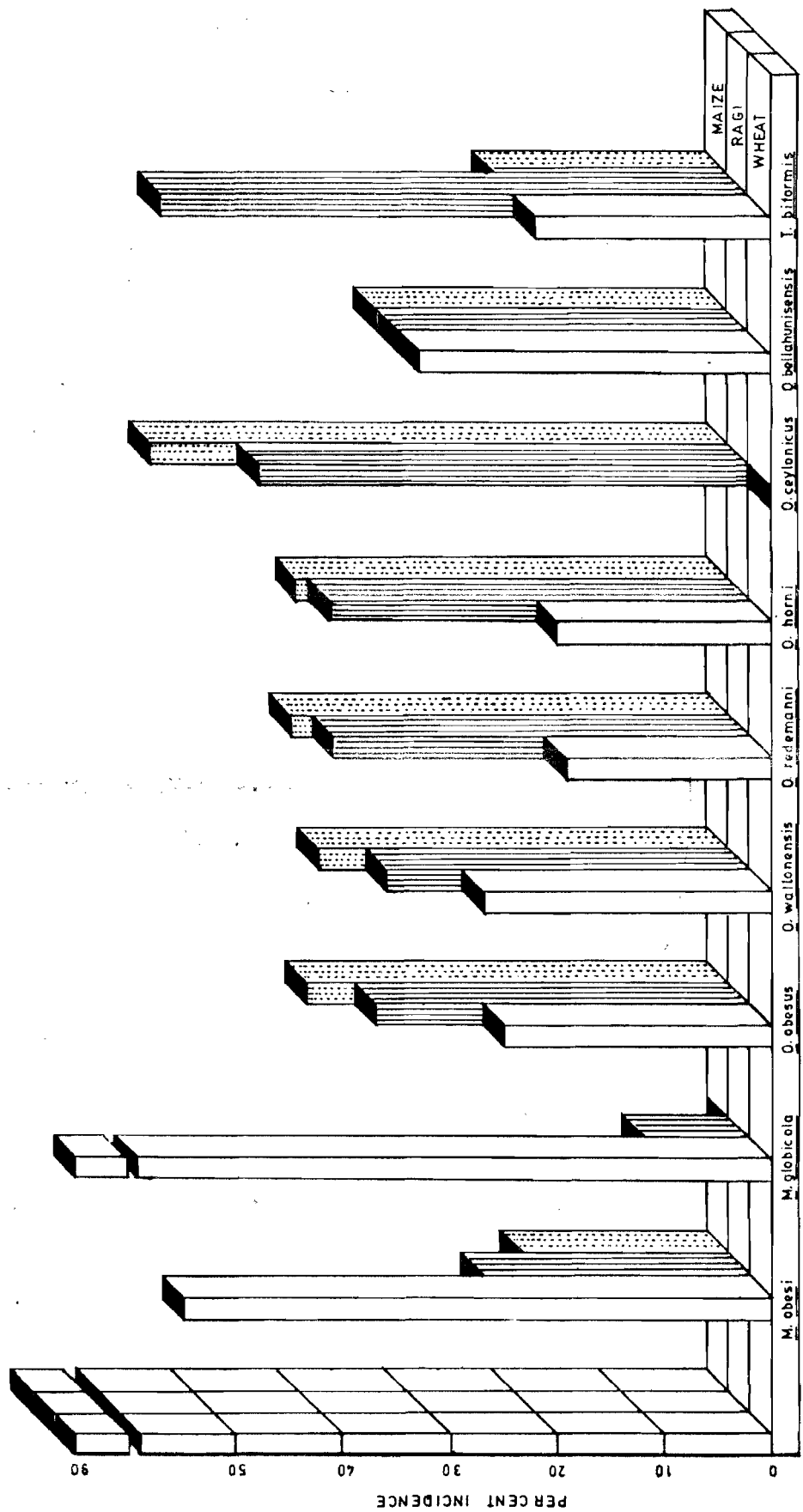


FIG10:RELATIVE PREFERENCE OF BAITS ATTACKED BY DIFFERENT SPECIES OF TERMITES
DURING 1985-86 AT MRS. HEBBAL.

4.1.1. Relative abundance of termite in the study area

The observations made in an area of 40 hectares, on the relative abundance of different species of dominant species both in cultivated and uncultivated area. During the course of the study, a total of 840 nests were located. The distribution of the four major species is shown in Table 3 and Fig.11.

Relatively more number of mounds or nests were recorded in uncultivated area (440) compared to cultivated area (400). On the whole, more number of mounds or nests of O.obesus (280) were recorded followed by M.obesi (220), O.wallonensis (200) and O.horni (140). In the cultivated area more number of mounds or nests of M.obesi (160) were recorded followed by O.obesus (120), O.wallonensis (80) and O.horni (40); whereas, in uncultivated the numbers were 60, 160, 120 and 100 nests/mounds, respectively (Table 3).

4.2. Some aspects of Ecology of the subterranean termite, Microtermes obesi

Detailed observations were made on the different stages, castes, swarming, post-swarming, foraging, natural enemies, fungal comb and its constituents of the subterranean termite M.obesi during the year 1983-84 and 1984-85.

Table 3: Relative distribution of nests of four major species of termites encountered at M.R.S. Hebhal

Sl. No.	Species	Total nests	Nests/ha	Number of nests	
				Culti-vated	Unculti-vated
1.	<u>Microtermes obesi</u>	220	5.50	160 (4/ha)	60 (1.50/ha)
2.	<u>Odontotermes horni</u>	140	3.50	40 (1/ha)	100 (2.50/ha)
3.	<u>O.obesus</u>	280	7.00	120 (3/ha)	160 (4.00/ha)
4.	<u>O.wallonensis</u>	200	5.00	80 (2/ha)	120 (3.00/ha)



FIG. 11: RELATIVE DISTRIBUTION OF NESTS OF FOUR MAJOR SPECIES OF TERMITES ENCOUNTERED AT MRS., HEBBAL, BANGALORE.

4.2.1. Description of different stages

4.2.1.1. Egg

Sub-oval, shiny dirty white in colour and measured 0.60 to 0.68 mm in length and 0.30 to 0.35 mm in width. Eggs were found in fungal combs (Plate -1).

4.2.1.2. Nymph

Milky white, 1 to 3.25 mm in length (Plate 2). They were present inside the fungal combs or chambers. The population of nymphs was generally more in the colony. Nymphs did not take part in any activity of the colony.

4.2.1.3. Alates

Newly hatched alate nymphs were observed in the colony during the first week of October. They differed from the nymphs in having wing buds, creamy white in the beginning and later turned to dark chocolate by sclerotization of the body. The alates were fully developed, by the last week of March and ready to emerge at any time. The alates were attended by workers till their emergence. The length of the alates (wings) ranged from 12.6 to 14.4 mm (Plate 3).

4.2.2. Description of different castes

4.2.2.1. Workers

Workers, sterile, apterous and less sclerotized measured 3.20 to 4.40 mm in length and 1.2 to 2.40 mm in width. The

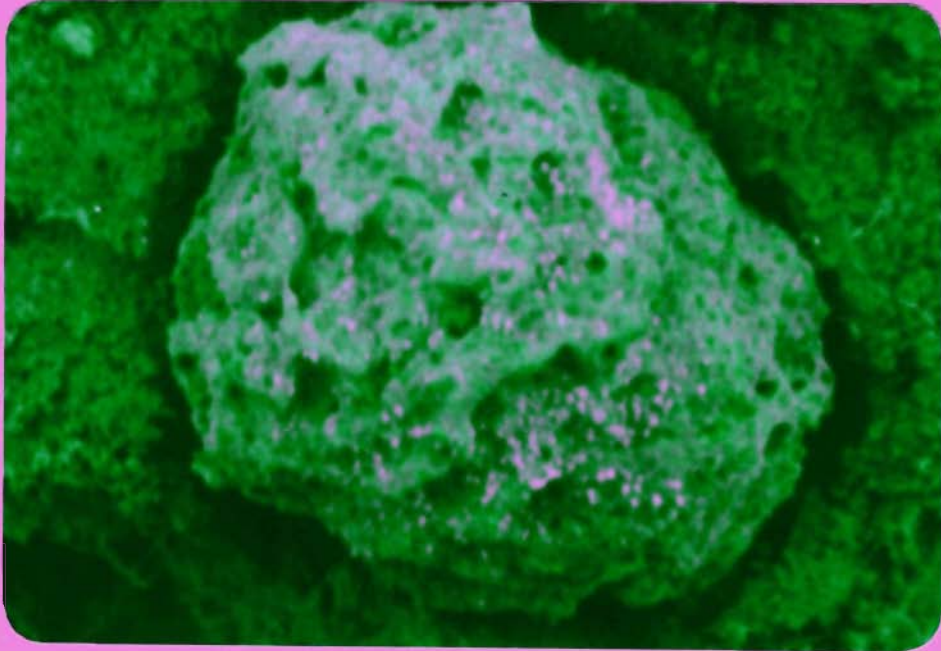


Plate 1 : M.obesi eggs on its fungus comb

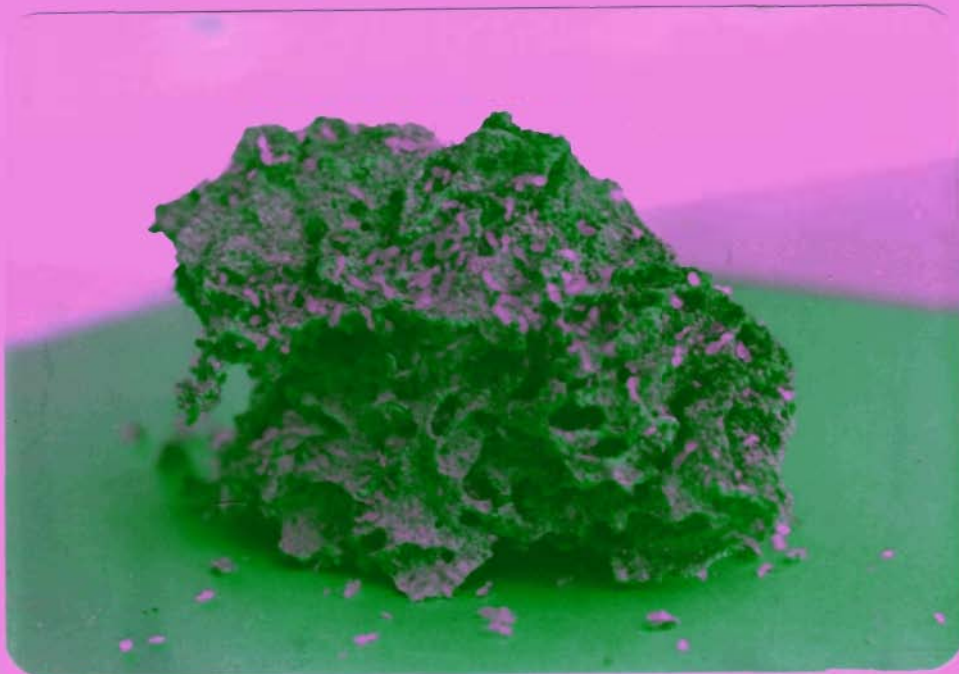


Plate 2 : M.obesi nymphs on its fungus comb

workers took part in carrying eggs, feeding other castes in the colony, construction of nests, cultivation of fungalcombs, nursing the young ones and collection of food for the colony.

4.2.2.2. Soldiers

They were also sterile, apterous, heavily sclerotized, 4.2 to 5.00 mm in length and 1.5 to 2.00 mm in width. Mandibles were sickle shaped and head strongly sclerotized (Plate 4). They were found defending the colony against enemies and were always associated with workers. When the soldiers were touched they squirted yellow liquid from the anterior region of the head and bit the enemies.

4.2.3. Swarming

During the study, swarming was noticed in the case of six species. All the six species swarmed during May to August as shown in Table 4.

Microtermes obesi

Emergence of alates took place only after the onset of monsoon showers during April to August (Table 5) and continued for a period of 14 weeks from the third week of May to fourth week of August 1983. Alate emergence was recorded during May in all the four nests observed followed by June, July and August. During the year 1984, the same pattern was followed (Table 5 and Fig.12).



Plate 3 : M.Obesi alate



Plate 4 : M.Obesi soldier

Table 4: Swarming period in different species of termites
at M.R.S. during 1983-84

Species	Month of swarming	Time	Remarks
1. <u>Microtermes</u> <u>obesi</u>	May-August 1983-84	18.15-19.15 h	24 to 48 hrs after the rain
2. <u>Odontotermes</u> <u>obesus</u>	May-June 1983-84	9.00 -10.30 h	Cloudy day pre- ceding the rain
3. <u>O.wallonensis</u>	May-June 1983-84	18.15-19.15 h	Preceding by rain during previous day
4. <u>O.redemanni</u>	May-August 1983-84	18.30-19.15 h	Preceding by rain during previous day
5. <u>O.horni</u>	May-August 1983-84	18.15-19.15 h	Preceding by rain during previous day
6. <u>T.biformis</u>	July 1983- 1984	18.30-10.00 h	Preceding by rain during previous day
7. <u>Speculitermes</u> sp.	May 1983- 1984	18.00-18.45 h	Rained previous day

Table 5: Swarming of the subterranean termite, M. obesi during different months/weeks of the year 1983-84 and 1984-85 at M.R.S.

Months/weeks		No. of alates emergence from 4 nests				Total	Mean	No. of alate emergence from 4 nests				Total	Mean				
		1983-84						1984-85									
		1	2	3	4			1	2	3	4						
1	2	3	4	5	6	7	8	9	10	11	12	13					
May	I	-	-	-	-	-	-	-	-	-	-	-					
	II	-	-	-	-	-	-	-	-	-	-	-					
	III	500	650	475	450	2075	518.75	210	180	150	165	705	176.25				
	IV	150	200	150	115	615	153.75	-	-	-	-	-	-				
June	I	50	35	70	65	220	55.00	75	65	50	60	250	62.50				
	II	450	475	380	350	1655	413.75	-	-	-	-	-	-				
	III	-	-	-	-	-	-	-	-	-	-	-	-				
	IV	-	-	-	-	-	-	-	-	-	-	-	-				
July	I	-	-	-	-	-	-	-	-	-	-	-	-				
	II	-	-	-	-	-	-	100	75	60	80	315	78.75				
	III	-	-	-	-	-	-	-	-	-	-	-	-				
	IV	40	50	80	60	230	57.50	55	65	65	60	245	61.25				
August	I	150	80	80	150	460	115.00	60	50	40	65	215	53.75				
	II	-	-	-	-	-	-	50	45	20	55	170	42.50				
	III	-	-	-	-	-	-	-	-	-	-	-	-				
	IV	100	120	100	75	395	98.75	15	15	30	35	95	23.75				
September to December	I	-	-	-	-	-	-	-	-	-	-	-	-				
	II	-	-	-	-	-	-	-	-	-	-	-	-				
	III	-	-	-	-	-	-	-	-	-	-	-	-				
	IV	-	-	-	-	-	-	-	-	-	-	-	-				

Table 5 - (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13
January 84 : I)												
to II)												
March 84 III)	-	-	-	-	-	-	-	-	-	-	-	-
IV)												
April : I	-	15	8	14	47	11.75	10	8	14	5	37	9.25
II	10											
III	-	-	-	-	-	-	-	-	-	-	-	-
IV	-	-	-	-	-	-	-	-	-	-	-	-
Total ..	1450	1625	1343	1279	5697		575	503	429	525	2032	

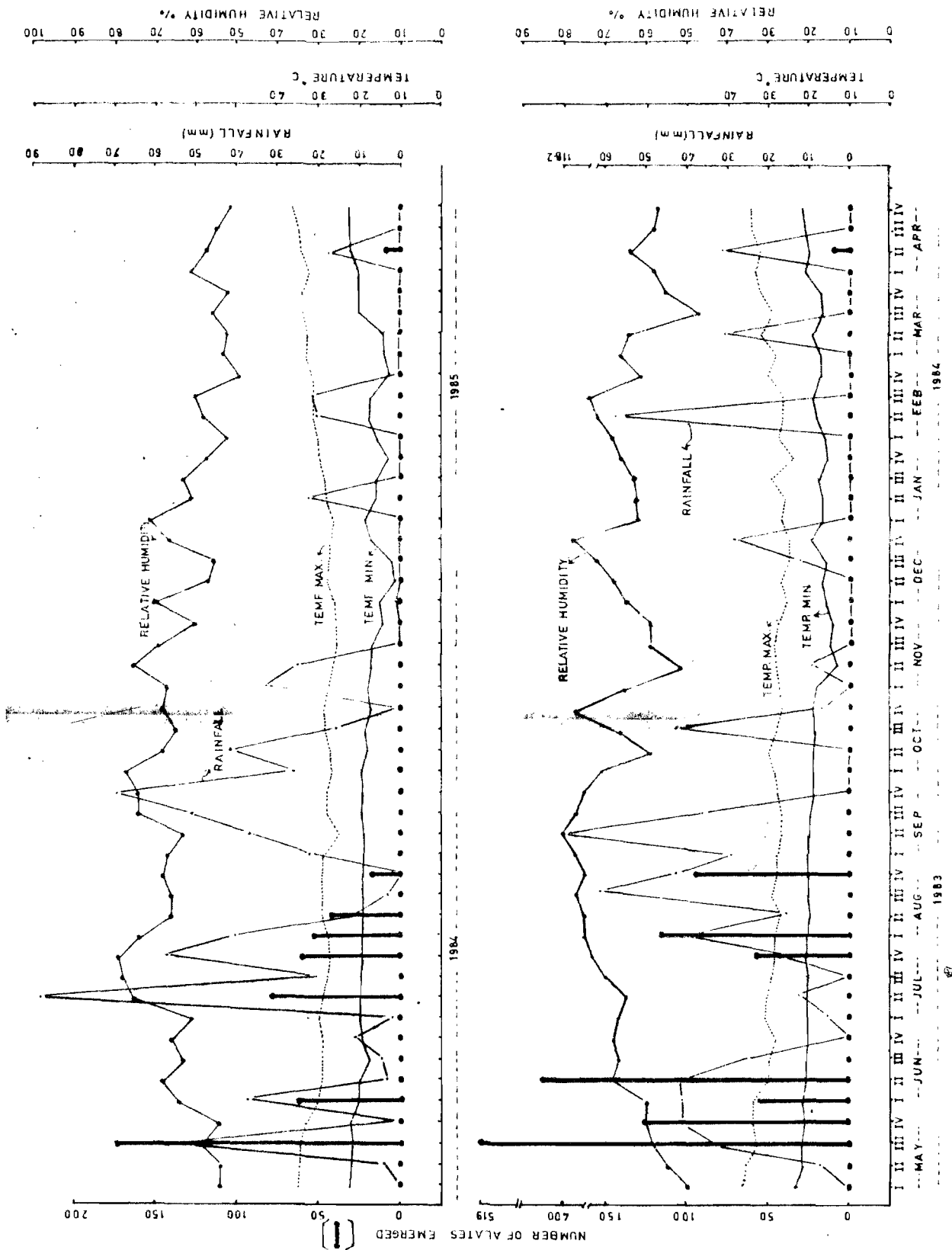


FIG.12: SWARMING OF THE SUBTERRANEAN TERMITE Microtermes obesi HOLMGREN DURING DIFFERENT MONTHS / WEEKS DURING THE YEAR 1983_84 AND 1984_85.

Swarming occurred after dusk between 18.15 to 19.15 h and lasted for 10-15 minutes depending on the number of alates ready to come out from the nest. The weather data prevailed during the year 1983-84, 1984-85 is presented in the Appendix V. The time required for the emergence of alates from the nest varied from 24 to 48 h after the first rain and 6 to 12 h with subsequent rain. From a single nest, alates emerged more than once in the same year depending on the development of reproductives and weather condition. In the present investigation, during both the year 1983-84 and 1984-85; alate emergence was recorded eight times from all the four nests, although the number emerged varied during different months of the year 1983-84 and 1984-85 (Table 5).

Swarming alates emerged through tiny (diameter 2-3 mm) subcircular emergence holes on the ground surface made by the workers. These emergence holes numbering three to four, were 5-6 cm apart from one another. Swarming of alates was slow in the first 2-3 minutes and later became rapid, several workers and soldiers were found moving about slowly with in a radius of 5 cm as alates emerged one by one at intervals of 4 to 5 seconds. Soldiers were guarding the holes. After the emergence from the hole the alates crawled for 2 to 4 cm on the surface outside and then flew upto a distance of 10 to 12 m in the air. If the alates were unable to fly, then workers carried them

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back immediately to the nest through the same hole. During this period soldiers were in guarding positions to prevent the entry of predatory ants.

4.2.3.1. Post-swarming

After the completion of emergence of alates, workers, and soldiers moved back to the nest through the emergence holes and sealed the opening.

After the emergence, the alates were attracted to light, if light source was available. Otherwise, they flew in the air for some distance (10-12 m) and fell to the ground before shedding-off the wings. After falling-down to the ground, cast-off their wings within about 30-50 seconds by turning and twisting their body. Later the male and female got together and started searching for their future nest or place. Normally the male followed the female in tandem almost touching the tip of abdomen of the female in a zig-zag manner. The males were seen moving erratically or every where in all direction in search of female. When once the male got the female and touched the abdominal tip with its mouth parts, the female also reciprocated by touching the male. Later the male followed the female to find a suitable site in the ground. Sometime two males tried to follow a single female for sometime (2-3 minutes) and sub-

sequently one of them gave up. The pair wandered for 5-7 minutes till they got a suitable site; and after locating it, both of them burrowed into the soil to construct a cell where further development took place.

Attempts to rear the couple in the laboratory did not succeed as the pairs died in 5-6 days.

4.2.4. Foraging

The foraging activity of M.obesi was studied for 3 years 1982-85. The number of foraging workers and soldiers varied from 18 to 150 and 1 to 3 respectively in a 3 meter row. The ratio was 0.0228 (Table 6). In another observation at a nest site, out of 2650 specimens collected while foraging, only 48 were soldiers and the remaining were workers. The ratio was 0.0181. No foragers were seen at the ground level. But the workers made the runways inside the soil at a depth of 10-12 cm along the rows of wheat plants.

The workers made their foraging subterranean exit at about 12 cm underground from the surrounding surface. The place at which the foraging workers came out of the runways varied from 2 to 15 m from the nest according to studies made on foraging runways of 3 nests. The foraging runways were observed on two directions, namely north-south and east-west at different depths (0-30 cm, 30-60 cm, 60-90 cm and

Table 6: Workers and soldiers of M.obesi involved
in foraging at the study site during 1982-83

Site No.	Subterranean runways on root zone of wheat		Ratio of workers & soldiers
	No.of workers	No. of soldiers	
1	80	1	0.0125
2	68	1	0.0147
3	150	3	0.0200
4	122	2	0.0163
5	18	1	0.0555
6	56	1	0.0178
Mean	82.33	1.5	0.0228

90-120 cm) in three nests of the study site during 1982-83 and 1983-84. More number of subterranean runways were recorded in north-south direction (7.99) than to east-west (4.65) (Table 7). Further, more runways were found in the top layer of the soil. In both the directions maximum of runways (3.00 to 1.66) were recorded at a depth of 60 cm. The depth at 60 cm had 66.7 per cent of total runways in north-south direction and 64.29 per cent of total runways in east-west direction. About 85-87 per cent of foraging runways were distributed in top 90 cm of soil depth in both directions.

The runways or galleries made by the workers for foraging were irregular in shape. Workers came along with a few soldiers to the place or source where the food was available and collected the food. Foraging was brisk during May to August and at a low ebb during December-March.

The foraging period varied from season to season. In summer it was from 05.30 to 09.00 h in the morning and 18.00 to 21.00 h in the evening; in the monsoon it was during 06.45 to 10.30 h and 16.00 to 18.00 h. While in winter, it was during 7.15 to 11.45 h and 15.30 to 18.00 h. Except during summer, most of the foraging took place during day light.

Table 7: Subterranean foraging runways of M. obesi at the study site during 1982-83

Soil depth (in cm)	Nest I				Nest II				Nest III				Average	
	No.of runways/nest.....				No.of runways/nest.....				No.of runways/nest.....				No.of runways/nest.....	
	(N-S)	(E-W)	(N-S)	(E-W)	(N-S)	(E-W)	(N-S)	(E-W)	(N-S)	(E-W)	(N-S)	(E-W)	(N-S)	(E-W)
0 to 30	2	1	2	1	1	1	3	2	2	2.33	(29.16)**	1.33	(28.66)	
30 to 60	3	1	3	2	2	2	3	2	3	3.00	(37.54)	1.66	(35.69)	
60 to 90	1	1	2	1	1	1	2	1	1	1.66	(20.77)	1.00	(21.50)	
90 to 120	1	-	1	1	1	1	1	1	1	1.00	(12.51)	0.66	(14.19)	
Total	7	3	8	5	5	5	9	6	7	7.99		4.65		

** Values in parentheses represent per cent to total

4.2.5. Natural enemies of the subterranean termite, M.obesi

During the period of investigation several natural enemies were encountered, including invertebrates and vertebrates.

Among the invertebrates, ants were the most common enemies of this subterranean termite. The ant, Leptogenys processionalis (Jerdon) was the most common and found pre-dating throughout the year. The ants were seen actively predating on termites at the base of the wheat plant. On an average, about 25 termites were harvested per minute during morning hours (7.30 h in August 1983). A total of 2150 termites were carried in a period of 90 minutes.

Other species of ants namely, Camponotus compresus Fab., Solenopsis geminata (Fab.), Monomorium indicum Fonal. Camponotus sericeus Fab., Oecophylla smargdina Fab. were also found predating on foraging workers and alates. Some dragonflies were also seen carrying termite nymphs when the fungal combs were exposed.

Vertebrate predators

Among the vertebrates, the frog, Rana tigrina Daud. and the toad, Bufo melanostictus Schneider were found pre-dating on alates near the water and light source during swarming. The lizard, Hemidactylus maculatus Dum & Bibr. commonly found predating on alates.

Among the birds, the sparrows (Passer domesticus Linn.), the common mynas (Acridotherus tristis Linn.), crows (Carvus splendens Vieillot and Carvus macrorhynchos Waglen, fowl (Gallus sp.) were found feeding on the swarming alates. Occasionally dogs also fed on alates (Appendix I).

4.2.6. Communication, alarm and defence

At the foraging site, when they were disturbed, they ran back to the foraging runways. At that time workers and soldiers touched each other by jerking their body and head.

Alarm: Termites touched face to face with the other members of foraging group and ran in all directions in a zig-zag way.

Defence: Soldiers defended their colony against enemies by squirting brownish yellow liquid from the mandibles.

4.2.7. Fungus comb of Microtermes obesi

Fungus combs were present in all the nests (20) that were observed during the period of investigation. They varied in shape and size (Plate 5), mostly round to oval. Each comb was in a separate earthen chamber (Plate 6). The number of fungal combs varied from 1-6 in an area of 2² meter. They were grey in colour and found at a depth of 30-90 cm below

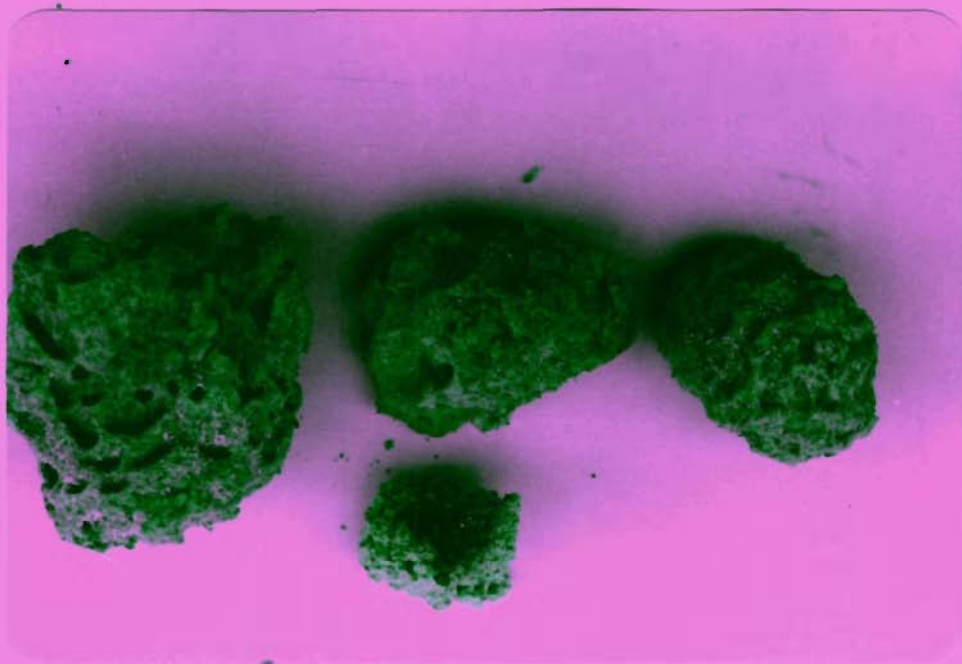


Plate 5 : Different sizes of M.obesi fungus comb

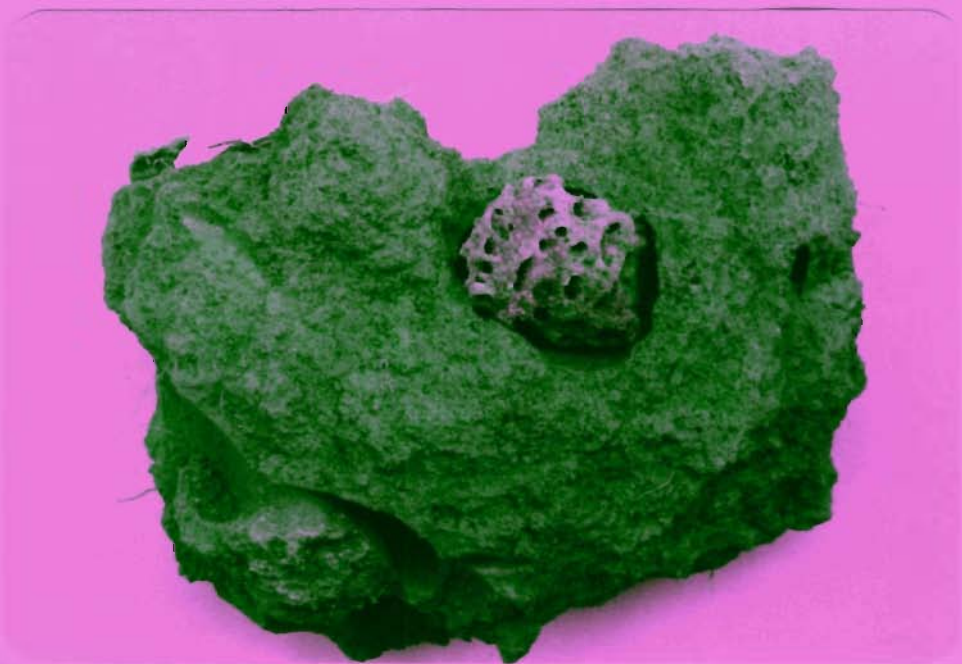


Plate 6 : M.obesi fungus comb in a earthen chamber

ground. The combs were made up of pellets of excreta and fungal growth plastered by means of anal secretion or saliva. The outer surface was rough and inner surface was smooth in texture.

The layers could be easily recognised in each comb viz. bottom (primary) and top (secondary). They were arranged one above the other. The combs measured 6.5 to 8.25 cm long and 3.25 to 4.75 cm wide. Eggs, nymphs and workers were seen on the combs. The combs were connected to runways spread in different directions.

4.2.7.1. Moisture content of the fungus comb

Moisture percentage and weight of the fungus combs both fresh and dry in the three seasons, summer (April-May), rainy (July-August) and winter (November-December) are presented in Table 8. The moisture content of the fungus comb varied from 45.61 to 55.81 per cent.

4.2.7.2. Chemical composition of the fungus comb

The data on chemical composition of the fungus comb of M. obsesi are presented in Table 9.

Outer and inner layers of the fungus combs were analysed. Fresh excreta was observed in the outer layer. In general, the pH of the fungal comb varied from 4.4 to 4.6.

Table 8: Moisture content and weight of fungus combs of the subterranean termite,
M. obesi

Sl. No.	Summer (April-March 1983)				Rainy season (July-Aug.83)				Winter (Nov.-Dec.1983)			
	A*	B	C	D	A	B	C	D	A	B	C	D
1	8.389	0.170	4.325	47.37	18.150	0.214	8.848	50.66	9.703	0.185	4.425	53.50
2	21.512	0.245	11.565	45.61	24.535	0.262	11.925	55.81	19.612	0.285	9.362	51.55
3	16.408	0.195	8.650	46.44	32.128	0.352	15.243	51.71	9.435	0.190	4.624	49.98
4	7.528	0.155	3.850	47.78	15.242	0.210	7.865	47.02	8.751	0.186	4.052	52.69
5	9.703	0.180	5.150	45.92	11.212	0.205	5.245	52.34	19.150	0.252	9.310	50.73
6	14.128	0.195	7.568	45.68	7.324	0.152	3.820	46.73	13.718	0.210	6.102	54.82
Range:	8.329 to 21.512	0.155 to 0.245	3.850 to 11.565	45.61 to 47.78	7.324 to 32.128	0.152 to 0.352	3.820 to 15.243	46.73 to 55.81	8.751 to 19.612	0.185 to 0.285	4.052 to 9.362	49.98 to 54.82
Mean:	12.944	0.236	6.851	46.50	18.098	0.232	8.791	50.71	13.394	0.218	6.312	52.21

Note: A = Weight of comb (g)
B = Weight of termites (g)
C = Dry weight of fungus Comb (g)
D = Moisture content (per cent)

Table 9: Chemical composition of fungus comb of M. obesi at Hebbal

Sample No.	Fungus Comb layer	Cellulose (%)	Lignin (%)	Carbon (%)	Nitrogen (%)	Crude fat (%)	Ash (%)	Cell: Lig ratio	C:N ratio
1	Outer	26.35	13.02	32.98	1.10	2.84	20.83	2.02	29.91
	Inner	24.92	14.20	31.54	0.99	3.10	21.10	1.75	31.55
2	Outer	24.25	12.80	32.00	1.01	2.92	21.25	1.89	31.65
	Inner	22.15	14.00	33.00	0.99	3.00	22.00	1.58	33.00
3	Outer	25.15	14.00	31.45	0.96	3.10	20.50	1.79	32.48
	Inner	24.25	15.00	29.36	0.92	2.60	21.00	1.61	31.87
Mean :	Outer	25.25	13.27	32.14	1.02	2.95	20.86	1.90	31.34
	Inner	23.77	14.40	31.30	0.97	2.90	21.36	1.64	32.14

The cellulose content varied from 22.15 to 26.35 per cent from different nests. There was slight difference in the cellulose content of outer layer (25.25 per cent) and inner layer (23.77 per cent) and the lignin content of inner layer was 14.40 per cent compared to outer layer 13.27 per cent. The cellulose and lignin ratio varied from 1.58 to 2.02.

The carbon content varied between 29.36 to 33.00 per cent in the fungus comb. The content of carbon was little higher in outer layer (32.14 per cent) than the inner layer (31.30 per cent). The nitrogen content varied from 0.92 to 1.10 per cent. Further, the outer layer had slightly higher nitrogen than the inner. The C:N ratio of the fungal comb varied between 29.91 to 33.00 and it was slightly higher in inner layer (32.14) than in outer layer (31.34).

Crude fat content ranged from 2.6 to 3.00 per cent. The outer layer contains slightly more (2.95 per cent) than the inner layer (2.90 cent). The ash content varied from 20.83 to 22.00 per cent. The inner layer contains more of ash (21.36 per cent) than the outer layer (20.86 per cent).

4.3. Host preference of the termites among the different agricultural crops and losses caused by termites

The data pertaining to per cent infestation of termites and the mean yield of ragi (finger millet) wheat, maize, setaria, bajra, groundnut, sunflower and niger under two main treatments at M.R.S. Hebbal, and A.R.S. Chintamani are presented below:

4.3.1. Infestation results

The mean per cent infestation in protected plots (1.09) significantly differed from unprotected plots (2.24) both at M.R.S. Hebbal, and A.R.S. Chintamani. Mean per cent infestation among the crops at M.R.S. Hebbal, showed maize to record the maximum per cent incidence (2.96) followed by wheat (1.83), niger (1.82), ragi (1.74), groundnut (1.67), bajra (1.41), setaria (1.25) and sunflower (0.64) (Table 10 and Fig.13). Maize differed significantly from rest of the treatments by recording higher infestation. Whereas, wheat, niger, ragi and groundnut were at par, but differed significantly from bajra, setaria and sunflower. Bajra and setaria registering higher per cent infestation over sunflower were at par but differed significantly from the sunflower.

In the protected plots, maize recorded highest

Table 10: Mean per cent infestation due to termites and grain yield (Q/ha) of different crops at M.R.S. (1983-1984)

Sl. No.	Crops (sub-treatments)	Mean per cent infestation			Mean grain yield (Q/ha)		
		Treated	Untreated	Mean	Treated	Untreated	Mean
1	Ragi	1.16 (1.07)	5.83 (2.41)	(1.74)	19.29	9.57	14.43
2	Wheat	1.53 (1.23)	5.89 (2.42)	(1.83)	17.03	4.44	10.74
3	Setaria	0.86 (0.92)	2.52 (1.58)	(1.25)	10.94	8.88	9.91
4	Bajra	0.80 (0.89)	3.77 (1.93)	(1.41)	11.35	9.25	10.30
5	Groundnut	1.13 (1.04)	5.32 (2.30)	(1.67)	10.46	5.24	7.85
6	Sunflower	0.33 (0.33)	0.95 (0.95)	(0.64)	10.66	8.15	9.59
7	Niger	1.71 (1.30)	5.51 (2.34)	(1.82)	3.85	1.81	2.83
8	Maize	3.77 (1.94)	15.95 (3.99)	(2.96)	19.81	9.25	14.53
Mean		(1.09)	(2.24)	-	12.92	7.12	-
CD at 5%	I :	0.27				0.64	
	II :	0.20				1.03	
	III :	0.28				1.46	
	IV :	0.36				1.47	
CD	I :	For comparing any two main treatment means					
	II :	For comparing any two subtreatment means					
	III :	For comparing any two subtreatments at fixed level of main treatment					
	IV :	For comparing any two main treatments at fixed level of subtreatment					

(Figures in parentheses are transformed square root values)

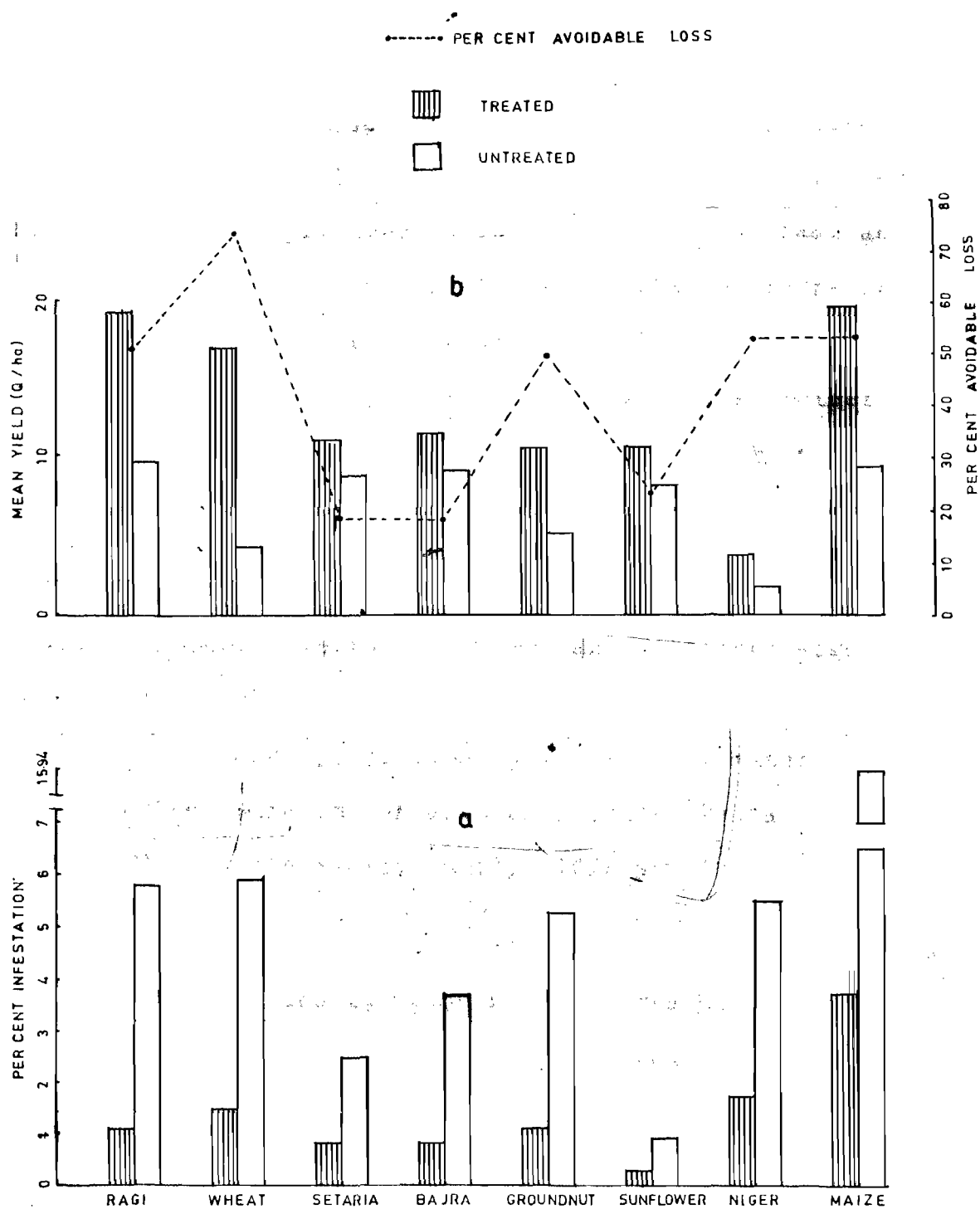


FIG.13: MEAN PER CENT INFESTATION (a), MEAN GRAIN YIELD AND PER CENT AVOIDABLE LOSS (b) OF DIFFERENT CROPS DUE TO TERMITES AT MRS. HEBBAL (1983-84).

per cent (1.94) infestation followed by niger (1.30), wheat (1.23), ragi (1.07), groundnut (1.04), setaria (0.92), bajra (0.89) and sunflower (0.33). Among these, maize differed significantly from other treatment by recording higher percentage of infestation. Niger, wheat, ragi and groundnut differed significantly with setaria, bajra and sunflower, but were on par with each other. Similarly ragi, groundnut, setaria, bajra were on par with one another but differed significantly from that of sunflower by recording higher per cent infestation.

Similarly in the unprotected plots, maize recorded higher per cent infestation (3.99) and differed significantly with rest of the treatments. Wheat, ragi, niger, groundnut differed significantly with bajra, setaria and sunflower but were on par with each other. Bajra, setaria and sunflower were significantly different from one another.

The result at A.R.S. Chintamani also showed the same trend. Among the crops, Maize recorded the highest per cent (3.77) infestation followed by wheat (2.26), ragi (2.22), niger (1.99), groundnut (1.82), bajra (1.68), setaria (1.67) and sunflower (0.37) (Table 11 and Fig.14). Maize differed significantly with all the treatments. Wheat differed significantly with niger, groundnut, bajra, setaria and sunflower

Table 11: Mean per cent infestation due to termites and mean grain yield (q/ha) of different crops at A.R.S. Chintamani (1983-84)

Sl. No.	Crops (sub-treatments)	Mean per cent infestation			Mean grain yield (q/ha)		
		Treated	Untreated	Mean	Treated	Untreated	Mean
1	Ragi	1.76 (1.32)	9.79 (3.12)	(2.22)	17.96	7.92	12.94
2	Wheat	2.07 (1.44)	9.59 (3.09)	(2.26)	15.55	3.90	9.73
3	Setaria	1.53 (1.21)	4.56 (2.13)	(1.67)	9.66	7.96	8.81
4	Bajra	1.16 (1.07)	5.23 (2.28)	(1.68)	9.35	7.70	8.52
5	Groundnut	0.90 (0.93)	7.43 (2.72)	(1.82)	9.14	5.22	7.18
6	Sunflower	0.00 (0.01)	0.81 (0.73)	(0.37)	9.57	7.40	8.49
7	Niger	1.59 (1.25)	7.45 (2.73)	(1.99)	3.33	1.25	2.29
8	Maize	5.80 (2.41)	26.45 (5.14)	(3.77)	18.07	7.05	12.56
Mean		(1.20)	(2.74)	-	11.58	6.05	-
CD at 5%		I:	0.32			0.76	
		II:	0.24			1.05	
		III:	0.34			1.49	
		IV	0.42			1.54	

- CD I : For comparing any two main treatment means
 II : For comparing any two subtreatment means
 III : For comparing any two subtreatments at fixed level of main treatments
 IV : For comparing any two main treatments at fixed level of subtreatments

(Figures in parentheses are transformed square root values)

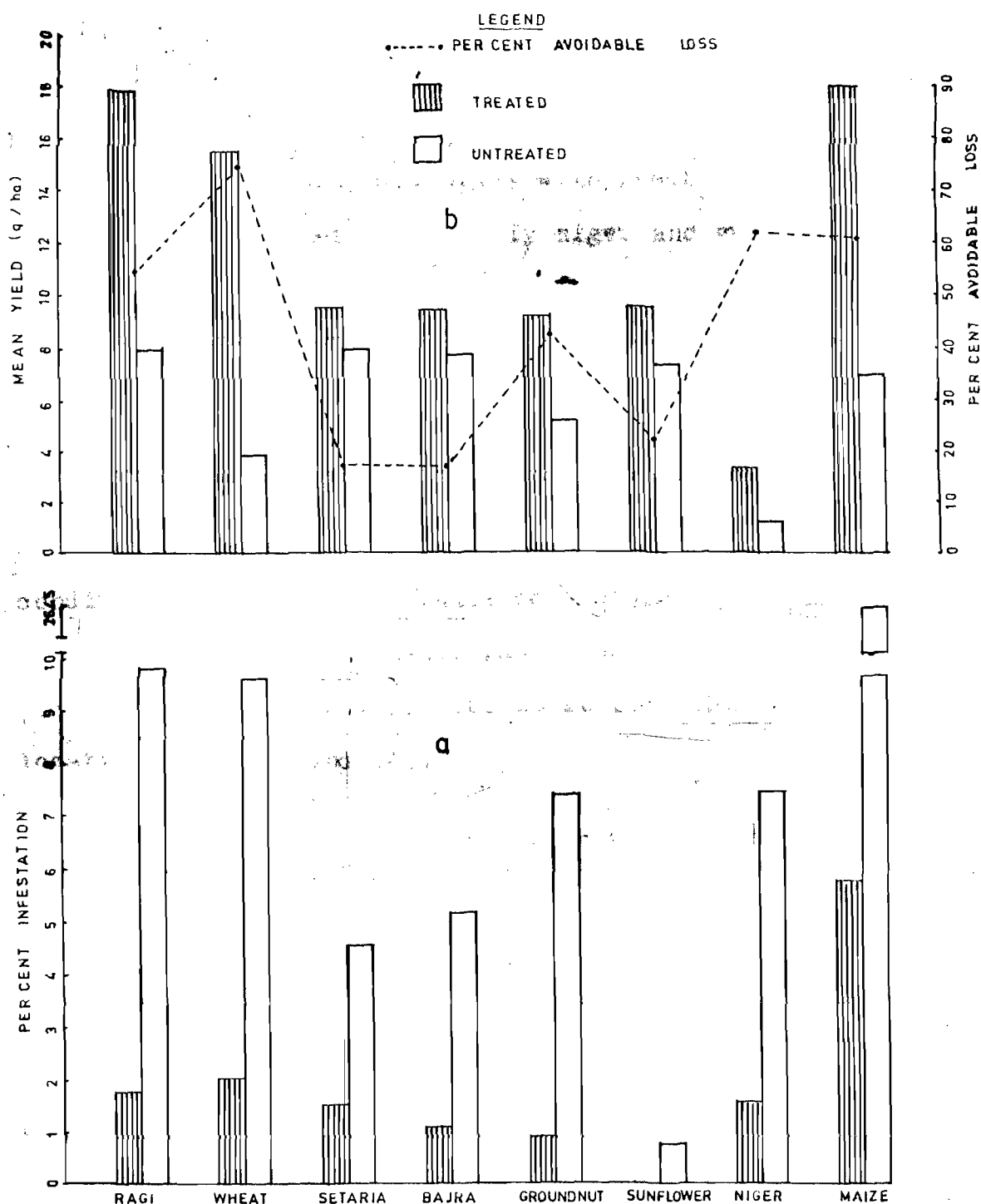


FIG.14: MEAN PER CENT INFESTATION (a), MEAN GRAIN YIELD AND PER CENT AVAILABLE LOSS (b) OF DIFFERENT CROPS DUE TO TERMITES AT ARS, CHINTAMANI (1983-84).

but was on par with ragi. Although ragi was on par with niger but differed significantly with groundnut, bajra, setaria and sunflower. Similarly niger and groundnut were on par, but significantly differed from bajra, setaria and sunflower. Groundnut, bajra and setaria were on par but significantly differed with sunflower (Fig.14).

Significant differences were noted in the per cent infestation in all crops between protected and unprotected conditions. Among them, maize recorded highest per cent of infestation and the least was in sunflower in both protected and unprotected conditions at both the experimental locations (Fig.13 and 14).

4.3.2. Yield data

At both the locations the mean yield of all the crops in protected plots was significantly higher than the unprotected plots. Similarly, the treated maize recorded higher yield over all the other crops except ragi which was on par.

At M.R.S. maize recorded higher grain yield (14.53 Q/ha) followed by ragi (14.43 Q/ha), wheat (10.74 Q/ha), bajra (10.30 Q/ha), setaria (9.91 Q/ha), sunflower (9.59 Q/ha), groundnut (7.85 Q/ha) and niger (2.83 Q/ha) (Table 10 and Fig.13).

Maize differed significantly from all the crops except ragi which was on par. Ragi and wheat also differed significantly from one another and with rest of the crops, although wheat was on par with bajra. Bajra and Setaria were observed to be significantly superior over sunflower, groundnut and niger, although it was on par with setaria. Other crops were significantly different from one another.

Protected maize, ragi and wheat recorded higher yield, these differed significantly with rest of the crops but the ragi and maize were on par and significantly different from that of wheat. Bajra, setaria, sunflower and groundnut were on par but significantly recorded higher yield over niger.

In the unprotected plots the yield of ragi, maize, bajra, setaria, sunflower were on par but different significantly with groundnut, wheat and niger. Groundnut and wheat were on par but differed significantly with niger.

At A.R.S. Chintamani ragi and maize registered the highest yield but were on par and differed significantly with rest of the treatments. Wheat and setaria were on par and wheat differed significantly from bajra, sunflower, groundnut and niger. Setaria was on par with bajra and sunflower but different from groundnut and niger. Groundnut and niger significantly differed with one another. Protected

maize, ragi and wheat recorded significantly the highest yield over other crops. Maize and ragi were on par but significantly differed with wheat. Wheat significantly different from setaria, sunflower, bajra, groundnut and niger. Niger recorded significantly the least yield (Table 11 and Fig.14).

In unprotected condition, setaria, ragi, bajra, sunflower and maize, though were on par with each other, differed significantly from groundnut, wheat and niger, the latter three crops too showed significant difference among them (Table 11).

The yields of different crops under protected condition differed significantly from the corresponding yields under unprotected conditions at both the experimental locations. The per cent increase over control was maximum in wheat (283.55) followed by maize (114.16), niger (112.70), ragi (101.56), groundnut (99.61), sunflower (30.79), setaria (23.19) and bajra (22.70).

Similarly the avoidable loss was maximum in wheat (73.92 per cent) followed by maize (53.30 per cent), niger (52.98 per cent), ragi (50.38 per cent), groundnut (49.90 per cent), sunflower (23.54 per cent), setaria (18.82 per cent), and bajra (18.50 per cent) at M.R.S. Hebbal.

The cost/benefit ratio was more/higher in wheat (1:8.07) followed by maize (1:4.98), groundnut (1:4.28), sunflower (1:3.31), ragi (1:3.2), niger (1:2.30), bajra (1:0.87) and setaria (1:0.52) (Table 12).

Whereas at A.R.S. Chintamani more or less the same trend was observed, i.e. wheat recorded maximum per cent (298.71) increase over control followed by niger (166.40), maize (156.31), ragi (126.76), groundnut (75.09), sunflower (29.32), bajra (21.42) and setaria (21.35). Similarly, wheat sustained the maximum avoidable loss (74.92 per cent) followed by niger (62.46 per cent), maize (60.98 per cent), ragi (55.90 per cent), groundnut (42.89 per cent), sunflower (22.68 per cent), bajra (17.65 per cent) and setaria (17.60 per cent). The cost benefit ratio was higher in wheat (1:7.47) and the least was in setaria (1:0.43) (Table 13).

It is seen from the data that maize was the most preferred host, which sustained maximum mean percent infestation (2.96 and 3.77) followed by wheat, niger, ragi and the sunflower is the least (0.64 and 0.37) at both experimental locations. The maximum avoidable loss was seen in wheat (73.92 and 74.92 per cent) followed by maize, niger, ragi and the least was in setaria and bajra. However, sunflower has recorded more avoidable loss compared to setaria and bajra inspite of the lower infestation.

Table 12: Estimated cost/benefit ratio after treatment (with Aldrin 5 per cent dust) of agricultural crops against termite damage at M.R.S. (1983-1984)

Sl. No.	Crops	Grain yield (Q/ha)		Per - cent increase over control	Per - cent avoidable loss	Added yield (Q/ha)	Value (Rs./ha)			Cost/benefit ratio
		Treated	Untreated				Cost/Q	Value of the produce	Cost of** the treatment incurred	
1.	Ragi	19.29	9.57	101.56	50.38	9.72	175	1701.00	530.00	1:3.2
2.	Wheat	17.03	4.44	283.55	73.92	12.59	340	4280.60	530.00	1:8.07
3.	Setaria	10.94	8.88	23.19	18.82	2.06	135	278.10	530.00	1:0.52
4.	Bajra	11.35	9.25	22.70	18.50	2.10	220	462.00	530.00	1:0.87
5.	Groundnut	10.46	5.24	99.61	49.90	5.22	435	2270.70	530.00	1:4.28
6.	Sunflower	10.66	8.15	30.79	23.54	2.51	700	1757.00	530.00	1:3.31
7.	Niger	3.85	1.81	112.70	52.98	2.04	600	1224.00	530.00	1:2.30
8.	Maize	19.81	9.25	114.16	53.30	10.56	250	2640.00	530.00	1:4.98

** : Cost of the insecticide at Rs.20/- per kg (Rs.500/ha for 25 kg) and labour charges Rs.30/-

Table 13: Estimated cost/benefit ratio after treatment (with Aldrin 5 per cent dust) of agricultural crops against termite damage at A.R.S. Chintamani (1983-1984)

Sl. No.	Crops	Grain yield (Q/ha)		Per-cent increase over control	Per-cent avoided loss	Added yield (Q/ha)	Cost/Q (Rs)	Value (Rs./ha)		Cost/benefit ratio
		Treated	Untreated					Total value of produce	Cost of the treatment incurred	
1	Ragi	17.96	7.92	126.76	55.90	10.04	175.00	1757.00	530.00	1:3.31
2	Wheat	15.55	3.90	298.71	74.92	11.65	340.00	3961.00	530.00	1:7.47
3	Setaria	9.66	7.96	21.35	17.60	1.70	135.00	229.50	530.00	1:0.43
4	Bajra	9.35	7.70	21.42	17.65	1.65	220.00	363.00	530.00	1:0.68
5	Groundnut	9.14	5.22	75.09	42.89	3.92	435.00	1705.20	530.00	1:3.21
6	Sunflower	9.57	7.40	29.32	22.69	2.17	700.00	1519.00	530.00	1:2.86
7	Niger	3.33	1.25	166.40	62.46	2.08	600.00	1248.00	530.00	1:2.35
8	Maize	18.07	7.05	156.31	60.98	11.02	250.00	2755.00	530.00	1:5.19

** Cost of the insecticide at Rs.20/- per kg (Rs.500/- per ha for 25 kgs) and Labour charges Rs.30/-.

Ragi

First incidence of termite was noticed when the crops was 54 days old. Soil sheathing was observed around the base of the plant due to O.obesus (Plate 7), and fed within the earthen galleries. When the crop was 75 days old, 1.08 and 6.80 per cent infestation in treated and untreated plots respectively was recorded. The infestation increased to 2.25 and 11.14 per cent in treated and untreated plots, respectively, by 115 days (Table 14). An average of 1.16 and 5.28 per cent infestation was recorded in the entire growth period in both conditions.

Wheat

Wheat crop started drying at 43 days of sowing and examination of such plants at the base recorded the presence of the subterranean termite, M.obesi. It attacks always from inside soil through the root system and then entered the stem from below. No sheathing was observed from outside. The termite ate the roots of the small plants and caused yellowing of the leaf blades followed by wilting and drying of plants (Plate 8). When the crop was 75 days old 1.77 and 6.75 per cent infestation was recorded in treated and untreated plots respectively and the same increased to 2.44 and 11.36 per cent by 115 days (Table 14). Mean per cent infestation was 1.52 and 5.89 in treated and untreated plots for the entire growth period.



Plate 7 : Ragi plants showing sheathing around
its base caused by Odontotermes obesi

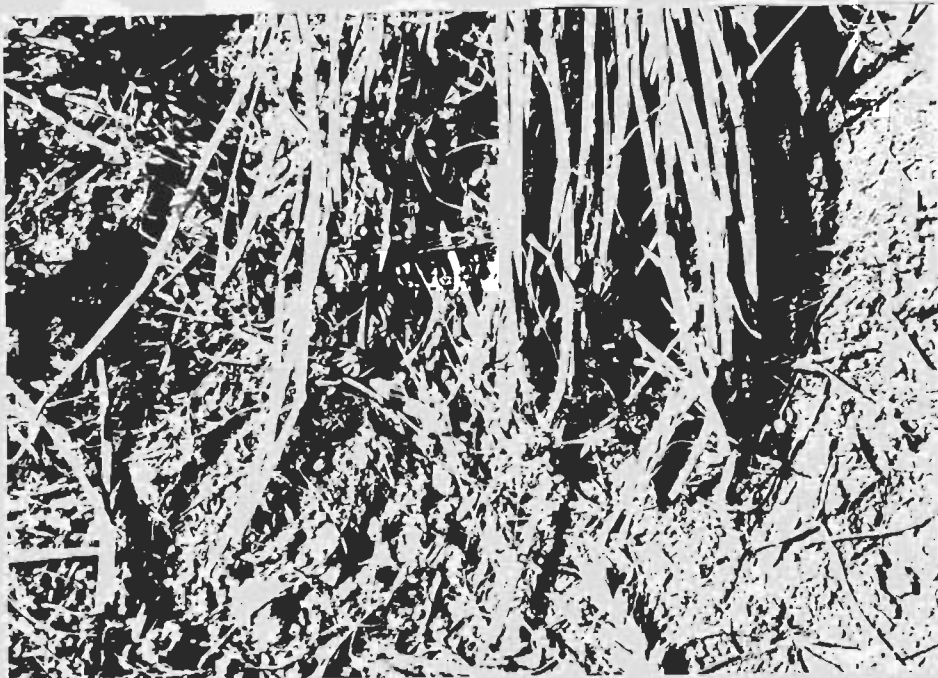


Plate 8 : Wheat plants damaged by M.obesi

Table 14: Per cent infestation of termites on different crops at 75 and 115 days after sowing at M.R.S. (1983-84)

Crops	Average plant population per plot		75 days after sowing				115 days after sowing			
			Average No. of infested plants		Per cent infested plants		Average No. of infested plants		Per cent infested plants	
	Treat- ed	Untrea- ted	Treat- ed	Untrea- ted	Treat- ed	Untrea- ted	Treat- ed	Untrea- ted	Treat- ed	Untrea- ted
Ragi	400	377	4.33	25.66	1.08	6.80	9.00	42.00	2.25	11.14
Wheat	600	572	10.66	38.66	1.77	6.75	14.66	65.00	2.44	11.36
Setaria	400	375	2.00	8.66	0.50	2.30	5.00	21.00	1.25	5.60
Bajra	200	188	1.00	8.66	0.50	4.60	3.00	13.33	1.50	7.09
Groundnut	80	73	0.33	4.33	0.41	5.93	1.00	6.33	1.25	8.67
Sunflower	48	43	-	-	-	-	0.66	1.00	1.37	2.32
Niger	340	318	2.66	16.66	0.78	5.24	8.66	29.00	2.54	9.11
Maize	50	45	0.66	6.00	1.32	13.33	2.00	13.66	4.00	30.35

Setaria

Setaria was found attacked by termites when the crop was 52 days old. The roots were damaged. The per cent of infestation was 0.50 and 2.30 at 75 days and it increased to 1.25 and 5.60 by 115 days in treated and untreated plots respectively. The mean per cent of infestation was 0.79 and 3.76 was recorded during the entire period of growth.

Bajra

Bajra was also attacked by both Odontotermes sp. and M. obesi, when the crop was 53 days old. At 75 days old, 0.50 and 4.60 per cent infestation was recorded and increased to 1.5 and 7.09 per cent by 115 days in treated and untreated plots respectively (Table 14). Whereas, the mean per cent infestation was 0.74 and 3.76 for the entire growth period of the crop.

Groundnut

Incidence of the pest termite noticed when the crop was 58 days old. The plant was attacked by both Microtermes obesi and Odontotermes spp. The attacked plants dried and wilted with no sheathing when it was attacked by M. obesi. The incidence was 0.41 and 5.93 per cent in treated and untreated plots at 75 days. The per cent incidence increased to 1.25 and 8.67 by 115 days (Table 14). The mean per cent

of incidence was 1.12 and 5.32 in treated and untreated plots for the entire growth period of the crop.

Sunflower

No incidence was observed in sunflower upto 75 days. Incidence was observed only when the crop was 90 days old, recording 1.37 and 2.32 per cent in treated and untreated plots respectively. An average of 0.32 and 0.94 per cent was recorded for the entire growth period of the crop.

Niger

Niger was attacked by both Odontotermes spp. and Microtermes obesi. The stalks of the plant were damaged and become hollow (Plate 9). When the crop was 75 days old, although the first incidence was noticed at 54 days old and the per cent damage was 0.78 and 5.24 per cent and it increased to 2.54 and 9.11 per cent by 115 days. The mean per cent of infestation was 1.77 and 5.51 per cent for the entire growth period.

Maize

On maize, the first attack was on prop roots at 52 days old crop and severe damage was noticed when the crop was 75 days old with 1.32 and 13.33 per cent. The damage was due to Odontoterrnes spp. and M. obesi. In severe cases

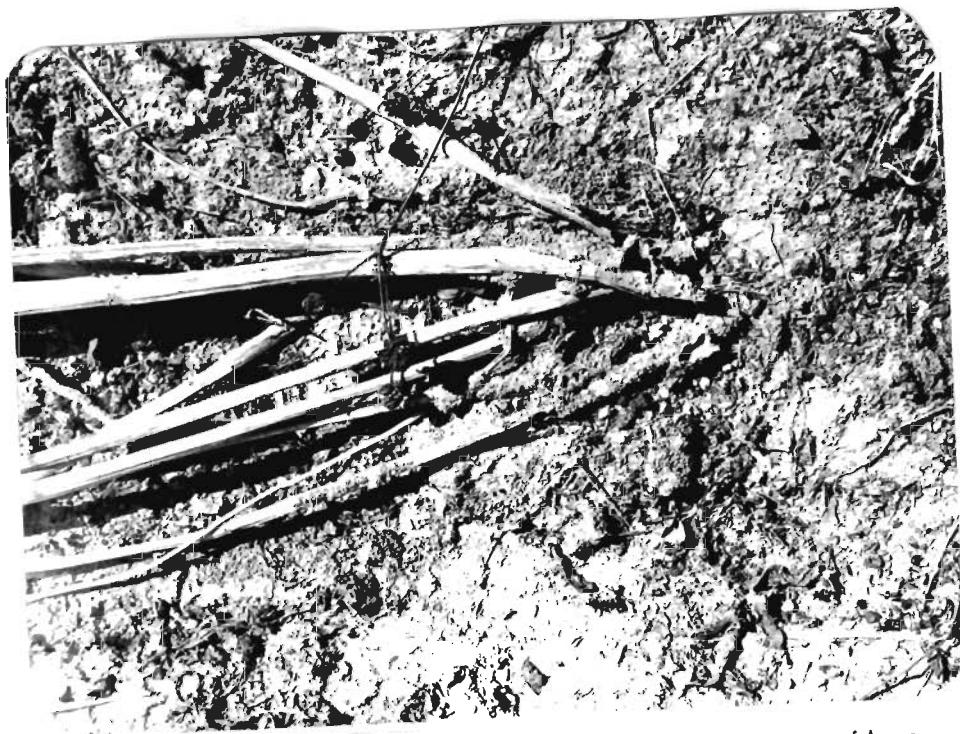


Plate 9 : Niger plants damaged by termites



Plate 10: Maize plants damaged by Odontotermes spp.

the plants lodged and the entire plants were attacked (Plate 10). The damage was increased to 4 and 30.35 per cent in treated and untreated plots respectively by 115 days (Table 14). The mean per cent infestation was 3.77 and 15.94 in treated and untreated plots respectively for the entire growth period of the crop, registering highest damage among the crops under observation.

At A.R.S. Chintamani, the same trend was observed (Table 15). However, the per cent infestation was higher in all the crops both at 75 and 115 days after sowing than at M.R.S. Hebbal.

4.4. To estimate the loss in wheat by subterranean termite, *Microtermes obesi* and its management

4.4.1. Infestation results

Mean per cent infestation differed significantly at different levels of irrigation as can be seen in Table 16. The mean per cent infestation was maximum (2.54 and 2.42) in no irrigation followed by normal (1.24 and 1.45) and frequent (1.00 and 1.05) irrigation respectively during the year 1979-80 and 1982-83.

Among the different levels of insecticide (aldrin 5 D and Aldrex 30EC) at fixed level of irrigation, maximum infestation was recorded in no insecticide (untreated check)

Table 15: Per cent infestation of termite on different crops at 75th day and 115th day after sowing at A.R.S. Chintamani (1983-84)

Crops	Average plant population per plot		75 days after sowing				115 days after sowing			
			Average No. of infested plants		Per cent infested plants		Average No. of infested plants		Per cent infested plants	
	Treat- ed	Untreat- ed	Treat- ed	Untreat- ed	Treat- ed	Untreat- ed	Treat- ed	Untreat- ed	Treat- ed	Untreat- ed
Ragi	450	433	7.66	44.33	1.70	10.23	14.33	66.00	3.18	15.24
Wheat	650	600	16.33	65.33	2.43	10.88	22.33	88.33	3.43	14.72
Setaria	465	447	5.66	22.66	1.21	5.06	11.33	31.00	2.43	6.93
Bajra	230	222	1.66	12.66	0.72	5.70	5.66	19.00	2.46	8.55
Groundnut	78	71	0.33	5.33	0.42	7.50	1.66	8.00	2.12	11.26
Sunflower	48	45	-	0.33	-	0.73	-	0.66	0.00	1.46
Niger	315	290	5.00	25.66	1.58	8.84	10.00	34.33	3.17	11.83
Maize	50	53	2.33	14.00	4.16	26.41	6.00	20.33	10.71	38.35

Table 16: Mean per cent infestation of termite, Microtermes obesi on wheat at M.R.S. during the year 1979-80 and 1982-83

Year 1979-80

Treatments	Aldrin 5 per cent dust				Aldrex 30 E.C. 0.3 per- cent	Control	Mean	
	25.00 kg/ha Broadcasting	37.50 kg/ha Broadcasting	25.00 kg/ha Row applica- tion	37.50 kg/ha Row applica- tion				
	1	2	3	4				5
No Irrigation	6.90 (2.62)		6.57 (2.56)	6.24 (2.49)	5.76 (2.39)	5.48 (2.33)	8.03 (2.83)	(2.54)
Frequent irri- gation	1.22 (1.10)		1.05 (1.02)	0.96 (0.97)	0.82 (0.90)	0.71 (0.84)	1.35 (1.61)	(1.00)
Normal irriga- tion	1.90 (1.37)		1.50 (1.22)	1.30 (1.14)	1.18 (1.08)	1.08 (1.04)	2.49 (1.57)	(1.24)
Mean	(1.70)		(1.60)	(1.53)	(1.46)	(1.41)	(1.85)	

CD @ 5% I : 0.18
 II : 0.04
 III : 0.08
 IV : 0.19

...Con

Table 16 - (Contd.)

Year 1982-83

1	2	3	4	5	6	7	8
No. Irrigation	6.72 (2.59)	5.93 (2.43)	5.76 (2.40)	5.09 (2.25)	4.67 (2.16)	7.44 (2.72)	(2.42)
Frequent irrigation	1.21 (1.10)	1.18 (1.08)	1.09 (1.04)	0.98 (0.99)	0.84 (0.92)	1.46 (1.20)	(1.05)
Normal irrigation	2.51 (1.58)	2.14 (1.46)	1.90 (1.40)	1.68 (1.29)	1.57 (1.25)	2.95 (1.71)	(1.45)
Mean	(1.75)	(1.66)	(1.61)	(1.51)	(1.44)	(1.88)	

CD@5% I: 0.08
II: 0.40
III: 0.07
IV: 0.10

CD I: For comparing any two main treatment means
II: For comparing any two sub treatments at fixed level of the main treatment
III: For comparing any two sub treatments at fixed level of the main treatment
IV: For comparing any two main treatments for fixed level of sub-treatments

(Figures in parentheses are transformed square root values)

(1.85 and 1.88) followed by aldrin 5 D at 25 kg/ha B.C. (1.70 and 1.75), 37.50 kg/ha B.C. (1.60 and 1.66), 25 kg/ha, R.A. (1.53 and 1.61), 37.50 kg/ha R.A. (1.46 and 1.51), and Aldrex 30 EC 0.3 per cent (1.41 and 1.44) respectively in the years 1979-80 and 1982-83. All the treatments differed significantly from each other. However, Aldrex 30 EC at 0.3 per cent was not only superior to check but also to all the other treatments (Table 16, Fig. 15).

At all irrigation levels, Aldrex 30 EC 0.3 per cent recorded the least per cent infestation followed by aldrin 5 D at 37.50 kg/ha R.A., 25 kg/ha R.A., 37.50 kg/ha B.C., 25 kg/ha B.C. and untreated check in both the years, Aldrex 30 EC 0.3 per cent was significantly superior to all other treatments. The minimum per cent infestation (0.84) was recorded in Aldrex 30 EC 0.3 per cent treated plot of frequent irrigation level during 1979-80 and the maximum per cent infestation (2.83) was recorded in untreated check during the same year at no irrigation level.

The per cent infestation at 115 days after sowing (a week before harvest) was presented in the Table 17, for both the years 1979-80 and 1982-83. Accordingly, the per cent infestation was maximum (17.48 and 18.53) in no irrigation followed by normal (3.85 and 4.67) and frequent (2.67 and

3.00) irrigation respectively during the year 1979-80 and 1982-83. However, there was no significant difference between normal and frequent irrigation, but both differed significantly with no irrigation.

Among the different level of insecticide the maximum infestation was recorded in untreated check (10.58 and 10.90) followed by aldrin 5 per cent dust at 25 kg/ha B.C. (9.00 and 9.70), 37.50 kg/ha B.C. (8.14 and 8.66), 25 kg/ha R.A. (7.40 and 8.46), 37.50 kg/ha R.A. (6.85 and 7.55),¹ and Aldrex 30 E.C. 0.3 per cent (6.11 and 7.14), respectively, during the year 1979-80 and 1982-83. All the treatments differed significantly with one another, except aldrin 5 D at 37.50 kg/ha B.C. and 25.00 kg/ha R.A.; and 37.50 kg/ha R.A. and 0.3 per cent Aldrex 30 E.C. which were on par during the year 1979-80 (Table 17). Similarly, during the year 1982-83, Aldrex 0.3 per cent 30 E.C. recorded the least per cent infestation, being significantly superior over all other treatments except aldrin 37.50 kg/ha R.A., which was on par. Aldrin 5 D at 37.50 kg/ha R.A., 25 kg/ha R.A. and 37.50 kg/ha B.C. were significantly superior over aldrin 5 D at 25 kg/ha B.C. and untreated check; although, aldrin 5 D dust at 37.5 kg/ha B.C. 25 kg/ha R.A. was on par; Similarly aldrin 25 kg/ha R.A. and 37.50 kg/ha R.A. were on par (Table 17).

Table 17: Per cent infestation of termite, Microtermes obesi Holmgren on wheat at 115 days after sowing during 1979-80 and 1982-83

Treat-ments	Aldrin 5 per cent dust				Aldrex Con-30 EC 0.3 per cent		Aldrin 5 per cent dust				Aldrex Con-30 EC 0.3 per cent		Mean	
	25.00 kg per ha broadcast	37.50 kg /ha Broadcast	25.00 kg /ha Broadcast	37.50 kg /ha Broadcast	25.00 kg /ha Broadcast	37.50 kg /ha Broadcast	25.00 kg /ha Broadcast	37.50 kg /ha Broadcast	25.00 kg /ha Broadcast	37.50 kg /ha Broadcast	25.00 kg /ha Broadcast	37.50 kg /ha Broadcast		
1979-80														
No irri-gation	18.51	18.04	16.72	15.45	14.76	21.42	17.48	20.45	18.02	18.33	16.41	15.63	22.77	18.53
Frequent irrigation	3.54	2.69	2.42	2.21	1.42	3.75	2.67	3.37	3.23	2.67	2.42	2.27	4.09	3.00
Normal irrigation	4.97	3.70	3.06	2.90	2.17	6.34	3.85	5.30	4.74	4.39	3.83	3.53	6.26	4.67
Mean :	9.00	8.14	7.40	6.85	6.11	10.58	-	9.70	8.66	8.46	7.55	7.14	10.90	-
1982-83														
CD at 5% : I : 2.40 II : 0.81 III : 1.40 IV : 2.69														
CD I : For comparing any two main treatment means II : For comparing any two subtreatment means III : For comparing any two subtreatments at fixed level of the main treatment IV : For comparing any two main treatments for fixed level of subtreatments														
CD at 5% : I : 1.67 II : 0.77 III : 1.34 IV : 2.05														

At all irrigation levels, Aldrex 30 E.C. 0.3 per cent recorded the least per cent infestation followed by aldrin 5 D dust at 37.50 kg/ha R.A., 25 kg/ha R.A., 37.50 kg/ha B.C., 25 kg/ha B.C. and untreated check in both the years; Aldrex 30 E.C. 0.3 per cent was significantly superior to all other treatments.

4.4.2. Yield results

The mean yield data of grain and straw of the wheat for the year 1979-80 and 1982-83 are presented in Tables 18 and 19.

4.4.2.1. Grain yield (1979-80)

The grain yields obtained in the main treatments differed significantly from one another. Frequent irrigation gave significantly higher yield (15.25 Q/ha) over normal (13.98 Q/ha) and no irrigation (6.17 Q/ha) levels (Table 18 and Fig.15).

Among the insecticides, Aldrex 30 E.C. 0.3 per cent recorded the maximum yield (13.29 Q/ha) followed by aldrin 5 D at 37.5 kg/ha, R.A. (12.98 Q/ha), 25 kg/ha R.A. (12.22 Q/ha), 37.5 kg/ha B.C. (11.58 Q/ha), 25 kg/ha B.C. (10.85 Q/ha) and untreated check (9.88 Q/ha). Among these, Aldrex 30 E.C. 0.3 per cent, aldrin 5 D at 37.5 kg/ha R.A. and 25 kg/ha R.A. were on par with one another and significantly

superior over aldrin 5 D at 37.5 kg/ha and 25 kg/ha B.C. and untreated check. Aldrin 5 D at 25 kg/ha R.A. was on par with aldrin 5 D at 37.5 kg/ha B.C. but was significantly superior over aldrin 5 D at 25 kg/ha B.C. and untreated check. Aldrin 5 D at 37.5 kg/ha B.C. was on par with aldrin 5 D at 25 kg/ha B.C. but significantly superior to untreated check. There was no significant difference between aldrin 5 D at 25 kg/ha B.C. and untreated check.

Insecticidal treatments at fixed level of irrigation, showed no significant differences among the treatments. Never the less, at no irrigation level, Aldrex 30 E.C. 0.3 per cent recorded maximum yield (8.00 Q/ha) and the minimum yield was recorded in untreated check (4.44 Q/ha). Similarly, at frequent irrigation level Aldrex 30 E.C. 0.3 per cent recorded the maximum yield (16.66 Q/ha) and the minimum yield was recorded in untreated check (13.70 Q/ha). In the same way, at normal irrigation level aldrin 5 D at 37.50 Kg/ha R.A. registered the highest yield (15.55 Q/ha) and the least yield was in untreated check (11.49 Q/ha).

Irrigation levels at fixed insecticidal treatments, similar trend was observed, in that there was no significant differences between the treatments.

4.4.2.2. Straw yield (1979-80)

The straw yield obtained at the irrigation levels were significantly different from one another. Frequent irrigation recorded significantly superior yield (11.97 Q/ha) over normal (9.75 Q/ha) and no irrigation (5.21 Q/ha) levels (Table 18 and Fig.15).

In the insecticidal treatments, Aldrex 30 E.C. 0.3 per cent (10.22 Q/ha), aldrin 5 D at 37.5 kg/ha R.A. (9.98 Q/ha) and aldrin 5 D at 25 kg/ha R.A. (9.38 Q/ha) were on par with one another but significantly superior over aldrin 5 D at 37.50 kg/ha B.C. (9.01 Q/ha), aldrin 5 D at 25 kg/ha B.C. (8.16 Q/ha) and untreated check (7.11 Q/ha). Aldrin 5 D at 37.5 kg/ha R.A. was on par with aldrin 5 D at 25 kg/ha R.A. and 37.5 kg/ha B.C. aldrin 5 D at 37.50 kg/ha B.C. was significantly superior (9.01 Q/ha) over untreated check (7.11 Q/ha) but was on par with aldrin 5 D at 25 kg/ha B.C. (Table 18).

In the case of insecticidal treatments at fixed level of irrigation, there was no significant difference between them. However, at no irrigation level, Aldrex 30 E.C. 0.3 per cent recorded the maximum yield (6.68 Q/ha) while the minimum yield was recorded in untreated check (3.64 Q/ha). But under frequent and normal irrigation levels aldrin 5 D at 37.50 kg/ha R.A. recorded the maximum yields (13.14 Q/ha)

and 11.11 Q/ha) and the minimum yields was recorded in untreated check (9.44 Q/ha and 8.24 Q/ha) respectively.

At fixed level of subtreatments, there was no significant difference between the treatments.

4.4.1.3. Grain yield (1982-83)

Frequent irrigation recorded significantly higher yield (14.63 Q/ha) over no irrigation (6.94 Q/ha) but was on par with normal irrigation (13.92 Q/ha) (Table 19 and Fig.15).

Among insecticidal treatments, aldrin 5 D 37.50 kg/ha R.A. accounted for the maximum yield (13.45 Q/ha) which was on par with Aldrex 30 E.C. 0.3 per cent (12.83 Q/ha), aldrin 5 D at 25 kg/ha R.A. (12.28 Q/ha), and aldrin 5 D at 37.50 kg/ha B.C. (11.66 Q/ha), but significantly superior over aldrin 5 D at 25 kg/ha B.C. (10.98 Q/ha) and untreated check (9.75 Q/ha). Though Aldrex 30 E.C. 0.3 per cent was on par with aldrin 5 D 25 kg/ha R.A., 37.50 kg/ha B.C. and 25 kg/ha B.C., proved to be superior over untreated check. There was no significant difference between the treatments aldrin 5 D at 37.50 kg/ha B.C., 25 kg/ha B.C. and untreated check.

There was no significant differences at fixed level of irrigation among insecticidal treatments. However, at no

irrigation level, Aldrex 30 E.C. 0.3 per cent recorded the maximum yield (8.88 Q/ha) and the minimum was in untreated check (4.63 Q/ha). Similarly at frequent and normal irrigation levels, aldrin 5 D at 37.50 kg/ha R.A. recorded the maximum yield (16.85 and 14.81 Q/ha) and the minimum yield was recorded in untreated check (13.14 and 11.48 Q/ha) respectively (Table 19).

Fixed level of insecticidal treatments exhibited no significant difference between them.

4.4.1.4. Straw yield (1982-83)

Among the irrigation levels, frequent irrigation registered significantly higher yield (11.48 Q/ha) over no irrigation (4.74 Q/ha) but was on par with normal irrigation (10.51 Q/ha) (Table 19 and Fig.15).

In the insecticidal treatments, aldrin 5 D at 37.50 kg/ha R.A. (10.06 Q/ha) accounted for maximum yield followed by Aldrex 30 E.C. 0.3 per cent (9.88 Q/ha) and aldrin 5 D at 25 kg/ha R.A. (8.98 Q/ha), these were on par with each other but significantly superior over aldrin 5 D 37.50 kg/ha B.C. (8.71 Q/ha), aldrin 25 kg/ha B.C. (8.55 Q/ha) and untreated check (7.27 Q/ha). Though Aldrex 30 E.C. 0.3 per cent was on par with aldrin 5 D at 25 kg/ha R.A. and aldrin 5 D at 37.50 kg/ha B.C. was significantly superior over

Table 19: Mean grain and straw yield of wheat (Q/ha)
during the year 1982-83

Treat- ments	Aldrin 5 per cent dust				Aldrex 30 E.C. 0.3 per cent	Con- trol	Mean
	25.00 kg/ha Broad- cast- ing	37.50 kg/ha Broad- cast- ing	25.00 kg/ha Row appli- cation	37.50 kg/ha Row appli- cation			
<u>GRAIN YIELD</u>							
No irriga- tion	5.55	6.66	7.22	8.70	8.88	4.63	6.94
Frequent irrigation	13.88	14.07	14.81	16.85	14.99	13.14	14.63
Normal irrigation	13.51	14.25	14.81	14.81	14.62	11.48	13.92
Mean :	10.98	11.66	12.28	13.45	12.83	9.75	-
C.D.at 5% : I :1.38; II : 1.97; III: N.S.; IV: N.S.							
<u>STRAW YIELD</u>							
No irriga- tion	4.18	4.63	4.90	5.20	5.46	4.05	4.74
Frequent irrigation	11.11	11.01	11.11	13.51	12.88	9.25	11.48
Normal irrigation	10.37	10.48	10.92	11.48	11.29	8.51	10.51
Mean :	8.55	8.71	8.98	10.06	9.88	7.27	
C.D.at 5%: I: 0.58; II: 1.20; III: N.S.; IV: N.S.							

C.D. I: For comparing any two main treatment means
 II: For comparing any two sub-treatment means
 III: For comparing any two subtreatments at fixed
 level of the main treatment
 IV: For comparing any two main treatments for fixed
 level of sub-treatments

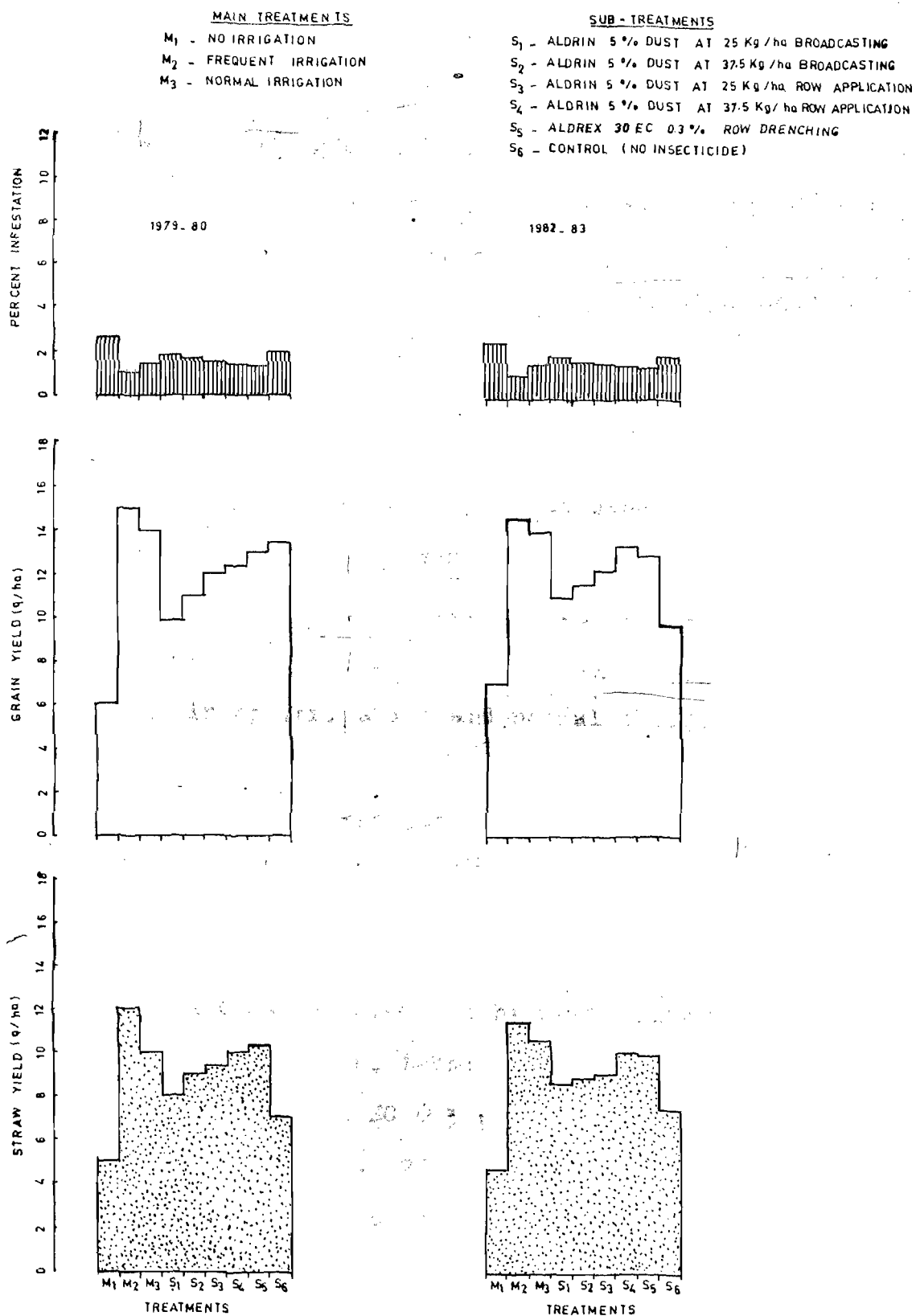


FIG. 15: GRAIN AND STRAW YIELDS(q/ha) OF WHEAT UNDER DIFFERENT INFESTATION LEVELS OF SUBTERRANEAN TERMITE, Microtermes obesi HOLM. (1979-80 AND 1982-83)

aldrin 5 D at 25 kg/ha B.C. and untreated check. Similarly, aldrin 5 D at 25 kg/ha R.A. which was on par with aldrin 5 D at 37.50 kg/ha B.C. and 25 kg/ha B.C. was found to be significantly superior to untreated check.

At fixed level of insecticides, there was no significant difference between the treatments.

Highest grain yield of 14.94 Q/ha was obtained in frequent irrigation as against 6.55 Q/ha of grain yield in no irrigation. The per cent increase over control (no irrigation) was 127.30 in frequent irrigation and 112.74 in normal irrigation. The per cent loss due to termite infestation in no irrigation and normal irrigation conditions was 56.10 and 6.61 respectively; whereas the avoidable loss was 56.10 and 52.99 per cent in frequent and normal irrigation respectively (Table 20 and Fig.16).

Similarly, among the insecticides aldrin 5 D dust at 37.50 kg/ha R.A. recorded the highest grain yield (13.22 Q/ha) with lowest per cent of termite infestation (1.46 and 1.51) followed by Aldrex 30 EC 0.3 per cent, aldrin 5 D at 25 kg/ha R.A., 37.50 kg/ha B.C., 25 kg/ha B.C. and untreated check. The per cent increase over control (no insecticide) was maximum in aldrin 5 D at 37.5 kg/ha R.A. (34.67) followed by Aldrex 30 E.C. 0.3 per cent (33.09), aldrin 5 D at 25.00 kg/ha

Table 20: Per cent loss and per cent avoidable loss in wheat due to subterranean termite, Microtermes obesi Holmgren at M.R.S. (1979-80 and 1982-83)

Treat- ments	Mean per- cent in- festation		Mean grain yield(q/ha)		Mean	Per cent increase over control	Per cent loss over best treat- ment	Straw yield (Q/ha)		Mean	Per cent increase over control	Per cent loss over best treatment	Per cent avoidable loss	
	1979-1982- 1980 1983		1979-1980	1982-1983										
Main treatments:														
M ₁	2.54	2.42	2.48	6.17	6.94	6.55	-	56.10	5.21	4.71	4.96	-	57.71	-
M ₂	1.00	1.05	1.02	15.25	14.63	14.94	127.30	-	11.97	11.48	11.73	136.49	-	57.71
M ₃	1.24	1.45	1.34	13.98	13.92	13.95	112.74	6.61	9.75	10.51	10.13	104.27	13.62	51.04
Sub-treat- ments:														
S ₁	1.70	1.75	1.72	10.85	10.98	10.92	11.22	17.41	8.16	8.55	8.36	16.22	16.82	13.95
S ₂	1.60	1.66	1.63	11.58	11.67	11.62	18.38	12.09	9.01	8.71	8.86	23.17	11.84	18.81
S ₃	1.53	1.61	1.57	12.22	12.28	12.25	24.80	7.32	9.38	8.98	9.18	27.63	8.65	21.65
S ₄	1.46	1.51	1.48	12.98	13.45	13.22	34.67	-	9.98	10.06	10.02	39.33	0.27	28.23
S ₅	1.41	1.44	1.42	13.29	12.83	13.06	33.09	1.17	10.22	9.88	10.05	39.72	-	28.43
S ₆	1.85	1.88	1.86	9.88	9.75	9.81	-	25.74	7.11	7.27	7.19	-	28.43	-

Note:
M₁ = No irrigation
M₂ = Frequent irrigation
M₃ = Normal irrigation
S₁ = Aldrin 5% dust at 25 kg/ha B.C.
S₂ = Aldrin 5% dust at 37.50 kg/ha B.C.
S₃ = Aldrin 5% dust at 25.60 kg/ha R.A.
S₄ = Aldrin 5% dust at 37.50 kg/ha B.C.
S₅ = Aldrex 30 E.C. 0.3 per cent
S₆ = Control (No Insecticide/Untreated check)

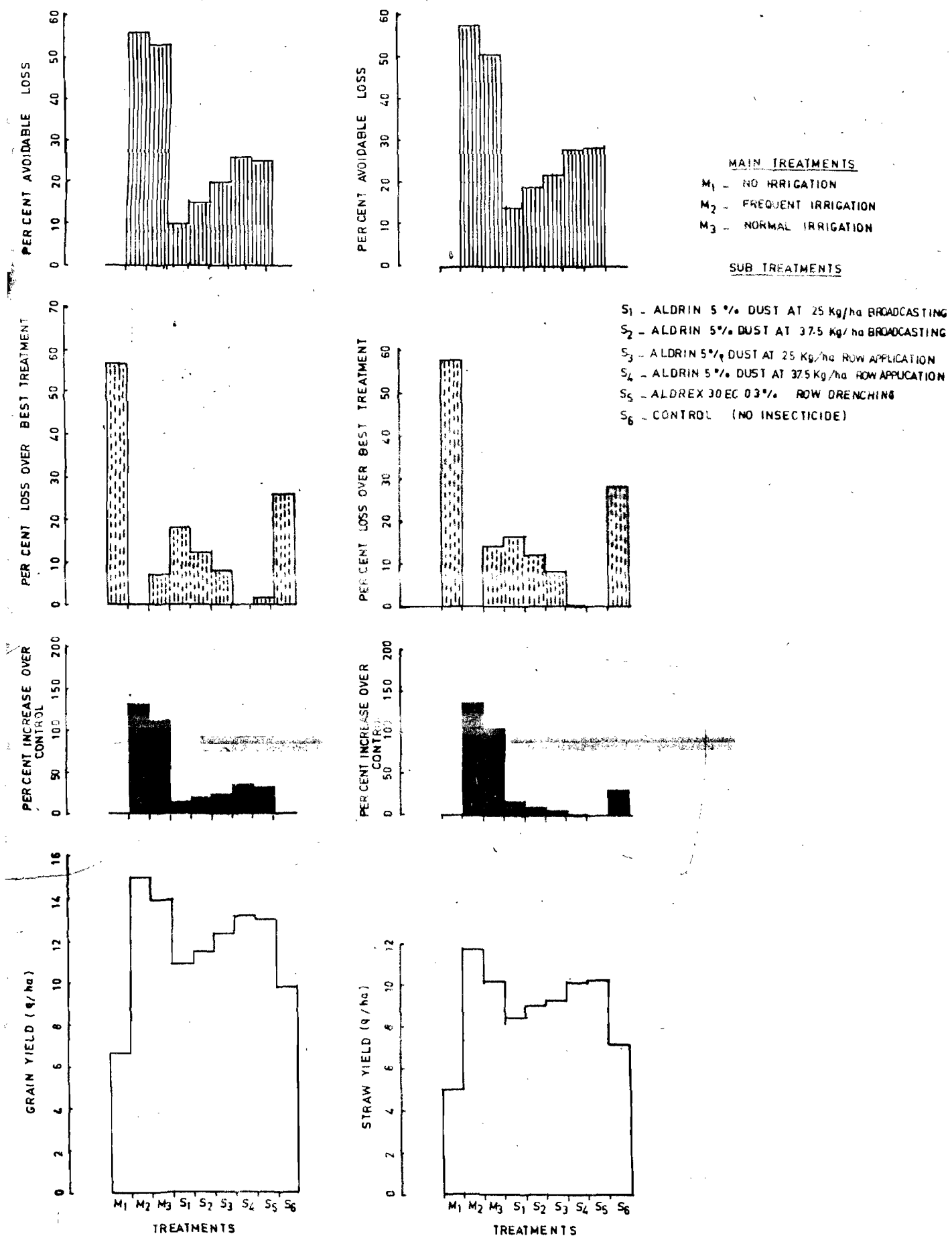


FIG.16: CROP LOSSES IN WHEAT DUE TO SUBTERRANEAN TERMITE
Microtermes obesi HOLM.

R.A. (24.80), 37.50 kg/ha B.C. (18.38) and 25 kg/ha B.C. (11.22). The difference in yield between aldrin 5 D at 37.50 kg/ha R.A. and untreated check was the loss in yield that was brought about by termite attack. The per cent loss due to termite accounted for 25.74 and the per cent avoidable loss was also 25.74 (Table 20 and Fig.16).

In respect of straw yield no irrigation recorded the minimum yield (4.96 Q/ha) as against the frequent irrigation, which registered the maximum yield (11.73 Q/ha) and in the normal irrigation it was 10.13 Q/ha. The per cent increase over control (no irrigation) was higher in frequent irrigation (136.49 per cent) while in normal irrigation it was 104.27 per cent. The per cent loss due to termite infestation in no irrigation and normal irrigation was 57.71 and 13.26 respectively, whereas, the per cent avoidable loss by frequent and normal irrigations 57.71 and 51.04. Similarly among the insecticides, Aldrex 30 E.C. 0.3 per cent drenching recorded the maximum yield followed by aldrin 5 D at 37.50 kg/ha, R.A. 25 kg/ha R.A., 37.50 kg/ha B.C., 25 kg/ha B.C. and untreated check. The difference between Aldrex 30 E.C. 0.3 per cent drenching and untreated check was caused by termite infestation. The per cent increase over no insecticide was maximum in Aldrex 30 E.C. 0.3 per cent

(39.72) and the least was in aldrin 5 D at 25 kg/ha B.C. (16.22). The per cent loss due to termite accounted for 28.43 and the per cent avoidable loss was also 28.43 (Table 20 and Fig.16).

DISCUSSION

V. DISCUSSION

The present studies were undertaken with the four main objectives: (1) To know the different species of termites and their relative abundance at the Main Research Station, Hebbal; (2) To study some aspects of ecology of the subterranean termite, Microtermes obesi Holmgren; (3) To understand the host preference and losses caused by termites; and (4) To estimate the loss to wheat by M.obesi and its management. The results of the above investigations are discussed in the following pages.

5.1. Species of termites and their relative abundance

In the present study ten species of termites were encountered. Among them, nine species were recovered on three types of baits namely, wheat, ragi, maize and straw. The most preferred host was wheat for M.obesi; maize and ragi for O.obesus. However, these two species were most active during the months of May-August, which also coincided with maximum number of wet days compared to rest of the year (Appendix II, III and IV; Fig.6, 7, 8). Earlier reports from India, (Faribar, 1980 and Sudhakar, 1983), Rhodesia (Mitchell, 1972) and Nigeria (Haverty et al., 1976 and Johnson et al., 1981) also corroborate with the present findings in respect of peak incidence of M.obesi and O.obesus during wet months from May-October and lowest incidence from November-April.

Temperature and relative humidity seems to have not much influence over the activity of termite as compared to rainfall (Fig. 5, 6, 7 and 8). All the species observed in the present study, were found during a short span of four months when there was intermittent rain, whereas, during the rest of the year their activity slowed down drastically, although there was not much change in temperature and relative humidity.

Out of the total of 783 baits found infested by the termites, 353 baits were attacked by O.obesus constituting 45.08 per cent. This was followed by M.obesi with 211 baits attacked, which accounted for 26.94 per cent. The next to follow in that order were O.wallonensis (84 and 10.72 per cent), O.horni (64 and 8.17 per cent), O.redemanni (36 and 4.59 per cent), O.ceylonicus (13 and 1.66 per cent) Trinervitermes biformis (9 and 1.14 per cent) and O.bellahunisensis (3 and 0.38 per cent) (Table 2 and Fig.9).

Among the three baits offered, wheat was more attractive to M.obesi with 54.97 per cent incidence followed by 25.59 and 19.43 per cent incidence on ragi and maize respectively. On the other hand, maize and ragi were more preferred to wheat by O.obesus with 39.66, 35.41 and 24.92 per cent incidence on maize, ragi and wheat respectively.

O.wallonensis which was the third dominant species almost had equal preference for maize (38.09 per cent) and ragi (34.52 per cent) and less preference for wheat (27.38 per cent). Similarly, the other dominant species O.horni and O.redemanni also had equal preference for maize and ragi over to wheat. O.ceylonicus did not prefer wheat straw, on the other hand, M.globicola preferred only wheat straw except on one occasion when it preferred ragi, out of ten baits infested (Table 3). In general Microtermes sp. had decided preference for wheat straw and Odontotermes spp. had less preference to wheat (Fig.10). The chemical composition of all the three straw as analysed by Lander (1949) do not give any clue to any of the composition being preferred by any of the species.

From the above discussion it is clear that among the ten species of termites found in the study area, Speculitermes did not occur on any of the baits, although the alates were collected during swarming. Therefore, it is concluded that Speculitermes does not feed on crop plants. Earlier reports also have not suggested any host plants of this species (Roonwal, 1970).

Out of the remaining nine species, more than 70 per cent of the total population belong to O.obesus and M.obesi.

Incidentally, these two species were also found attacking standing crops at various stages of growth under rainfed conditions at M.R.S. Hebbal. Bait studies using dung and wood made by Sudhakar (1983), revealed the above two species constituting 90 per cent of the population of the twelve species occurring at A.R.S. Chintamani.

O.horni although fourth in the order of abundance was mainly common on eucalyptus and mulberry in and around the study area. O.wallonensis, constitutes 10.72 per cent of incidence on baits and attacked the standing crops like maize, niger, groundnut, sunflower, bajra and ragi. The remaining species had no consequence of any significant importance as pests of crops.

Relative distribution of nests of four major species encountered at M.R.S. Hebbal

During the course of a two year study, a total of 840 nests were located in the study area comprising 40 hectares. The study area had both cultivated and uncultivated land. The distribution of the four major species as shown in Table 3 and Fig.11, reveals two distinct characteristics that might influence the dominance of species in cultivated and uncultivated areas. It is evident that M.obesi being subterranean, can escape destruction of nests during preparatory cultivations and also capable of feeding on roots from below ground-surface, thus surviving in the cultivated

area. Therefore, maximum number (160) of M.obesi nests were found in the cultivated areas and the least number (60) in uncultivated areas. On the otherhand, nests of Odontotermes obesus, O.wallonensis and O.horni were more in uncultivated areas compared to cultivated areas (Table 3). Similarly Wood et al. (1977) have reported more number of subterranean termite (Microtermes sp.) nests in cultivated field compared to Odontotermes sp. Observations made by Rajgopal (1979) also agree with the present findings. He found more number of O.wallonensis nests in forest and uncultivated lands compared to nests found in the cultivated fields.

The study area has been under cultivation almost for more than 70 years, eversince the School of agriculture was started in 1913 at Hebbal, Bangalore. However, about two decades back some parts of cultivated field were converted into grassland, which was less disturbed in the following years favoured the incidence of more number of nests of Odontotermes spp.

The number of nests of O.horni a subterranean termite like M.obesi, is low in the cultivated areas than in the uncultivated areas. One of the probable reason might be the nesting pattern and the foraging behaviour between these two subterranean species. While Odontotermes horni came above

ground, made sheathing before foraging. M.obesi neither made any sheathing nor appeared above ground. The colony of these two species also differed in that, the O.horni like other Odontotermes had a compact nest in which all the members including the queen and fungus comb were found together. Whereas, in M.obesi the queen was separated quite away from the fungal combs and also lived deeper in the soil, which made it more secure. Therefore, any disturbance of the soil was more harmful to O.horni than to M.obesi.

Microtermes obesi being underground feeder, is less subjected to predatism compared to the above ground feeders of Odontotermes spp. Microtermes obesi dominates in graminaceous field crops (Roonwal, 1983), because of availability of roots of plants for feeding. Whereas, Odontotermes spp. can find plenty of suitable cellulose material on above ground in the uncultivated field and the nests are undisturbed, thereby creating more scope for increased establishment of colonies compared to cultivated fields.

5.2. Some ecological aspects of the subterranean termite, M.obesi

The colony of Microtermes obesi consisted of eggs, nymphs and other castes in the nest. The biological

activities of this termite were similar to other subterranean termites and other mound building species (Mukerji and Mitra, 1949a; Roonwal, 1958 and 1960; Lee and Wood, 1971; Roonwal and Rathore, 1975).

Alates

In the present study newly hatched alate nymphs were noticed in the nest, from first week of October to March, at a depth varying from 60-90 cm and about 60 cm away from the fungal comb, in a separate cell. They were ready to emerge in April and May and emergence continued till August. The number of alates from a single cell varied from 80-120.

The fungal combs measuring 6.5 to 8.25 cm long and 3.25 to 4.75 cm wide were located 30-90 cm deep underground. Each comb was in a separate earthen chambers (Plate 6) and the number of fungal combs varied from 1-6 in a 2 m² area. All the stages - eggs, nymphs and castes comprising workers and soldiers were present in fungal comb, which were connected by runways spread in different directions. Similar observations have been made by Sudhakar (1983).

Swarming occurred eight times in a year from a single nest. Workers prepared ground for the alates to emerge, by constructing separate chamber nearer to the surface, in which

the emerging alates congregated and later moved to another small chamber constructed by worker on the day of emergence. Small subcircular emergence holes were prepared by workers on the small chambers just few minutes before emergence of alates with soldiers remaining on ground near the emergence hole.

Swarming, occurred between 18.15 and 19.15 h on the days preceded by rain. Observations on the swarming pattern of M.obesi during 1983-84, for the whole year from four nests revealed, multiple batches of alates emerging depending upon the rainy days from May to August. However there was clear gap of 4-5 weeks between the two emergence from June third week to July third week inspite of required quantity of precipitation. There was a definite trend of emergence in all the four nests observed, with maximum number (ave.518.75) of alates emerging during the third week of May and gradually declining during 4th week (ave.153.75) of May to a minimum (ave.55.00) during 1st week of June. Again the numbers increased (ave. 413.75) during the second week of June with no further emergence over next 5 weeks until 4th week of July, when a small (ave.57.5) batch of alates emerged from each nest followed by an increased emergence (ave.115) in the first week and another emergence (ave.98.75) during the 4th week of August; with a break of 2 weeks. No further

emergence noticed from the first week of September to April second week 1984, inspite of intermittent rain during September, October and December 1983 and also during February and March 1984 (Fig.12).

During 1984-85, the first emergence of alates started in the second week of April (ave.:11.75) from all the 4 nests, preceeded by 30.9 mm rain. The next emergence, after a break of 4 weeks; was in the third week of May with an average of 176.25 alates preceeded by 51.20 mm rain. During fourth week of May there was no rain and consequently no emergence. Again in the first week of June, there was an emergence (ave. 62.50) which was preceeded by 37.5 mm rain, followed by a break of 4 weeks from second week of June to first week of July, during which there was less than 10 mm rain per week. During 2nd week of July there was 87.7 mm of rainfall, which triggered another emergence (ave.78.75), but surprisingly no emergence was noticed during third week of July inspite of 20.1 mm of rain; However, in the subsequent week there was another emergence (61.25), when there was 56.8 mm rain and emergence continued (53.75 and 42.50) during first and second week of August inspite of low rainfall with 4 and 11.5 mm respectively. Understandably, there was no emergence during third week of August which received no rain, but in the next week there was emergence (ave. 23.75) inspite of only 2 mm

rain. From September first week of 1984 to April first week of 1985 there was no emergence. Here again September and October 1984 months received more rain (261.30 mm) than July and August (184.40 mm) as with the previous year; but no emergence in both the years. This clearly indicates that M.obesi swarming occurs only between April and August end, when rain occurs but not before and after inspite of rains.

A perusal of the Table 5, revealed the number of alates emerging from each nest under observation during 1983, varied from 1279 to 1625 whereas the number during 1984 was far less with minimum and maximum being 429 and 575. The causes for the reduction of the number of alates in 1984 as compared to 1983, in all the four nests could not be identified. However, in the weather chart (Appendix V), the number of weeks receiving more than 10 mm rain was 11 during 1983, when the maximum number of alates emerged compared to 7 weeks during 1984. Perhaps, the May and June rains may be crucial for maximum emergence of M.obesi as is seen in the present observations. During 1983, there was an average of 1141.25 alates emerged from each nest when there was a rain of 155.10 mm compared to only 238.75 alates emerged/nest in the same months during 1984 when the rainfall was less than 100 mm. There were 4 emergence contributing to 79.76 per cent of total emergence during May-

June 1983 compared to only two emergence in 1984, although in both the years there was a total of eight emergence from each nest. All earlier workers reported the swarming of Microtermes obesi in the months of June-August after sunset (Pruthi, 1939; Vishnoi, 1959 and Sudhakar, 1983). Roonwal and Rathore (1975) have reported the swarming of Microtermes obesi in day time between 10.30 to 13.30 h during June-August at Jodhpur. In the present study no such emergence during day time was noticed in the course of two years observations. However, it may be confessed here that constant watch on these nests in the study site could not be kept during the study period for any stray emergence; although Odontotermes obesus emergence was noticed between 9 to 10.30 h on cloudy days preceeding rain. However, Sudhakar (1983) has also seen M.obesi emerging between 18.50 to 19.00 h.

Other species of termites including O.horni, O.redemanni, O.wallonensis, T.biformis and Speculitermes sp. were observed emerging in the evening between 18.00 to 20.00 h. All these findings corroborates with the observations of Escherich (1911); Bugnion (1915); John (1925); Pruthi (1939); Mukerji and Mitra (1949a); Vishnoi (1959); Banerjee (1966); Roonwal and Bose (1964); Roonwal and Chhotani (1966); Roonwal (1970); Rajgopal (1979); Peter and Radhakrishna (1981) and Sudhakar (1983).

Foraging

The workers made their subterranean exit at about 12 cm underground from the surrounding surface for foraging. The place, at which the foraging workers came out of the runways, varied from 2-15 m from the nest. More runways were found upto a depth of 60 cm (Table 7).

Foraging occurred any time of the day, depending upon the weather conditions. It was active during May to August and very low from December to March. Normally foraging was active during early morning and evening hours except during summer when commencement of foraging was little advanced (5.30 h) in the morning and delayed (18.00 h) in the evening. It was mostly during day time in the remaining period. However, there was not much difference in foraging time and also season of M.obesi as observed in the present study and that of other species of termites, reported by earlier workers (Coaton, 1958; Grasse and Noirot, 1958 and 1961; Sands, 1961a; Bodot, 1967; Ohiagu and Wood, 1976; Wood, 1978; Rajgopal and Veeresh, 1981; Veeranna and Basavalingappa, 1981; Johnson et al., 1981).

Natural enemies

All those predators reported earlier on other termites (Maxwel Lefroy and Howlett, 1909; Fletcher, 1914; and Mathur,

1962) have also been observed in the present study, particularly at the time of swarming. Among the six species of ants predating on workers, the ponerinae ant, Leptogenys processionalis was more common near the foraging site. This ant has been claimed as number one enemy of foraging termites by Negi (1934) Rajgopal and Ali (1984) and Shivashankar and Veeresh (1986). In the present study also, it was observed that this ant took advantage of the presence of M.obesi near root zone of wheat for active predating. This ant, on an average, harvested about 25 termites per minute during morning hours and a total of 2150 termites were carried over a period of 90 minutes.

Communication, alarm and defense

In the study, when the termites were disturbed at the foraging site, they ran back to the foraging runways. Workers and soldiers touched each other by jerking their body and head. They also touched face to face with the other members of the foraging group and ran in all directions. Soldiers defended the colony against enemies by squirting brownish yellow liquid from their mandibles. All these observations are in conformity with the reports of Emerson (1929), Krishna (1969) and Machnitz and Tho (1974).

Fungal Comb of *M.obesi*

The shape, size and structure of the fungal comb observed during the course of the present study agrees with the description of Holmgren (1913) and Sudhakar (1983). Maximum number of fungal combs observed were, six per 2 m² area. The fungal combs, constructed with pellets of excreta, had two layers, arranged one above the other with a concavity at the bottom in overgrown combs in the nests of *O.obesus* and attributed the concavity to their feeding from the bottom portion.

Analysis of the fungal comb of *M.obesi* revealed the moisture content to vary from 45.61 to 55.81 per cent (Table 8), cellulose lignin ratio varied from 1.58 to 2.02. The C:N ratio was 29.91 to 33.00 and the ash content ranged from 20.83 to 22.00 per cent. The crude fat per cent varied from 2.60 to 3.10 (Table 9). The above findings compare favourably with the components found in fungal combs of other species (Becker and Seifert, 1962; Rajgopal, 1979). The moisture content of the fungal comb did not vary significantly from summer to rainy season. The range between 45 to 55 per cent favourably compare with the moisture content 51.3 per cent of the fungal comb of *O.obesus* (Roonwal, 1960) and *O.wallonensis* (Rajgopal, 1979). Similarly, cellulose was higher than the lignin as reported by Becker and Seifert (1962) in *Macrotermes* sp. and *Odontotermes* sp. and by Rajgopal

(1979) in O.wallonensis. Further, Becker and Seifert (1962) claimed that, Macrotermitinae species have low digestion capacity for cellulose and as a consequence, higher cellulose content was observed in the comb. The C:N ratio also agree with the findings of Matsumoto (1976) in M.malacensis and Rajgopal (1979) in O.wallonensis. The higher C:N ratio may be due to the presence of low amount of N in the fungal comb, as reported by Hesse (1957), and Sands (1969).

The ash content varied between 20.50 to 22.00 per cent, which favourably compare with that (23 per cent) in M.falciger (Hesse, 1957) and 22.87 per cent in O.wallonensis (Rajgopal, 1979). However, ash content as low as 10.7 was reported by Becker and Seifert (1962) in O.redemanni. The higher ash content may be due to the presence of higher mineral content in the fungal comb (Hesse, 1957).

The crude or total fat content of 2.6 to 3.10 per cent in the fungal comb of M.obesi, is comparable with that of 2 to 5 per cent in the fungal comb of O.wallonensis (Rajagopal, 1979). The reason for low crude fat content may be due to the greater capacity of this species to degrade the fatty substances or due to the presence of low organic matter.

The pH of the fungal comb varied from 4.4 to 4.6 which is almost in line with the findings of Hesse (1957) in

Macrotermes spp. where it ranged from 4.3 to 4.5; and of Rajgopal (1979) who recorded a pH of 4.6 to 4.8 in the fungal comb of O.wallonensis.

On the whole, both moisture content and the chemical composition of the fungal comb of M.obesi does not differ much from fungal combs of other species analysed, except in respect of cellulose: lignin ratio, which in the present study ranged between 1.58 to 2.02 as compared to 0.55 in O.obesus, 0.49 in O.redemani (Becker and Seifert, 1962); However, it favourably compared with O.wallonensis (1.53; Rajgopal, 1979).

5.3. Host preference and losses caused by termites

Experiments were conducted at two locations (M.R.S. Hebbal, and A.R.S. Chintamani under rainfed conditions) endemic to termites, to assess the losses to dry land crops by termite foraging. The eight crops selected at both the locations are commonly grown in these areas and all of them are subjected to termite attack. The difference in yield between chemically protected and unprotected and percent infestation by termites were considered as avoidable loss due to termite.

Among the eight dry land crops tested, maize seems to be the most susceptible to termites with the infestation

varying from 15.95 to 26.45 per cent in untreated plots. This was followed by ragi and wheat with the infestation varying from 5.83 to 9.79 per cent in ragi and 5.89 to 9.59 per cent in wheat. The incidence on groundnut and niger was almost equal at both the locations with infestation ranging from 5.32 to 7.45 per cent. Setaria and bajra had less than 5 per cent infestation. The least preferred host was sunflower with less than one per cent infestation (Table 10 and 11). Sudhakar (1983) found similar results. According to him, the maximum infestation was in maize (38.48 per cent) followed by ragi (14.01 per cent), niger (12.08 per cent), groundnut (8.21 per cent) and no infestation in sunflower.

In all crops the susceptibility increased with the age of the crop and also the moisture content. The per cent infestation in 75 day old crop was far less compared to the infestation on 115 day old crop.

In maize the per cent infestation ranged from 13.33 to 26.41 at 75 days old, which increased to 30.35 to 38.35 by 115 days; Similarly in wheat it varied from 6.75 to 10.88 per cent at 75 days and increased to 11.36 to 14.72 per cent by 115 days. All other crops showed similar trend in that the infestation increased with age of the crop at both the places (Table 14 and 15).

From the Appendix VI it is clear that at M.R.S.Hebbal, the rain received during the months of July, August and September 1983 was maximum (382.30 mm) upto 75 days old crop where the incidence of termite was less; compared to October-November 1983, (58.50 mm); when the termite incidence increased.

Similar trend was observed at A.R.S. Chintamani, where the rain received during the first 75 days after sowing (i.e. August, September and October, 1983) was maximum (297.3 mm) during which period the infestation was comparatively less. Later months (November-December, 1983) recorded less (50.8 mm) rain, with the result the infestation increased (Appendix-VII). Similar observations have been made by Veeresh (1983).

The avoidable yield losses, closely followed per cent incidence of termites in all the crops at both the locations.

Ragi was subjected to the attack by both O.obesus and M.obesi. When it was attacked by O.obesus, soil sheathing was noticed around the base as was observed by Sudhakar (1983); whereas, M.obesi attack did not reveal any sheathing. The per cent increase in grain yield over untreated check was 101.56 and 126.76; while the avoidable loss was 50.38 and 55.90 per cent when the infestation was 5.83 and 9.79 per cent at M.R.S. and A.R.S. respectively. Rajgopal (1979) reported

5.50 per cent loss and Sudhakar (1983) recorded the avoidable loss of 35.29 to 36.41 per cent with an infestation ranging from 14.01 to 14.23.

Wheat was mostly attacked by subterranean termite. The termite ate the roots of plants and caused yellowing of the leaf blades followed by wilting and drying of plants. The per cent increase in grain yield over untreated check was 283.55 and 298.71; the avoidable loss was 73.92 and 74.92 per cent when the incidence was 5.89 and 9.59 per cent at M.R.S. and A.R.S. respectively. The present findings are in partial agreement with the findings of Hussain (1935); Sharma (1959); Sood et al. (1970); Srivastava and Lal (1973); Nair (1975); Johnson (1981); Varma and Kashyap (1980) and Roonwal (1981); according to whom, the grain yield loss varied from 6-40 per cent.

Setaria and bajra seem to tolerate better, to the termite attack than rest of the crops tested, as the per cent increase and avoidable loss was only 21 to 23 and 17 to 19 per cent respectively; with an infestation ranging from 2.52 to 5.23 per cent. Ajayi (1980) reported a termite infestation less than 10 per cent on bajra.

Groundnut plants were attacked by both Odontotermes spp. and M. obesi, which fed on the root system, resulting in wilting and death of the plants. Pods were damaged by making small holes on kernels. These observations agree with the findings of Beeson (1940); Sharma (1967); Kaushal and Deshpande (1967); Rawat et al. (1970); Rajgopal (1979); Johnson et al. (1981) and Amin and McDonald (1981).

In the present study the per cent increase in pod yield was 99.61 and 75.09 over untreated check, the avoidable loss was 49.90 and 42.89 per cent with an infestation of 5.32 and 7.43 per cent at M.R.S. and A.R.S. respectively. These findings corroborates with those of Rawat et al. (1970) who recorded less infestation and increased yield in treated plots; whereas in untreated plant the loss was 35.2 per cent and the avoidable loss was 52.8 per cent. Sudhakar (1983) also reported the avoidable loss of 50.25 to 51.19 per cent with a mean infestation of 7.01 to 8.21 per cent. However, Kaushal and Deshpande (1967), recorded 27 per cent pod loss due to termites in untreated plots.

Sunflower, with less than one per cent termite infestation, suffered 22.68 to 23.54 per cent of avoidable loss suggesting that even sporadic incidence of termite attack on sunflower has to be taken note of in obtaining higher yields. Elsewhere, the infestation was reported

upto 23 per cent (Anonymous, 1986). However, Sudhakar (1983) claimed nil attack by termites on sunflower.

The per cent increase in grain yield over untreated check was 30.79 and 29.32; the avoidable loss was 23.54 and 22.68 per cent at M.R.S. and A.R.S. respectively.

Niger was also attacked by Odontotermes sp. and Microtermes obesi. The termites fed on the roots resulting in lodging of plants. The per cent increase in grain yield was 112.70 and 166.40 over untreated check; whereas, the avoidable loss was 52.98 and 62.46 per cent with mean per cent infestation of 5.51 and 7.45 at M.R.S. and A.R.S. respectively. These results are in close agreement with the observations of Veeresh (1983). According to him, niger was subjected to severe attack of termites and the loss was reported upto 57.20 per cent. However, Sudhakar (1983) recorded the avoidable loss of 31.31 to 37.83 per cent with an infestation ranging from 8.23 to 12.08 per cent.

Maize was attacked by Odontotermes spp. and M.obesi. Both the species damaged the prop roots and in severe cases, the plants lodged with the entire plants being attacked, as reported earlier by several workers (Beeson, 1940; Srivastava, 1959; Kushwaha, 1960; Wood et al., 1980; Roonwal, 1981; Sudhakar, 1983; Veeresh, 1983).

The per cent increase in grain yield over untreated check was 114.16 and 156.31; while the avoidable loss was 53.30 and 60.98 per cent with an infestation of 15.95 and 26.45 at M.R.S. and A.R.S. respectively. But, Sudhakar (1983) recorded avoidable loss from 13.10 to 21.78 per cent with an infestation of 27.42 to 38.48 per cent. Bigger (1966) and Johnson and Wood (1979) claimed 33 to 70 per cent yield loss. Which more or less conforms to the present findings relating to yield loss. Fifteen to 30 per cent termite infestation reported from India by Agarwal and Sharma (1954) and Veeresh (1983) as well as 29 per cent infestation reported from Nigeria by Sands (1977) are in line with the present findings.

In the present investigations all the crops differed significantly in terms of both per cent incidence and yield (Q/ha) from protected to unprotected; the incidence being higher in unprotected and the yield being superior in protected.

In the present study attempts were made to compute the cost/benefit ratio for all crops. It was maximum in wheat (1:7.47 to 8.07) followed by maize (1:4.98 to 5.19), groundnut (1:3.21 to 4.28), ragi (1:3.20 to 3.31), sunflower (1:2.86 to 3.31), niger (1:2.30 to 2.35), bajra (1:0.68 to 0.87)

and setaria (1:0.43 to 0.52). The reason for high cost/benefit ratio in wheat and maize is due to the susceptibility of the crops to the termite attack.

Loss to wheat by *Microtermes obesi* and its management

Experiments conducted for two seasons at M.R.S. Hebbal to estimate the loss caused by the subterranean termite, *M.obesi* and also its management in wheat is discussed hereunder:

Among the irrigation levels, no irrigation recorded maximum termite infestation (2.48 per cent) followed by normal irrigation (once in ten days) (1.34 per cent) and frequent irrigation (once in five days) (1.02)(Table 20). They differed significantly from each other. Irrigation itself has increased the yield significantly compared to no irrigation, but at the same time has reduced termite infestation significantly. Although apparently it looks that the difference between irrigated and unirrigated has not induced much difference in per cent infestation recording 2.48 per cent and 1.02 per cent in no irrigation and frequent irrigation respectively. But the per cent infestation due to termite was maximum when the crop was 115 days old (a week before harvest)(Table 17). It varied between 17.48 to 18.53 in no irrigation followed by normal (3.85 to 4.67 per-

cent) and frequent irrigation (2.67 to 3.00 per cent). Among the different levels of insecticide the maximum infestation was recorded in untreated check (10.58 to 10.90 per cent) and minimum was in Aldrex 30 EC 0.3 per cent (6.11 to 7.14 per cent). No irrigation and no insecticide treatment accounted for the highest per cent infestation (21.42 to 22.77) and the lowest was in frequent irrigation with Aldrex 30 E.C. 0.3 per cent (1.42 to 2.27). The yield differences are very significant with 25.74 per cent loss attributed to termite attack only. Similarly Verma et al. (1976), Sandhu and Sohi (1977) and Verma (1980), has reported that the number of damaged tillers by termites in wheat crop was highest in plots irrigated once as compared to 3 or 4 times during the entire crop period.

Highest grain yield (14.94 Q/ha) was obtained in plots applied with insecticide and irrigated frequently as against the lowest yield (6.55 Q/ha)(Table 20) with insecticide and no irrigation suggesting that irrigation alone has significant influence in increasing the yield.

The per cent loss in no irrigation and normal irrigation was 56.10 and 6.6 per cent respectively compared to frequent irrigation. This loss was due to the combined effect of irrigation and insecticide. Whereas the avoidable loss was 56.10 and 52.99 per cent in frequent and normal

irrigation respectively (Table 20) compared to untreated check where no irrigation was given.

Among the different levels of insecticide, maximum infestation was recorded in untreated check (1.86) and the least per cent infestations were in aldrin 5 D at 37.50 kg/ha R.A. (1.44) and Aldrex 30 E.C. 0.3 per cent (1.42), correspondingly recording lowest yield (9.81 Q/ha) and highest yield (13.22 and 13.06 Q/ha) in untreated check and aldrin 5 D at 37.50 kg/ha R.A. and Aldrex 30 E.C. 0.3 per cent respectively.

At no irrigation level, maximum infestation was recorded in untreated check (2.77 per cent) accounting for the lowest grain yield (4.25 Q/ha). Least infestations were observed in aldrin 5 D at 37.50 kg/ha R.A. (2.32 per cent) and Aldrex 30 E.C. 0.3 per cent drenching (2.24 per cent) both of which registered highest grain yields (7.81 Q/ha and 8.44 Q/ha) respectively. The increase in grain yield in the insecticide treated can be attributed to the control of termites as no other insect pests were noticed on the crop even in the untreated except for termite attack.

Similarly at frequent and normal irrigation levels, the least infestations and maximum yields were observed in aldrin 5 D at 37.50 kg/ha R.A. and Aldrex 30 E.C. 0.3 per cent drenching as compared to untreated check.

Among the insecticides aldrin 5 D at 37.50 kg/ha R.A. recorded the highest grain yield (13.22 Q/ha) with least per cent infestation followed by Aldrex 30 E.C. 0.3 per cent, aldrin 5 D at 25 kg/ha R.A., 37.50 kg/ha B.C. 25 kg/ha B.C. and untreated check. The difference in yield between aldrin 5 D at 37.50 kg/ha R.A. and untreated check was the loss in yield which was brought about by termite attack. The per cent loss due to termite was 25.74 and so also the per cent avoidable loss was 25.74. Therefore, both no irrigation and no insecticide accounted for a total loss of 56.10; of which 25.74 per cent loss was due to termite infestation alone (Table 20).

The per cent increase in grain yield over control was maximum in aldrin 5 D at 37.50 kg/ha R.A. (34.67) and the least was in aldrin 5 D at 25 kg/ha B.C. (10.92), when compared to untreated check (no insecticide).

The per cent avoidable loss was more in aldrin 5 D at 37.50 kg/ha R.A. (25.74), Aldrex 30 E.C. 0.3 per cent (24.86), aldrin 5 D at 25 kg/ha R.A. (19.87), 37.50 kg/ha B.C. (15.52) and 25 kg/ha B.C. (10.09) (Table 20). These findings are in close agreement with the report of Verma *et al.* (1976), who found aldrin at 1.875 kg a.i/ha with irrigation and aldrin at 1.875 kg a.i/ha pre-sowing treatments to be the profitable treatments yielding 47 and 46.06 per cent net gain over control.

In the present study all the insecticidal treatments recorded highest grain yield over untreated check. The increase in all insecticide treated plots over no insecticide, can not be attributed entirely to the control of termites, as hundred per cent control of termites was not obtained even in the best treatment. However, the effect of termite damage on the yield loss is evident by these experiments, as the low yield of both grain and straw was directly proportional to the incidence of termite attack. It is seen from the Table 20 that the yield was 14.94 Q/ha when the incidence was 1.02 per cent. Upto 1.75 per cent incidence, for every 0.5 per cent increase in per cent incidence there was almost 100 kgs of loss in grain yield. An increase in the incidence from 1.75 to 2.00 per cent, resulted in a loss of 200 kgs grain, and further increase from 2.00 to 2.25 per cent, accounted for the loss of 300 kgs of grain yield.

These findings conform with the reports of Ghose, (1964) Sood et al. (1970); Batra, (1976), and Huque (1977). According to them application of aldrin 5 D at 25 kg/ha not only controlled the termite infestation but also increased the yield.

Highest straw yield was obtained in frequent irrigation (11.73 Q/ha) and lowest yield was in no irrigation (4.96 Q/ha) and the reason for low yield was due to combined

effect of irrigation and termite infestation. The per cent loss in no irrigation and normal irrigation was 57.71 and 13.62 respectively, when compared to frequent irrigation; and the per cent avoidable loss was 57.71 and 51.04 in frequent and normal irrigation, when compared to no irrigation (Table 20).

At no irrigation levels, untreated check recorded the lowest yield (3.84 Q/ha) and highest yield was in Aldrex 30 E.C. 0.3 per cent (6.07 Q/ha); the yield was very low compared to frequent and normal irrigation due to the irrigation effect; further, the yield was lowest in no insecticide treatment (untreated check), because of not only irrigation but also due to termite infestation. Therefore, low yield here is due to combined effect of irrigation and insecticide.

Similarly, both frequent and normal irrigations recorded the highest straw yield in aldrin 5 D at 37.50 kg/ha R.A. (13.32 and 11.29 Q/ha) and Aldrex 30 E.C. 0.3 per cent (12.92 and 11.15 Q/ha) and the lowest yield was in untreated check (9.34 and 8.37 Q/ha) respectively.

Among the insecticides, Aldrex 30 E.C. 0.3 per cent recorded the highest straw yield (10.05 Q/ha) followed by aldrin 5 D at 37.50 kg/ha R.A. (10.02 Q/ha), 25 kg/ha R.A.

(9.18 Q/ha), 37.50 kg/ha B.C. (8.86 Q/ha), 25 kg/ha B.C. (8.36 Q/ha) and untreated check (7.19 Q/ha). The difference in yield between Aldrex 30 E.C. 0.3 per cent and untreated check is attributed to termite attack. The per cent loss due to termite was 28.43; and due to irrigation was 29.28.

The per cent increase and per cent avoidable loss over control was maximum in Aldrex 30 E.C. 0.3 per cent and the least was in aldrin 5 D at 25 kg/ha (Table 20). The reason may be due to irrigation or termite effect or the combined effect of both.

SUMMARY

VI. SUMMARY

The present studies were carried out at the Main Research Station, Hebbal, on both cultivated land and uncultivated land and at the Agricultural Research Station, Chintamani on cultivated land only.

During the period of study ten species of termites under four genera of the family termitidae were recorded. These genera include, Microtermes, Odontotermes, Speculitermes and Trinervitermes. The following were the termite species encountered.

1. Microtermes obesi Holmgren
2. M.globicola Wasmann
3. Odontotermes bellahunisensis (Holmgren and Holmgren)
4. O.ceylonicus (Wasmann)
5. O.horni (Wasmann)
6. O.obesus Rambur
7. O.redemanni (Wasmann)
8. O.wallonensis (Wasmann)
9. Speculitermes sp.
10. Trinervitermes biformis (Wasmann)

Among the ten species encountered during the study, nine species were recovered on three types of baits namely

wheat, ragi and maize straw, the most preferred host was wheat for M.obesi, maize and ragi for O.obesus. Other dominant species, like O.wallonensis and O.horni had equal preference for maize and ragi and less preference for wheat. All the species were most active during the months of May to August.

Out of the total 783 baits infested by the termites, 253 were attacked by O.obesus, (45.08 per cent); M.obesi was found in 211 baits accounting for 26.94 per cent. The rest were in the following order; O.wallonensis (10.72 per cent), O.horni (8.17 per cent), O.redemanni (4.59 per cent) O.ceylonicus (1.66 per cent), T.biformis (1.14 per cent) and O.bellahunisensis (0.38 per cent).

Relatively more number of nests or mounds were recorded in uncultivated area (440) compared to cultivated area (400). In the cultivated area more number of nests of M.obesi (160) were found, whereas in uncultivated area more number of O.obesus mounds (160) were recorded.

Eggs of M.obesi were sub-oval, shiny and dirty white in colour. Nymphs milky white; the alate nymphs creamy white in the beginning and later turned to chocolate colour. Workers and soliders were sterile castes; former ones were less sclerotized than the latter ones. All these stages were found in fungal combs.

Swarming was noticed in six species. All the six species swarmed during May-August. The swarming of M.obesi took place only after the onset of South West monsoon during April to August end. Swarming occurred after dusk between 18.15 to 19.15 h and lasted for 10-15 minutes. The number of swarmings were more during May-June compared to July-August.

Foraging occurred any time of the day depending upon the weather conditions and it was more active during June to August and very low from December to February. Normally foraging was active during early morning and evening hours except in summer. When commencement of foraging was little advanced (5.30 h) in the morning and delayed (18.00 h) in the evening.

Natural enemies of M.obesi included both invertebrates and vertebrates. Among invertebrates ants were the most common enemies. Out of six species of ants recorded, the ant L.processionalis was the most common and found predating on M.obesi throughout the year. Vertebrates including frogs, toads, lizards, and birds predated mostly on alates near water and light source.

The fungal combs of M.obesi were found at a depth of 30-90 cm below ground. The number of fungal combs varied from 1-6 in an area of 2 m². All the stages namely eggs,

nymphs, workers and soldiers were found in the fungal combs. The moisture content of the fungal comb varied from 45.61 to 55.81. The cellulose content was higher and varied from 22.15 to 26.35 and the cellulose-lignin ratio ranged from 1.58-2.02. The average carbon content was 31.72; whereas the total nitrogen content was 1.00; and the C:N ratio varied from 29.91 to 33.00. The crude fat and ash content ranged from 2.6 to 3.10 per cent and 20.83 to 22.00 per cent respectively. Similarly the pH of the fungal comb fluctuated from 4.4 to 4.6.

Among the eight dry land crops, maize was the most preferred by termites with the infestation varying from 15.95 to 26.45 per cent in untreated plots and the least preferred was sunflower with less than one per cent infestation. The per cent grain yield loss was maximum in wheat (73.92) followed by maize (53.30), niger (52.98), ragi (50.38), groundnut (49.90), sunflower (23.54), setaria (18.82) and bajra (18.50). Similarly the cost-benefit ratio was maximum in wheat (1:8.07) followed by maize (1:4.98), groundnut (1:4.28), sunflower (1:3.31), ragi (1:3.2), niger (1:2.30), bajra (1:0.87) and setaria (1:0.52) at M.R.S. Hebbal. Almost similar trend was exhibited at A.R.S. Chintamani; where the per cent grain yield loss and cost/benefit ratio was maximum in wheat and the least was in setaria.

The experiments conducted on wheat loss and termite management revealed that, no irrigation recorded maximum termite infestation (2.48 per cent) followed by normal irrigation (1.34 per cent) and frequent irrigation (1.02 per cent). The per cent loss in grain yield in no irrigation and normal irrigation was 56.10 and 6.61 respectively, compared to frequent irrigation and this loss was due to combined effect of irrigation and insecticide. The avoidable loss was 56.10 and 52.99 per cent in frequent and normal irrigation compared to no irrigation.

Among the different levels of insecticide aldrin 5 D at 37.50 kg/ha R.A. recorded higher grain yield (13.22 Q/ha) with low per cent infestation followed by Aldrex 30 E.C. 0.3 per cent aldrin 5 D at 25 kg/ha R.A., 37.50 kg/ha B.C. 25 kg/ha B.C. and untreated check. The per cent grain yield loss due to termite was 25.74. Therefore, both no irrigation and no insecticide sustained a total loss of 56.10 per cent of which 25.74 per cent loss was due to termite infestation alone.

Similarly, the highest straw yield was obtained in frequent irrigation (11.73 Q/ha) and lowest yield was in no irrigation (4.96 Q/ha). The per cent loss in no irrigation and normal irrigation was 57.71 and 13.62 respectively;

compared to frequent irrigation and the avoidable loss was 57.71 and 51.04 in frequent and normal irrigation. Among the insecticide levels Aldrex 30 EC 0.3 per cent recorded highest straw yield (10.05 Q/ha) and the lowest was in untreated check (7.19 Q/ha). The per cent loss due to termite accounted for 28.43 and due to irrigation accounted for 29.28 per cent.

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* Original not seen

APPENDICES

APPENDIX I

Natural enemies of the subterranean termite, M. obesi (Holmgren)

Class/Order	Family/ Subfamily	Species
Hymenoptera	Ponerinae	<u>Leptogenys processionalis</u> (Jordan)
	Formicinae	<u>Camponotus compressus</u> (Fab.)
		<u>Camponotus sericeus</u> (Fab.)
		<u>Oecophylla smaragdina</u> Fab.
	Myrmecinae	<u>Monomorium indicum</u> Forel. <u>Solenopsis geminata</u> Fab.
Odonota	Libellulidae	<u>Pantala flavescens</u> (Fab.)
Aves		<u>Corvus splendens</u> (Vieillot) (House crow)
		<u>Corvus macrorhynchus</u> Wagler (Jungle crow)
		<u>Passer domesticus</u> (Lin.) (House sparrow)
		<u>Milvus migrana</u> (Boddaert) (Pariack kite)
		<u>Acridotherus tristis</u> (Linn.) (Mynah)
		<u>Gallus</u> sp. (Fowl)
Reptilia		<u>Hemidactylus maculatus</u> (Garden lizard)
Amphibia	Ranidae	<u>Rana tigrina</u> Daud.
	Bufonidae	<u>Bufo melanasticta</u> Schneider
Arachnida		<u>Amblyscius</u> sp.

APPENDIX II

Relative preference of wheat straw by different species of termites in the field (1985-1986)

Months	Wheat straw		Species			
	Number placed	Number attacked	<u>M.obesi</u>	<u>O.obesus</u>	<u>O.wallo-nensis</u>	Other species
September 85	25	17	7	6	1	2
October	25	15	5	5	3	1
November	25	11	5	4	2	-
December	35	6	2	2	1	-
January 86	35	9	4	2	1	1
February	35	9	4	3	1	-
March	45	11	5	4	1	-
April	45	13	5	4	2	1
May	45	32	13	11	3	4
June	60	44	19	16	4	3
July	60	45	24	15	2	3
August	60	47	23	16	2	4
Total		259	116	88	23	19

APPENDIX III

Relative preference of ragi straw by different species of termites in the field
(1985-1986)

Months	Ragi straw		Species				Other species
	Number placed	Number attacked	<u>M.obesi</u>	<u>O.obesus</u>	<u>O.wallo-nensis</u>	<u>O.horni</u>	
September 85	25	16	5	6	2	2	1
October	25	14	4	5	2	2	1
November	25	12	5	4	2	1	-
December	35	7	2	3	1	1	-
January 86	35	10	2	3	2	2	1
February	35	9	2	4	1	1	1
March	45	12	2	5	2	1	2
April	45	13	3	5	2	1	2
May	45	33	5	16	4	3	5
June	60	43	8	23	3	4	5
July	60	45	7	26	4	3	5
August	60	46	9	25	4	4	4
Total		260	54	125	29	25	27

APPENDIX IV

Relative preference of maize straw by different species of termites in the field
(1985-1986)

Months	Maize straw		Species				Other species	
	Number placed	Number attacked	<u>M.obesi</u>	<u>O.obesus</u>	<u>O.wallo-nensis</u>	<u>O.horni</u>		
September	85	25	15	4	7	1	2	1
October		25	14	1	8	2	2	1
November		25	14	2	7	2	2	1
December		35	6	1	3	1	1	-
January	86	35	10	1	5	2	1	1
February		35	11	2	6	1	1	1
March		45	10	1	6	1	1	1
April		45	11	2	5	2	1	1
May		45	34	5	16	4	5	4
June		60	46	8	25	5	4	4
July		60	45	6	26	5	3	5
August		60	48	8	26	6	3	5
Total		264	41	140	32	26	25	

Appendix V

Weather data of M.R.S., Hebbal, Bangalore during different months of the year 1983-84 and 1984-85

Months	Week	Temperature °C		Relative humidity (%)	Rain fall (mm)	
		Maximum	Minimum			
1	2	3	4	5	6	
May	83	I	36.35	23.68	50.00	-
		II	35.12	21.88	55.00	7.0
		III	33.50	22.00	59.00	32.0
		IV	34.15	21.17	60.00	41.0
June		I	33.88	21.87	60.00	40.8
		II	30.56	20.61	69.00	41.3
		III	30.18	20.61	67.00	25.4
		IV	28.42	20.30	68.00	0.7
July		I	30.71	20.44	67.00	5.2
		II	30.50	20.53	65.00	12.1
		III	29.18	20.45	70.00	-
		IV	28.67	20.73	73.00	16.0
August		I	28.53	20.15	75.00	38.6
		II	26.65	19.98	78.00	15.3
		III	28.91	20.21	77.00	61.7
		IV	27.77	20.20	75.00	43.0
September		I	27.95	20.37	77.00	29.0
		II	26.97	20.02	80.00	118.2
		III	26.91	19.55	77.00	36.5
		IV	27.77	18.57	75.00	0.3
October		I	28.43	19.00	71.00	-
		II	30.48	19.08	59.00	-
		III	28.21	17.77	66.00	42.7
		IV	26.80	19.45	77.00	6.80
November		I	27.60	17.60	65.00	-
		II	27.90	13.31	51.00	9.0
		III	28.28	15.17	59.00	-
		IV	27.41	14.71	59.00	-
December		I	25.50	16.17	65.00	-
		II	26.87	17.18	68.00	-
		III	25.02	15.61	72.00	12.0
		IV	24.93	19.44	78.00	28.5

1	2	3	4	5	6
January 84	I	26.76	16.53	62	-
	II	25.78	16.01	63	-
	III	28.86	18.03	63	-
	IV	24.00	15.25	66	-
February	I	27.52	15.91	68	-
	II	26.57	18.02	72	57.6
	III	26.34	18.70	74	-
	IV	30.01	16.87	61	-
March	I	28.10	16.85	66	-
	II	31.35	18.82	64	30.6
	III	28.47	15.77	47	-
	IV	32.85	16.77	55	-
April	I	33.51	21.19	58	-
	II	31.59	20.14	64	30.9
	III	33.60	21.12	58	-
	IV	33.92	21.59	57	-
May	I	35.01	22.75	54	-
	II	35.06	22.15	54	3.8
	III	34.73	21.26	58	51.2
	IV	33.50	22.20	54	-
June	I	30.50	19.88	64	37.5
	II	29.05	20.16	68	3.1
	III	29.02	17.41	63	45.0
	IV	29.02	19.41	66	10.9
July	I	30.37	19.63	61	1.3
	II	28.28	19.78	75	87.7
	III	27.28	19.60	77	20.1
	IV	26.84	19.38	79	56.8
August	I	27.41	19.21	74	40.0
	II	29.00	19.03	66	11.5
	III	28.61	19.08	66	3.0
	IV	29.14	19.35	68	-
September	I	28.62	18.64	67	22.1
	II	25.30	18.72	63	36.6
	III	27.41	20.01	74	50.5
	IV	29.28	19.18	74	69.0

	1	2	3	4	5	6
October	I	25.66	19.72	76	26.2	
	II	27.21	18.17	68	41.7	
	III	28.65	18.73	65	15.2	
	IV	28.40	17.48	68	-	
November	I	27.34	17.87	67	32.6	
	II	26.45	17.17	75	24.7	
	III	25.37	17.12	69	-	
	IV	25.36	14.60	60	-	
December	I	25.62	15.05	70	0.4	
	II	27.78	11.45	57	-	
	III	27.03	12.25	55	-	
	IV	27.02	16.87	66	-	
January 85	I	26.06	18.45	71	-	
	II	27.41	16.02	61	22.0	
	III	27.76	15.87	63	-	
	IV	28.65	13.11	57	-	
February	I	29.64	15.40	52	-	
	II	30.78	17.08	58	2.0	
	III	31.00	16.85	60	21.0	
	IV	30.92	13.04	49	-	
March	I	33.27	14.60	53	-	
	II	32.68	13.98	52	-	
	III	33.60	20.20	56	-	
	IV	33.75	20.14	52	-	
April	I	32.20	20.04	61	-	
	II	33.98	22.55	57	17.1	
	III	34.97	22.21	55	1.0	
	IV	35.61	22.43	51	-	

Appendix VI

Weather data of M.R.S. Hebbal, Bangalore, during different months of the year 1983

Months	Temperature ^o C		Relative humidity (%) average	Rainfall (mm)
	Maximum	Minimum		
January 1983	27.7	13.4	58.5	-
February	31.9	17.3	52.0	-
March	31.2	19.6	45.0	8.5
April	35.1	21.7	47.0	1.9
May	35.8	22.9	58.5	80.0
June	37.4	20.8	66.0	108.2
July	36.6	21.2	71.0	33.3
August	28.0	26.0	79.0	158.6
September	27.0	19.6	77.5	190.4
October	28.5	18.8	66.5	49.5
November	27.8	15.2	57.0	9.0
December	25.6	17.0	71.5	40.5

Appendix VII

Weather data of A.R.S. Chintamani during different
months of the year 1983

Months	Temperature °C		Relative humidity mean (%)	Rainfall (mm)
	Maximum	Minimum		
January 83	27.3	13.1	61	0.0
February	31.8	17.9	58	0.0
March	34.0	18.9	60	12.4
April	35.3	22.7	47	-
May	35.0	23.0	61	97.1
June	31.9	NA	61	109.7
July	30.5	NA	66	48.4
August	28.5	22.5	76	128.2
September	27.4	21.4	76	134.9
October	27.9	22.2	70	34.2
November	27.4	18.4	63	10.7
December	24.9	18.9	74	40.1

NA = Not available

Appendix VIII

Weather data of M.R.S., Hebbal, Bangalore, during different months of the year 1985-86

Months	Temperature °C			Relative humidity (%)			Rain-fall (mm)
	Maximum	Minimum	Average	Maximum	Minimum	Average	
September 1985	28.99	19.66	24.32	91.00	59.00	75.00	178.00
October	27.82	17.96	22.89	90.00	54.00	72.00	98.10
November	26.16	15.15	20.65	90.20	50.40	70.30	57.30
December	29.18	15.44	22.31	89.42	51.23	70.32	0.40
January 1986	26.10	14.70	20.40	92.00	53.00	72.50	22.00
February	29.00	15.40	22.20	92.00	41.00	66.50	23.00
March	32.30	19.00	25.65	85.00	37.00	61.00	-
April	34.70	21.10	27.90	85.00	36.30	60.65	2.00
May	34.20	21.50	27.85	83.00	37.00	60.00	69.20
June	29.70	20.30	25.00	92.00	58.00	75.00	114.00
July	29.5	19.70	24.60	90.00	54.00	72.00	68.00
August	27.8	19.40	23.60	89.00	59.00	74.00	85.10

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