

**STUDIES ON THE DUNG FEEDING TERMITES
AND THEIR ROLE IN REMOVAL OF DUNG
UNDER DRY LAND CONDITIONS**

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UNIVERSITY OF AGRICULTURAL SCIENCES
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**STUDIES ON THE DUNG FEEDING TERMITES
AND THEIR ROLE IN REMOVAL OF DUNG
UNDER DRY LAND CONDITIONS**

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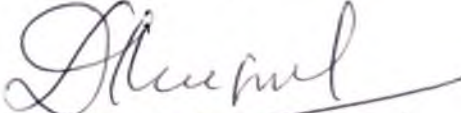
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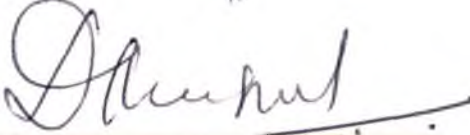
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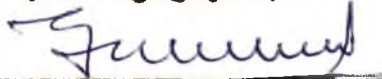
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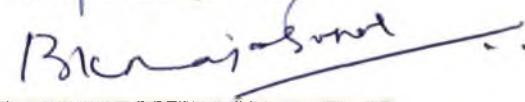
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INTRODUCTION

CHAPTER I

INTRODUCTION

Termites are exopterygote insects living in colonies like any other social insects. They are polymorphic and the individuals of the colony are differentiated into various castes, which exhibit division of labour to perform various biological activities. Their role in the disintegration of wood and decomposition of organic matter and other cellulose materials are wellknown. They depend entirely upon wood, either living or dead or plant litter, cow dung and humus as they are capable of digesting cellulose by virtue of their intestinal bacteria and protozoans.

Majority of termite species are known to inhabit soil either as mound builders or underground dwellers. These species form a dominant group of soil fauna and play an important role as degrading agents in the tropical forests.

Affirmative attempts with regard to the assessment of loss to dung and farm yard manure are lacking, eventhough termites play an important role as litter decomposers in the ecosystem. They feed on important manures like dung, farm yard manure, root stubbles, dry leaves and humus. Termites cover almost all materials including wood, dung, organic

debris and plant left overs after harvest by earthen sheeting and convert them into heaps of mud, thus deplete the nutrient content of the soil.

Among the several types of organic matter, farm yard manure is one of the major source of nutrients to the crops which supplies nitrogen, phosphorous, potassium and other macro and micro nutrients. Animal dung forms an important component of farm yard manure which is regarded as of great value by cultivators from time immemorial. In India, 67.10 per cent (11,4737000 ha.) of the total cultivated area is mainly depending on farm yard manure to maintain fertility status of the soil. In Karnataka, out of 11,159000 ha cultivated area 7,432000 ha (66.4 per cent) are incorporated with farm yard manure (Anonymous, 1982) as source of major plant nutrients and to maintain the soil fertility. Under dry farming conditions, the soil is supplemented with only farm yard manure which constitute the major part of the total cultivated area.

There is no information available on the qualitative and quantitative estimation of loss of dung and FYM by termites in relation to soil fertility. Therefore, the present investigations have been undertaken to study the various termite species associated with the removal of dung

and farm yard manure and loss in the form of organic matter and nutrients caused by them.

The important objectives of the study are as follows:

1. Survey and collection of dung feeding termites in and around Bangalore.
2. Foraging behaviour, seasonal incidence of dung feeding termites and their interaction with dung beetles.
3. Effect of moisture and different soil depths on the activity of termites.
4. Preference of baits, their loss and rate of removal of dung and FYM by termites.
5. Physico-chemical properties of termite modified soil.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

The literature pertaining to the studies on dung feeding termites and their role in removal of dung is reviewed under the following headings.

- 2.1 Termites associated with dung.
- 2.2.1 Mode of foraging in termites.
- 2.2.2 Effect of ecological factors on foraging.
- 2.3 Role of termites as destroyers of organic matter.
- 2.4 Rate of removal of various organic materials by termites.
- 2.5 Physico-chemical properties of termite modified soils.
- 2.1 Termites associated with dung

The order Isoptera comprises about 2,000 species of termites in the world. Among these, 69 species belonging to 4 families associated with dung in various regions of the world are reviewed and presented in Appendix I.

Out of 300 species of termites reported from India (Chhotani, 1980), 13 species belonging to 2 families were recorded on the dung.

According to Roonwal (1970) Odontotermes obscurus (Rambur) feeds mainly on woody surface, debris such as small twigs, bark fragments, dry leaves, grasses and cow dung. Roonwal and Bose (1964) recorded Microtermes mycophagus (Desneux) under cowdung, heaps of grass and logs of wood.

The stored food within the galleries of Speculitermes cyclops (Wasmann) and Dicospiditermes incola (Wasmann) consisted of small heaps of tiny pieces of grass blades and cowdung (Basalingappa, 1971).

According to Rajagopal (1983a) following species of termites feed on dung in Karnataka - Myriotermitis sp., Speculitermes sinhalensis Roonwal and Sen-Sarma, Dicospiditermes incola (Wasmann), Pericapritermes sexlonicus (Holmgren), Odontotermes bellahunisensis Holmgren & Holmgren, O. brunneus (Wagen), O. obscurus (Rambur), O. fedemanni (Wasmann) and O. gallonensis (Wasmann).

2.2.1 Mode of foraging in termites

Normally termites depend on their glandular secretion for communicating one another during collection of food.

Andrews (1911) demonstrated that odour trails were connected with foraging in Nasutitermes. The origin of the odour and trail lies in the sternal gland (Stuart, 1963).

Colco (1982) made observations on the trail laying behaviour of Macrotermes nicholseni (Sjostedt) where major workers were the dominant castes in foraging parties. He reported that the food influenced the trail - laying and recruitment behaviour of termites.

Foraging strategies of Macrotermes carbonarius Hagen, Longipeditermes sp. and Hapitatitermes sp. were restricted by the quality, abundance and distribution of food (Matsumoto, 1982). Intensity and abundance of food was directly proportional to foraging and food reserves in Trinervitermes sp. of Northern Nigeria (Sands, 1961) on the other hand, it appeared to be inversely proportional in Trinervitermes trinervoides (Sjostedt) and in Hodotermes gambiae (Hagen) (Coaton, 1958).

In Macrotermes escheri (Deaneux) the workers and soldiers went out on foraging expeditions during which they marched in a column under the leaves. When disturbed, soldiers raised their abdomen and struck the dry leaves with their mandibles, thus producing rhythmic rattling sound (Bugnion, 1915).

Rooswal (1970) reported that in Trinervitermes biformis (Wasmann) foraging workers set out at sunset in thousands. They marched in an ordinary column and on either side soldiers took positions to protect the columns. When alarmed, workers quickly returned to the nest but soldiers remained on guard until all the workers were in. Mixed parties of workers, major and minor soldiers of Trinervitermes geminatus (Wasmann) emerged through circular foraging holes. The minor soldiers moved rapidly in all directions around the periphery of the foraging area and took position (Chiagu and Wood, 1976).

Abe (1979) studied the range of food material eaten by the termites. Fallen leaves, wood and humus were the most common food materials. Dietspiditermes penerosus (Haviland) dominated among humus feeders.

In Odontotermes gallionensis (Wasmann), only the workers took part in foraging while soldiers guarded them. Foraging parties followed an underground galleries of 6 to 9 cm in diameter, from 3 to 30 m from the mound. The foraging was always under the earthen sheeting. (Rajgopal and Veeresh, 1981).

Veeranna and Basalingappa (1981) made observations on foraging behaviour of O. gallionensis on several infested trees. Workers formed 93 per cent of the foraging population.

The number of workers found per centimeter square of the covered runways ranged from 0.4 to 12 over a 24 hour period. The workers formed a single gallery constructed runways covering 93 square centimeter.

According to Badertscher *et al.* (1983) the foraging parties of Macrotermes subhyalinus (Rambur) and division of labour based partly on caste and age. Major workers formed 88.8 per cent of the foraging parties, minor workers 9.2 per cent, soldiers 2 per cent and nymphs 3 per cent of the population.

LaPage *et al.* (1973) used toilet paper rolls in studying the foraging behaviour of subterranean termites and noticed 96 per cent attack by Gnathotermitis perplexus (Banes) and 14 per cent attack by Heterotermes aureus (Snyder). Termites located and fed on toilet paper much more quickly than they did on wooden block. Similar observations were made by Haverly *et al.* (1975) in Arizona of U.S.A.

Location of food sources by two species of subterranean termites Gnathotermitis tubiformans (Buckley) and Amitermes wheeleri (Desneux) was studied by using toilet rolls and dung pade. There was no attack on the buried baits compared to baits placed on the surface (Petershank *et al.*, 1980).

Collins (1981) carried out a baiting study and showed that the fungus growing Macrotermitinae took 95 per cent of the litter removed by termites (25 per cent of the annual litter production) in Nigeria.

2.2.2 Effect of ecological factors on foraging

Coaton (1958) reported that the Hodotermes mosambicus foraged during the day in open air, but never at night during colder months. Foraging was observed during clear and windless days between 10.00 and 16.00 hour and in summer the foraging took place in the cooler hours, late in the evening and early morning.

The open forager, Anacanthotermes sp. was found collecting Camel dung around wells in southern Arabia at a time when there was no grass available (Harris, 1961) and termites were found rapidly consuming the large quantities of Elephant dung deposited around water holes compared to other ones (Weir, 1971).

Heterotermes indicola (Wasmann) preferred wood having 80-100 per cent moisture content. The observations of Hardy (1970) and of Sen-Sarna and Chatterjee (1968) have shown that a soil with a moisture content of 15-20 per cent seemed to be preferred by the genus Microcerotermes.

According to Johnson et al. (1981), the foraging activity of Microtermes was stimulated after heavy rain and declined at the end of wet season under Nigerian conditions. Less than 5 per cent bait was attacked during the dry season but surface foraging rapidly increased after the first rains (Ferrar, 1982).

According to Haverly et al. (1974) the number of foragers increased with increased temperature, in case of Heterotermes aureus. Slightest amount of rain during summer months greatly increased foraging intensity.

Foraging in Trinervitermes geminatus was mainly accomplished during the dry season (mid October to the end of April) for periods of 2-3 hour daily either early in the morning, in the evening or occasionally both in the morning and evening (Ohiagu and Wood, 1976). The duration and daily pattern of foraging was partly dependent on temperature, with a lower temperature threshold of 20°C and an upper threshold of 35°C below or above which foraging was restricted (Ohiagu, 1979).

Veeranna and Basalingappa (1981) recorded more than 27°C temperature inside the foraging galleries and runways of O. pallonensis when foraging ceased during dry months of the year (October to May). The active foraging of the T. geminatus occurred during September-October and March-April

in northern Nigeria (Sands, 1965). In the Ivory coast, T. trinervius foraged throughout the year, although the intensity of foraging was related to the seasonal weather pattern with maximum activity during September and October after heavy rains and the minimum in dry season during December to May (Bodot, 1967).

Haverty et al. (1974) developed a modified bait sampling method by using toilet paper rolls to examine the abiotic factors regulating foraging. H. aureus foraged during day and night throughout the year with minimal activity from December to February highest during summer but found erratic.

The intensity of foraging in the subterranean harvester termite, Anacanthotermes ochraceus (Burn.) was at its maximum in July, August and September. The peak activity was observed in the second week of August (Hosny and Said, 1980), in Egypt. The highest foraging activity of Anacanthotermes macrocephalus Desneux in the desert grass land ecosystem in India was observed in the dry season (October-June) and was lowest during the rainy season (July-September), while a reverse trend was observed in the non-harvesting species O. obsus and Microtermes sp. (Parihar, 1980). Rajagopal and Veeresh (1981) observed two peak foraging periods in O. gallonensis, from April to June and other from October to December. Higher temperature and more sunshine hours in the day reduced the foraging activity.

2.5 Role of termites as destroyers of organic matter

In the forest ecosystem, termites play an important role as degrading agents. According to Hopkins (1966) the rate of decay of wood is largely dependent on the activities of termites in Nigeria. The beneficial activity of termites to soil was summarised by Chatterjee (1972) as the soil burrowing activity served to increase the rate of rainfall infiltration and aeration of both top and sub soil. Many termites eat away the rotten wood and help in their disintegration of bodies and wings of termites often increases the nitrogen content of the soil.

Abe (1982) studied the role of termites in a tropical rain forest, where many fungus growing termites carried much of soil and microorganisms into the wood and helped in the degradations of wood. Termites accounted for a major turn over of dead grasses and wood in the desert ecosystem in Mexico and contributed significantly to the rapid decomposition of perennial plant leaves, grasses and dung (Whitford, 1982).

According to Rajagopal (1983b) termites were the dominant litter consumers in the forest, and as such efficient degraders of litter because they were the most excellent agents to combine the organic matter with microorganisms.

2.4 Rate of removal of various organic materials by termites

Coaton (1960) made observations on destruction of grazing by harvester termites. He found that the over grazing by livestock promoted increased termite abundance and damage in South Africa to the tune of total destruction of grass.

The rate of dung removal by termites was found to be 10-18 per cent/month and was found that only a minute quantity of the radio-active P_{32} added to dung and removal by termites could be detected in surrounding vegetation after 5 months when the rainy season started (Weir, 1971).

In order to estimate the loss to newly fallen leaves, the loss of previously marked leaf area was considered, on an average 1.7 per cent of the total surface area of the leaf litter disappeared per week in one plot and 2.9 per cent per week in the other plots located near the mounds of Macrotermes gahani Hagen. The amount of leaf litter removed by the termite was estimated at 38.8 kg/ha/week (Matsumoto, 1978).

Okwaki (1980) estimated the rates of consumption of soil and organic matter by individual workers of Cubitermes spp. The consumption of soil varied between

0.72 to 0.911 mg/termite/day and of organic matter between 0.65 to 0.84 mg/termite/day and he estimated the annual consumption of soil and organic matter of 69-88 mg/m² and 62-81 mg/m², respectively. The termite consumption was attributed to a decrease in the organic content which have a deleterious effect on the soil and the termite activity could result in damage to pastures by accelerated erosion and denudation. Rajagopal and Veeresh (1983) estimated the losses to root stubbles due to the attack of O. wallonensis on four crops, which ranged from 7.7 to 91.1 per cent. The maximum being in sunflower (91.1%) followed by niger (88.97%), maize (42.72%) and finger millet (7.76%).

Termites were observed to harvest large amounts of dry matter especially at the end of the dry season. In grazed sahel, termites removed 4 kg N/ha/year and in cultivated sahel 3 kg/ha/year (Penning, 1980).

Wetselar (1980) estimated 16 kg/ha/year of litter N₂ loss due to termites, grass hush fire and litter decomposition. It was believed that termites might consume annually an amount of dry plant material (2270 kg/ha/year) close to the total litter production (2700 kg/ha/year). Consumption of wood by artificially isolated colonies of the fungus growing termite Macrotermes bellicosus (Sneathman) was 94-194 mg/g of termite/day and had removed an estimated

60 per cent of annual wood fall and 3 per cent of annual leaf fall (Collins, 1981).

According to Ferrar and Watson (1970) termites played an important role in removing dry dung pads from Australian pastures thereby improving soil and releasing substantial areas for new growth. They fed on the fibre in the dung pads, replacing it with soil in about 12 weeks. Attacks on wet dung were less frequent.

According to Cee (1977) during the dry season the activity of coprophagous beetles on elephant dung decreased as the termite activity increased. The rate at which termites attack on dung was significantly differing from other treatments and the dung (4.55 litre) deposited during the period of the study was potentially removed within 85 days. Attacks on both natural and artificial dung pads by Gnathamitermes tubiformans and Amitermes wheeleri were estimated by the number of holes chewed in thin plastic film barriers placed between the soil and dung pads (Ettershank et al., 1980).

Whitford et al. (1982) studied the role of G. tubiformans in the decomposition of cattle dung herbaceous plants and wood. G. tubiformans removed dung at a rate of 0.63 g/day, accounting for a total loss of 19.5-100 per cent from July-September.

Studies carried out in Nigeria showed that dung was broken down quickly in the dry season, when termites were the main degradation agents, than in the wet season (Omalika, 1981).

Veeresh et al. (1982) carried out an experiment on the effect of termite activity on the fertility status of the soil in Karnataka. In the plots treated with soft wood, dung and grass, the organic carbon content of the soil was significantly higher in protected plots compared with plots subjected to termite attack.

2.5 Physico-chemical properties of termite modified soil

Mechanical composition:

Joachim and Kandish (1940) found more clay and less coarse sand in the mound soil of O. redemanni compared to surrounding soil in Sri Lanka. Similar observations were made by Pathak and Lehri (1959), Banerjee and Mohan (1976) in India.

Kemp (1955) found 67.2 per cent clay and 26.5 per cent sand in mounds of Cubitermes umbratus Williams compared with 30.8 and 63.0 per cent respectively from surrounding soil. According to Harris (1956) and Watson (1962), very

little difference was observed in mound soil and the surrounding soil. Soil aggregates of one mm size was more in termite free soils compared to termite worked soils (Spear et al., 1975). Samra et al. (1979) reported that the termite gallery soil of Q. wallonensis had more clay, silt and less sand than the surrounding soil. The coarse sand content in the mound soil was comparatively lower and the fine sand content higher than the surrounding soils of Q. wallonensis, Q. obesus and Q. redemanni. The clay content was more in Q. wallonensis and Q. obesus. However, not much difference was observed in the mounds of Q. redemanni compared to the surrounding soils (Rajagopal et al., 1982).

Bulk density:

Ghilarev (1962) reported that the bulk density of termitaria soil of Anacanthotermes ahngerianus (Jacobson) was $1.1129/\text{cm}^3$ as compared to $1.226 \text{ g}/\text{cm}^3$ for the surrounding grey desert soil in central area of U.S.S.R. whereas, it was of the magnitude of $1.00 \text{ g}/\text{cm}^3$ in forest soil compared to $1.27 \text{ g}/\text{cm}^3$ in fallow lands in the Congo (Maldaque, 1964). Mound soils of Q. wallonensis, Q. obesus and Q. redemanni had lower bulk density than the adjacent soils (Rajagopal et al., 1982).

Water holding capacity:

The water holding capacity of mound soil was as high as that of adjacent soil (Pathak and Lehri, 1959), but low water holding capacity has been reported in Africa (Kemp, 1955). Similarly varying water holding capacity in mound soil is reported by Pendleton (1941), Ghilarov (1982) and Rajagopal *et al.* (1982).

pH:

There was no difference in pH between mound soil and the surrounding soil (Mukerji and Mitra, 1949; Hesse, 1955 and Stoops, 1964). However, an increase in pH of mound soil relative to surrounding soil has been reported by many workers (Sen, 1944; Shrikhande and Pathak, 1948; Gokhale *et al.*, 1958; Watson 1962, Rajagopal *et al.*, 1982). Decreased pH of mound soil was also reported by Banerjee and Mohan (1976). Saura *et al.* (1979) recorded the lower pH in the termite galleries than in the surrounding soil.

Electrical conductivity:

A higher electrical conductivity in termite modified soil was observed by Lee and Wood (1971) and Rajagopal *et al.* (1982).

Organic matter:

Mound soils have a higher organic matter content than the surrounding soils (Holdway, 1933; Lee and Wood, 1971; Banerjee and Mohan, 1976). Badawi *et al.* (1982) observed higher content of the organic matter in the earthen runways of *Pseudotermes hybostoma* (Deeneux). According to Rajagopal *et al.* (1982) the organic matter content in the mound soils of *O. galliensis* and *O. obesus* was higher than surrounding soil whereas in *O. rasilmani* mound soil it was lower than surrounding soil. However, lower organic matter content in mound soil than surrounding soil has been reported by Grassie and Joly (1941), Hesse (1955) and Steepe (1964).

Organic carbon:

Increased organic carbon was found in the termite free soil (Spears *et al.*, 1975). In contrast Gupta *et al.* (1981) reported that earthen galleries present on the surface of litter and standing dead shoots contained higher content of organic carbon. According to Laker *et al.* (1982) *Tripterotermes tripteroides* mound soil contained higher organic carbon compared to the surrounding soil.

Total Nitrogen:

Joachim and Kandiah (1940) showed reduction in total

nitrogen of mound soil in comparison with surrounding soil. On the contrary, mound soil showed higher values of total nitrogen than surrounding soil as reported by Shrikhande and Pathak (1948), Pathak and Lehri (1959), Banerjee and Mohan (1976), Gupta et al. (1981), Rajagopal et al. (1982) from India and Lee & Wood (1971) from Australia.

C:N ratio:

According to Hesse (1955) and Maldague (1959), there was no difference in the C:N ratio of termite soil and surrounding soil. But variation has been reported from 2.7 to 18.82 depending upon the place and species of termites (Joachim and Kandiah, 1940; Shrikhande and Pathak, 1948; Boyer, 1955; Maldague, 1959 and Pathak and Lehri, 1959). Further Rajagopal et al. (1982) observed slightly higher C:N ratio in the O. redemanni mound compared to the surrounding soil.

Exchangeable Calcium and Magnesium:

The mound soils had higher calcium content than the surrounding soils (Lee and Wood, 1971), calcium content upto 7 times greater than surrounding soil has been shown by Sen (1944), Pathak and Lehri (1959) and Banerjee and Mohan (1976). The earthen galleries present on the soil surface, on debris etc. were having more exchangeable calcium than surrounding soil (Gupta et al., 1981).

According to Lee and Wood (1971), Banerjee and Mohan (1976) and Rajagopal et al. (1982) the magnesium was more in the earthen galleries of termite and in the termite mound soils compared to surrounding soil.

Available Potash:

Available potash was slightly higher in earthen galleries (Samra et al., 1979) and also in mound soils (Rajagopal et al., 1982) compared to surrounding soil.

Available Phosphorous:

Higher phosphorous content in termite modified soil compared to surrounding soil was observed (Sen, 1944; Pathak and Lehri, 1959; Rajagopal et al., 1982). Gokhale et al. (1958) found no significant difference in P in the termite soil compared to adjacent soils whereas, Lee and Wood (1971) reported little difference of phosphorous in mounds and other structures relative to surrounding soil.

Cation Exchange Capacity:

In most of the termite modified soils the cation exchange capacities were higher than in surrounding soil, but sometimes there was little difference in galleries of Odontotermes sp. (Shrikhande and Pathak, 1948) and occasionally there was a reduction as compared to soil in the mounds of

Q. redemanni (Josephin and Kandiah, 1940). Lee and Wood (1971) found that increase in CEC in termite modified soils was roughly correlated with organic matter content relative to surrounding soil.

Cation exchange capacity of Q. wallonensis and Q. obscurus (Dharwad) mounds were greater than their respective surrounding soils but in Q. redemanni mound (Mudigere) it was low (Rajagopal et al., 1982).

MATERIAL AND METHODS

CHAPTER III

MATERIAL AND METHODS

This study was conducted at the Main Research Station, University of Agricultural Sciences, Hebbal, Bangalore, during 1983-84. The material used and methods followed are presented under the following headings.

3.1 Survey and collection of termites

A survey was carried out to know the dung feeding fauna of termites in and around Bangalore during the study period. Several places were visited for survey and collection of dung feeding termites in Bangalore district (Appendix II). Observations were also made on the foraging strategy of some dung feeding termites. Cattle dung, Horse, Sheep and Elephant dung pads were looked for termite collection.

Soldier and worker termites were collected from various places on the day old to two month old dung, and also on farm yard manure, and they were preserved with proper labels for identification and further studies. These species were identified by comparing with departmental termite collections.

Aspirator, forceps, camel hair brush, hand knife, scalpel, thick polythene sheet (1 sq.m) and glass vials of

5x1 cm containing 75 per cent alcohol with tight rubber stopper were employed for the collection.

3.2 Seasonal incidence of dung feeding termites

Termites were also collected from two pasture lands and one regularly grazing land at monthly interval from April 1983 to March 1984 to study the dung feeding termite fauna and seasonal incidence. The weather data pertaining to the study period both at Hebbal and G.K.V.K. Campuses are presented in Appendix III. The localities were 1) U.A.S. Dairy Farm Hebbal, 2) Military Dairy Farm situated 9 km North to Bangalore city and 3) Gandhi Krishi Vignana Kendra, New Campus of U.A.S. situated 12 km North to Bangalore.

While collecting termites number of unattacked (fresh) as well as attacked dung pads in the area of 2 ha. in each locality were taken into account for working out per cent attack of dung pads by termites.

Study site

A study site of 8 ha area was selected at the U.A.S. dairy and poultry farm at Main Research Station, Hebbal, which lies at an altitude of 899 m MSL, longitude of 77°35' East and 12°58' North of the equator. This site has a well

drained red sandy loam soil with pH of 6.2. Part of the area was used for cultivation of MB-21 fodder grass, part of it, as a pasture land and remaining area was left fallow.

The presence of a number of small and large termite mounds in the centre as well as boundry portions were marked in the study site for collecting the dung feeding termites.

3.3 Incidence of dung beetles and termites

Observations were made on the foraging and incidence of dung pads by dung beetles and termites based on coverage of dung pads in the form of earthen sheeting. 170 dung pads of 6 litre each were placed near the mound in the form of disc of 25-30 cm diameter and 8-10 cm height in an area of 17x10 m in the U.A.S. Main Research Station, Hebbal during October-December 1983. The number of uninfested, infested viz., 0-25 per cent, 25-50 per cent, 50-75 per cent, 75-100 per cent of the dung pad covered by termite earthen sheeting were recorded.

Observations were also made at 10 days interval to take the count of the number of dung beetle, dung beetles + termites and termite infested dung pads at each observations and for calculating the per cent attack.

3.4 Effect of moisture on the activity of termites

A study was carried out from April 1983 to March 1984 in U.A.S. dairy farm, Hebbal to know the moisture preference of termites in soil while foraging on dung. Number of dung pads, freshly covered with wet earthen sheeting out of 100 dung pads, were considered and soil samples were drawn under different weather conditions of the year. Soil samples were drawn upto 7 cm depth and filled in the soil sampling box and moisture was determined by following oven dry method.

Observations were also made during November and December 1983 to know the effect of watering on the termite activity in the cocconut basins. These basins were applied with different manures. A total of 120 cocconut plants free from termite attack were marked in the M.A.S. farm Hebbal. Each of the following manure was placed at the base of 20 cocconut plants, out of which 10 plant basins were watered at 4 days interval - dried dung, farm yard manure, FYM + ash (8:1), Biogas slurry (fully digested) and leaf litter (partially decomposed).

Another 20 plant basins were left without manure, out of which 10 were watered at 4 days interval. Watering was continued upto the end of the December 1983.

The total number of coconut plants infested by termites in watered and unwatered basins were recorded. Per cent attack of coconut plants was calculated based on the number of plants attacked by termites under each manure.

3.5 Termites infestation to different baits at various depths in the soil

Studies were carried out on the termite infestation to different baits at various depths during October 1983 to January 1984 in the U.A.S. dairy farm Hebbal. Six depths were selected and randomly arranged in 6 plots of 5x10 m size. One litre of each bait was placed at 20 spots randomly. The following were the depths and baits employed in the experiment.

Depths: 0 cm (surface), 7.5 cm, 15 cm, 30 cm, 45 cm and 60 cm.

Baits : Cowdung, cowdung + ash (8:1), farm yard manure, FYM + ash (8:1) and leaf litter.

Observations were made after 3 months by removing and examining galleries from different depths for their attack. Thus per cent infestation of each bait at each depth was calculated.

3.6 Preference study of various baits and assessment of loss due to termites

An experiment was conducted in an area of 30x10 m

along with the presence of four medium sized active mounds at U.A.S. poultry farm, Bangalore during September 1983. The following baits were used as the treatments.

- T₁ = Farm yard manure (protected)
- T₂ = Farm yard manure (unprotected)
- T₃ = FYM + ash (protected) (8:1)
- T₄ = FYM + ash (unprotected) (8:1)
- T₅ = Cow dung (protected)
- T₆ = Cow dung (unprotected)
- T₇ = Cow dung + ash (protected) (8:1)
- T₈ = Cow dung + ash (unprotected) (8:1)
- T₉ = Cow dung + Mound soil (protected) (8:4)
- T₁₀ = Cow dung + Mound soil (unprotected) (8:4)
- T₁₁ = Biogas slurry (fully digested) (protected)
- T₁₂ = Biogas slurry (fully digested) (unprotected)
- T₁₃ = Leaf litter (partially decomposed) (protected)
- T₁₄ = Leaf litter (partially decomposed) (unprotected)
- T₁₅ = Surrounding soil (barren plot) (as check without any bait).

Six litre of each bait was placed randomly at a distance of 2 meters. The design followed was simple Randomised Complete Block Design with 4 replications. The protected treatments were sprayed with Aldrin 30 EC (5 ml. in 1 litre of water) to prevent the termite attack. Both protected and unprotected cowdung, cowdung + ash and cowdung +

mound soil treatments were covered by nylon net fixed on the iron frame as shown in the Fig.1 to prevent the entry of dung beetles under wet condition. Samples of all these baits were dried under the shade and preserved for analysis of organic carbon, phosphorous and potassium in the initial materials. Termite attacked baits and heaps of soil replaced by termites in place of various baits were drawn after 3½ months using core sampler, 5 cm above the soil surface. These samples were kept in paper bags and labelled with treatment, replication number and date of collection.

Preparation of samples for analysis:

The initial baits, termite infested baits and heap of soil replaced in place of baits were made into fine powder using pestle and mortar, passed through a 2 mm sieve, further powdered and made into pass through 0.5 mm sieve, preserved in polythene bags with labels.

Estimation of organic carbon:

Organic carbon was analysed by following Walkley and Black's wet oxidation method as given by Jackson (1967).

Per cent loss of baits was calculated by the following formula considering organic carbon content in all the treatments.

Fig.1 Nylon mesh cover to prevent dung beetles

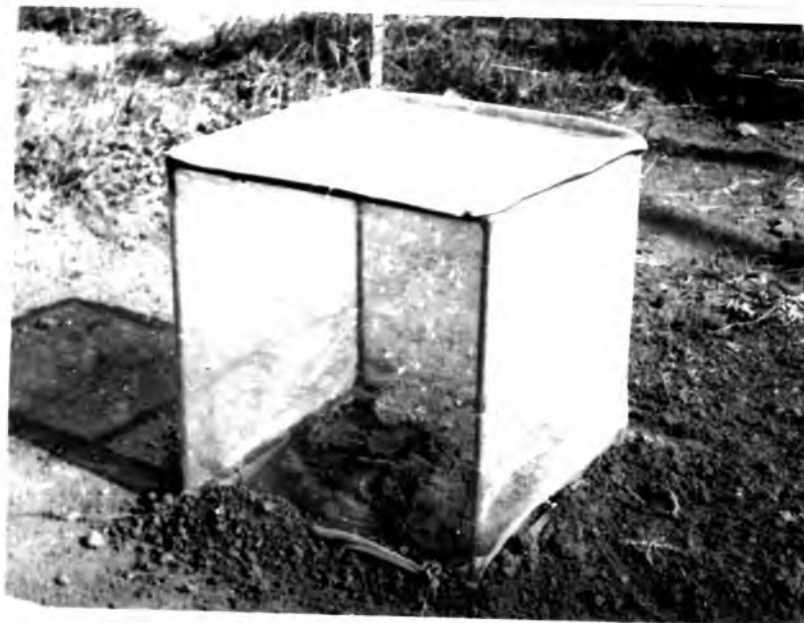


Fig.1

$$\begin{array}{r}
 \text{Per cent organic} \\
 \text{carbon due to} \\
 \text{termite left} \\
 \text{over bait}
 \end{array}
 =
 \begin{array}{r}
 \text{Per cent organic} \\
 \text{carbon in} \\
 \text{termite infested} \\
 \text{bait}
 \end{array}
 -
 \begin{array}{r}
 \text{Per cent organic} \\
 \text{carbon in the} \\
 \text{surrounding soil}
 \end{array}$$

$$\begin{array}{r}
 \text{Per cent} \\
 \text{loss of} \\
 \text{bait}
 \end{array}
 =
 \frac{
 \begin{array}{r}
 \text{Per cent organic} \\
 \text{carbon in the} \\
 \text{protected bait}
 \end{array}
 -
 \begin{array}{r}
 \text{Per cent organic} \\
 \text{carbon due to termite} \\
 \text{left over bait}
 \end{array}
 }{
 \begin{array}{r}
 \text{Per cent organic carbon in} \\
 \text{the protected bait}
 \end{array}
 }
 \times 100$$

Student 't' test was followed to test the difference in the nutrients like per cent organic carbon, per cent phosphorus and per cent potassium in the initial as well as termite attacked baits.

Estimation of phosphorous and potassium

A known weight of dried sample was digested by wet oxidation method using triacid mixture (HNO_3 , H_2SO_4 and HClO_4 at 10:1:4) as described by Jackson (1967) and the solution was preserved for determination.

Phosphorous was determined by Vanadomolybdophosphoric yellow colour method in nitric acid media and measuring the colour intensity at 420 nm wave length as described by Jackson (1967). Potassium was determined by flame photometer as described by Jackson (1967).

Change in the per cent P_2O_5 and per cent K_2O was calculated in both termite infested and uninfested baits.

Another experiment was laid out in an area of 15x10m to confirm the preference of termites to various baits by estimating population in each bait during October and November 1983. The following baits were Fresh dung, Fresh dung + Ash (8:1), Fresh dung + Mound soil (8:4), Dry dung, Farm yard manure, FYM + Ash (8:1), Biogas slurry and Leaf litter.

Six litre of each bait was placed randomly at a distance of 3 meters in the form of heap of 25-30 cm diameter and 10-15 cm height. The foraging termites including soldiers and workers were collected and their population was estimated when maximum baits were infested with termites. Termites along with left over baits were sampled by using core sampler of 5 cm diameter with 8 cm height and placed in polythene bags with cotton pad dipped in the formalin for anaesthetising termites. Then the whole material was transferred to bucket containing water and allowed for settling the soil and floating the termites. Termites along with debris were removed carefully and placed on the polythene paper. The number of workers and soldiers were counted directly with the help of forceps.

3.7 Rate of removal of dung and FYM by termites

Two separate experiments were laid out in an area of 15x10 m during October 1983 to January 1984 to study the rate of removal of dung and FYM due to termites by sampling at following intervals.

T_1 = Control (Dung/FYM treated with Aldrin 30 EC);
 T_2 = 7 days; T_3 = 15 days; T_4 = 30 days; T_5 = 45 days;
 T_6 = 60 days; T_7 = 90 days; T_8 = 120 days.

The intervals were considered as treatments in both the cases. The design adopted was a simple randomised complete block design with 6 replications. At each spot six litre of dung/FYM was placed in the form of heap of 25-30 cm diameter and 10.15 cm height. Samples were drawn separately from both termite infested dung pads as well as FYM treatments. These samples were prepared and analysed for per cent organic carbon by adopting the same methodology as in the previous study (3.2). The rate of removal of dung and FYM was worked out separately by calculating per cent loss under each treatment by adopting the following formula.

$$\begin{array}{l} \text{Per cent organic} \\ \text{carbon due to} \\ \text{termite left over} \\ \text{dung/FYM} \end{array} = \begin{array}{l} \text{Per cent organic} \\ \text{carbon in termite} \\ \text{infested dung/FYM} \end{array} - \begin{array}{l} \text{Per cent organic} \\ \text{carbon in the} \\ \text{surrounding soil} \end{array} \quad \text{arbon in}$$

$$\text{Per cent loss of dung/FYM due to termite attack} = \frac{\text{Per cent organic carbon in the control} - \text{Per cent organic carbon due to termite left over dung/FYM}}{\text{Per cent organic carbon in control}} \times 100$$

Data were analysed using angular transformation.

3.8 Physico-chemical properties of soil replaced by termites in place of dung

The physical and chemical properties of termite modified soil in place of dung were analysed for three important dung feeding termites viz., Odontotermes horni, O. obscurus and O. wallonensis by comparing with surrounding soil. From the experimental site, a total of ten soil samples in each species were collected, mixed thoroughly and a representative sample of 500 g was drawn for the purpose of analysis.

Physical properties:

Particle size distribution:

The gravel distribution was estimated by direct sieving the respective samples in a 2 mm sieve. Mechanical analysis was carried out by hydrometer method. Apparent and absolute specific gravity, maximum water holding capacity, pore space and volume expansion were determined by Keen's Cup Method as outlined by Piper (1966).

Chemical properties:

pH: This was measured in 1:2.5 (Soil:Water) suspension after stirring intermittently for 30 minutes by using a pH meter with glass-colonel combination electrode.

Electrical conductivity: 1:2.5 (Soil:water) extract was measured with a conductivity bridge using cell having cell constant units.

Organic carbon: Organic carbon was analysed by Walkley and Black's wet oxidation method as given by Jackson (1967). The organic matter content was obtained by multiplying organic carbon value by 1.724.

Available nitrogen: Available nitrogen was determined by alkaline Permanganate method outlined by Subbaiah and Asija (1956).

Total nitrogen: Total nitrogen was estimated by the Kjeldahl's Method as outlined by Jackson (1967).

Ca, Mg, Na & K were determined in the neutral 1N NH_4O AC extracts, which were obtained in the CEC determination. For determining Ca and Mg an extract was titrated against standard verceenate solution whereas Na and K were determined by using astronic - 121 flame photometer, outlined by Jackson (1967).

Available phosphorus: Available P was determined by Bray's No.1 extractant for acid soils and Olsen reagent for alkaline soils. The P in the extracts was estimated by the chlorostannous reduced molybdophosphoric acid blue colour method (Jackson, 1967). The intensity of colour was read by using a red filter in Klett Somerson Colorimeter.

EXPERIMENTAL RESULTS

CHAPTER IV

EXPERIMENTAL RESULTS

The experimental results on the studies of dung feeding termites and their role in dung removal under dry land conditions are presented under the following headings:

4.1 Survey and collection of dung feeding termites

The present investigation has revealed the association of fourteen species of termites on dung in and around Bangalore. These species belong to eight genera under Rhinotermitidae and Termitidae. The different species of termites and their association with various dung pads are presented in Table I.

According to the Table I all the termite species were commonly associated with Cattle dung. Apart from the Cattle dung, Odontotermes wallonensis was observed on Sheep pellets, O. bellahunisensis on Horse dung, O. horni on both Horse and Elephant dung, O. obesus on Horse, Elephant and Sheep pellets during the study.

4.2 Foraging behaviour of dung feeding termites

a) Heterotermes sp.

In this species there was no earthen sheeting and no

Table I. Different termite species associated with dung pads of various animals in and around Bangalore

Sl.No.	S p e c i e s	Cattle	Horse	Elephant	Sheep
I	Rhinotermitidae				
1.	<u>Heterotermes</u> sp.	+	-	-	-
II	Termitidae				
2.	<u>Microcerotermes</u> sp.	+	-	-	-
3.	<u>Dicuspitermes fletcheri</u> (Holmgren and Holmgren)	+	-	-	-
4.	<u>Macrotermes etherae</u> (Deaneux)	+	-	-	-
5.	<u>Odontotermes bellahunisensis</u> (Holmgren and Holmgren)	+	+	-	-
6.	<u>Odontotermes ceylonicus</u> (Wasmann)	+	+	-	-
7.	<u>Odontotermes feae</u> (Wasmann)	+	-	-	-
8.	<u>Odontotermes horni</u> (Wasmann)	+	+	+	-
9.	<u>Odontotermes obesus</u> (Rambur)	+	+	+	+
10.	<u>Odontotermes redemanni</u> (Wasmann)	+	-	-	-
11.	<u>Odontotermes wallonensis</u> (Wasmann)	+	-	-	+
12.	<u>Microtermes obesol</u> Holmgren	+	-	-	-
13.	<u>Speculitermes sinhalensis</u> Roorwal and Sen-Sarma	+	-	-	-
14.	<u>Trinervitermes biformis</u> (Wasmann)	+	-	-	-

+ : Present - : Absent

sign of foraging activity was observed on the dung until the dung pad was physically removed. The foraging party consisted of both workers and soldiers and was found feeding on the semi dried dung pad.

b) Microserotermes sp.

In this species there was no earthen sheeting on the dung pad and the attack was found from the bottom of dung pad. Foraging parties consisted of both workers and soldiers.

c) Dicusspiditermes fletcheri

Foraging activity was not noticed from outside. This species was found foraging under the dung pads without constructing any earthen sheeting on the surface. Foraging parties consisted of both workers and soldiers. With little disturbance, soldiers made 'hissing' sound in the foraging area. Usually foraging of this species was observed under the semi dried to partially decomposed dung pads.

d) Macrotermes natalense

Foraging parties consisted of both major and minor workers and soldiers which foraged openly on the ground without earthen sheeting over the dung. With slightest disturbance they were found to enter the foraging hole

which was under the dried leaves, soldiers were making rattling sound as a defensive mechanism while returning to the foraging hole. The foraging holes were indicated with small heaps of mud upto 7 cm height on the surface.

e) Odontotermes bellahunisensis

This species was found foraging on Cattle dung as well as on Horse dung. It was observed on semi dried dung under covered earthen sheeting made out of smaller aggregation of soil particles. There were small galleries and runways in the soil placed in dung pads. Both workers and soldiers were included in the foraging party and active foraging was observed to be only after rainfall.

f) Odontotermes ceylonicus

This species was found commonly foraging on semi dried to fully dried Cattle and Horse dung pads by constructing earthen sheeting. It was found in the company of O. obesus within a single dung pad. Both the species were identical in foraging on separate portion of a dung pad, but there were irregular common passages between two portions. The active foraging was observed during rainy season.

g) Odontotermes feae

Both soldiers and workers included in the foraging

party. They foraged the dung by covering earthen sheeting made out of larger aggregation of soil particles. This species was found to be very rare during the survey and collection of termites and could not be made any detailed observations.

h) Odontotermes horni

This species was quite common in and around Bangalore on the dung and other organic matter. They covered the dung pads with the earthen sheeting made out of larger aggregation of soil particles (Fig.2) compared to other members of the genus. Both workers and soldiers were involved in foraging (Fig.3). The foraging was found on moist dung as well as on dried dung and even on the heaps of farm yard manure (Fig.4) placed in the field just after early monsoon rains. Workers were engaged in foraging by making galleries in the soil replaced in place of dung and soldiers were guarding them.

Slight disturbance caused soldiers to make rattling sound from inside the earthen sheeting which made all the workers and some soldiers to run into the subterranean galleries and remaining soldiers to move to the disturbed portion of the dung pad to prevent the entry of ants. Soldiers secreted brown defensive substance which was gummy

Fig.2 Earthen sheeting on the dung by Odontotermes horni

Fig.3 Workers and soldiers of O.horni in the foraging site



Fig.2



Fig.3

Fig.4 Heap of FYM infested with O.horni



Fig.4

in nature. 2-4 foraging holes of 0.4 to 0.6 cm diameter were found under the dung pad. Foraging was more frequent during rainy season and their activity decreased as the dry season approached.

1) Odontotermes obscurus

This species was the commonest and most dominant among the dung feeding termites. Foraging activity of this species was observed throughout the year with an increased activity during May and October and decreased during January-March. However, unusual increased activity was observed after the rainfall in the month of February. Both workers and soldiers were included in the foraging of fresh as well as dry dung. Apart from Cattle dung it was also found foraging on farm yard manure, Horse, Elephant and Sheep pellets under covered earthen sheeting. There were medium sized runways in the soil replaced in place of dung pads (Fig.5).

2) Odontotermes gedonanni

Both workers and soldiers were involved in the foraging. It was found on fresh dung to month old dung and even on leaf litter by covering earthen sheeting made out of medium sized aggregation of soil particles. There were medium sized galleries in the soil replaced in place of dung.

**Fig.5 Foraging runways of O.obesus in the
dung replaced with soil**



Fig.5

k) Odontotermes wallonensis

In this species foraging activity was observed under the fully covered earthen sheeting of bit coarser soil particles on the dung pad. Both soldiers and workers were found feeding on Cattle dung as well as on Sheep pellets. They made medium sized galleries in the dung pad which was entirely replaced with soil. The foraging was noticed on day old to fully dried dung. There were two peak foraging periods during April to June and October to December.

l) Microtermes obesei

In this species foraging party consisted of workers and with less number of soldiers. The activity of these was noticed from bottom of the dung pad and earthen galleries were small with 0.2 to 0.3 cm diameter. Though fine soil particles were filled in place of dung, but no earthen sheeting was noticed on the surface, only a thin film of dried dung was left on the surface.

m) Speculitermes sinhalensis

This species was found foraging under partially and fully decomposed dung pads and even on the farm yard manure. Foraging party consisted of only workers. The workers were found to feed only on fully decomposed dung

pads already attacked by other species. Sometimes it was found foraging under the dung pad covered with earthen sheeting of O. obesus and O. sylvanicus as inquiline. Its activity was found more during rainy season. In addition to the dung, it was also observed on leaf litter, stubbles etc.

n) Trinervitermes biformis

This species was found foraging in the open ground without earthen sheeting. Foraging party consisted of major and minor soldiers and workers. More number of minor soldiers were present near the periphery of the foraging site than the foraging hole. Few major soldiers were also observed moving in the foraging site. Major and minor workers were engaged in collecting dried fragments of dung and found carrying to their nest through the foraging hole. Foraging activity was more during cooler hours of the day just after the rain apart from regular foraging after dusk.

4.3 Seasonal incidence of different termite species associated with dung

1. U.A.S. Dairy Farm and Military Dairy Farm, Hebbal:

The data on the seasonal incidence of major termite species recorded and their per cent attack on the dung pads in pasture land of U.A.S. dairy farm and Military dairy

farm of Hebbal have been presented in the Table II and III respectively. Graphical representation in the form of histogram (Fig.6) showed that the species Odontotermes obesus was the most dominant among the 10 termite species attacking dung pads (Table II) in U.A.S. dairy farm. Its activity was found throughout the year but there were two peak periods of incidence on dung pads during April to July (41.15 to 63.19%) and September to December (54.57 to 64.12%). Low incidence was recorded in the month of August (27.69%) and from January to March (21.23 to 39.89%). However, there was more incidence (39.87%) in February compared to January (21.23%) where there was least attack. The same trend of its incidence was observed in the Military dairy farm, Hebbal (Table III, Fig. 7).

O. wallonensis was the next dominant species after O. obesus in attacking dung. Its attack was observed throughout the year but had two peak periods of incidence during April to July (1.63 to 7.06%) and October to December (2.7 to 8.18%). Low incidence (0.43 to .67%) was recorded during January to March with least attack in January. Almost the same trend in Military dairy farm, Hebbal was observed except little difference of increased activity during March.

Table II. Seasonal incidence of different species of termites associated with dung and their per cent attack in pasture land of U.A.S. Dairy Farm, Bangalore (April 1983 to March 1984)

Species	Month											
	April	May	June	July	August	September	October	November	December	January	February	March
1. <u>Odontotermes bellabuniensis</u>	-	3 (0.31)	2 (0.20)	-	3 (0.48)	1 (0.16)	2 (0.25)	1 (0.09)	1 (0.14)	-	1 (0.15)	-
2. <u>O. ceylonicus</u>	1 (0.10)	4 (0.41)	1 (0.10)	2 (0.33)	-	4 (0.64)	3 (0.38)	2 (0.19)	2 (0.28)	-	4 (0.6)	-
3. <u>O. horri</u>	4 (0.43)	8 (0.83)	17 (1.7)	4 (0.66)	12 (1.92)	5 (0.8)	16 (2.03)	5 (0.49)	6 (0.84)	2 (0.3)	6 (0.91)	2 (0.22)
4. <u>O. obscurus</u>	377 (41.15)	606 (63.19)	446 (44.68)	257 (43.04)	172 (27.69)	340 (54.57)	504 (64.12)	614 (60.91)	390 (54.77)	141 (21.23)	262 (39.87)	299 (33.67)
5. <u>O. wallonensis</u>	15 (1.63)	64 (6.67)	19 (1.9)	12 (2.00)	8 (1.28)	8 (1.28)	56 (7.12)	22 (2.18)	22 (3.08)	3 (0.45)	7 (1.06)	6 (0.67)
6. <u>Microcerotermes</u> sp.	-	1 (0.10)	-	-	-	-	-	-	1 (0.14)	-	-	-
7. <u>Speculitermes sinhalensis</u>	-	2 (0.20)	-	1 (0.16)	-	-	-	-	-	-	-	-
8. <u>Trinervitermes biformis</u>	-	-	-	1 (0.16)	1 (0.16)	-	1 (0.12)	1 (0.09)	-	-	-	-
9. <u>Microtermes obesi</u>	1 (0.10)	22 (2.29)	8 (0.80)	2 (0.33)	4 (0.64)	9 (1.44)	16 (2.03)	7 (0.69)	1 (0.14)	-	8 (1.21)	1 (0.11)
No. of termites infested dung pads.	398 (43.44)	710 (74.02)	493 (49.59)	279 (46.56)	200 (32.36)	367 (58.9)	598 (76.08)	652 (64.68)	423 (59.4)	146 (21.98)	289 (43.8)	308 (34.68)
Total number of dung pads	916	959	998	597	621	623	786	1008	712	664	657	888

Figures in parenthesis represent per cent attack.

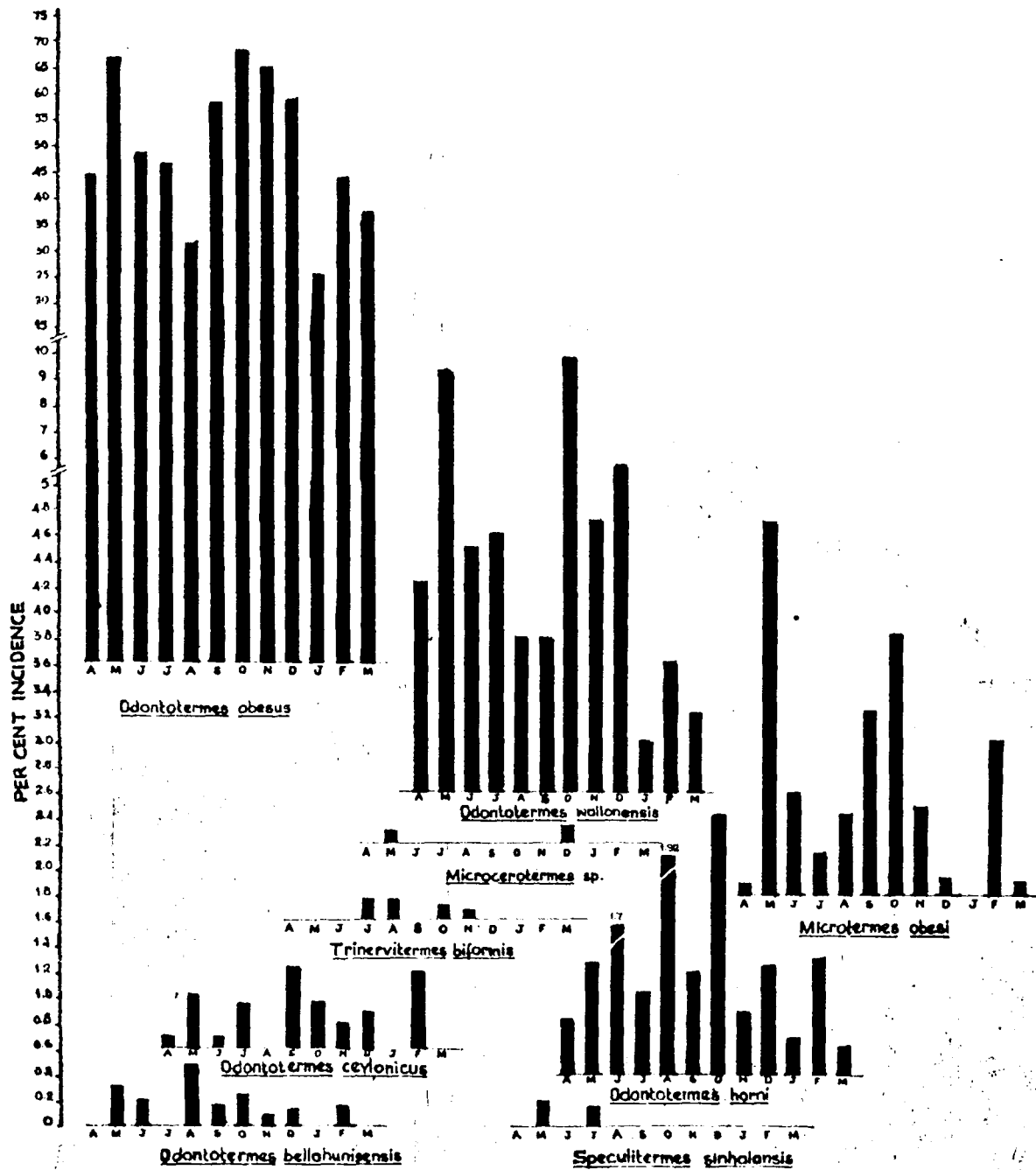


FIG.6 SEASONAL INCIDENCE OF DUNG FEEDING TERMITES IN U.S. DAIRY FARM.

Table III. Seasonal incidences of different species of termites associated with dung in pasture land with their per cent attack at Military dairy farm, Bangalore (April 1983 to March 1984)

Sl. No.	Species	Month											
		April	May	June	July	August	September	October	November	December	January	February	March
1.	<u>Odontotermes bellahuniensis</u>	-	-	-	¹ (0.19)	¹ (0.23)	-	⁴ (0.5)	¹ (0.16)	² (0.36)	-	² (0.30)	¹ (0.16)
2.	<u>O. ceylonicus</u>	¹ (0.15)	⁶ (1.60)	³ (0.37)	¹ (0.19)	¹ (0.23)	⁶ (0.57)	¹⁵ (1.88)	⁴ (0.66)	² (0.36)	-	² (0.31)	-
3.	<u>O. Horni</u>	³ (0.46)	¹⁹ (1.91)	¹³ (1.61)	³ (0.58)	² (0.47)	⁵ (0.48)	²⁶ (3.27)	¹⁸ (2.99)	⁶ (1.08)	² (0.38)	⁴ (0.61)	⁴ (0.65)
4.	<u>O. obesus</u>	³¹³ (48.60)	⁶⁶⁸ (67.40)	³⁷⁴ (46.57)	²³⁶ (45.91)	¹³⁹ (33.01)	⁴⁷⁵ (45.84)	⁵⁰⁴ (63.47)	³⁵³ (58.63)	³⁰⁷ (55.41)	¹⁰³ (19.73)	²⁵² (39.00)	²¹⁸ (35.67)
5.	<u>O. wallonensis</u>	¹¹ (1.70)	⁷⁰ (7.06)	³⁰ (3.73)	⁶ (1.16)	³ (0.71)	⁴⁵ (4.34)	⁶⁵ (8.18)	³² (5.31)	¹⁵ (2.70)	³ (0.57)	⁵ (0.77)	¹⁰ (1.63)
6.	<u>Dicuepiditermes fletcheri</u>	-	-	-	-	-	-	¹ (0.12)	-	-	-	-	-
7.	<u>Microtermes obesi</u>	³ (0.46)	¹⁹ (1.91)	¹⁵ (1.86)	¹ (0.19)	⁶ (1.42)	²⁷ (2.60)	²⁸ (3.52)	⁸ (1.32)	⁹ (1.62)	-	⁵ (0.77)	² (0.32)
8.	<u>Microcerotermes</u> sp.	-	-	-	-	-	-	² (0.25)	-	-	-	-	-
9.	<u>Speculitermes sinhalensis</u>	-	-	¹ (0.19)	-	-	-	¹ (0.12)	-	-	-	¹ (0.15)	-
10.	<u>Trinervitermes bififormis</u>	-	-	-	-	-	¹ (0.09)	-	¹ (0.16)	-	-	-	-
	No. of termites infested dung pads	331 (51.39)	782 (78.80)	436 (54.29)	248 (48.24)	152 (36.10)	559 (53.95)	646 (81.36)	417 (69.10)	341 (61.55)	108 (20.68)	271 (41.95)	235 (38.46)
	Total number of dung pads	644	991	803	514	421	1036	794	602	554	522	646	611

Figures in parenthesis represent per cent attack

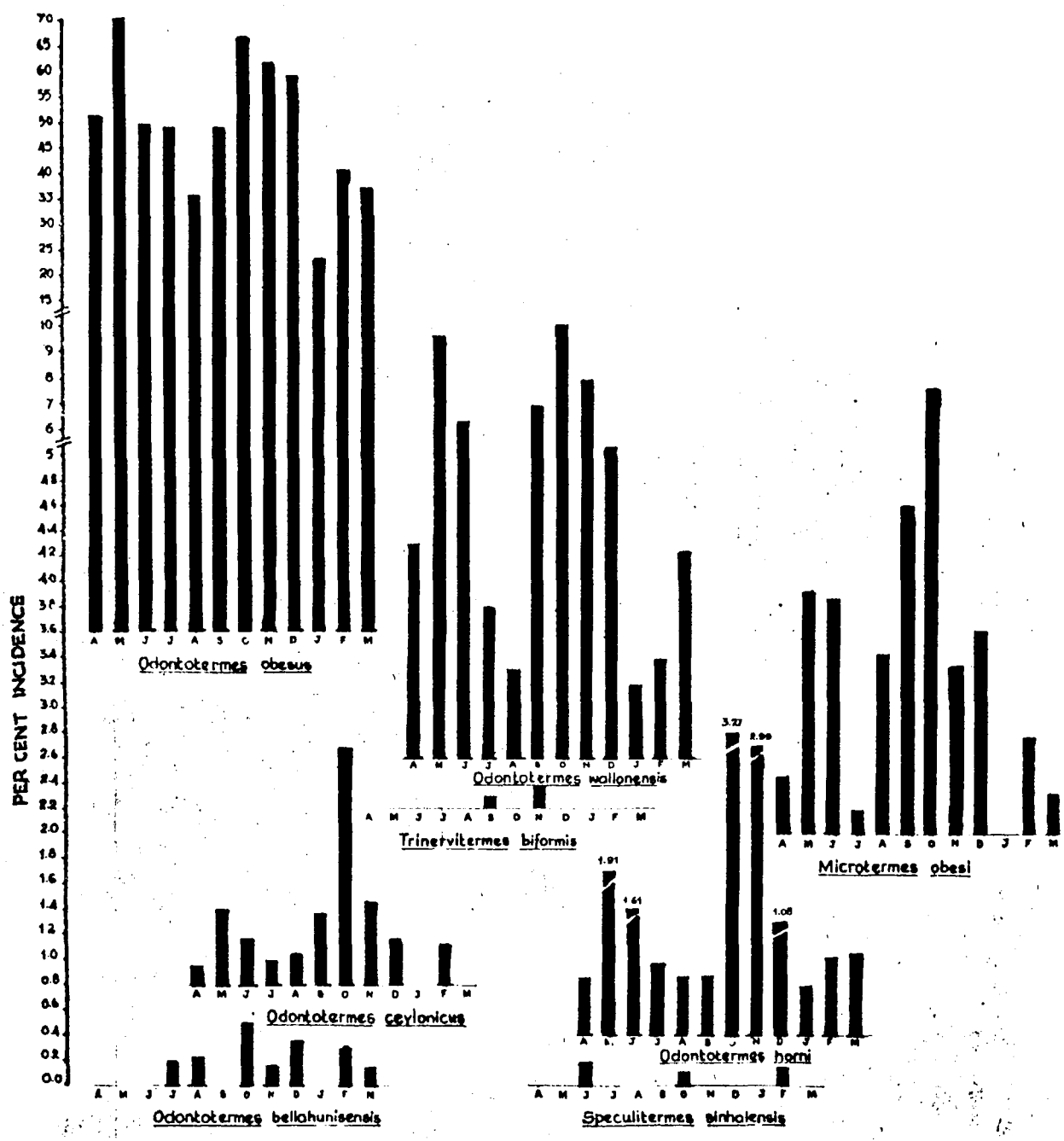


FIG.7 SEASONAL INCIDENCE OF DUNG FEEDING TERMITES IN MILITARY DAIRY FARM.

In Q. horni, the incidence was maximum (1.7 to 2.03%) during June, August and October months and least (0.45 to 0.67%) during January-March at U.A.S. dairy farm whereas higher incidence was observed during May to June and October to November (1.61 to 3.27%) in Military dairy farm, Hebbal.

In Q. ceylonicus, the maximum attack (1.88%) was observed during October in military dairy farm and (0.64%) during September in U.A.S. dairy farm. The activity of this species on dung was absent in January and March in both the pasture lands.

Increased incidence of Q. bellahunisensis was recorded during October (0.5%) in military dairy farm and during May and August (0.31 to 0.48%) in U.A.S. dairy farm. A reduced degree of activity was also recorded during other months of the year except during January, March and April at both the pasture lands.

Maximum attack (2.03 to 2.29%) of Microtermes obesi was observed during May and October, moderate incidence (0.80 to 1.44%) during June, September and February in U.A.S. dairy farm. Same trend was observed in pasture land of military dairy farm except in February where the incidence (0.77%) was comparatively low.

Occasional attack of Microcerotermes sp. was noticed during May and December at U.A.S. dairy farm and it was noticed only in October in military dairy farm. Speculitermes siphaliensis was found to attack dung pads during May and July while collecting other termite species in U.A.S. dairy and during June, October and February in military dairy farm. Very low incidence of Trinervitermes biforais was noticed during July, August, October and November in U.A.S. dairy farm and was observed only during September and November in Military dairy farm.

2) Grazing land of Gandhi Krishi Vigyan Kendra:

The data on the seasonal incidence of major termite species recorded on dung pad at G.K.V.K. Campus of U.A.S. have been presented in Table IV. Graphical representation (Fig.8) showed that the Odontotermes obsesus was the most dominant species among dung feeding termites found in the grazing land. Its incidence was noticed throughout the year with maximum (70.79%) during October 1983 and minimum (13.25%) during January 1984. Moderately increased incidence (53.39 to 62.72%) was observed during May, November and December.

O. hornei was the second dominant species noticed throughout the year with maximum incidence (7.82%) during

Table IV. Seasonal incidence of different termite species associated with dung and their per cent attack in a grazing land of Gandhi Kriehi Vignana Kendra, Bangalore (April 1983 to March 1984)

Species	Month											
	April	May	June	July	August	September	October	November	December	January	February	March
1. <u>Odontotermes bellahunisensis</u>	-	-	1 (0.86)	-	-	1 (0.49)	2 (0.88)	1 (0.45)	-	-	-	-
2. <u>O. ceylonicus</u>	-	-	2 (1.73)	1 (0.63)	-	2 (0.99)	2 (0.88)	1 (0.45)	1 (0.45)	1 (0.28)	1 (0.37)	1 (0.42)
3. <u>O. horni</u>	2 (1.86)	3 (1.77)	9 (7.82)	1 (0.63)	3 (2.50)	10 (4.99)	9 (3.98)	8 (3.61)	4 (1.15)	1 (0.37)	4 (1.68)	1 (0.46)
4. <u>O. obesus</u>	35 (32.71)	106 (62.72)	45 (39.13)	65 (41.40)	31 (25.83)	81 (40.29)	160 (70.79)	118 (53.39)	194 (56.23)	35 (13.25)	102 (43.03)	69 (32.09)
5. <u>O. wallonensis</u>	1 (0.93)	4 (2.36)	1 (0.86)	2 (1.27)	1 (0.83)	1 (0.49)	9 (3.98)	4 (1.80)	5 (1.44)	-	2 (0.84)	1 (0.46)
6. <u>Microtermes obesi</u>	-	3 (1.77)	3 (2.60)	-	1 (0.83)	8 (3.98)	10 (4.42)	4 (1.80)	-	-	8 (3.37)	1 (0.46)
7. <u>Dicuspiditermes fletcheri</u>	-	-	-	-	-	-	-	-	17 (0.28)	-	1 (0.42)	-
8. <u>Speculitermes sinhalensis</u>	-	-	-	1 (0.63)	-	-	-	-	1 (0.28)	-	-	-
9. <u>Trinervitermes bififormis</u>	-	-	1 (0.86)	-	-	1 (0.49)	-	1x (0.45)	-	-	-	-
No. of termite infested dung pads	38 (35.5)	116 (68.63)	62 (53.91)	70 (44.58)	36 (30.0)	104 (51.74)	192 (84.96)	137 (61.99)	206 (59.71)	37 (14.01)	118 (49.78)	73 (33.02)
Total number of dung pads	107	169	115	157	120	201	226	221	345	264	237	215

Figures in parenthesis represent per cent attack.

x = Attack of both Trinervitermes bififormis and O. obesus (on a single dung pad)

y = Attack of both Dicuspiditermes fletcheri and O. ceylonicus (on a single dung pad)

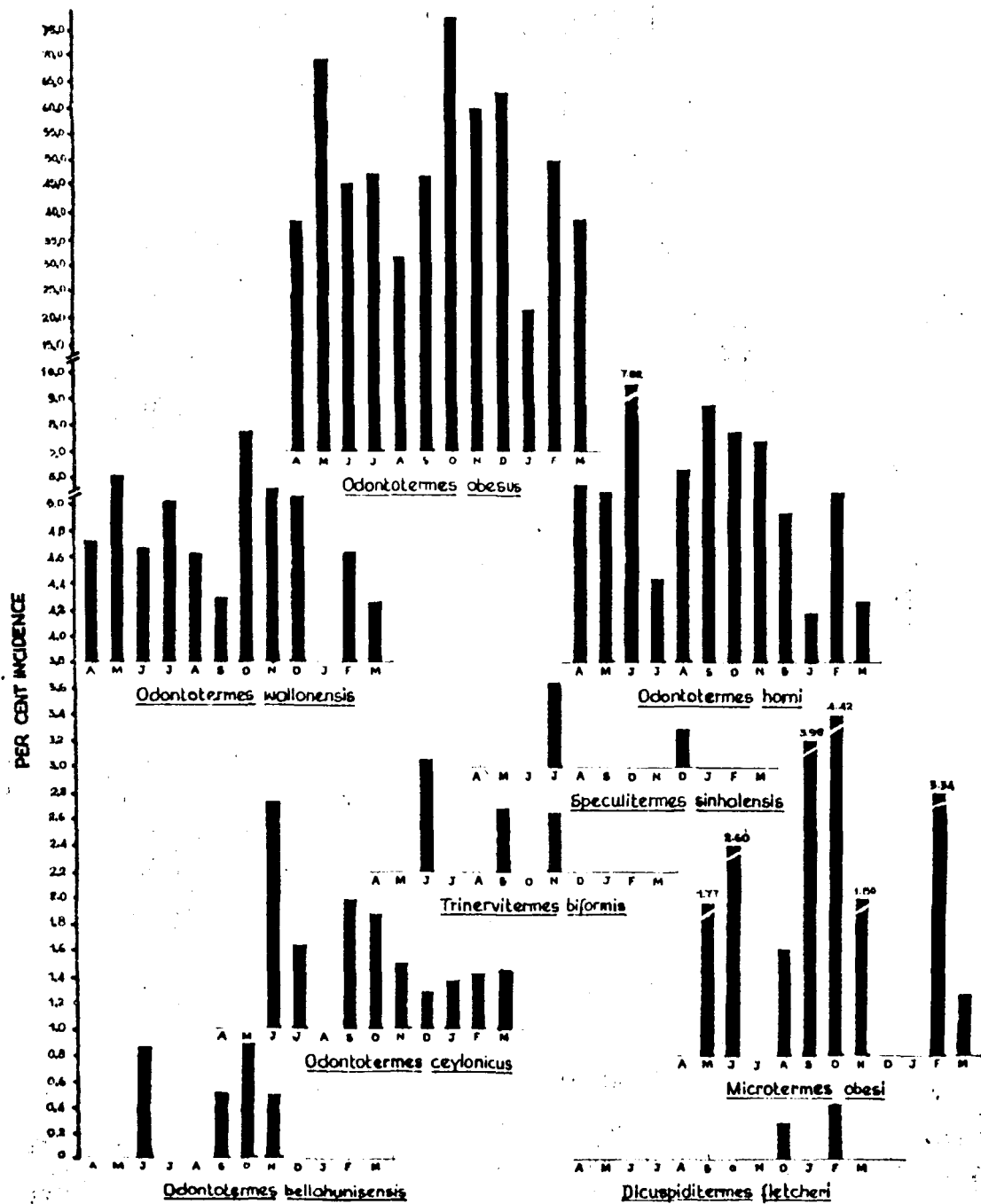


FIG.8 SEASONAL INCIDENCE OF DUNG FEEDING TERMITES IN G.K.V.K FARM.

June and moderately increased incidence (3.61 to 4.99%) during September, October and November. Lower incidence (0.37 to 0.46%) was noticed during January and March.

The incidence of *O. wallonensis* was more (2.36 to 3.99%) during May and October and no incidence was noticed in January.

In *O. caylonicus* the incidence was noticed in all the months except during April, May and August but it was more (1.73%) in June.

Except June, September, October and November, there was no incidence of *O. bellahunisensis* and higher incidence (0.86 to 0.89%) of this species was noticed during June and October.

Incidence of *Microtermes obesi* was observed in all the months except during April, July, December and January with maximum incidence (4.42%) during October.

There was no regular incidence of *Dicuspitermes fletcheri* except during December and February. Likewise the occurrence of *Speculitermes sinhalensis* was noticed in July and December and *Trinervitermes bifornis* in June, September and November.

4.4 Incidence of dung beetles and termites

The per cent attack of dung beetles, dung beetles and termites, termites alone at different intervals and earthen sheeting of varied percentages is presented in Table V. From the table, it can be seen that out of 170, 12 (7.05%) and 4 (2.35%) dung pads were attacked by dung beetles Helicopris bucephalis (Fabricius) and termite Odontotermes obscurus, respectively on 10th day after placing the dung pads. There was no further attack of dung pads by dung beetles after 10 days (Fig.9). Both dung beetle and termites attacked dung pads were noticed only after 40 days and increasing trend was noticed upto 90th day with maximum attack of 10 (5.88%) dung pads. It was observed that the number of dung pads (19.98%) attacked by termites increased after 20 days. The dung pads of 0-25% earthen sheeting were in the ascending order upto 30th day with maximum of 43 (25.29%), afterwards descending trend was noticed. Number of dung pads with 50-75 per cent earthen sheeting were in the increasing trend upto 60th day and then decreased, whereas 75-100 per cent covered earthen sheeting was observed after 30 days and their number increased upto 90 days with highest attack of 158 (92.94%) out of 170 dung pads.

Table V. Incidence of dung beetles and termites with varied earthen sheeting at different interval

Sl. No.	Inter-val in days	No. of dung beetles attacked dung pads*	No. of dung beetle+ termites attacked dung pads*	No. of termite attacked dung pads*	No. of dung pads covered by termite earthen sheeting			
					0-25% covered	25-50% covered	50-75% covered	75-100% covered
1	10	12 (7.05)	-	4 (2.35)	4 (2.35)	-	-	-
2	20	12 (7.05)	-	34 (19.98)	33 (19.4)	1 (0.58)	-	-
3	30	12 (7.05)	-	77 (45.29)	43 (25.29)	25 (14.70)	7 (4.1)	2 (1.17)
4	40	11 (6.47)	1 (.58)	128 (75.29)	25 (14.69)	38 (22.20)	19 (11.17)	46 (27.05)
5	50	9 (5.29)	3 (1.76)	133 (78.25)	16 (9.41)	27 (15.86)	22 (12.94)	68 (40.29)
6	60	7 (4.11)	5 (2.94)	140 (82.35)	9 (5.28)	13 (7.64)	25 (14.70)	95 (54.70)
7	70	6 (3.52)	6 (3.52)	157 (92.35)	5 (2.94)	12 (7.05)	21 (12.34)	119 (78.14)
8	80	3 (1.76)	9 (5.29)	158 (92.94)	-	6 (3.52)	3 (1.76)	149 (87.64)
9	90	2 (1.17)	10 (5.88)	158 (92.94)	-	-	-	158 (92.94)

* Out of a total of 170 dung pads. Figures in parenthesis represent per cent attack.

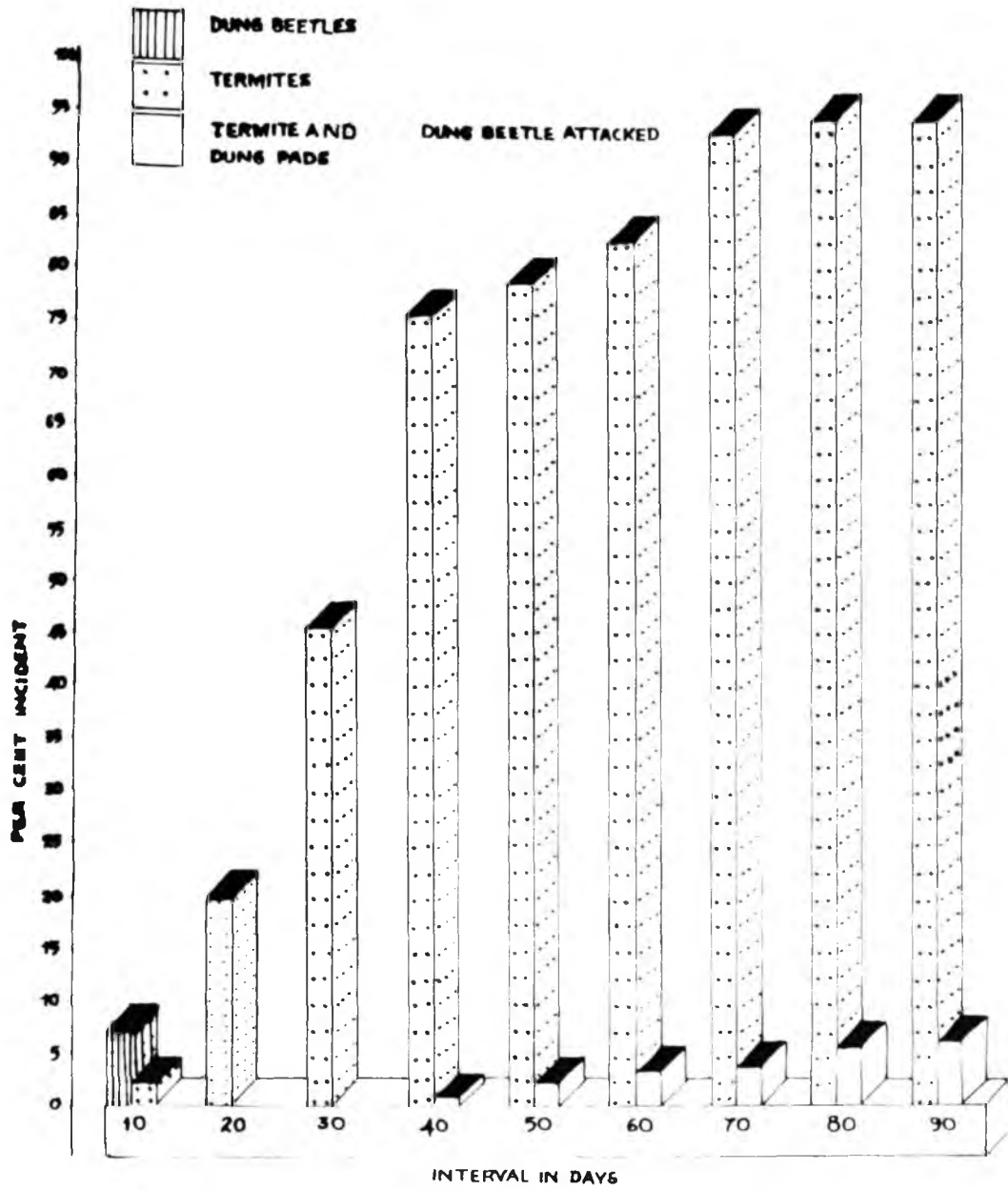


FIG. 9 PER CENT INCIDENCE OF DUNG BEETLES AND TERMITES

The active foraging of termites on these dung pads was noticed after 20 days and it was moderate upto 30th day. There was a steep increase in the attack (75.29%) of dung pads after 40 days and was continued upto 90 days.

4.5 Effect of soil moisture on the activity of termites

The per cent attack of dung by termites at different moisture levels in soil is presented in Table VI. From the table, it is evident that the soil moisture ranging from 15.34 to 18.45 per cent was the most preferred soil moisture at which per cent attack of dung pads was as high as 76 to 84 (Fig.10). At higher soil moisture from 22.05 to 25.40 per cent the termite activity was reduced and per cent attack of dung pads by termites was low (19.20 per cent). Termite activity was moderately higher at soil moisture ranging from 10.25 to 15.15 per cent with 63 to 78 per cent dung pads attacked and even at 7.11 to 9.73 per cent soil moisture, 61 to 68 per cent termite attack was noticed. At lower moisture level ranging from 1.45 to 6.97 per cent where the termite activity was comparatively less. Still the per cent attack of dung pads ranged from 10-56 with an average of 31.87 per cent. was observed.

The effect of watering on the termite activity at the base of coconut plants is presented in Table VII and

**Table VI. Per cent attack of dung pads by termites
at different moisture levels
in the soil**

Sl. No.	Soil moisture		Per cent attack of dung pad	
	Range	Mean	Range	Mean
1.	1.45 - 6.97	3.64	10 - 56	31.87
2.	7.22 - 9.73	8.63	61 - 68	64.25
3.	10.25 - 15.15	13.37	63 - 78	72.50
4.	15.34 - 18.45	17.05	76 - 84	78.25
5.	19.86 - 23.12	21.56	17 - 61	38.50
6.	22.05 - 25.40	23.63	6 - 43	19.20

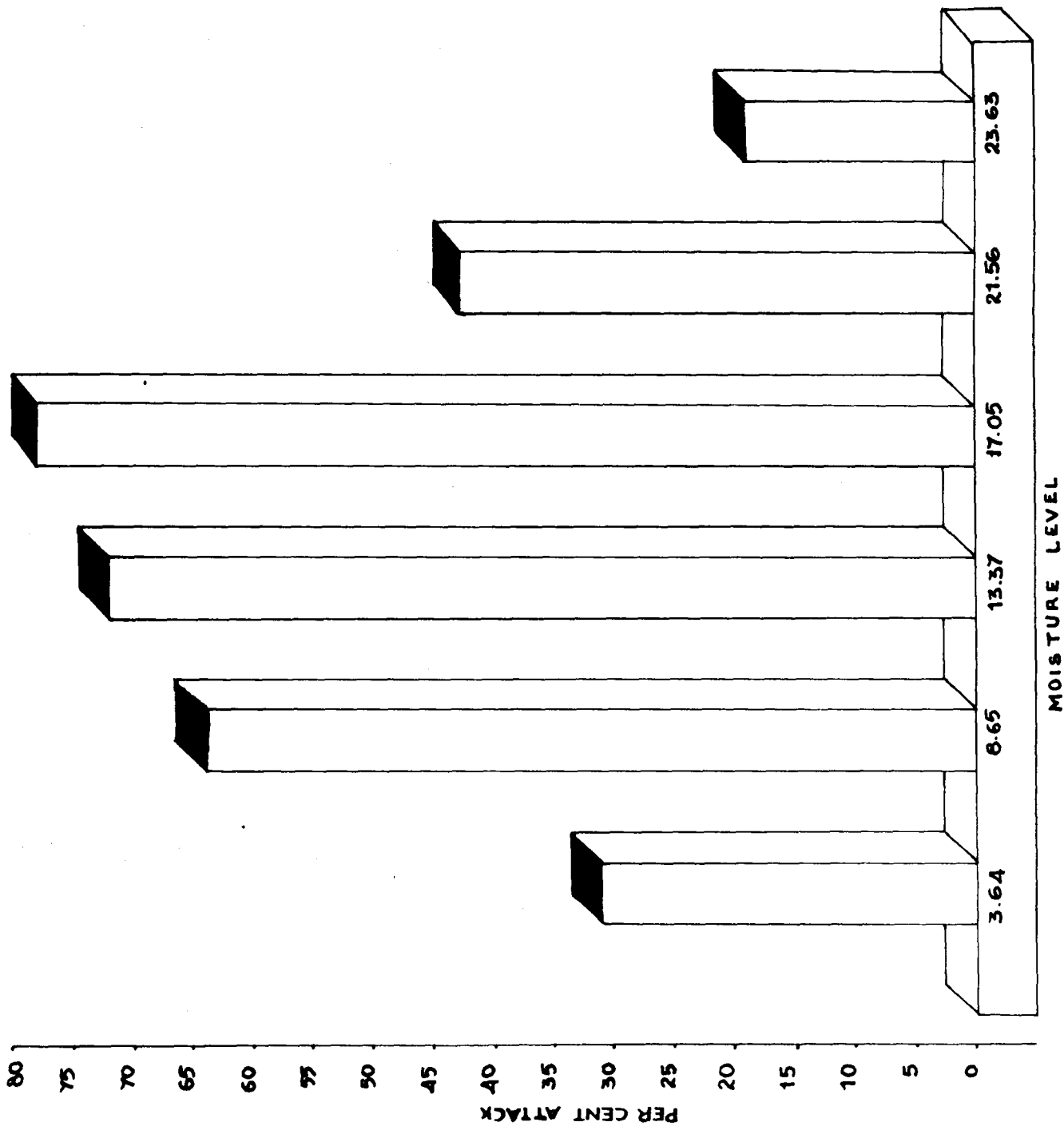


FIG.10 PER CENT ATTACK OF DUNG PADS AT DIFFERENT MOISTURE LEVELS IN THE SOIL .

Table VII. Effect of watering on the termite activity in the coconut plant basins at M.R.S. Hebbal

Sl. No.	Manures used	Total No. of coconut plants	Coconut plants without watering		Total No. of coconut plants	Coconut plants with watering	
			No. of coconut plants attacked	Per cent attack		No. of coconut plants attacked	Per cent attack
1.	Dry dung	10	10	100	10	8	80
2.	FYM	10	8	80	10	5	50
3.	FYM + ash (8:1)	10	-	-	10	-	-
4.	Biogas slurry	10	2	20	10	-	-
5.	Leaf litter	10	10	100	10	6	60
6.	Control (check)	10	9	90	10	5	50

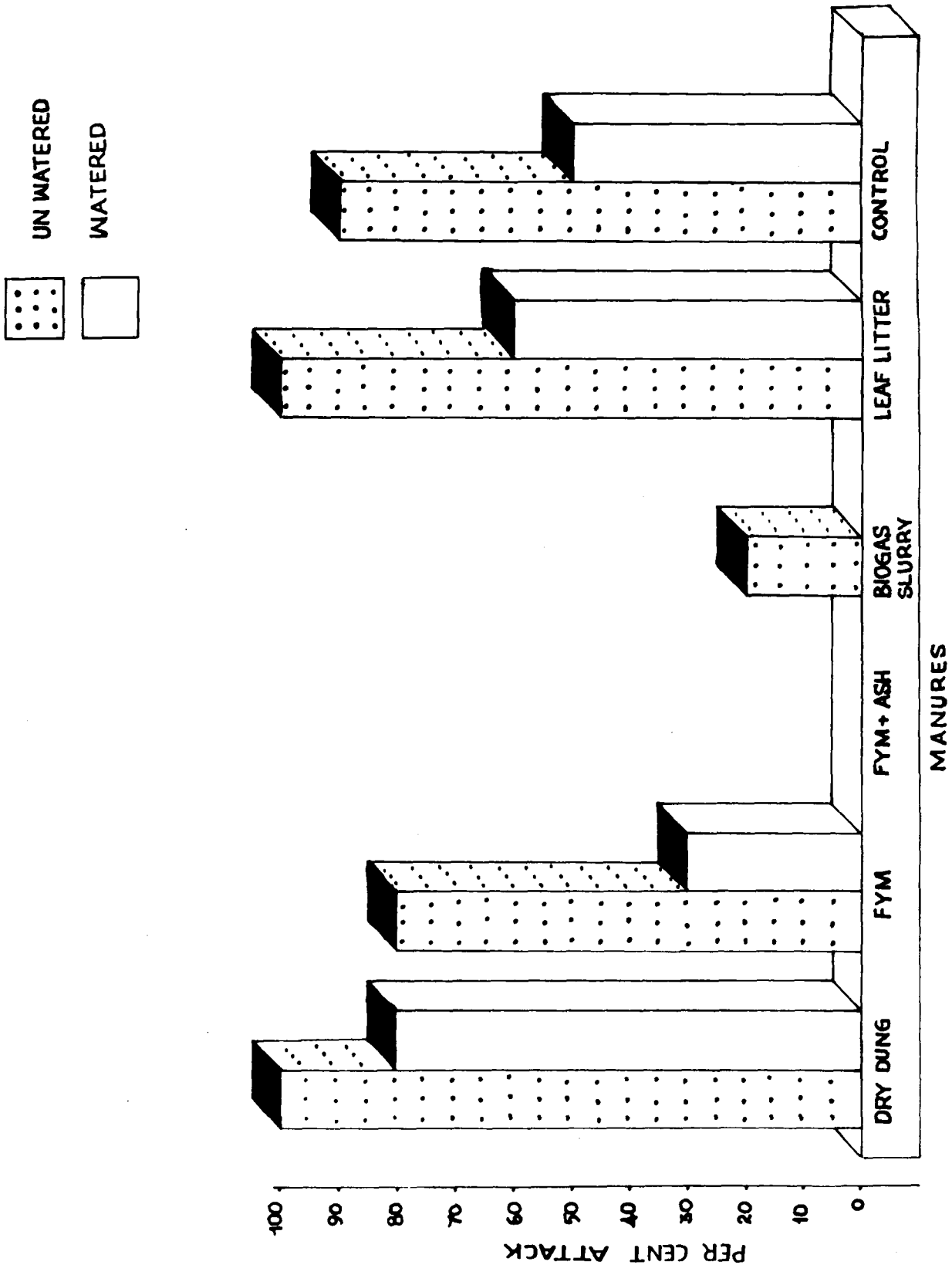


FIG. 11 EFFECT OF WATERING ON THE TERMITE ACTIVITY IN THE COCONUT PLANT BASINS.

Fig.11. The coconut plant basins received dry dung and leaf litter regularly every year as source of manure in the natural conditions. It was evident from the table, that all the plants were attacked by termites, under unwatered conditions. Whereas in the watered condition, the per cent attack was reduced to 80 and 60 per cent in cowdung (Fig.12) and leaf litter applied plants, respectively.

The per cent attack of coconut plants was reduced from 80 per cent to 30 per cent from unwatered plants to watered plants at 4 days interval. There was no attack on coconut plants applied with FYM + ash (8:1) under both watered and unwatered conditions. In biogas slurry applied plants only 20 per cent attack was noticed under unwatered conditions compared to watered condition, where there was no incidence of termites. Ninety per cent attack was noticed in control plants without watering (Fig.13) and manure compared to 50 per cent attack in plants with watering and without manure (as check for watered plants).

4.6 Termite infestation of different baits at various depths in the soil

The data given in the Table VIII indicated that all the baits were eaten by termites at surface level with cent per cent attack in both cowdung and leaf litter followed by FYM (90%), cowdung + ash (25%), FYM + ash (10%). Similarly,

Fig.12 Termite attack on the dung and base of the coconut plant under watered condition

Fig.13 Termite attack extended on the coconut plant in the absence of manure under unwatered condition



Fig.12



Fig.13

Table VIII. Termite infestation to different baits at various depths in the soil.

Sl. No.	Depth (cm)	No. of condung baits attacked	Per cent attack	No. of condung+ ash baits attacked	Per cent attack	No. of FYM baits attacked	Per cent attack	No. of FYM+ ash baits attacked	Per cent attack	No. of leaf litter baits attacked	Per cent attack
1	0.0m	20	100	5	25	18	90	2	10	20	100
2	7.5	20	100	2	10	15	75	1	5	20	100
5	15	17	85	-	-	7	35	-	-	13	65
4	30	7	35	-	-	4	20	-	-	6	30
5	45	1	5	-	-	-	-	-	-	2	10
6	60	-	-	-	-	-	-	-	-	-	-

all the baits were attacked by termites with maximum in cowdung (100%) and leaf litter (100%) followed by FYM (75%), cowdung + ash (10%) and FYM + ash (5%) at 7.5 cm depth of soil. In 15 cm depth cowdung (85%), leaf litter (65%) and FYM (35%) and at 30 cm depth cowdung (35%), leaf litter (30%) and FYM (20%) were attacked. In 45 cm depth, only leaf litter (10%) and cowdung (5%) attack was noticed. But there was no attack of termites to any of the baits at 60 cm depth.

4.7 Preference of baits and their loss by termites

4.7.1. Preference of baits

The preference of termites to various baits is presented in Table IX. According to the Table, the cowdung was the most preferred bait with cent per cent attack and 183.8 mean termite population per 628 cc of sample followed by FYM, leaf litter and cowdung + mound soil with 107.11, 100.70 and 100.14 mean termite population per sample respectively. Biogas slurry with 50 per cent attack and 76.8 mean termite population, cowdung + ash with 25 per cent attack and 21.0 mean termite population, FYM + ash with 25 per cent attack with no termite activity while drawing these samples was noticed.

4.7.2. Assessment of loss and depletion of organic carbon

The contents of the Table IX clearly indicate that

Table IX. Preference of various baits to termites and their per cent loss due to them.

Sl. No.	Bait	Per cent attack by termites	Per cent organic carbon in protected baits	Per cent organic carbon in the unprotected baits	Per cent loss	Termite population/628 cc of sample (mean)
1.	Farm yard manure	100	11.575	4.920	68.1209	107.11
2.	Farm yard manure + Ash (8:1)	25	9.870	9.200	19.2502	*
3.	Cowdung (Fresh)	100	38.520	2.557	97.0742	185.80
4.	Cowdung + Ash (8:1)	25	24.195	18.954	26.7527	21.0
5.	Cowdung + mound soil (8:4)	100	8.272	3.977	66.7915	100.14
6.	Biogas-slurry (fully digested)	50	15.100	10.580	38.0794	76.8
7.	Leaf litter (partially decomposed)	100	18.29	8.36	61.0169	100.7

* There was no termite activity while sampling.

the loss of baits in the ascending order was cowdung (97.07%), FYM (68.12%), cowdung + mound soil (66.79%), leaf litter (61.01%), biogas slurry (38.07%), cowdung + ash (26.73%), FYM + ash (19.25%) which have been graphically represented in the form of histogram along with per cent organic carbon in the protected and unprotected baits which was used in the determination of loss in each bait (Fig.14).

The contents of the Table X has clearly indicated that there was reduction in organic carbon content in all the treatments. The extent of reduction in nutrients was more in case of unprotected treatment from termites compared to protected treatments. The maximum depletion of per cent organic carbon was noticed in unprotected fresh dung (T_8) and least in protected FYM + ash (T_3) treatments.

Comparison of mean organic carbon content in the treatments in the beginning of the experiment with that of end of the experiment in each treatment separately indicated the significant reduction in the per cent organic carbon. The statistical analysis (Table X) has proved that difference between the two means in protected cowdung (T_5), cowdung + ash (T_7) and in unprotected FYM (T_2), FYM + ash (T_4), cowdung (T_6), cowdung + ash (T_9), cowdung + mound soil (T_{10}) and leaf litter (T_{14}) was highly significant. The difference between two means in protected FYM (T_1), FYM + ash (T_2), biogas

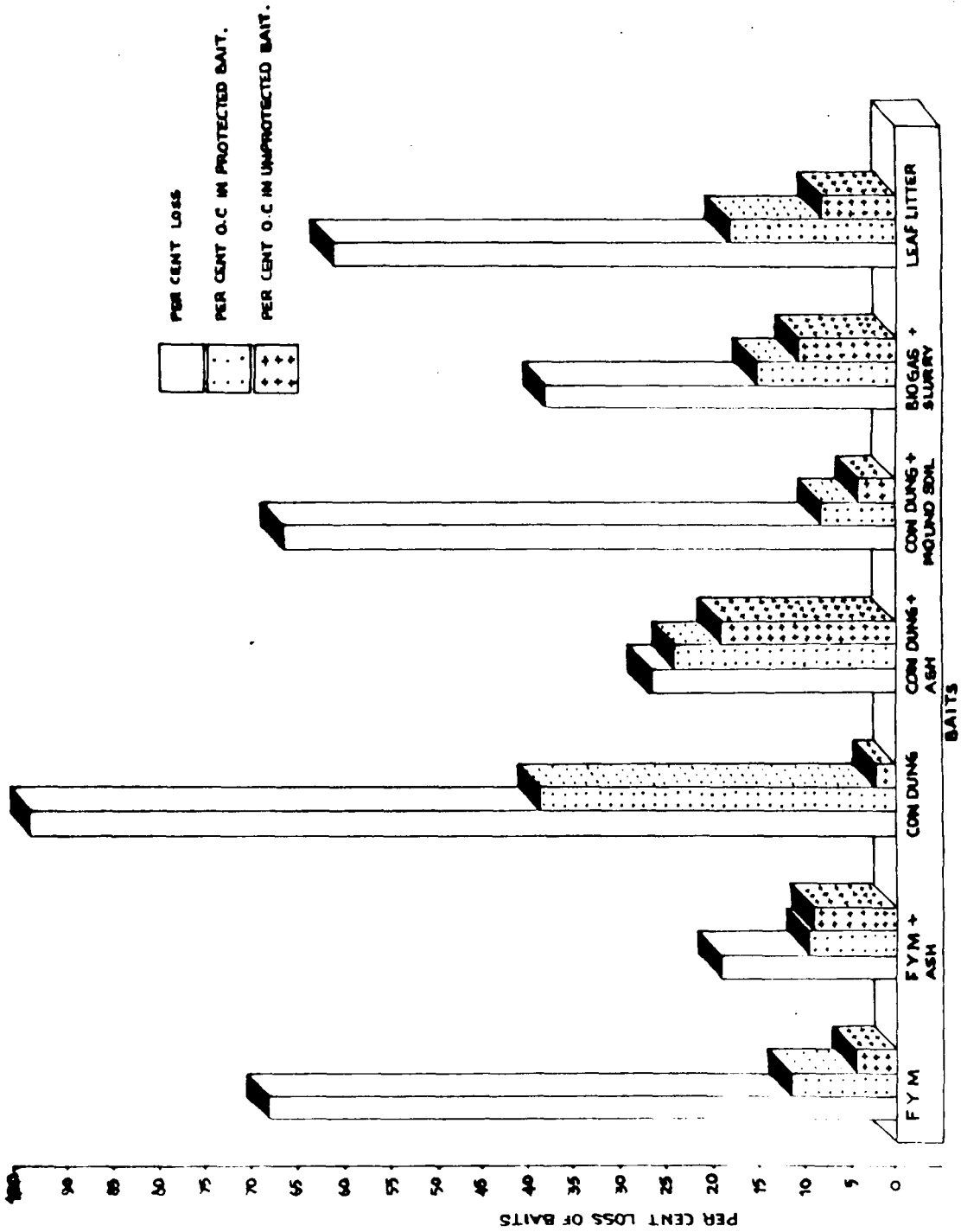


FIG. 14 PER CENT LOSS OF DIFFERENT BAITS BY TERMITES.

Table X. Student 't' test for depletion of organic carbon in different treatments.

Treatment	Per cent organic carbon at the beginning of the experiment (Mean)	Per cent organic carbon at the end of the experiment (Mean)	Depletion of per cent organic carbon	Student 't' value
T ₁	12.750	11.575	1.175	3.61*
T ₂	12.750	04.920	7.830	24.28**
T ₃	10.165	9.870	0.295	4.25*
T ₄	10.165	9.200	0.965	26.80**
T ₅	41.890	38.520	3.370	6.82**
T ₆	41.890	2.357	39.533	59.40**
T ₇	26.125	24.195	1.930	7.18**
T ₈	26.125	18.957	7.168	28.51**
T ₉	9.610	8.272	1.338	3.12
T ₁₀	9.610	3.977	5.632	49.74**
T ₁₁	17.030	15.100	1.930	4.19*
T ₁₂	17.030	10.580	6.450	3.46*
T ₁₃	19.540	18.290	1.250	6.95**
T ₁₄	19.540	8.360	11.180	12.39**
T ₁₅	1.230	1.230	-	-

Table 't' at .05 - 5.182 ** - Significant at 1%
 .01 - 5.841 * - Significant at 5%

slurry (T_{11}) treatments was significant, whereas in protected fresh dung + mound soil (T_9) it was non-significant.

4.7.3 Depletion of per cent K_2O content

The difference between per cent K_2O (mean) content at the beginning of the experiment and at the end in each treatment indicated the significant reduction in the per cent K_2O content. The statistical student 't' test (Table XI) has proved that the difference between two means in unprotected cowdung (T_6), cowdung + mound soil (T_{10}) and leaf litter (T_{14}) was highly significant. The difference between two means in protected cowdung + mound soil (T_9), leaf litter (T_{13}) and in unprotected biogas slurry (T_{12}) was significant, whereas in protected FYM (T_1), FYM + ash (T_2), cowdung (T_5), cowdung + ash (T_7), biogas slurry (T_{11}) and unprotected FYM + ash (T_4), cowdung + ash (T_8) was non-significant.

4.7.4 Change in the per cent P_2O_5 content

The difference between per cent P_2O_5 content at the beginning of the experiment and at the end under each treatment separately indicated the change in the per cent P_2O_5 . Statistical student 't' test (Table XII) has proved that the difference between the two means in unprotected FYM (T_2),

Table XI. Student 't' test for depletion of per cent K_2O content in different treatments.

Treatment	Per cent K_2O at the beginning of the experiment (Mean)	Per cent K_2O at the end of the experiment (Mean)	Depletion in K_2O content	Student 't' value
T ₁	0.6257	0.6074	0.0183	1.7085
T ₂	0.6257	0.4000	0.2257	8.9680**
T ₃	1.3237	1.2750	0.4870	2.6557
T ₄	1.3237	1.2640	0.0597	0.9000
T ₅	0.8736	0.8058	0.0678	2.2959
T ₆	0.8736	0.3572	0.5165	25.2428**
T ₇	1.4866	1.4741	0.0125	0.1536
T ₈	1.4866	1.4382	0.0484	0.9234
T ₉	0.6605	0.6025	0.0580	3.6793*
T ₁₀	0.6605	0.4653	0.1952	11.3012**
T ₁₁	0.7725	0.7215	0.0510	2.7132
T ₁₂	0.7725	0.5398	0.2327	3.3503*
T ₁₃	0.4533	0.4440	0.0093	4.6360*
T ₁₄	0.4533	0.2665	0.1868	34.0075**
T ₁₅	0.3910	0.3910	-	-

Table 't' at .05 - 3.182, ** - Significant at 1%
 .01 - 5.841, * - Significant at 5%

Table XII. Student 't' test for change in the per cent P_2O_5 content in different treatments

Treatment	Per cent P_2O_5 at the beginning of the experiment (Mean)	Per cent P_2O_5 at the end of the experiment (Mean)	Change in P_2O_5	Student 't' value
T ₁	0.2954	0.2940	0.0014	0.2872
T ₂	0.2954	0.2498	0.0456	8.2790**
T ₃	0.2042	0.2134	0.0092	0.3300
T ₄	0.2042	0.2040	0.0002	1.0690
T ₅	0.2534	0.2510	0.0026	2.2532
T ₆	0.2536	0.1658	0.0878	40.4000**
T ₇	0.2355	0.2352	0.0003	0.7600
T ₈	0.2355	0.2248	0.0107	17.6917**
T ₉	0.2319	0.2256	0.0063	0.2300
T ₁₀	0.2319	0.2270	0.0049	13.6795**
T ₁₁	0.2939	0.2931	0.0008	1.9694
T ₁₂	0.2939	0.2513	0.0426	10.4478**
T ₁₃	0.2934	0.2328	0.0606	0.8846
T ₁₄	0.2334	0.2044	0.0290	45.9500**
T ₁₅	0.0116	0.0116	-	-

Table 't' at .05 - 3.182, ** - Significant at 1%
 .01 - 5.841, * - Significant at 5%

cowdung (T_8), cowdung + ash (T_9), cowdung + mound soil (T_{10}) biogas slurry (T_{12}) and leaf litter (T_{14}) was highly significant, whereas in protected FYM (T_1), FYM + ash (T_3), cowdung (T_5), cowdung + ash (T_7), cowdung + mound soil (T_9), biogas slurry (T_{11}), leaf litter (T_{13}) and in unprotected FYM + ash (T_2) was non-significant.

4.8 Rate of removal of dung and FYM by termites

The per cent removal of dung and FYM by termites at different intervals are presented in Table XIII. Graphical representation of per cent rate of removal of dung and FYM is also shown in the form of histogram (Fig.15). According to the contents, the per cent rate of removal of dung was significantly higher than treated dung where there was no activity of termites. The removal rate of dung after 7, 15, 30, 45 and 60 days were significantly different from each other. Though highest removal of dung was observed in treatment T_8 (120 days), but it was on par with earlier treatments T_6 (60 days) and T_7 (90 days) with least per cent rate of removal. It is also evident from the Table XIII that there was a steep increase in the per cent rate of removal per day on 45th day (T_5) compared to earlier treatments.

The per cent rate of removal of FYM was significantly

Table XIII. Rate of removal of dung and FIM by termites at different intervals.

Sl. No.	Sampling interval (days)	Per cent removal of dung	Per cent rate of removal of dung per day	Per cent removal of FIM	Per cent rate of removal of FIM per day
1	Control (T ₁)	0.022 (0)	-	0.0065 (0)	-
2	7 (T ₂)	12.73 (5.01)	0.71	10.86 (3.80)	0.54
3	15 (T ₃)	22.92 (16.19)	1.59	19.48 (9.50)	0.61
4	30 (T ₄)	40.70 (42.65)	1.76	25.12 (19.36)	0.65
5	45 (T ₅)	61.94 (77.49)	2.32	30.67 (31.54)	0.81
6	60 (T ₆)	79.02 (96.35)	1.25	45.69 (51.26)	1.31
7	90 (T ₇)	80.60 (97.15)	0.02	53.92 (65.34)	0.46
8	120 (T ₈)	80.73 (97.38)	0.007	54.86 (66.90)	0.052

F-test	**	**
C.D. at (5%)	2.35	4.37
C.D. at (1%)	3.08	5.73
SEM \pm	0.85	1.58
CV %	6.93	8.17

Figures within the parenthesis are original values.
Data were analysed using angular transformation.

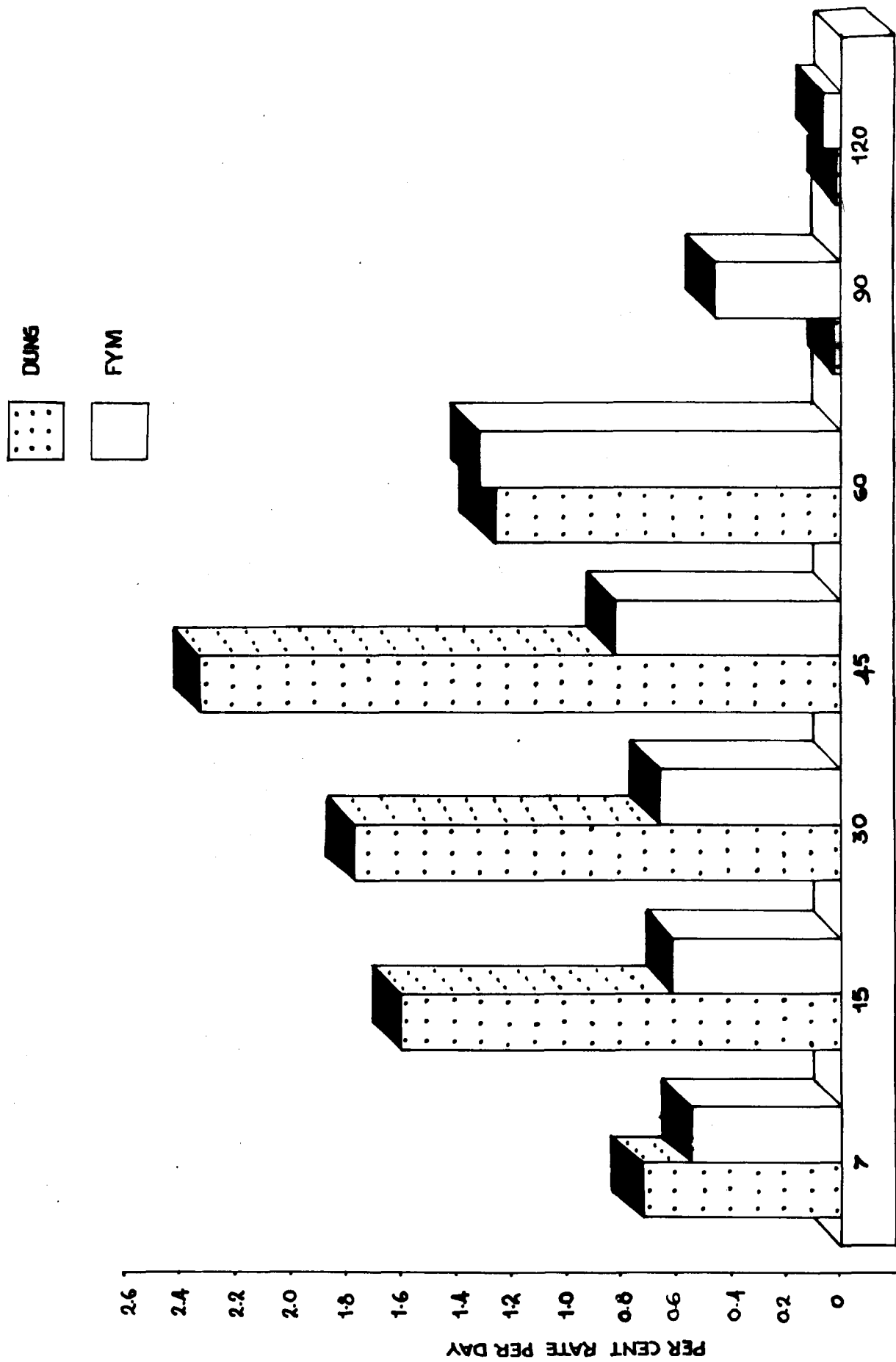


FIG.15 PER DAY RATE OF REMOVAL OF DUNG AND FYM BY TERMITES AT DIFFERENT INTERVALS.

higher than treated FYM where there was no termite activity (Table XIII). The per cent removal of FYM after 7, 12, 30, 45 and 60 and 90 days were significantly different from each other. The highest per cent removal was found in treatment T₈ (120 days) which was on par with treatment T₇ (90 days). The least per cent removal was observed in the treatment T₂ (7 days). There was a steep increase in the per cent rate of removal per day on 60th day.

4.9 Physical and chemical properties of termite modified soil in place of dung

4.9.1 Physical properties

The data on physical properties of termite modified soils in place of dung of Q. horni, Q. obesus, Q. wallonensis and surrounding soils are presented in Table XIV.

Gravel:

From the data, it is evident that the gravel is absent in Q. obesus modified soil in place of dung. The gravel content in the Q. horni, Q. wallonensis and surrounding soils were of the magnitude of 1.65, 0.74 and 3.9 per cent respectively.

Coarse sand:

The coarse sand content in the Q. horni, Q. obesus

Table XIV. Physical properties of termite modified soil in place of dung (Expressed in percentage/otherwise stated)

Sl. No.	Characteristics	Termite soil			Surrounding soil (Mean)
		<i>Odontotermes horni</i> (Mean)	<i>O. obesus</i> (Mean)	<i>O. wallonensis</i> (Mean)	
1.	Gravel	1.65	-	0.74	3.9
2.	Coarse sand	46.25	27.25	43.25	53.75
3.	Fine sand	31.85	36.00	33.00	25.52
4.	Silt	7.50	14.50	10.30	7.50
5.	Clay	12.50	20.00	12.70	11.50
6.	Apparent specific gravity (G_m/cm^3)	1.73	1.51	1.64	1.74
7.	Absolute specific gravity (G_w/cm^3)	2.40	2.72	2.43	2.58
8.	Total pore space	61.12	72.32	65.87	53.16
9.	Maximum water holding capacity	36.27	51.68	39.62	34.51
10.	Volume expansion	3.59	5.05	4.53	2.36

and Q. wallonensis termite modified soil in place of dung was 46.25, 27.25 and 43.25 per cent, respectively whereas in the surrounding soil it was 53.75 per cent.

Fine sand

Fine sand content in the Q. horni, Q. obesus and Q. wallonensis modified soil was 31.85, 36.00 and 33.00 per cent, respectively whereas in surrounding soil it was 25.52 per cent.

Silt

The silt content of Q. obesus and Q. wallonensis modified soil was 14.50 and 10.30, respectively. The silt content of the Q. horni modified soil and surrounding soil did not differ and it was only with 7.5 per cent.

Clay

The clay content of Q. obesus was more compared to other two termite modified soils and surrounding soil. It was 12.50, 20.0, 12.70 and 11.50 per cent, respectively in Q. horni, Q. obesus, Q. wallonensis and surrounding soil.

Apparent specific gravity

Apparent specific gravity of termite modified soil was lower than the surrounding soils but there was not much

difference between the modified soils of Q. horni and surrounding soil. The apparent specific gravity of Q. horni, Q. obesus, Q. wallonensis and that of surrounding soil was 1.73, 1.51, 1.64 and 1.74 g/cm³, respectively.

Absolute specific gravity

Absolute specific gravity was slightly higher in Q. obesus modified soil compared to other soils. The absolute specific gravity of Q. obesus, Q. horni, Q. wallonensis and surrounding soil was 2.72, 2.40, 2.43 and 2.58 gm/cm³, respectively.

Total pore space

Total pore space is higher in termite modified soil than the surrounding soil. Among termite modified soil more pore space was noticed in Q. obesus compared to other two species. The termite modified soil by Q. horni was having lower pore space compared to other two. The pore space of Q. horni, Q. obesus, Q. wallonensis and surrounding soil was 61.12, 72.32, 65.87 and 53.16 per cent, respectively. Maximum water holding capacity of termite modified soil was relatively greater than surrounding soil. Among termites modified soils the maximum water holding capacity of Q. obesus soil was greater compared to Q. horni and Q. wallonensis. The maximum water holding capacity of Q. horni, Q. obesus,

Q. wallonensis and surrounding soil was 36.27, 51.68, 39.62 and 34.51 per cent, respectively.

Volume expansion

Volume expansion of soils worked by Q. horni, Q. pbesus, Q. wallonensis was 3.59, 5.05 and 4.53 per cent as compared to surrounding soil which was 2.36 per cent. In Q. pbesus modified soil greater volume expansion was noticed compared to other two termite modified soils. Relatively greater volume expansion was found in termite modified soils compared to surrounding soil.

4.9.1 Chemical properties

The data on chemical properties of termite modified soils in place of dung and surrounding soil are presented in Table XV.

pH:

The pH of termite modified soils was greater than surrounding soil (6.2). Among the termite modified soils by Q. horni and Q. wallonensis had pH 7.32 and 7.16, respectively whereas in the Q. pbesus it was 6.70.

Electrical conductivity

The electrical conductivity of termite modified

Table XV. Chemical properties of termite modified soil in place of dung.

Sl. No.	Characteristics	Termite soil			Surrounding soil (Mean)
		<i>O. tototermes borni</i> (Mean)	<i>O. obesus</i> (Mean)	<i>O. wallonensis</i> (Mean)	
1.	pH (1:2)	7.32	6.70	7.16	6.20
2.	Electrical conductivity mhos/cm	0.35	0.20	0.25	0.05
3.	Organic carbon (%)	1.77	2.59	3.32	1.18
4.	Organic matter (%)	3.05	4.46	3.99	2.03
5.	Available nitrogen (%)	0.072	0.086	0.084	0.020
6.	Total nitrogen (%)	0.216	0.258	0.252	0.091
7.	C/N ratio	8.19	10.03	9.20	12.96
8.	Exch. calcium (me/100 g)	3.45	6.3	5.55	2.40
9.	Exch. Mg (me/100 g)	2.25	2.35	2.60	0.70
10.	Exch. K (me/100 g)	0.92	0.97	0.94	0.28
11.	Exch. Na (me/100 g)	0.76	0.63	0.71	0.44
12.	CEC (me/100 g)	19.4	30.6	27.30	4.70
13.	Available phosphorous (ppm)	2.86	3.07	2.95	1.18

soil was greater than the surrounding soil. The electrical conductivity of termite modified soil of Q. obesus, Q. horni and Q. wallonensis was 0.20, 0.35 and 0.25 mmhos/cm, respectively whereas in case of surrounding soil it was 0.05 mmhos/cm.

Organic carbon and organic matter

The organic carbon content in the termite modified soil was greater than surrounding soil. The organic carbon content in Q. horni, Q. obesus and Q. wallonensis was 1.77, 2.59 and 2.32 per cent, respectively whereas in the surrounding soil it was 1.18 per cent. Organic matter content in the termite modified soil was greater compared to surrounding soil. The organic matter content of Q. horni, Q. obesus and Q. wallonensis was 3.05, 4.46 and 3.99 per cent, respectively whereas in case of surrounding soil it was 2.03 per cent.

Available nitrogen

The available nitrogen content was greater in the termite modified soil compared to surrounding soil. The available nitrogen content in the Q. horni, Q. obesus and Q. wallonensis was 0.072, 0.086 and 0.084 per cent, respectively compared to surrounding soil which was 0.02 per cent. Moderately higher nitrogen content was observed in all termite modified soils with maximum in Q. obesus.

Total nitrogen

Same trend was observed in total nitrogen content in all termite modified and surrounding soils as observed in the available nitrogen.

C/N ratio

C/N ratio of termite modified soil was low compared to surrounding soil. It recorded 8.19, 10.03, 9.20 and 12.96 per cent in Q. horni, Q. obscurus, Q. wallonensis and surrounding soils, respectively.

CEC

Cation exchange capacity of termite modified soil was greater than surrounding soil. CEC was greater in Q. obscurus compared to Q. horni and Q. wallonensis modified soil. Lowest CEC was observed in Q. horni.

Exchangeable cations

Exchangeable calcium, magnesium, potassium and sodium content in the termite modified soils was greater than the surrounding soil. The exchangeable calcium content in Q. obscurus, Q. horni and Q. wallonensis was 6.3, 3.45 and 5.55 me/100 g respectively, whereas in surrounding soil it was 2.40 me/100 g.

The exchangeable magnesium content in the Q. horni, Q. obesus and Q. wallonensis soil was 2.25, 2.35 and 2.60 me/100 g, respectively compared to surrounding soil which was 0.70 me/100 g.

The exchangeable potassium content in the Q. horni, Q. obesus and Q. wallonensis soil was 0.92, 0.97 and 0.94 me/100 g whereas in surrounding soil it was 0.28 me/100 g.

The exchangeable sodium content in the Q. horni, Q. obesus and Q. wallonensis modified soil was 0.76, 0.63 and 0.71 me/100 g, respectively compared to surrounding soil which was 0.44 me/100 g.

Available P_2O_5

Available phosphorous content in the termite modified soil was greater compared to surrounding soil. The available P_2O_5 content in the Q. horni, Q. obesus and Q. wallonensis was 2.86, 3.07 and 2.95 ppm respectively whereas in case of surrounding soil it was 1.18 ppm.

DISCUSSION

CHAPTER V

DISCUSSION

An attempt has been made to study the importance of termites in relation to the cattle dung and other organic matter under dryland conditions during 1982-84 at the University of Agricultural Sciences, Bangalore.

Termites play an important role in the depletion of nutrient content of the soil by feeding important manures like dung, FYM, leaf litter, root stubbles and humus under covered earthen sheeting and converting them into heaps of mud.

Animal dung formed an important component of farm yard manure and it is one of the major sources of nutrients for plant growth among several types of organic matter supplemented to the soil to maintain fertility status under dryland conditions in India. As a result of continuous feeding by termites on the dung and other organic matter, the fertility status and physical condition of the soil is highly hampered for the plant growth. Therefore, the present study was aimed to understand the important species of dung feeding termites in and around Bangalore; foraging behaviour of dung feeding termites; seasonal incidence of different

termite species associated with dung; and their interaction with dung beetles; effect of soil moisture and different soil depths on the activity of termites; preference of baits, assessment of loss and rate of removal of dung and FYM by termites, physico-chemical properties of termite modified soil. The results of these findings are discussed here under.

5.1 Survey and collection of dung feeding termites

Among the fourteen species of termites collected around Bangalore, two species viz., Odontotermes bellahunisensis and O. wallonensis were reported earlier as dung feeders (Rajagopal, 1983). The remaining twelve species were reported for the first time on dung and FYM from Bangalore. These are Heterotermes sp., Microserotermes sp., Macrotermes estherae, Dicuspiditermes fletcheri, O. ceylonicus, O. fess., O. horni, O. obsus, O. redemanni, Microtermes obesi, Speculitermes sinalensis and Trinervitermes bifurcatus.

Rasalingappa (1971) observed cowdung in the stored food of Dicuspiditermes incola and Speculitermes ovlops in Dharwad. Rajagopal (1983a) also reported Eurytermes sp., S. sinalensis Roonwal and Sen-Sarma, D. incola (Wasmann), Pericapritermes ceylonicus (Hulagren), O. brunneus (Hagen), O. obsus (Hambur), O. redemanni (Wasmann) as dung feeders

from different agro-climatic regions of Karnataka.

Similarly, Moonwal (1970) recorded Anitermes sp; Tremotermes dehraduni Moonwal and Sen-Sarma, S. sinhalensis, Microtermes mycophagus (Desneux) and Q. obesus feeding on dung from different parts of India.

Apart from Cattle dung Q. wallonensis on Sheep pellets Q. bellahunisensis on Horse dung Q. horni on both Horse and Elephant dung, Q. obesus on Horse, Elephant dung Sheep pellets were observed in the present study. Similarly, Ferrar and Watson (1970) recorded 46 species of termites on the dung of Kangaroo, Wombat, Camel, Cattle and Sheep in Australia.

5.2 Foraging behaviour of dung feeding termites

Observations on the foraging activity of important dung feeding termites were made in the present investigation. The species foraging on dung pads without constructing any earthen sheeting include Heterotermes sp. Microcerotermes sp. Speculitermes sinhalensis, Dicospiditermes fletcheri, Microtermes obesi, Trinervitermes biformis and Macrotermes estherae. The nests are found to be subterranean in these species.

Except in Speculitermes sinhalensis, both workers and soldiers were involved in foraging activity in all species observed in the present study. In case of S. sinhalensis only workers were involved in foraging. The soldiers of both D. fletcheri and M. estherae were found to produce rattling noise as a defensive mechanism while foraging outside.

Other species like Odontotermes bellahunisensis, O. ceylonicus, O. fagei, O. horni, O. obsus, O. redemanni, O. wallonensis were found to construct earthen sheeting on the dung with aggregation of various sized soil particles depending on the size of the termite species. Both workers and soldiers were involved in foraging in these species also. Moisture in the soil was found to be an important factor for the continuous activity of these termites during monsoon and post monsoon periods. In addition to dung they also fed on other organic matter like dry grass, litter and dead wood etc. Similar observations were made by Moonwal (1970) in O. obsus which foraged mainly on woody surface, debris such as twigs, dry leaves and cowdung. Rajagopal (1983b) reported that O. redemanni played an important role in degradation of leaf litter in forest areas and other organic matter like dung, woodlogs etc. in combination with micro organisms.

The increased foraging activity of Q. obesus was recorded during May to October and decreased during January to March in Bangalore, whereas Parihar (1980) found its highest foraging activity from July to September under Kajaethan conditions.

5.3 Seasonal incidence of different termite species associated with dung

Among all the dung feeding termites recorded in the present study Q. obesus was the most dominant species closely associated with dung in all the months in a year. Increased incidence of these termites was observed after first monsoon rains and continued upto the post monsoon period (October-December). However, decreased incidence was noticed in majority of the species during August perhaps may be due to heavy and continuous rainfall (20 days out of 31 days) which has hindered the termite activity. Lower incidence was noticed during the months of dry season (January-March) except there was increased incidence during February after an unusual rainfall (57 mm on 14th Feb.) during that period. According to Haverly et al. (1974), slightest amount of rain during summer months greatly increased the activity of Heterotermes aureus under Arizona (U.S.A) conditions. Similarly, Ferrar (1982) recorded the low activity during dry season and increased activity after the first rain under Australian conditions. Parihar (1980)

observed the highest activity during rainy season in the non-harvesting species of Q. obsus and Microtermes sp. whereas reverse trend was noticed in the harvesting termites, Anacanthotermes macracanthus in the desert grass land ecosystem in India. Johnson et al. (1981) also found the activity of Microtermes sp. stimulated after heavy rain and declined at the end of the wet season. On the contrary, Omalika (1981) reported that the dung was broken down quickly in the dry season, when termites were the main degradation agents than in the wet season when the fungi have played an important role under Nigerian conditions.

5.4 Incidence of dung beetles and termites

The per cent attack of dung beetles, dung beetles and termites and termites alone at different intervals showed, that the dung beetle activity was restricted to moist dung only whereas termite attack was found minimum in the moist dung. But the activity was increased after 40th day may be attributed to the disturbance caused by the beetles and more moisture content of the dung. Similarly, Coe (1977) observed that the activity of coprophagous beetles on Elephant dung decreased as that of termites increased and also dung beetle activity was confined to moist dung in Kenya. The beetles disturbed dung pads and thus rendered termites less attractive than the undisturbed

dung. These results are in confirmation with the present findings where in the termite attack was noticed on the dung pads already disturbed by dung beetles only in the later stage. Ferrar and Watson (1970) also reported that the attack of termites on wet dung were less frequent.

5.5 Effect of soil moisture on the activity of termites

The most preferred moisture percentage of soil ranged from 15.34 to 18.45 which was evident from the per cent attack of dung pads by termites. The lower and higher content of the soil moisture than the preferred moisture were found to be unfavourable for its activity. Similarly, the observations of Hardy (1970) and Sen-Sarma and Chatterjee (1968) have shown that a soil with a moisture content of 15-20 per cent seemed to be preferred by the genus Microcerotermes and surface activity was markedly affected by moisture (Ferrar, 1982). Harris (1961) observed the open foraging ^{of} Anacanthotermes sp. ^{which} collected camel dung around water wells in southern Arabia. Similar observations were made by Weir (1971) on termite which consumed large quantities of elephant dung deposited around water holes.

The attack of termites on coconut plants applied with dried dung, FYM, FYM + ash, biogas slurry, leaf litter

was at reduced level under watered conditions and increased under unwatered conditions. This was mainly due to the frequency of disturbances caused by watering at four days interval. There was no sign of attack of termites on plants applied with FYM + ash under both watered and unwatered conditions which may be attributed to the prevention of termite activity by dehydrative nature of ash.

5.6 Termite infestation of different baits at various depths in the soil

Among five baits (cowdung, cowdung + ash, FYM, FYM + ash and leaf litter) placed at '0' to '60 cm depth in the soil. There was no difference in the attack of cowdung and leaf litter at '0' and 7.5 cm depth except in the FYM, FYM + ash and cowdung + ash where attack was decreased at 7.5 cm depth. However, termite attack on the baits was noticed upto 45 cm depth only in cowdung and leaf litter. Beyond this depth, no bait was attacked which indicated that the termites confined their subterranean galleries only in the sub soil surface upto 45 cm.

Etterbank et al. (1980) made observations on the location of baits by Opahamitermes tubiformans and Asitermes wheeleri where the surface baits were readily attacked by foraging individuals of the termites compared to baits buried in the soil which is in confirmation with the present investigation.

5.7 Preference of baits and their loss by termites

Cowdung was the most preferred bait among the several baits tried in the present study followed by FYM and leaf litter with cent per cent attack. There was significant increase of mean termite population in these baits. The least preferred bait was found to be FYM + ash with no population and presence of smaller patches of earthen sheeting might be due to abrasive and dehydrating nature of ash which hindered the activity of termites.

For the first time the qualitative and quantitative loss of various baits were estimated by developing a technique, considering per cent organic carbon in the protected and unprotected baits and surrounding soil which was used as correction factor. The per cent loss of seven baits ranged from 19.25 to 97.07 per cent. The maximum loss was recorded in the cowdung followed by FYM, cowdung+mound soil, leaf litter, biogas slurry, cowdung + ash and FYM + ash. Rajagopal and Veeresh (1983) found maximum loss of root stubbles in sunflower and the least in the finger millet.

The qualitative loss of different baits was estimated by considering depletion of important plant nutrients like organic carbon, P_2O_5 and K_2O . The organic carbon content in the protected baits from termites was significantly higher than the unprotected baits. The depletion of organic

carbon content in unprotected baite from termites was maximum in the cowdung followed by leaf litter and least was recorded in the unprotected FYM + ash. There was slight depletion of per cent organic carbon in baite protected from termites, may be attributed due to extraneous weather factors.

The per cent K_2O content of the protected baite was significantly higher than the unprotected baits. Under unprotected treatments the highest per cent K_2O depletion was recorded in cowdung followed by biogas slurry and least was observed in the cowdung+ash. There was little depletion of K_2O content in the protected treatments may be due to weather factors.

The per cent P_2O_5 content of the unprotected bait was significantly lower than the protected baite. The highest of per cent P_2O_5 was recorded under unprotected cowdung and it was lowest under unprotected FYM + ash. There was little depletion of per cent P_2O_5 content in all the protected baits except FYM + ash treatment in which there was slight increase in P_2O_5 content attributed due to washing of ash by rain leaving the mixture of FYM and little ash. The present findings are in broader agreement with the reports of Okwakol (1980), that the consumption of organic matter by termites was attributed to a decrease in the organic content which has a deleterious effect on the soil fertility. Similarly, Veeresh et al. (1982) observed higher content of organic carbon and available potash in the soil sampled from the plots treated with cowdung, soft wood, grass and protected from termite attack

compared to the plots subjected for termite attack which is also in confirmation with the present study. In contrast to present investigation they also found increased phosphorous content in the unprotected plots compared to protected.

The findings of the Hajagopal and Veeresh (1983) with regard to the loss of nutrients in maize root stubbles, a loss of 0.408 kg of N, 0.214 kg of P_2O_5 and 0.438 kg of K_2O per ha was observed. Similarly, in niger, a loss of 0.178 kg N, 0.067 kg P_2O_5 and 0.223 kg K_2O per ha and sunflower with 0.014 kg of N, 0.046 kg P_2O_5 and 0.137 kg of K_2O per ha was observed. The loss of NPK was considerable, in addition to depriving the only natural organic matter available to the dry land fields which is on par with the present investigations on the loss of seven baits. Most of the termite species carry food materials (Organic matter) to their nest thus immobilizing nutrients in their nest.

5.8 Rate of removal of dung and FYM by termites

Gradual increase in the rate of removal of dung was observed from 7th to 45th day, and decreased from 60th day. This rate of removal was directly related to the activity and population of termites along with availability and condition of the food (dung). The highest rate of removal per day was found on 45th day (2.32%) and the lowest on 120th day (0.0077). Decreased activity on 7th and 15th day may be

attributed to the higher moisture content of the dung. Decreased activity in the later stages may be due to reduced amount of food availability.

Gradual increase in the rate of removal in respect of FYM was observed from 7th day to 60th day and decreased from 90th day. The highest rate of removal per day was found on 60th day (1.31%) and the lowest on 120th day (0.052%) of observation. Decreased activity on 7th and 30th day may be due to moisture content in the FYM as well as lack of cellulose material due to decomposition, which does not attract the termites and thus decreased activity of termites was noticed. In a broader agreement with the present study Ferrar and Watson (1970) observed termites feeding on the cellulose content of dung pads, replacing it with soil in about 12 weeks. Similar observations were made by Coe (1977) on the removal of dung (4.55 litre) in about 85 days which is in confirmation with the present investigation wherein 96.35 to 97.15 per cent of the dung (6 litres) was successfully removed in about 60 to 90 days and in case of FYM (6 litres) 65.34 to 66.90 per cent was successfully removed within 90 to 120 days. Whitford (1982) recorded the rate of removal of dung by Gnathasitermes tubiformans of about 0.63 g per day accounting for a total loss of 19.5 to 100 per cent in three months.

5.9 Physico-chemical properties of termite modified soil

5.9.1 Physical properties

There was no gravel in the Q. obesus modified soil whereas in case of Q. horni and Q. wallonensis, very low per cent of gravel was noticed compared to surrounding soil. Similar observations were made by Lee and Wood (1971) on different species of Australian termites. The size of particles used may be limited by the maximum size that a worker termite can carry as it was noticed in the larger species Nasutitermes longipennis (Hill) of workers with 5 to 6 mm in length incorporated 1-3 per cent gravel in their nests. Similar findings were also observed in respect of workers of Q. horni and Q. wallonensis. They used gravel in constructing the earthen sheeting on the dung.

Coarse sand content in all the termite modified soils was comparatively lower than the surrounding soil but higher content was found in bigger species like Q. horni, whereas lower content was noticed in Q. obesus which is smallest among three species. This may be due to the fact that these species of termites are not able to carry the coarser sand particles compared to surrounding soil as reported by Lee and Wood (1971) and Banerjee and Mohan (1976), Rajagopal et al. (1982). Likewise, Jonshin and Kandiah (1940) found that the mound soil of Q. redemanni contained less

coarse sand than the surrounding soil. Fine sand content was higher in all the termite modified soils compared to surrounding soil, but the higher content was found in the smaller sized species of Q. obesus and lower content in bigger species of Q. horni. These results are in close confirmation with the findings of Lee and Wood (1971), Hesse (1955), Nye (1955), Harris (1956) and Stoops (1964). They have reported that more fine sand fraction in the termite soil where surrounding soils are rich in clay. The higher content of fine sand may be due to the fact that these termite species were able to carry this fraction for construction of earthen sheeting on the dung and galleries in the soil replaced in place of dung. On the contrary, a lower content of fine sand of fraction was observed in mound soil of Q. obesus compared to surrounding soil (Banerjee and Mohan, 1976).

The silt content of Q. obesus modified soil was greater than Q. wallonensis and surrounding soils. There was no difference in the silt content of Q. horni modified soil and surrounding soil. Except Q. horni, these results are corroborate with the findings of Banerjee and Mohan (1976), Lee and Wood (1971). Samra et al. (1979) reported higher proportion of silt in the termite soil than the surrounding soil.

Clay content in the termite modified soil was greater than surrounding soil. Among termite modified soils, highest clay content was noticed in Q. *obesus* modified soil compared to Q. *horni* and Q. *wallonensis* with slightly higher in the former soil. Similarly, higher clay content in the mounds of *Cubitermes umbratus* was reported by Kemp (1955) from Tanganyika. Joachim and Kandiah (1940) found increased clay in Q. *redemani*. Banerjee and Mohan (1976) observed greater clay in the mounds of Q. *obesus* than surrounding soil. Rajagopal et al. (1982) reported higher contents of clay in mound soils of Q. *wallonensis* and Q. *obscurus*. However, not much difference was observed in the mound soils of Q. *redemani* as compared to surrounding soils. Samra et al. (1979) recorded higher clay content in earthen galleries of Q. *wallonensis*.

The apparent specific gravity (B.D.) of termite modified soil was lower than the surrounding soil. However, not much difference was found between the modified soil of Q. *horni* and surrounding soil. Similar difference was found by Ghilarov (1962), Maldague (1964) and Rajagopal et al. (1982).

The pore space of the termite modified soils was greater than the surrounding soil. This increased pore space may be due to the presence of higher amount of organic

matter and clay. Among the termite modified soils the highest pore space was observed in modified soil of Q. obesus whereas least was in the Q. horni. The increase in organic matter and clay would add significantly to the total pore space of termite soil (Banerjee and Mohan, 1976), which is on par with the present findings wherein increased pore space may be due to left over dung portion in the termite modified soil.

Termite modified soil had higher water holding capacity than the surrounding soil perhaps due to higher organic matter and clay. Likewise studies conducted elsewhere have indicated that higher water holding capacity of the sound soil was related to organic matter (Pathak and Lehari, 1959) and clay content (Boyer, 1948). Rajagopal *et al.* (1982) reported that Q. reissmanni soil had low water holding capacity than the adjacent soil in plantation area. But soils of Q. wallonensis and Q. obesus had greater than surrounding soil in plains in Karnataka.

5.9.2 Chemical Properties

The pH of the termite modified soils (Odontotermes horni, Q. obesus and Q. wallonensis)^{was higher} than surrounding soil. Among these three termite modified soils, Q. horni modified soil was having highest pH and lowest was in the Q. obesus. Similar trend was observed by Boyer (1955), Kemp (1955),

Watson (1962). According to Sen (1944), Shrikhande and Pathak (1948), Gokhale et al. (1958) and Rajagopal et al. (1982), the increased pH is due to accumulation of calcium carbonate in the termite worked soils. In contrast, Samra et al. (1979) recorded the lower pH in the termite galleries than in the surrounding soil.

Electrical conductivity of termite modified soil was higher than the surrounding soil. Among termite modified soils greater electrical conductivity was observed in the *Q. horni* and lower EC in the *Q. obscurus*.

The findings of Lee and Wood (1971) and Rajagopal et al. (1982) were on par with the present investigations. They observed higher electrical conductivity in termite modified soil may be attributed to the organic carbon content in the termite modified soils.

Organic carbon content in the termite modified soils was greater than surrounding soils. The highest organic carbon was found in *Q. obscurus* which was attributed due to left out portions of dung in soil replaced in place of dung. Similarly, Gupta et al. (1981) reported that earthen galleries on the surface of litter and standing dead shoots contained higher content of organic carbon. In contrast, Spears et al. (1981) recorded increased organic carbon in the termite free soils.

Among these termites, the modified soil of Q. obesus replaced in place of dung was having highest nitrogen content and lowest was in Q. horni. Similarly, Gupta et al. (1981) observed higher content of nitrogen in the earthen galleries constructed on leaf litter dead shoots etc. which is in confirmation with the present investigations.

C/N ratio of termite modified soil was comparatively lower than the surrounding soil. Among modified soils Q. horni was lowest and Q. pallidus was highest. In the same way Joachim and Kandiah (1940) reported that the C:N ratio was slightly lower than the adjacent soil.

Organic matter was greater in termite modified soils than the surrounding soil. Similar reports were available from other places (Graese and Joly, 1941; Hesse, 1955; and Steops, 1964). Badawi et al. (1982) observed higher content of the organic matter in the earthen runways of Termitopsis hyostoma (Desneux), which agrees with the present findings. The increased organic matter may be attributed due to left out portions of dung in the termite modified soil.

Termite modified soils have greater content of available and total nitrogen than the surrounding soil.

Cation exchange capacity of termite modified soils was greater than the surrounding soils. Among the termite modified soils, the highest C.E.C. was observed in the modified soils of Q. obesus and lowest in the Q. horni which may be attributed due to the left over dung in the termite modified soil. Findings of Lee and Wood (1971) are in confirmation with present observations. Rajagopal et al. (1982) recorded greater CEC in the mound soils of Q. wallonensis and Q. obesus (Dharwad) compared to surrounding soil. On the contrary, they also reported the lower CEC in the mound soil of Q. redemanni (Mudigere).

The exchangeable calcium, magnesium, potassium, sodium are greater in all the termite modified soils compared to surrounding soils. Among all the modified soils highest calcium was in Q. obesus, magnesium in Q. wallonensis and sodium in Q. horni compared to surrounding soil. Highest available potash was noticed in the termite modified soil of Q. obesus which is in confirmation with the findings of Samra et al. (1979) and Rajagopal et al. (1982). Similar observations were made on higher calcium content in the termite soil (Lee and Wood, 1971; Sen, 1944; Pathak and Lehari, 1959; Banerjee and Mohan, 1976; Gupta et al. 1981) and higher magnesium content in the earthen galleries of termites (Lee and Wood, 1971; Banerjee and Mohan, 1976).

The available phosphorous content in the termite modified soils was greater than the surrounding soils. These results are in confirmity with the earlier findings of Sen (1944), Pathak and Lehri (1959) and Rajagopal et al. (1982).

SUMMARY

CHAPTER VI

SUMMARY

Investigations have been carried out during 1982-84 on the dung feeding termites in and around Bangalore; their foraging behaviour; seasonal incidence of termites associated with dung and their interaction with dung beetles; effect of moisture and different soil depths on the activity of termites; preference of baits, assessment of loss and rate of removal of dung and FYM by termites and physico-chemical properties of termite modified soil.

Studies conducted on dung feeding termites revealed fourteen species representing eight genera belonging to Rhinotermitidae and Termitidae of Isoptera. Among the dung feeding termites recorded from Bangalore, Odontotermes obesus was the most dominant species. Apart from Cattle dung O. bellahunisensis on Horse dung, O. wallonensis on Sheep pellets, O. horni on both Horse and Elephant dung, O. obesus on Horse, Elephant and Sheep dung were recorded in the present study.

The foraging behaviour of different dung feeding termites was observed on different aged dung and FYM. The species Heterotermes sp. Microcerotermes sp. Dicuspitermes

fletcheri, Speculitermes sphenalensis, Macrotermes esterhasei, Microtermes obovatus, Trinervitermes bifurcatus were found foraging directly on dung pads without constructing any earthen sheeting, whereas Odontotermes bellahuniensis, O. ceylonicus, O. fuscus, O. horni, O. obovatus, O. redemanni and O. wallonensis were found to construct clear earthen sheeting on the dung while foraging. Increased foraging activity of these species was observed during monsoon and post-monsoon periods compared to dry season.

The seasonal incidence of dung feeding termites in pasture lands of U.A.S. dairy farm and military dairy farm Hebbal and grazing land of Gandhi Krishi Vignana Kendra, Bangalore revealed that the higher incidence of dung feeding termites was observed more during monsoon and post-monsoon periods, while lower incidence was recorded during dry season. However, increased incidence was observed only in February might be due to the occurrence of unusual rainfall. Among the dung feeding termites, O. obovatus was recorded highest incidence followed by O. wallonensis in U.A.S. dairy farm as well as in military dairy farm, and O. horni in grazing land of Gandhi Krishi Vignana Kendra, Bangalore.

The per cent incidence of dung beetles was maximum on the wet dung and their attack was not noticed after 10 days. The dung pads disturbed by dung beetles were attacked by

termites only after 40 days and continued upto 90 days. The number of termites attacked dung pads were gradually increased after 20 days. The dung pads with varied per cent earthen sheeting covered were observed at different intervals in the present study.

The most preferred moisture level in the soil to attack the dung pads found to be 15.30 to 18.45 per cent. The lower and higher content of the soil moisture than the preferred one found to be unfavourable for termite activity.

The incidence of termites on coconut plants when applied with dried dung, FYM, FYM+ash, biogas slurry and leaf litter was found to be at reduced level under watered condition compared to unwatered condition. Maximum attack of termites on coconut plants was noticed in plants applied with cowdung followed by leaf litter and least was in biogas slurry and no attack in the FYM+ash.

All the baits (cowdung, leaf litter, FYM, cowdung+ash and FYM+ash) were attacked by the termites at surface level and 7.5 cm depth, with varying degree of attack ranging from 100 per cent to 10 per cent and 100 per cent to 5 per cent respectively. Cowdung, leaf litter and FYM were attacked at 15 cm and 30 cm depths with varying degree ranging from 85 to 35 per cent and 35 to 20 per cent respectively. At 45 cm

depth only leaf litter and cowdung were attacked at lower degree. There was no attack at 60 cm depth.

The most preferred bait was cowdung with cent per cent attack and highest mean termite population followed by FYM and leaf litter and least preferred bait was FYM+ash. The loss of baits and nutrients caused by termites was highest in the cowdung followed by FYM and least was observed in FYM + ash.

The maximum depletion of nutrients like organic carbon, per cent K_2O and P_2O_5 were estimated in unprotected cowdung followed by leaf litter, biogas slurry and FYM in the depletion of organic carbon per cent K_2O and P_2O_5 respectively. The depletion of nutrients was least in the unprotected FYM + ash.

The removal rate of dung gradually increased from 7th day onwards and continued to 45th day which decreased from 60th day and rate of removal was completely reduced from 90th to 120th day. The highest rate of removal per day was found on 45th day and the least on 120th day of treatment. In case of FYM, the highest rate of removal per day was on 60th day and the lowest on 120th day of the treatment.

The physico-chemical properties of Q. obscurus, Q. horni and Q. wallonensis modified soils were analysed in the present

study. The gravel and coarse sand content in the termite modified soil was lower than surrounding soil. In case of soil modified by Q. horni, the higher gravel and coarse sand content was noticed whereas absence of gravel and least coarse sand observed in Q. obscurus. However, the fine sand and silt of termite modified soil were higher in Q. obscurus than surrounding soil. Generally the clay content was greater in all these termite modified soil than surrounding soil. Among them, higher clay content was estimated in Q. obscurus and least in the Q. horni. There was increased pH, organic carbon, organic matter and total nitrogen content observed in termite modified soil than the surrounding soil. C/N ratio of termite modified soil was found lower than the surrounding soil in all the three species. The cation exchange capacity of termite modified soil in all the three species was greater than the surrounding soil. The exchangeable cations like calcium, magnesium, potassium and sodium were greater in termite modified soil of all the three species than surrounding soil. Among termite modified soils, higher calcium and potassium in Q. obscurus, magnesium in Q. wallenensis and sodium in Q. horni, were observed. The available P_2O_5 was also considerably greater in the modified soils by all the three species than surrounding soil. The highest and the lowest P_2O_5 content was estimated in Q. obscurus and Q. horni modified soils respectively.

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APPENDICES

APPENDIX I. TERMITES ASSOCIATED WITH DUNG IN VARIOUS REGIONS OF THE WORLD

Species ----- Place ----- References -----

MASTOTERMITIDAE

Mastotermes darwiniensis Froggatt. Australia Ferrar and Watson, 1970,
Gay and Calaby, 1970.

HODOTERMITIDAE

Araacanthoitermes sp. North Africa Harris, 1970.

RHINOTERMITIDAE

Heterotermes ferox (Froggatt) Australia Ferrar and Watson, 1970.

Heterotermes P. paradoxus (Froggatt) Australia Ferrar and Watson, 1970.

H.P. intermedius Hill. Australia Ferrar and Watson, 1970.

Schedorhinoitermes intermedius (Brauer) Australia Ferrar and Watson, 1970,
Gay and Calaby, 1970.

S. seciusus (Hill) Australia Ferrar and Watson, 1970.

Peanmotermes rajasthanicus
Roonwal & Bose Oriental region Roonwal and Bose, 1960.
(India)

TERMITIDAE

Amitermes sp. Oriental region Roonwal, 1970.

Amitermes abruptus Gay Australia Ferrar and Watson, 1970.

Appendix I (Continued)

Species

Place

References

<i>A. acillie</i> Gay	Australia	Ferrari and Watson, 1970.
<i>A. boreus</i> Gay	Australia	Ferrari and Watson, 1970.
<i>A. darwini</i> Hill	Australia	Ferrari and Watson, 1970
<i>A. denticatus</i> Hill	Australia	Ferrari and Watson, 1970 Gay & Calaby, 1970.
<i>A. deplanatus</i> Gay	Australia	Ferrari and Watson, 1970.
<i>A. eucalypti</i> Hill	Australia	Ferrari and Watson, 1970
<i>A. exilis</i> Hill	Australia	Ferrari and Watson, 1970.
<i>A. kernans</i> (Hill)	Australia	Ferrari and Watson, 1970, Gay & Calaby, 1970.
<i>A. gracilis</i> Gay	Australia	Ferrari and Watson, 1970.
<i>A. bartmeyerii</i> (Silvestri)	Australia	Ferrari and Watson, 1970.
<i>A. bastatus</i> (Haviland)	Eastern Islands (Ethiopian region)	Bouillon, 1970.
<i>A. lanceolata</i> Gay	Australia	Ferrari and Watson, 1970.
<i>A. latidens</i> Mjoberg	Australia	Ferrari and Watson, 1970.
<i>A. lativentris</i> Mjoberg	Australia	Ferrari and Watson, 1970, Gay & Calaby, 1970.
<i>A. laurensis</i> Mjoberg.	Australia	Ferrari and Watson, 1970.

Appendix I (Continued)

Species	Place	References
<u>A. nodicus</u> Hill	Australia	Ferrar and Watson, 1970.
<u>A. neogermannus</u> Hill	Australia	Ferrar & Watson, 1970, Gay & Calaby, 1970.
<u>A. obtusidens</u> Mjoberg.	Australia	Ferrar and Watson, 1970.
<u>A. parvus</u> Hill	Australia	Ferrar and Watson, 1970.
<u>A. peramaring</u> (Silvestri)	Australia	Ferrar and Watson, 1970.
<u>A. vitipicus</u> Hill	Australia	Ferrar and Watson, 1970.
<u>A. westraliensis</u> Hill	Australia	Ferrar and Watson, 1970.
<u>A. wheeleri</u> (Desneux)	Australia	Ferrar and Watson, 1970.
<u>A. xylophagus</u> Hill	Australia	Ferrar and Watson, 1970.
<u>A. sp. nr. br. colonus</u> Hill	Australia	Ferrar and Watson, 1970.
<u>A. sp. nr. dentosus</u> Hill	Australia	Ferrar and Watson, 1970.
<u>A. sp. nr. eucalypti</u> Hill	Australia	Ferrar and Watson, 1970.
<u>A. sp. nr. obtusidens</u> Mjoberg	Australia	Ferrar and Watson, 1970.
<u>A. sp. noelose</u> offinites	Australia	Ferrar and Watson, 1970.
<u>Acroploferes fumosus</u> (Hagen)	South Texas	Banks and Snyder, 1920.
<u>Praxipernes dehraduni</u> Roonwal and Sen-Sarma	Oriental region	Roonwal, 1970.

Appendix I (Continued)

Species	Place	References
<u>Dryitermes</u> (<u>Beesonitermes</u>) sp.	Karnataka	Rajagopal, 1983.
<u>Gnathamitermes grandis</u> (Light)	Mexico	Light, 1930
<u>G. perplexus</u> (Banks)	Mexico	Weesner, 1970
<u>G. tubifarmans</u> (Buckley)	Israel	Petershank <u>et al.</u> , 1980, Whitford <u>et al.</u> , 1982.
<u>Microcerotermes cavus</u> Hill.	Australia	Ferrar and Watson, 1970
<u>M. distinctus</u> Silvestri	Australia	Ferrar and Watson, 1970.
<u>M. nervosus</u> Hill	Australia	Ferrar and Watson, 1970.
<u>M. serratus</u> (Froggatt)	Australia	Ferrar and Watson, 1970, Gay and Calaby, 1970.
<u>Speculitermes sinhalensis</u> Roonmal and Sen-Sarma	Oriental region Karnataka	Roonmal, 1970. Rajagopal, 1983.
<u>S. cyclopes</u>	South India (Karnataka)	Basalingappa, 1971.
<u>Synhamitermes brevicorniger</u> (Silvestri)	Brazil & Argentina	Silvestri, 1903.
<u>Pleuspilitermes incola</u> (Wasmann)	South India (Karnataka)	Basalingappa, 1971; Rajagopal, 1983.
<u>D. nemorosus</u> (Haviland)	West Malaysia	Abe, 1979.
<u>Neocapritermes opacus</u> (Hagen)	Brazil and Argentina	Silvestri, 1903.
<u>Procapritermes ceylonicus</u> (Holmgren)	Hainan Island and Southern China	Harris, 1963.

Appendix I (Continued)

S p e c i e s

Place

References

Pericapritermes ceylonicus (Holmgren) Karnataka Rajagopal, 1983.

MACROTERTITINAE

Macrotermes mycophagus (Desneux) Oriental Region Moonwal, 1970.
Odontotermes obesus (Rambur) Oriental Region Moonwal, 1970.
O. brunneus (Hagen) Karnataka Rajagopal, 1983.
O. wallonensis (Wasmann) Karnataka Rajagopal, 1983.
O. redemani (Wasmann) Karnataka Rajagopal, 1983.
Nasutitermes eucalypti (Hjoberg) Australia Ferrar and Watson, 1970.
N. kumberleyensis (Hjoberg) Australia Ferrar and Watson, 1970.
N. longipennis (Hill) Australia Ferrar and Watson, 1970.
N. torresii (Hill) Australia Holt and Coventry, 1982.
Procornitermes lespesi (Muller) Australia Ferrar and Watson, 1970.
Tumulitermes comatus (Hill) Brazil and Argentina Emerson, 1952.
T. dalbiensis (Hill) Australia Ferrar and Watson, 1970.
T. dalbiensis (Hill) Australia Ferrar and Watson, 1970.

APPENDIX II

Places surveyed for the dung feeding termites
under dryland conditions in Bangalore
district

<u>Taluk</u>	<u>Locality</u>	
Anchal	Bannerghatta (National Park)	
	Kithaganahally	
Bangalore North	Allalasaandra	Hessarghatta
	Anruthahally	Hunsaranahally
	Avalahally	Jakkur
	Bagalur	Kodegehally
	Bettahalsur	Peenya
	Bystarayapura	Ramagondanahally
	Gandhi Krishi Vignana Kendra (UAS New Campus)	Thindlu
		Yelahanka
Bangalore South	Arekere	
	Banashankari	
	Gnanabharathi (Bangalore University Campus)	
	Hejjala	
	Kenchinahally	
	Kengeri	
	Madivala	
	Hayandahally	
	Yediyur	
Devanahally	Devanahally	
Hoskote	Jadigenahally	
Kanakapura	Bilidale	
Nelamangala	Nelamangala	
Ramanagara	Bidadi	

APPENDIX III: Weather data prevailing during 1983-84 at U.A.S. Main Research Station, Hebbal, Bangalore

Month	Temperature (°C)		Relative humidity (%)	Evaporation mm of (Hg)	Sunshine (hrs/day)	Rainfall (mm)
	Mean	Max. Min.				
January 1983	27.7	13.4	85	4.7	9.5	-
February	31.9	17.1	75	5.7	9.9	-
March	34.2	19.6	65	7.2	10.2	8.5
April	35.1	21.7	66	8.1	10.1	1.9
May	35.8	22.9	79	7.2	9.7	80.0
June	37.4	20.8	83	5.4	6.6	272.0
July	36.6	21.2	87	5.5	5.5	33.5
August	28.0	20.1	91	3.6	4.4	158.6
September	27.3	19.6	88	3.1	4.1	190.4
October	28.5	18.8	81	4.2	7.3	49.5
November	27.8	15.2	78	3.6	9.1	9.0
December	25.6	17.0	85	3.6	5.9	8.1
January 1984	27.2	16.5	83	4.4	7.9	-
February	27.7	17.3	84	4.5	8.7	57.6
March	31.1	17.0	76	6.1	8.9	-
April	33.4	20.9	79	6.7	9.4	30.9

APPENDIX III (Continued): Weather data prevailing during 1983-84 at Gandhi Krishi
Vignana Kendra, Bangalore

Month	Temperature (°C)		Relative humidity (%)	Evaporation mm of (HG)	Sunshine (hrs/day)	Rainfall (mm)
	Max.	Min.				
	Mean	Mean				
January 1983	28.3	12.7	57	10.1	9.3	-
February	32.7	17.0	49	10.3	10.0	-
March	34.6	20.0	47	12.3	10.6	-
April	35.2	22.3	59	16.9	10.5	7.0
May	34.5	21.8	61	16.9	7.0	102.6
June	30.7	20.0	67	16.3	6.7	169.7
July	29.8	19.8	68	15.3	5.2	77.2
August	27.8	19.4	75	16.3	3.3	163.1
September	27.3	19.4	79	16.8	4.5	162.0
October	28.3	18.4	76	16.1	5.7	69.6
November	27.8	15.6	65	13.7	9.1	-
December	25.7	16.5	71	13.5	5.7	42.4
January 1984	27.0	15.9	63	11.7	8.4	-
February	27.7	16.8	62	12.3	7.7	48.5
March	31.2	17.5	51	11.3	8.8	70.1
April	33.0	20.5	57	16.5	9.5	17.5

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