ASPECTS OF THE CHEMICAL CONCENTRATION OF *Trirervilermes geminatus* WASMANN (ISOPTERA; MATERIAL

BY

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A thesis submitted in partial fulfillment of the requirements for the decree of Master of Science in Zoology, submitted to the Postgraduate School, Ahmadu Bello University, Zaria

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AHMADU BELLO UNIVEPSITY,
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AUGUST, 1982

THESIS APPROVAL

This thesis by BAYO AYOMIKE meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University and is approved for its contribution to scientific knowledge.

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DECLARATION

I declare that this work is wholly the author's and has not been part of any presentation for any other degree.

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ACKNOWLEDGEMENT

I express my kind gratitude to Drs. C.O. Ajakaiye, J.O.D. Adegboye and C.G. Vajime for the tremendous help they rendered and for their critical study of the text, as co-supervisors of this research.

I am immensely indebted to Drs. M.K. Ahmed, of the Department of Agronomy; M.M. Kapu, of the Department of Biological Sciences; and C.E. Ohiagu, of the Department of Crop Protection; Mr. Bode Ojuola and most especially to Mr. N.A. Ogunwole, who helped me in various ways.

Many thanks to Mr. Lawal and his staff; Messrs. J. Akpeji and C. Otuonghe; Peter Badejo, Yemi Yesufu, Olufemi Peters, Ayo Osunloye, Toni Akporhonor, Tracolis Caifas and my numerous other colleagues. I am also grateful to L. Adowei and T. Aken'ova.

I must mention my indebtedness to my uncle, Dr. C. Ikomi, who was so helpful all through.

And lastly, to my parents, Mr. and Mrs. J.O.S. AYOMIKE, and to my GOD I shall even be most invaluably indebted.

AYOMIKE BABO

ZARIA. AUGUST, 1982.

ABSTRACT

This work was conducted with simples collected from the University Farm, to study the chemical compositions in *Trirervilermes geminatus* and the grass pieces in its mound. The characteristics studied were percentages of ash, organic matter, lipid, protein and carbohydrate and also calcium, magnesium, potassium, phosphorus, iron, Zinc, cobalt and copper.

The percentage composition of ash in the feed represented the highest recorded. This, however, did not reflect directly on the concentration of mineral elements in the feed, the highest concentrations occurring in the worker caste, as a result of accumulation. The composition of ash and the concentration of mineral element were directly proportional, in the insect.

Ionic concentration was of two general patterns :-

K > Ca > Mg > P > Fe > Zn in the feed

and

K > P > Ca > Mg > Fe > Zn in the insect except in the reproductives where the most abundant element was phosphorus. Zinc, was found to be more abundant in all the insect castes than the feed,

Organic matter concentration was lowest in the feed, the high value occurring in the minor soldiers, The feed also showed the leastccon-centration of lipids, in the insects, the reproductives had the highest values followed by the major soldiers, Crude protein was most

abundant in the reproduetives and least in the feed. Second highest values occurred in the workers and, then, the major soldiers. Carbohydrate concentration was highest in the feed. The minor soldiers had more carbohydrate than all other castes. Major soldiers and workers came next, in that order.

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CHAPTER ONE

I. INTRODUCTION

I.I Subject of Study and Justification

The probable relationship between the chemical concentration of *Trinervitermes geminatus* Wasmann and the concentration of the grass which occurs within its mound is the subject of this investigation.

The economic importance of termites in the tropics, where they do enormous damage, and are among the most numerous soil-dwelling animals, has been documented by Coaton, 1951, Sands, 1960; Ausat, *et.al.*, 1960; Das, 1962; Bigger, 1965; Harris, 1969; Ohiagu, 1976; Watson and Gay, 1976; and Collins, 1977. It has been reported that in the process of nutrient recycling, termites can cause severe denudation of grasslands, even competing with livestock in the removal of grass and reduction of primary productivity. Grass removal has been estimated to be about 14.6kg per hectare per annum in a South African veldt. Bodine (1973) stated that the desert termite, *Gnathatritermes tubiformans* Buckley, removed 360kg of grass per hectare per annum in West Texas. In Nigeria, Ohiagu (1979a)gave a grass removal rate (volume) of approximately 81kg per hectare per annum for *T. geminatus* at Nsukka.

1.2. Research Objectives

In view of the well known and wide spread destruction of the grassland by termites, it is necessary to investigate not only the distribution of the termites in the grasslands,

but also to determine the relationship between the nutrient concentration of the grass and the chemical concentration of the termites. Therefore, the main objective of this study is to carry out chemical analyses on the termite and its food material, with the sole purpose of determining (1), the nutrient status of the grass and (2), the extent of accumulation of the various nutrients in the termite. The findings of this study would not only contribute to our knowledge of the chemical concentration of the termite and its food, but also give us an insight into the metabolic efficiency of the termite in metabolizing nutrients in its tissues.

CHAPTER TWO

11. LITERATURE REVIEW

11.1 THE TERMITES

Termites are isopterans, which constitute a small group of insects of approximately 2000 species (Lee and Wood, 1971, Haverty, 1974). They have been classified into six families namely-

1. MASTOTERMITIDAE
2. KALOTERMITIDAE
3. HODOTERMITIDAE (5 sub-families)
4. RHINOTERMITIDAE (6 Sub-families)
5. SERRITERMITIDAE
6. TERMITIDAE (4 Sub-families)

The first five subfamilies are collectively known as the lower termites while the sixth (Termitidae), which includes approximately 75% of all known species, make up the higher termites.

All termites are social animals (Wilson, 1970) and are found mainly in the tropical and subtropical regions (Krishna, 1969; Collins, 1977), although a few species have been reported from the warmer temperate countries (Imms, 1948; Araujo, 1970; Harris, 1970; Weesner, 1970).

Many workers have reported that termites live in colonies with a complex social system, within mounds or termitaria (Thompson, 1917, 1919; Meyer, 1930; Coaton, 1949; Imms, 1948; Noirot, 1970; Lee and Wood, 1971; Longhurst, 1977; and Ohiagu, 1977). A colony consists of four main castes which

fall into two main categories, viz - the reproductive and sterile forms. The reproductive caste consists of the primary and supplementary reproductives. The former is represented by kings and queens which are responsible for the founding and propagation of new colonies, the latter on the other hand never leave the colony and serve as substitutes for kings and/or queens and also complement -the egg-laying of queens, should this fall below the necessary level for the maintenance of the colonies. The sterile castes include individuals which may be apterous males and females and consists of soldiers for defence and workers for labour, and defence (Malaka, 1962a). Every colony also contains numerous miniature individuals of various ages undergoing development into some or all of the above castes, the direction of differentiation acquired before the first moult, appearing to depend on pheronomes produced by members of the reproductive and soldier castes (Lee and Wood, 1971).

II.I.I Economic Importance of Termites

In India, species of *Microtermes* and *Odontotermes* are known for their damage to sugar-cane and wheat (Bigger, 1965). The magnitude of damage, which is of permanent nature, caused to tea by live-wood feeding termites (*Microtermes* spp.) in certain districts of North-East India has been estimated to be at least 1% of annual yield (Das, 1962). *Kalotermes militaris*, *K. difficus* and *K. greeni* are known to cause severe injure to the living tissue of the tea bush in Ceylon (Fernando, 1962). Experimental findings

have shown that four species, *Microtermes redeniensis* Sjost , *M. albopertitus* Sjost , *Allodontermes tenax* Silv. and *Ancistrotermes latinotus* Holmgren , all of which are responsible for damage to living plants, predominantly cause losses to annual crops in Southern Tanzania (Bigger, 1965). In addition, *Odontotermes zambesiensis* Sjost , *O. latericius* Har. and *Macrotermes bellicosus* Smeath. are sometimes found attacking crops, but seem to prefer dead or woody materials. *A. latinotus* has been recorded elsewhere in Tanzania as doing damages to cotton (Harris, 1961). A survey by Sands (1960) revealed that cassava losses ranged from less than 1% to 40%, while losses in groundnuts were usually less than 10%, except in Bornu where up to 25% losses, occurred Losses to guinea corn and maize were from 2 to 20%, 15-20% in upland rice while yam losses were from 1 to 65 - 70%. The termites responsible for these losses included *M. bellicosus, M. natalensis* Har. , *Ancistrotermes sp., Odontotermes sp, Pseudacanthotermes militaris* Hagen , *T. geminatus* and *Amitermes evuncifer* Silv.

Besides tea, in Ceylon, *M. militaris* has been recorded on rubber, species of *Albizzia, Grevillea, Artocarpus, Eucalyptus* and *Toona* used in re-afforestation. Constructional and structural timber are damaged in different parts of the world by termites of the family Rhinotermitidae. Of these, *Hodotermes indicola* Wasmann is known to cause heavy damages to timbers and fabricated timber stores in India (Aunt *et.al*,.1962). *Odontotermes obesus* Rambur and *O. parvidens* Holmg. have also been reported, by Roonwal *et.al.*(1962), to cause damages to wood. Harris (1962)

reported that a survey of houses in Jamaica showed that infestation of structural wood of 45 to 80% and the Building Research Institute, Accra, suggested the annual cost of repairing buildings damaged by termites in West Africa was of the order of 10% of their capital cost. Laboratory experiments by Mill and Hey (1974) showed that termites, including *Microtermes sp.*, *Odontotermes sp.*, and *Macrotermes subhyalinus* Rambur , removed 90.46% of wood provided within a period of 30 days, in Northern Nigeria.

This economic importance of the termites has prompted diverse studies on their behaviour, biology and ecology in many parts of the world to facilitate the control of the pests (Narayanamurti, 1962).

II. 1.2. Distribution of Termites

In Australia, termites are particularly common in tropical savannas (Lee and Wood, 1971). Typical are *Amitermes vitiosus*, *Tumulitermes hastilis*, *Nasutitermes triodiae*, *Drepanotermes rubiceps* and *Schedorhinotermes intermedius*. The only commonly occurring European species are *Kalotermes flavipes* and *Leucotermes lucifugus* (Imms, 1948). Ahmad (1960) describing the termite fauna of West Pakistan reported the occurrence of 41 species, which are representative of the Kalotermitid, Hodotermitid, Rhinotermitid and termitid termites. The higher termites are poorly represented in the arid regions.

In Nigeria, Sands (1961a)identified five species of the genus *Trinervitermes* which are extensively distributed from North of the rainforest into neighbouring countries to latitude 15 - 16.N (Sands, 1965a). Ruelle (1970) reported

the occurrence of other termites such as *M. subhyalinus* throughout the guinea, sudan and sahel savanna regions of Nigeria.

Some other studies have shown a relationship between soil structure and distribution of termite species (Wood and Ohiagu, 1976). *Kalotermes kempae* and *Microtermes luteus* are known to be limited to areas of grey soils and black clays in the Tanzanian dry bushland (Kemp, 1955). Mounds of *A. vitiosus* in Northern Australia are more commonly found in areas of increasing clay proportion. Watson and Gay (1976) have made an estimate of 350 mounds per hectare for *Drepanotermes sp.* in Australia. Ohiagu (1976), citing Murray, gave a mound density estimate of 534 mounds per hectare for *Trinervitermes trinervoides* in a South African veldt. Sands (1965b) has given an estimate of 735 mounds per hectare for *T. guttulatus* near Zaria.

II. 1.3. TERMITE POPULATIONS

There are few estimates of population of subterranean mound-building termites and there are no reliable estimates of the total numbers of any habitat (Lee and Wood, 1971). This is attributable to the difficulty in sampling termite populations which are cryptic and very aggregated (Lee and Wood, 1971). However, several attempts have been made to estimate populations of mound inhabiting species. Nel'degue (1961) made a single estimate of population of subterranean (500 per metre square) and mound-building ($347.6 m^{-2}$) termites in *Brachystegia* forest in the Congo. Lee and Wood (1968) estimated the population of mound-building

Nasutitermes exitiosus in Australia at 600m^{-2} in Nigeria, Sands (1965a) estimated the population of *T. geminatus* to be between 494 and 1235.5m^{-2}.

II. 1.4. Behaviour of Termites

The feeding habits and foraging pattern of termites have been other areas of considerable interest to workers. Cleveland (1923, 1924, 1925a, 1925b) reporting on *Termopsis* sp. Heer and *Reticulitermes* sp. Holmg. found that these species were capable of almost indefinite existence on a diet of pure cellulose. He also established that there is a relationship between the feeding habit of termite castes and their intestinal fauna. Harris (1969) revealed that the food materials collected by workers were shared by regurgitation with the other castes, only a portion being retained by the individual worker for its own sustenance. However, Wilke (1930b) detected the sharing of large pieces of food, among foraging workers, quite apart from the trophallactic regurgitation of food to the dependant castes and nymphs. In the fungus-growing Macrotermitinae the food brought by the workers is only partly digested before being made up into fungus-combs, which are later eaten after enrichment by fungus growing on them. In his study of five species of *Trinervitermes*, Sands (1961) found that the harvesting habit is most strongly developed in *T. geminatus* (as *T. ebamensis*) and two species, *T. occidentalis* and *T. australiensis*, were found not to store grass at all in their mounds. In these species relative humidity and temperature are known to be important variables affecting this foraging behaviour and, is thus seasonal: soil surface temperatures greater than 35°C in the evening and less than 20°C

in the morning inhibit foraging during the evening and morning, respectively (Sands, 1961; Chiegu, 1979). Studying *A. evuncifer*, Maleka (1980b) observed that the rate of tube-building, in the absence of lowest humility (72% R.H.) and highest temperature (27.5°C), but in the presence of food, the rate was lowest at a period when humility and temperature were comparatively high.

An assessment of the grass consumption by workers while foraging has been reported by Chiegu (1979) for the genus *Trinervitermes*. He observed that emerging workers and those returning to the mound after foraging showed little or no appreciable difference in weight. On dissecting some foraging workers, Sands (1961) found that fragments of fresh green grass were in the oesophagus and crop of *T. ebeurianus* (etc.)

II.2. CHEMICAL CONCENTRATION OF BIOLOGICAL MATERIALS

II.2.1 Ash and Organic Matter CONCENTRATION

The ash of a biological material is an analytical term for the inorganic residue that remains after the incineration of the organic matter. Its content and concentration are directly proportional to the nature of food ignited and on the method of ashing (Obodo, 1982). The ash is, therefore, not the same as the inorganic matter present in the original food material, since there may be losses due to volatilization or chemical interaction between the constituents (Obodo, 1982) and also due to the presence of elements as chlorine and macronutrients like silicon and sulfur which may not have been analysed for (Salisbury and Ross, 1969).

Adams (1975) reported a percentage ash content ranging from 29 to 49% for legume-grass forages. Corresponding total dry nutrient (TDN) or organic matter concentration ranged from 51 to 71%. Studying three species of three genera of fresh water fish, Oni (1979) gave ash content values ranging from 10.36 to 14.76% and organic matter content values of 85.3 to 89.64%.

II.2.2. Lipid Concentration

The term, lipids, is most frequently applied to a heterogeneous group of compounds which show relative insolubity in water and high solubility in monpolar solvents such as chloroform and acetone. Lipids are essentially vital to the structure and biological function of cells as they are components of subcellular membranes and constituents of lipoprotein carrier molecules (Downer, 1973; Obodo, 1982). The fat soluble fraction of most leaves varies between 0.2 and 1.7%, but ranges as high as the 7% found in Sagebrush (Morrison, 1950). Lipid concentration of fodder plants in the Sahel savanna Zones of Africa have been reported by Bartha (1970). He gave values ranging from 0.68 to 4.61% for different grass species and Obodo (1982) obtained lipid concentrations ranging from 2.62 ± 0.01 to 3.88 ± percent for same Nigerian seeds. Accounts demonstrate that the lipid concentration of insects varies greatly, although polyunsaturated fatty acids and sterols comprise the two major lipid classes for which insects display an absolute requirement (House, 1958). However, the fat-soluble vitamins, carotene and x-tocophesol, are also essential dietary constituents.

II.2.3 Crude Protein Concentration

The measure of protein in a biological material is usually taken as the total nitrogen content. The problem of the presence of non-protein nitrogen compounds is overcome, as these compounds, generally, represent a negligible quantity of nitrogen in biological materials (Obodo, 1992). Many workers have reported on crude protein contents. Butterworth (1965) obtained 7.6% for fresh green grass in East Africa, while Lowe et., al.,(1964) have reported a protein composition of 8.24% for Ugandan grasses. Bartha (1970) reported values ranging from 5.54 to 6.42% for some grass species while Adams (1975) gave a range of 6.6 to 33.2% for dairy cattle feeds. Kapu(1975) reported a value of 13.97 ± 1.17 for some fodder plants in Northern Nigeria.

Certain factors are known to greatly influence the content of crude protein in plants: uptake of nitrogen which is an important integral of proteins, is known to be linked to the interference of ions like calcium and potassium (Jacobson et. al., 1972). Aging is also known to result in a decrease in concentration of this element in plants (Fleming, 1973).

II.2.4 Carbohydrate Concentration

Carbohydrates, along with lipids and proteins, form the principal classes of organic compounds that are found in insects and other organisms. Carbohydrates contribute to the structure and function of all tissues, and can be found in nuclei cytoplasm and membranes of cells, as well as in the extracellular hemolymph and supporting

tissues (Chippendale, 1978). The term denotes polyhydroxy aldehydes and ketones and their derivatives. Barthe(1970) reported a range of 33.28 to 51.42% as the carbohydrate contents of some fodder plants in Africa. Meleed and Minson (1974) have reported values ranging from 62.6 to 69.1% as the carbohydrate content of certain grasses. Obodo (1982) gave values ranging from 68.04 to 86.69% as the carbohydrate content of testes of some seeds while he reported a range of values of 3.57 to 66.9% for the nuts of these seeds. Insect carbohydrates are present both in free form and combined with other molecules, including purines, pyricidines, proteins and lipids (Chippendale, 1978). In general, carbohydrate metabolism in insects is similar to that found in vertebrates; however, insects, unlike vertebrates, possess an exoskeleton that is rich in the amino polysaccharide, chitin. They also contain a disaccharide, trehalose, which acts as a storage form of glucose. Special features of insect carbohydrate metabolism, therefore, centre around the synthesis and hydrolysis of these compounds.

II. 2 5. Status of Mineral Elements

Van Itallie (1938), Cohen (1973), Cunningham (1964), Scarth (1976) and De Bruin (1978) have reported extensively on the interrelationships between nutrient levels of animals and plants, and also on the influence of the chemical composition of soils on these relationships. Most of the mineral elements have a multiple function in metabolism and their metabolic activity is affected by or related to other minerals, vitamins, or hormones (Hays, 1977).

Ions can interact in two ways called antagonism and synergism (Cunningham, 1964); antagonism means that uptake of one ion inhibits or interferes with the uptake of another ion while synergism is when the uptake of one stimulates the uptake of another. Competition for the same active sites on specific 'carriers' (Epstein, 1956) is the most widely accepted explanation of antagonism between ions, but an earlier suggestion was that it arose because the sums of cations in plants (Na + K + Ca + Mg expressed in m-equiv/100g dry weight) were constant (Cunningham 1963). If this is true, this would explain why the increasing uptake of one cation depresses the uptake of the others. Actual amounts of various minerals taken up may, therefore, not represent the need of the plant but, rather, only reflect a luxury composition (Scarth, 1976).

In a study of tropical forages, De Souza (1978) quoted Comide/as (1976) having reported that the age of plant is an important factor affecting chemical composition and nutritive values of forages. Fleming (1973) pointed out that the classical concept of a forage plant growing to maturity is a relatively rapid intake of minerals in early growth stages, with a relatively low production of dry matter. As photosynthetic areas increase dry matter production, mineral concentration decrease due to natural dilution processes. This decrease in the ready availability of stored mineral elements has also been reported for animals (Jacobson, et.al, 1972).

Bock (1972) reported that insects do not differ markedly in their fundmental qualitative requirements for biochemical nutrients that must be obtained by ingestion and assimilation, nor do they show fundmental differences from other animal forms. However, they are known to specifically concentrate certain mineral elements which play important roles in their metabolism (Stagg, 1956).

(a) CALCIUM

Studies have shown a ten-fold range of concentration (0.29 to 2.8%) of calcium in whole plants subjected to analysis (Austin, 1960; Siegel, *et.al.*, 1952). Concentration ranging from 0.32 ± 0.08 to 0.36 ± 0.08 percent have been reported for three species of grass (Long, *et.al.*, 1972). From a five-year forage study Adams (1975) reported that calcium levels ranged from 0.01 to 2.61% with a coefficient of variation of 28%. Kegu (1975) reporting on a variety of grasses gave a mean concentration of 0.3%.

Ninety-nine percent of calcium in animals is located in the bone and teeth and only 1% is in the soft tissues (Thompson and Worker, 1976). Concentrations reported by Amerman, *et.al.*, (1971) for important internal organs of cattle were all reported in ppm, whereas the bone showed a calcium concentration of 38.2%.

(b) MAGNESIUM

This element is essential in photosynthesis and also shows a wide range of concentration (Wolds, *et.al.*, 1954; Adams, 1975). Cunningham (1954) reported a range of 0.09 to 0.28% for Italian ryegrass while Jones (1965).

reported a mean value of 0.12% in Kales. Long, *et.al.*, (1972) reported values of 0.15 to 0.25% for some grasses while Kapu (1976) gave a mean of 0.23% for ten species of grass. Adams (1976) reported that the range of variability for magnesium was from 0.07 to 0.75% with a coefficient of variation of 33%.

In the animal body, magnesium is the fourth most plentiful cation and the second most abundant intracellular. Rook and Storry (1962) have reported about 50 to 70% of total body magnesium in bone and the remainder in soft tissues. Ammerman *et.al.*, (1974) have reported values ranging from 626 to 968 ppm for the internal organs of cattle and a value of 5600 ppm for bone.

(c) POTASSIUM

Potassium is present in plants in quantities larger than that of any other mineral element (Black, 1968). Concentrations ranging from 1.26 to 5.0% were obtained by Cunningham, (1967) while Bartha (1970) reported 1.08 to 4.3%. Long *et.al.*, (1972) gave values ranging from 1.33 to 2.09% and Kapu (1976) obtained 2.56%. Adams, (1975) reported that the coefficient of variation of the concentration of potassium was 32% and mean concentration was 1.68%.

Potassium is not stored to any large extent in the bone; it exists in the body primarily as a cellular constituent. Reports (Ammerman *et.al.*, 1974) indicate it is the single most abundant element in the soft tissues with concentration ranging from 1.12 (in the Kidney) to 1.82% (in the spleen) of cattle.

(d) PHOSPHORUS

This mineral is extremely mobile in plants and Cunningham (1964) reported a range of 0.12 to 0.59% in rye-grass while Long *et.al.*, (1972) gave 0.23 to 0.31%. Kapu (1975) reported 0.2% and 0.2% for browse and grass, respectively. The element had a range of 0.07 to 0.74% with a coefficient of variation of 25% (Adams, 1975). Weiss (1976) summarised the phosphorus values of 1030 grass samples. Results indicated that 76% of the grasses contained less than 0.20% phosphorus, 51% of the grasses contained less than 0.15% phosphorus; and 20% of the grasses contained less than 0.10% phosphorus.

Phosphorus represents about 1% of the body weight of animals, with approximately 80% of the total in the bones and 20% in the soft tissues (De Sousa, 1978). Accounts show that the phosphorus in the body, excluding the bone tissue, is second only to potassium (Underwood *et.al.*, 1974). They reported concentrations which ranged from 0.78 (in the muscle) to 1.51% (in the spleen) of cattle.

(e) MINOR OR TRACE ELEMENTS

Adams (1975) reported that there are wide differences between low and high values for many trace elements within a given type of food, and the variation for forages range from 42 to 100%. He further reported a range of concentrations from 10 to 2599 ppm for iron. According to De Sousa (1978) Andreasi *et.al.*,(1969) have reported values ranging from 119 to 494 ppm and 114 to 415 ppm for some grasses, during dry and wet seasons, respectively. In another report, Gonide *et.al.*,(1969) obtained 442 ppm for *Melinis minutiflora*,

in Brazil. (Cunha et.al., (1964) indicated that iron concentration in the liver of normal cattle was 200 to 300 ppm and Ammerman et.al., (1971) reported that calves had liver iron concentrations ranging from 160 to 235 ppm.

Zinc has a concentration of 8 to 300 ppm, with a coefficient of variability of 63%, in forages (Adams, 1975). Andreassi et.al., (1963) reported dry season concentration of 60 to 69 ppm and wet season concentrations of 35 to 48 ppm. De Sousa (1978) quoted 22 to 28 ppm in grasses from Mato Grosso and 15 to 58 ppm in other species from Nordeste reported by Fernandes and Carnaúba (1976) / Zinc levels of 8-68 ppm have also been obtained in grasses (De Sousa, 1978). Zinc is an essential nutrient for animals, functioning largely or entirely in enzyme systems and being involved in protein synthesis, carbohydrate metabolism and other many biochemical reactions (Miller, 1972). Committee on Mineral Nutrition (1973) suggested that 60 to 100 mg zinc per 100 ml blood is a normal level for cattle (De Sousa, 1978).

Copper is an important constituent of several plant proteins and enzymes. De Sousa (1978), quoting Teixeira et.al., (1971) reported copper levels of 2.50 to 3.04 ppm in an experiment carried out on grass in central Brazil. Liver copper level of cattle ranged from 100 to 400 ppm, however, deficiency only occurs when this level falls lower than 25 ppm (Cunha et.al., 1964). Cobalt has not been demonstrated as essential for the growth of higher plants (Gauch, 1972). Fernandes and Carneiro (1976) reported values ranging from 0.06 to 0.1 ppm in grasses. Although Cunha et.al., (1964) reported that a liver cobalt level of 0.01 ppm, in

cattle, suggested extreme deficiency. Looney *et.al.*,(1975) noted that virtually all the dose of cobalt fed to sheep was excreted in five days.

II. 3. RESEARCH METHODOLOGY

Even as considerable amount of work has been done on termites, there is insufficient information on their chemical concentration and the relationship of this to that of their feed. The present study is proposed to provide such information, which is also expected to be useful in a more detailed future examination of the interaction of the insect and their feed at the molecular level. It is hoped that the final study to reveal the attractant and repellent components of particular plant species would supply information necessary for a programme of development of resistant strains in plants. This would be useful in facilitating the control of the insect in an integrated control programme.

For this purpose, a survery of *T. geminatus* will be made. Ash, organic matter, lipid, crude protein and carbohydrate concentration, as well as the concentration of some mineral elements in the insect and the grass material (feed) found within the termite mounds will be analysed, to reveal the relationship between the insect and their direct nutrient source.

CHAPTER THREE

III. MATERIALS AND METHODS

III.1. SITE; SOIL, CLIMATE AND VEGETATION

Materials used in this study were collected from the Department of Biological Sciences Ecological plot at the Ahmadu Bello University Farm situated on the Zaria - Sokoto Highway, Nigeria. In this area, apart from superficial deposits, there are underlying rocks of precambrian to early Paleozoic age (Wright and McCurry, 1969; McCurry, 1973). The rocks are composed mostly of both metamorphic and igneous rocks, termed basement-complex because of their intricate pattern (McCurry, 1973). The climate has a marked seasonality owing to alternation of two contrasting air masses moving across the area: a dry continental air mass ("harmattan") from the N.E. and a humid maritime air mass from the S.W. The latter follows the passage of the inter-tropical discontinuity (meeting point of the air masses). A single rainy season occurs in this area and the dry season is from November to March (Kowal and Knabe, 1972).

The mean annual rainfall in Samaru is 43" - 48" (112cm - 122cm) with a single peak occurring in August (Kowal and Knabe, 1972). The relative humidity ranges from mean monthly values of 43.4 - 81.2% R.H in the morning to about 29 - 70% R.H. in the afternoon from the months of April to August, (Kowal and Knabe, 1972.) During the dry season, the humidity decreases from 76% to 15% R.H. in the morning and from 63% to 11% in the afternoon from the

months of September to February. The mean annual temperature is about 25°C with the mean minimum (about 12°C) in December, and the mean maximum temperature at the hottest part of the year (March - April) being 37°C.

When undisturbed by man and on suitable soils, vegetation reaches a climax of closed but light wood canopy with trees around 75' (23m) in height. The predominant trees are *Isoberlinia doka* Craib and Stapf and *I. dalzielli* Craib and Stapf (Collins, 1977a). Other commonly occurring trees include *Afzelia africana, Parkia clappertoniana, Combretum bundoriacum* and *Butyrospermum paradoxum*. There are also dense stands of grasses such as *Andropogon gayanus* Kunth, *Eragrostis tremula, Cymbopogon giganteus* and *Pennisetum pedicellatum* (Jackson, 1970 ; Collins, 1977a).

Collection of samples was carried out between the months of April and December, 1981, and June, July, 1982. The termite mounds were dug up and placed on a 'sand-bed', as described by Ohiagu (1978).

Laboratory analyses were carried out in the Department of Biological Sciences, A.B.U. as well as in the Soil Science section of the Institute for Agricultural Research, Samaru, Zaria. Every treatment (see below) was replicated twice.

III.2. ANALYSIS OF SAMPLES

III.2.1 Treatment of Samples

a. Insect Samples

The mounds were completely broken down and the different castes were separated from each other and also from particles of sand and cut-grass (feed) material. Due to the small size

of the individuals (dry weight, in mg: 0.2, 0.7, 1.4 and 3.7 for the minor and major soldiers, workers and reproductives, respectively) insects of identical castes were pooled together. The specimens were then placed in petri-dishes and dried to constant weight in the oven at 60°C for about 48 hrs (over 72hrs for major soldiers). The dried samples were then ground to powder in a mortar and kept in the oven for a further 3hrs, to get rid of all moisture. The powder was then allowed to cool in a dessicator, and on cooling was stored in a clean dry specimen bottle.

b. Plant Samples

Plant samples were obtained from the mounds after they had been broken down. These strips of grass stored in the mound by the insect were carefully sifted to remove soil particles from them.

The grass samples were dried in the oven (to eliminate moisture) for 48 hrs. at 70°C. The samples were blended with an electric blender, on cooling, and finally ground to powder in a mortar. The ground materials were kept in the oven at 60°C for a further 3hrs. and stored in specimen bottles, after cooling in a dessicator.

III.2.2. Determination and Analysis of Inorganic Matter (Ash Concentration

About one gram of the cooled powdered grass sample (five hundred milligrams for the insect) was weighed into a crucible of known weight. The crucible was then placed in a Muffler furnace, set at 600°C, and ignited for 18hrs.

The crucible and its content were allowed to cool in a dessicator and the weight determined. The ash concentration was determined as follows:

wt. of crucible = a

wt. of crucible + sample = b

wt. of crucible + sample (after ignition) = c

wt. of sample (after ignition) = c-a = Ash

$$\therefore \quad \% \text{ Ash} = \frac{c-a}{b-a} \times 100\%$$

III.2.2.a Insect Samples

Five millilitres of 3N hydrochloric acid were added to the ash residue in the crucible (see above), and to empty crucibles for control treatment, after samples had been allowed to cool to room temperature. The crucibles and contents were allowed to stand for 15 to 30 mins. Ten millitres of de-ionised water were added and the solutions were filtered into 50ml conical flasks. The filterates were made up to mark with de-ionized water. The solutions were monitored for Calcium (Ca), Magnesium (Mg), Potassium (K), Iron (Fe), Copper (Cu), Chromium (Cr), Cobalt (Co) and Zinc (Zn) using a Perkin-Elmer Modal 290B atomic absorption spectrophotometer*. Phosphorus was read using a Baush and Lamb Spectronic 20 at 440nm. The percentage concetration of these elements was calculated as described in appendix 3.

III.2.2b Plant Samples

Five hundred milligrams of the powdered sample was weighed into a 500ml Kjeldahl digestion flask and 25ml Tenary solution (20ml concentrated sulphuric acid; 80ml Perchloric acid and 650ml concentrated Nitric acid) were

*The Perkin-Elmer Corporation (1971), Norfolk, Conn., U.S.A.

added. The same quantity of the tenary solution was measured into an empty 500ml Kjeldahl flask for the control treatment. The flasks were heated on a Kjeldahl's digestion heating mantle, set at 80°C, for 30mins. The colour of the solution changed from rust brown to colourless. The flasks were then allowed to cool to room temperature and 10ml de-ionized water was added to each and shaken vigorously, to wash the sides of the flask. The digest was filtered into 50ml conical flask and made up to the mark with deionized water in each case. The solution was monitored for the elements listed in III.2.2a and their percentage concentration also determined as described in appendix 3.

III.2.3. Determination and Analysis of Organic Matter Concentration

The weight of organic matter in the sample was regarded as the complement of the ash content in the sum total of the sample used in III.2.2.

wt. of crucible = a

wt. of crucible + sample = b

wt. of crucible + sample (after ignition) = c

wt. of sample = b-a

wt. of ash = c-a

wt. of organic matter = b-a-(c-a)

= b - a - c + a

= b - c

$\therefore$ % O.M = $\frac{b-c}{b-a}$ x 100%.

III.2.3.i Estimation of Crude Protein Concentration

The protein concentration of a biological samples or can be estimated from the total nitrogen after conversion of the protein nitrogen to ammonium salt by digestion which involves acid hydrolysis known as Kjeldahl.

Between 100 and 250mg of the cooled powdered insect sample (500mg for the plant) was weighed into a 500ml Kjeldahl flask. To the sample 2g (3g for the plant) of catalyst (containing 100g sodium sulphate, 10g cupric sulphate and 1g selamium) were added. These quantities were also weighed respectively into empty 500ml flasks, to serve as blanks in the experiments separately involving the insect and plant. Ten millilitres concentrated sulphuric acid were added into each flask, and digestion was carried out by heating the flasks and contents on a Kjeldahl digestion heating mantle, in a fume cupboard, at 100°C until a colour change occurred from black to light blue, in the flasks which contained samples. The digestion was continued for another 2hrs. at 70°C, by which time the solutions became colourless. The digest was then allowed to cool to room temperature and 10mls of deionized water were added. The flasks were shaken vigorously in order to rinse the sides. The solution (now light blue in colour) was poured into a 50ml volumetric flask and made to mark with deionized water.

Two millilitres of the diluted digest were pipetted into a micro-Kjeldahl distillation apparatus and 10ml 4N sodium hydroxide were added. The ammonia released was trapped in 10ml 1N boric acid into which three drops of a methyl

blue and methyl red indicators (see appendix 1) had been added. The colour of the mixture at this stage was purple but this later turned light green with the ammonia. The light green solution was titrated against 0.05*N* Sulphuric acid. The end point was reached when the solution turned purple again. As in the other experiments the figure used in calculating percentage nitrogen was obtained after subtracting the values for the blanks. See appendix 4 for calculation.

The total crude protein was the value obtained on multiplication of percentage nitrogen by an appropriate constant, K. Proteins usually represent 16% of the total concentration of organic materials and the constant is derived as the quotient on division of the total organic matter (100%) by 16, which gives 6.25.

therefore,

$$\text{Crude Protein} = K \times \%N$$

See table 1 for appropriate constant for some organic materials.

Table 1. Nitrogen-Protein Conversion Factors[+]

Food Type	Factors for converting Nitrogen to Protein
Egg	5.68
Milk	6.38
Others	6.25[++]
Rice	5.95
Barley,Oats,Rye,Wheat	5.83[+++]
Soy beans	5.71
Wheat flour, other cereals	5.70
Gelatin	5.55
Peanuts, Brazilnuts	5.46
Nuts and other seeds	5.30
Almonds	5.18

\+ Obtained from Obodo (1982)

++ Used for insect samples

+++ Used for plant samples

III.2.3.ii. Determination of the Lipid Concentration

The lipid concentration of a biological sample can be estimated by directly extracting lipids from the dry powdered samples exhaustively, using suitable lipid-extracting solvents. The difference between the final and initial weights of the apparatus represents the weight of lipids present.

About one gram of the powdered sample was weighed (w_1) into a thimble of known weight (w). They together weighed w_0. Penger chips were added to the extraction flask and the total weight of the flask (with contents) and chips was obtained (w_2). About 50ml ethyl ether were added to the

flask. The thimble was inserted in a condenser which was in turn connected to the extraction flask. The thimble rod was used to lower the thimble until it was submerged in the ether. Water was allowed to run to keep the condenser cool. The flask was heated on a heating mantle, with a slow increase in temperature until the ether boiled rapidly. The thimble was kept in the boiling ether for 10 - 12mins, then the thimble rod was raised until the thimble was above the boiling ether, and this position was maintained for a further 20-25mins. Heater was turned off and slid back from under the flask. When the flask had cooled, the condenser was removed and, using a hot-plate in a fume cup-board, all the ether was evaporated from the flask. The flask and content were then weighed until a constant weight was obtained, (w_3).

wt. of lipid = $w_3 - w_2 = w_4$

$\therefore$ % lipid = $w_4/w_1 \times 100$).

III.2.3.iii. Determination of Carbohydrate Concentration

Since proteins, lipids and carbohydrates make up organic matter, the carbohydrate concentration was obtained by subtracting the sum of protein and fat from the value obtained for organic matter

Organic matter	= a
Protein	= b
Fat (lipid)	= c
Carbohydrate	= d

but,

$$a = b + c + 1$$

$$= \frac{b + c + 1}{a} = C$$

$$d = a - (b + c)$$

$$= a - b - c.$$

III.3. Statistical Analysis

To determine the statistical relationship between the results obtained, an analysis of variance was carried out to show the least significant differences. The method used and results obtained are given in appendix 5.

CHAPTER FOUR

IV. RESULTS

IV.1 Ash Concentration

The percentage concentration of ash ranged from 21.22 to 33.35 with a mean ± S.E. of 26.38 ± 1.46, as shown in Table 2. The histograms of these values are shown in Fig.1. Analysis of variance showed a significant difference at the 1% level between the values recorded for the worker and reproductive castes. The values for the major and minor soldiers were not significantly different from each other at this level.

IV.2 Organic Matter Concentration

The values obtained as the organic matter concentration with their mean ± S.E. are given in table 3. Figure 2 shows the histograms for these values for the different mounds. Analysis of variance also showed the values to be significantly different at the 1% level for the worker and reproductive castes, while the values for the major and minor soldiers did not differ significantly from each other at this level, (appendix 5).

IV.3. Lipid Concentration

Highest values were recorded for the reproductives (Table 4). Figures 3 and 14 show the histograms of the values for the different mounds and the mean values, respectively. The values differed significantly ($P \leq 0.01$) among the different castes and the food.

IV.4 Crude Protein Concentration

Values obtained are given in Table 5. Histograms for these values are shown in Figs. 4 and 15. No significant differences existed between the values for the major and minor soldiers, at the 1% level. However, the differences between the values recorded for the workers and reproductives and these two castes were statistically significant ($P \leq 0.01$).

IV.5. Carbohydrate Concentration

Means ± S.E. of the percentage carbohydrate concentration for the termite and grass are tabulated in Table 6 and shown in histograms in Figs. 5 and 16. Analysis of variance showed statistically significant differences ($P \leq 0.01$) between the values recorded for the different insect castes and the feed.

IV.6. Mineral Elements

The means ± S.E. obtained for the different castes and the feed are shown in Table 16. The histograms for these values are given in Fig. 17. The values obtained were significant different ($P \leq 0.01$) among the different castes and the feed.

a) Calcium Concentration

Table 7 and Fig. 6 show the values obtained for the different mounds and the histograms of these values, respectively. A high concentration occurred in the worker caste (Table 17).

b) Iron Concentration

Mean ± S.E. shown in table 18 and the histograms of these values appear in Fig. 17. Mound values and corresponding histograms are given in Table 8 and Fig.7, respectively.

Table 17 shows that the concentration of this element is higher in the insect, except the minor soldier, than in the feed.

c) Magnesium Concentration

Table 9 and Fig. 7 give the values and the histograms of these values, for the different mounds, respectively. Figure 17 and 18 show the ratio of concentration of the element in relation to the food and the worker, respectively.

d) Potassium Concentration

This element was heavily accumulated in the worker (Tables 10, 16, 17 and 18; Figs. 9 and 17). Values and histograms of these values, for the mounds, are shown in Table 10 and Fig. 9, respectively.

e) Phosphorus Concentration

The highest concentration for this mineral element also occurred in the worker (Tables 11,16,17 and 18; Figs.10 and 17). Mound values and corresponding histograms are given in Table 11 and Fig. 10 respectively.

f) Zinc Concentration

Table 12 and Fig. 11 give the values and corresponding histograms (in ppm) recorded for this element, for the different mounds. As shown in Tables and 16 and 17, the concentration of the element in all the insect castes exceeded its concentration in the food.

g) Cobalt and Copper Concentration

These elements were not detectable during monitoring within the absorbance range of the standard solutions used (appendix 2).

TABLE 2

The mineral (ash) concentration of termite and grass expressed as percentage of dry weight.

MOUNDS	PERCENTAGE COMPOSITION				
	FEED	WORKER	REPROD.	MAJ. SOL	MIN. SOL
1	25.43	11.47	5.67	5.47	5.46
2	21.22	14.01	5.49	4.98	4.89
3	23.3	16 73	6.09	5.12	5.00
4	23.51	13.28	6.73	5.47	5.28
5	22.76	12.99	7.11	5.73	5.06
6	21.83	12.31	5.45	5.18	4.99
7	30.03	12.56	7.89	5.89	6.21
8	32.67	12.91	6.68	5.89	5.37
9	33.35	15.53	8.24	6.69	6.18
10	29.69	17.79	7.02	6.42	5.42
$\bar{X}$	26.38	13.96	6.64	5.68	5.39
S.E.	1.46	0.65	0.31	0.18	0.15

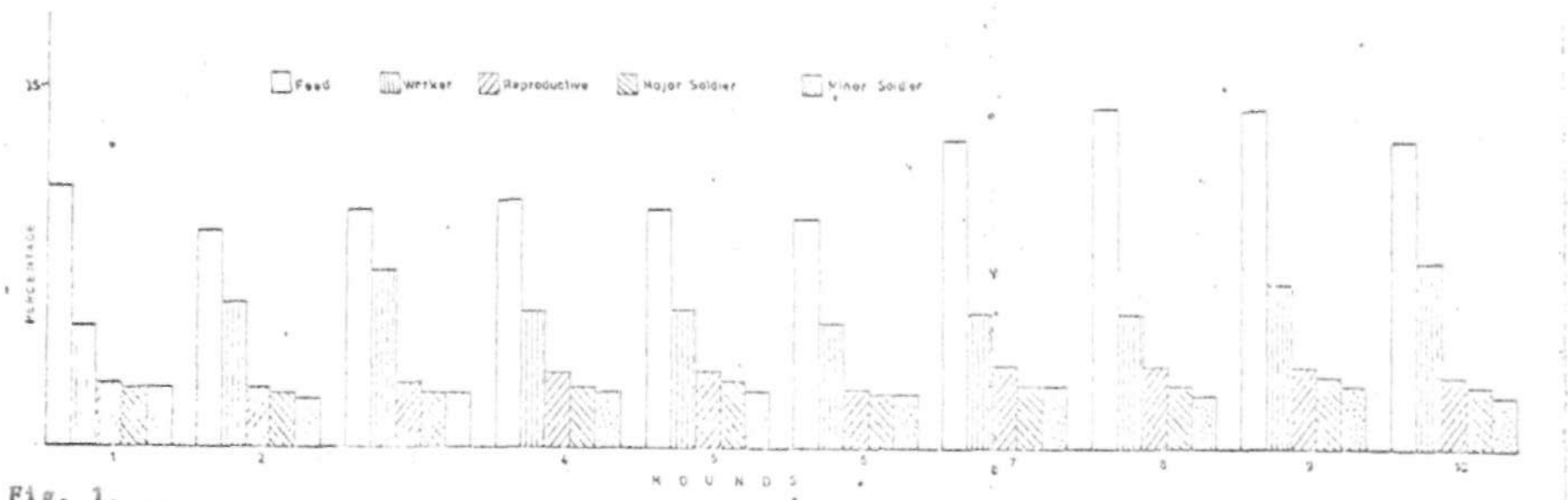


Fig. 1. HISTOGRAMS OF THE PERCENTAGE COMPOSITION OF ASH IN THE INSECT AND FEED.

TABLE 3

The organic matter concentration of termite and grass expressed as percentage of dry weight.

MOUNDS	PERCENTAGE COMPOSITION				
	FEED	WORKER	REPROD.	[illegible] SOL.	MIN. SOL.
1	74.57	88.53	44.33	94.53	44.54
2	88.78	85.99	94.51	95.02	95.13
3	76.7	83.27	93.91	94.88	95.00
4	76.49	86.72	93.27	94.53	94.72
5	87.34	87.01	92.89	94.27	94.94
6	78.17	87.69	91.55	94.82	95.01
7	69.97	87.41	92.11	94.11	93,79
8	67.33	87.19	93.32	94.11	94.63
9	66.65	84.47	91.76	92.31	93.82
10	70.31	82.21	92.98	93.58	94.58
$\bar{X}$	75.43	88.05	93.36	94.22	94.82
S.E.	2.44	0.65	0.31	0.25	0.15

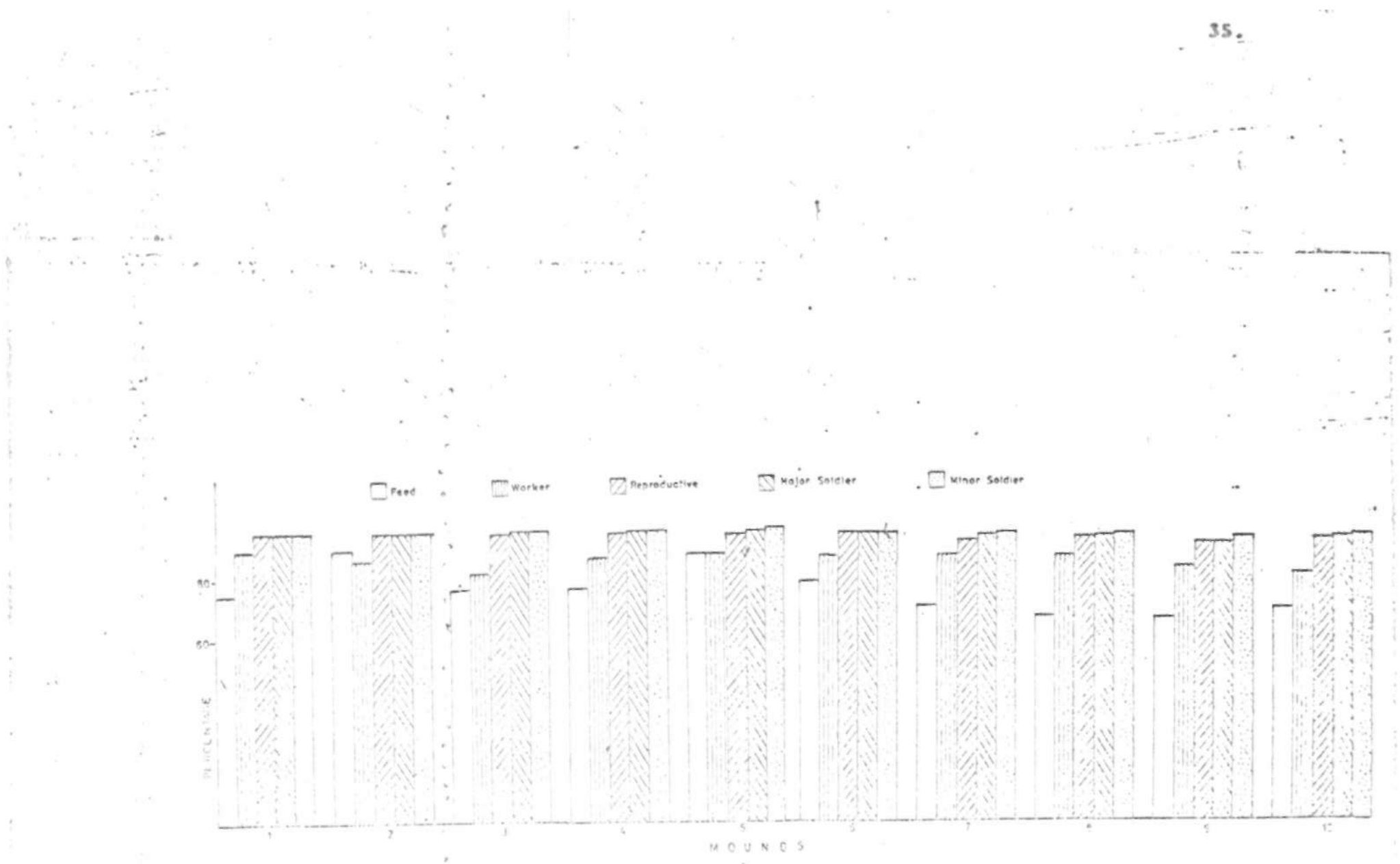


Fig. 2. HISTOGRAMS IN THE PERCENTAGE COMPOSITION OF ORGANIC MATTER IN THE INSECT AND FEED

TABLE 4

The lipid concentration of termite and grass expressed as percentage of dry weight.

MOUNDS	PERCENTAGE COMPOSITION				
	FEED	WORKER	REPROD.	MAJ. SOL.	MIN.SOL.
1	0.65	6.67	17.84	4.99	3.66
2	1.10	5.18	18.21	5.38	4.00
3	0.75	3.53	18.05	3.78	2.66
4	0.51	5.07	17.73	8.00	3.14
5	1.59	6.45	18.00	7.32	4.50
6	2.70	6.70	18.07	8.53	3.70
7	2.40	4.62	18.90	5.98	4.91
8	1.29	4.70	18.40	6.46	3.73
9	1.21	4.16	17.47	6.08	2.98
10	0.78	5.18	17.92	7.55	3.09
$\bar{X}$	1.30	5.26	18.06	6.41	3.63
S.E.	0.23	0.31	0.12	0.46	0.22

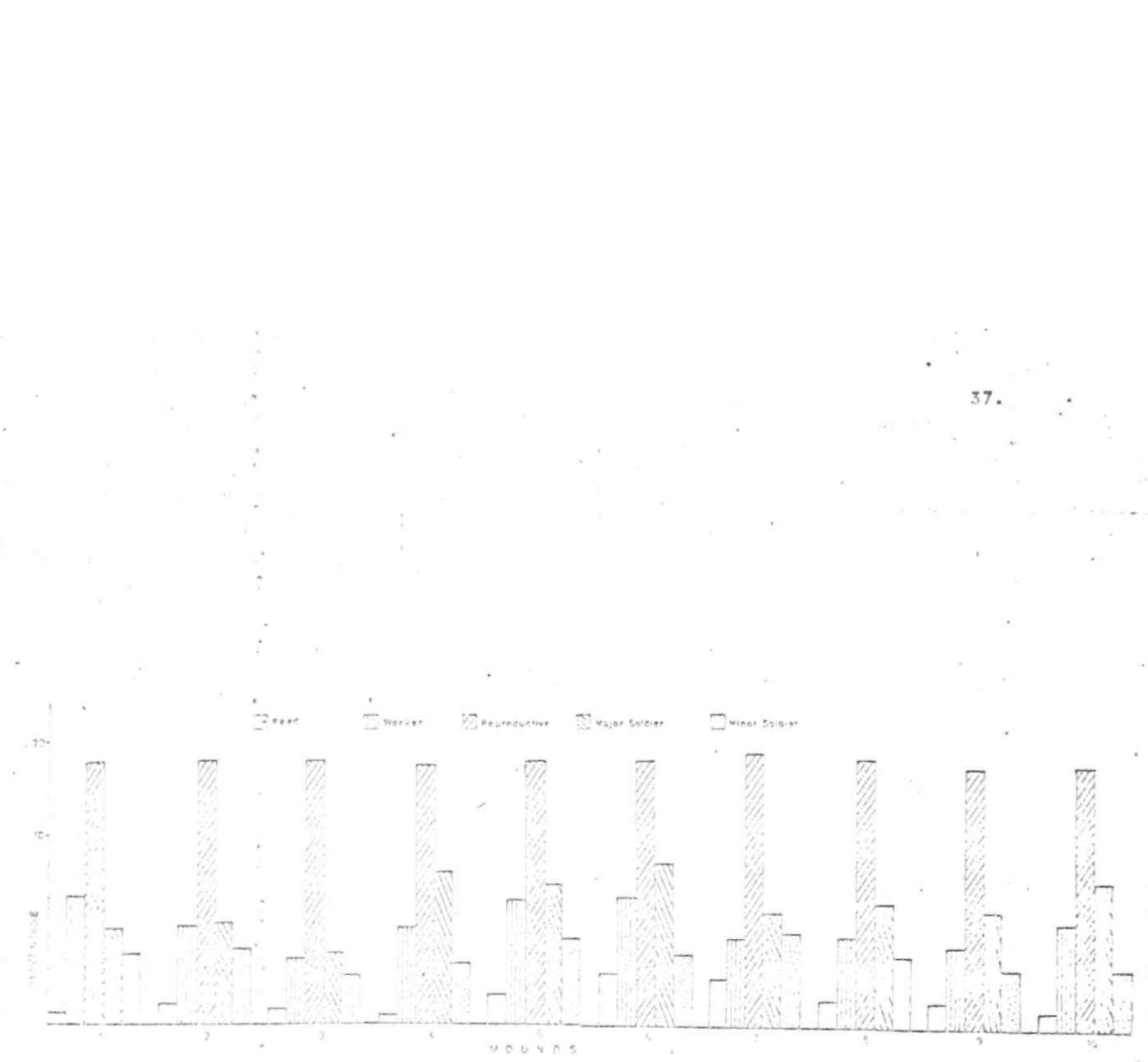


Fig. 3. HISTOGRAMS OF THE PERCENTAGE COMPOSITION OF FAT IN THE INSECT AND FEED

TABLE 5

The protein concentration of termite and grass expressed as percentage of dry weight.

MOUNDS	PERCENTAGE COMPOSITION				
	FEED	WORKER	REPROD.	MAJ. SOL	MIN.SOL.
1	2.57	39.44	55.19	36.19	36.50
2	1.05	45.13	55.00	35.31	37.40
3	2.04	52.51	56.31	36.87	38.31
4	2.57	47.81	58.75	36.81	36.50
5	3.03	52.51	53.37	38.50	37.50
6	3.03	43.75	55.87	38.87	37.25
7	2.57	42.87	55.13	36.87	35.87
8	4.60	50.00	58.25	40.13	39.00
9	4.06	51.37	54.75	38.94	38.19
10	2.04	50.31	56.75	38.50	37.37
$\bar{X}$	2.76	47.57	56.24	37.71	37.39
S.E.	0.32	1.43	0.43	0.48	0.30

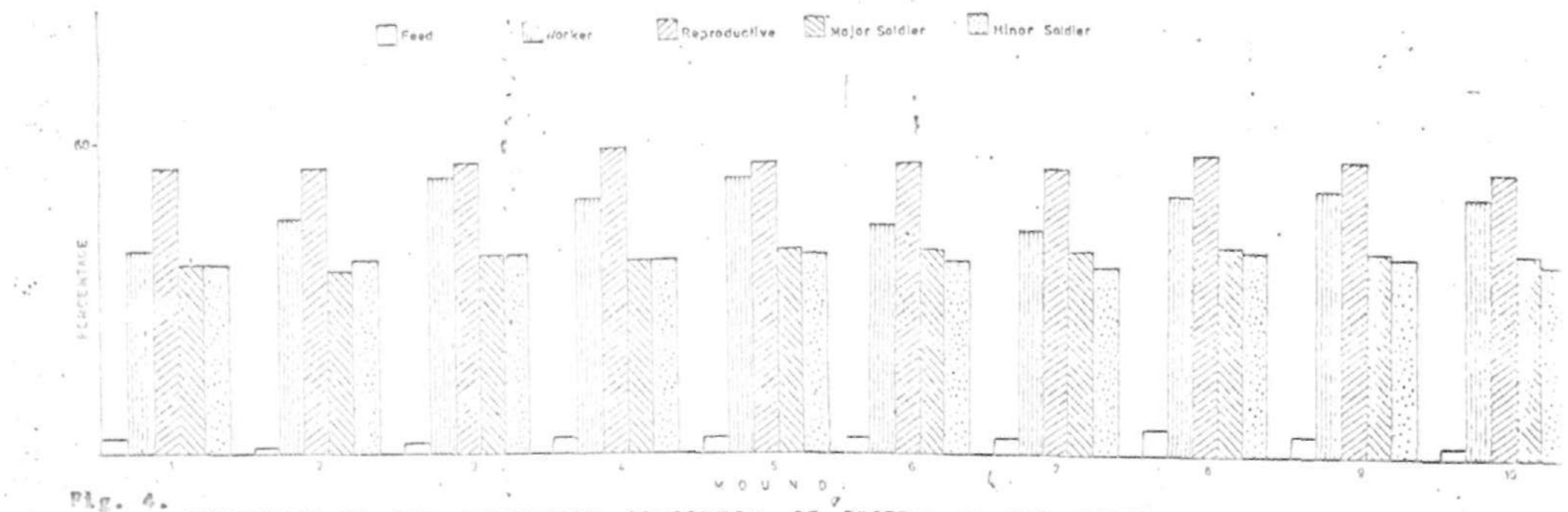


Fig. 4. HISTOGRAMS OF THE PERCENTAGE COMPOSITION OF PROTEIN IN THE INSECT AND FEED

TABLE 6

The carbohydrate concentration of termite and grass expressed as percentage of dry weight.

MOUNDS	PERCENTAGE COMPOSITION				
	FEED	WORKER	REPROD.	MAJ. SOL	MIN.SOL.
1	71.35	42.42	21.30	58.33	54.69
2	86.62	35.68	21.30	54.33	53.69
3	73.91	27.23	19.55	51.23	54.07
4	73.41	33.84	16.79	49.72	55.08
5	82.72	28.05	18.52	48.39	52.91
6	72.17	37.24	20.61	47.42	54.06
7	65.00	39.95	18.03	51.26	53.01
8	61.41	32.49	20.17	47.52	51.90
9	61.38	28.91	18.05	47.25	52.65
10	67.49	26.42	20.31	47.53	53.12
$\bar{X}$	71.55	35.28	19.47	50.68	53.62
S.E.	2.64	1.76	0.49	1.22	0.31

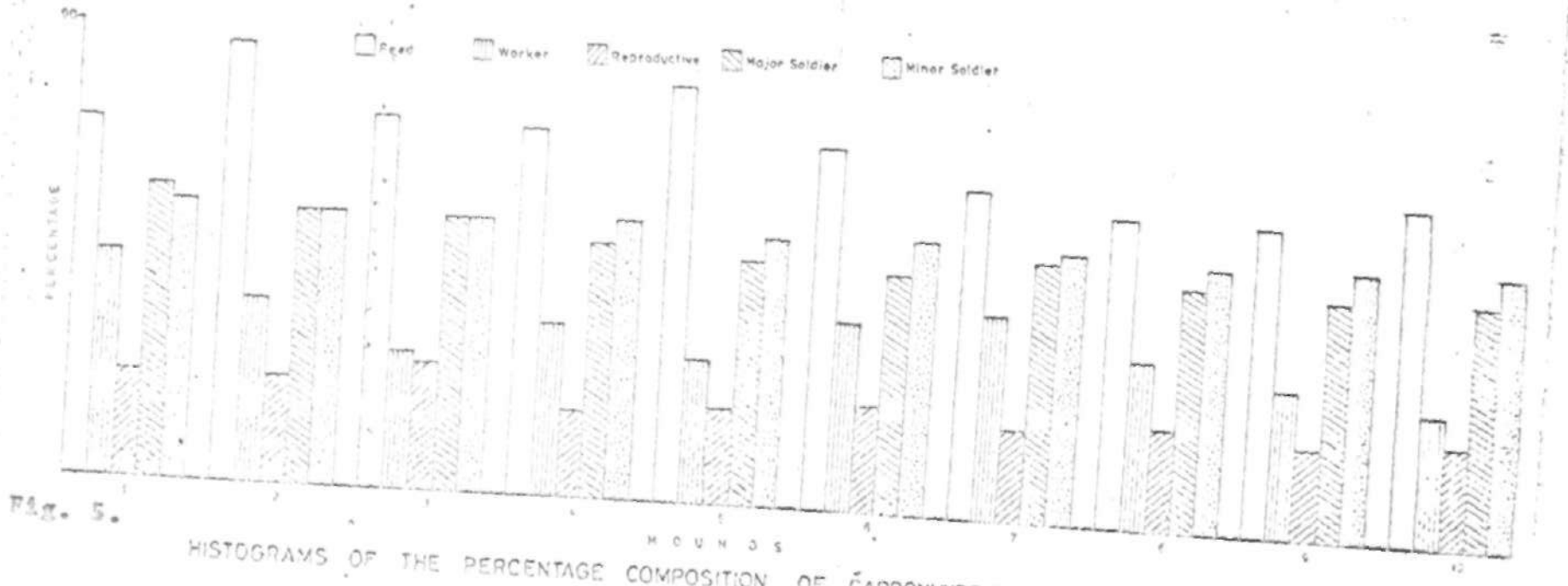


Fig. 5.

HISTOGRAMS OF THE PERCENTAGE COMPOSITION OF CARBONHYDRATE IN THE INSECT AND FEED

TABLES 7

Calcium concentration of termite and grass expressed as percentage of dry weight.

MOUNDS	PERCENTAGE CONCENTRATION				
	FEED	WORKER	REPROD.	MAJ. SOL.	MIN. SOL.
1	0.32	0.28	0.11	0.15	0.05
2	0.27	0.33	0.16	0.13	0.05
3	0.35	0.29	0.17	0.16	0.05
4	0.38	0.39	0.17	0.16	0.05
5	0.31	0.25	0.16	0.13	0.07
6	0.36	0.24	0.15	0.13	0.04
7	0.17	0.23	0.16	0.12	0.05
8	0.20	0.45	0.17	0.12	0.07
9	0.15	0.33	0.16	0.13	0.06
10	0.12	0.30	0.17	0.12	0.07
$\bar{X}$	0.26	0.32	0.16	0.13	0.05
S.E.	0.03	0.02	0.003	0.003	0.006

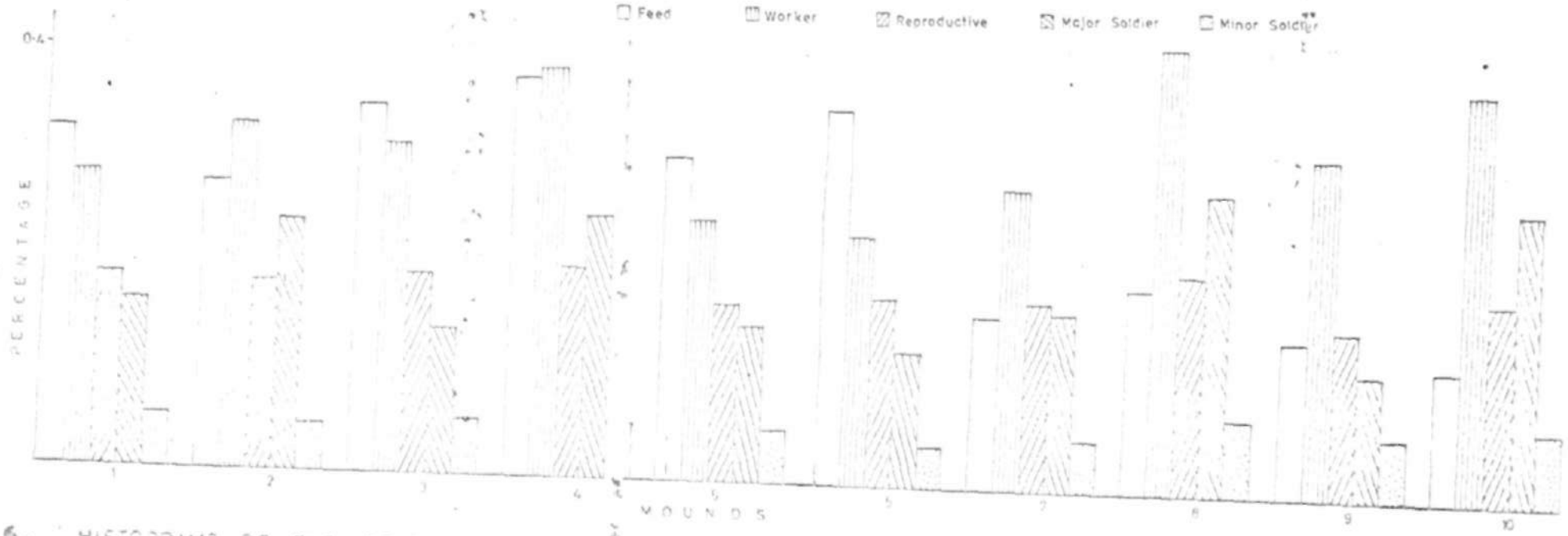


Fig. 6. HISTOGRAMS OF THE PERCENTAGE CONCENTRATION OF CALCIUM IN THE INSECT AND FEED

TABLE 8

Iron concentration of termite and grass expressed as percentage of dry weight.

MOUNDS	CONCENTRATION IN ppm				
	FEED	WORKER	REPROD.	MAJ. SOL.	MIN. SOL.
1	78	162	94	67	19
2	62	158	55	63	21
3	52	159	45	54	23
4	48	173	85	59	21
5	55	164	48	63	17
6	61	176	75	53	19
7	72	181	120	69	21
8	69	157	63	47	22
9	53	177	71	64	21
10	32	218	117	71	25
$\bar{X}$	58.2	172.5	77.3	63.2	20.9
S.E.	4.2	5.7	8.42	2.62	0.71

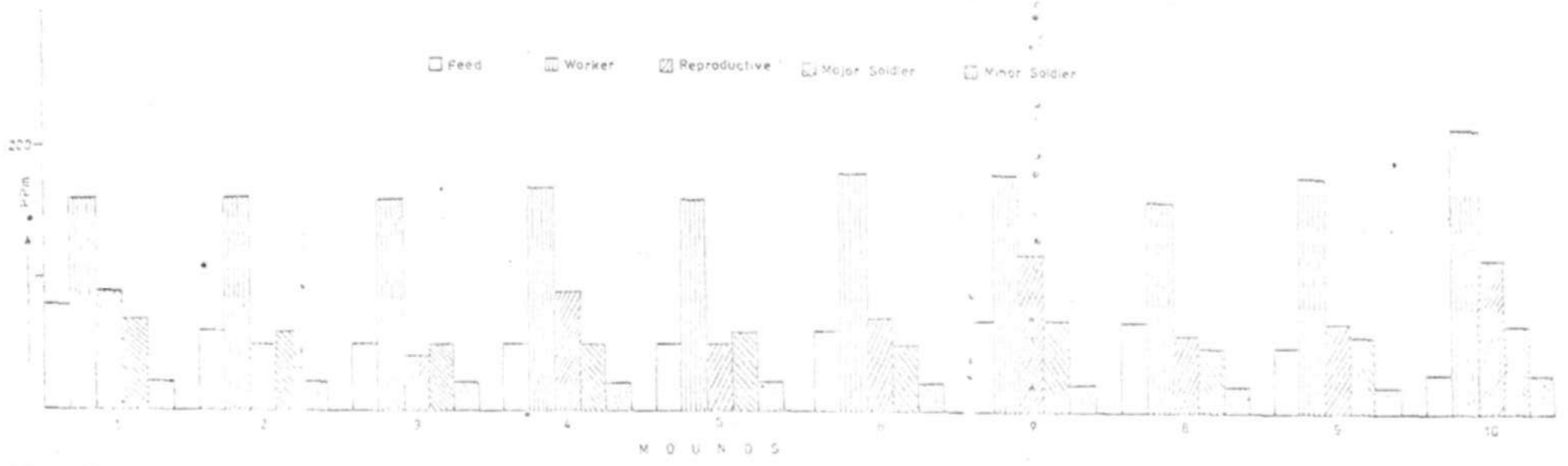


Fig. 7. HISTOGRAMS OF CONCENTRATION (in ppm) OF IRON IN THE INSECT AND FEED

TABLE 9

Magnesium concentration of termite and grass expressed as percentage of dry weight.

MOUNDS	PERCENTAGE CONCENTRATION				
	FEED	WORKER	REPROD.	MAJ. SOL.	MIN. SOL.
1	0.08	0.21	0.13	0.08	0.03
2	0.11	0.16	0.07	0.08	0.03
3	0.15	0.17	0.04	0.07	0.03
4	0.13	0.21	0.13	0.09	0.02
5	0.15	0.20	0.11	0.08	0.03
6	0.12	0.19	0.07	0.09	0.03
7	0.15	0.18	0.06	0.11	0.03
8	0.11	0.22	0.12	0.11	0.02
9.	0.15	0.25	0.15	0.12	0.03
10	0.18	0.25	0.09	0.10	0.03
$\bar{X}$	0.13	0.21	0.11	0.09	0.03
S.E.	0.007	0.01	0.013	0.005	0.01

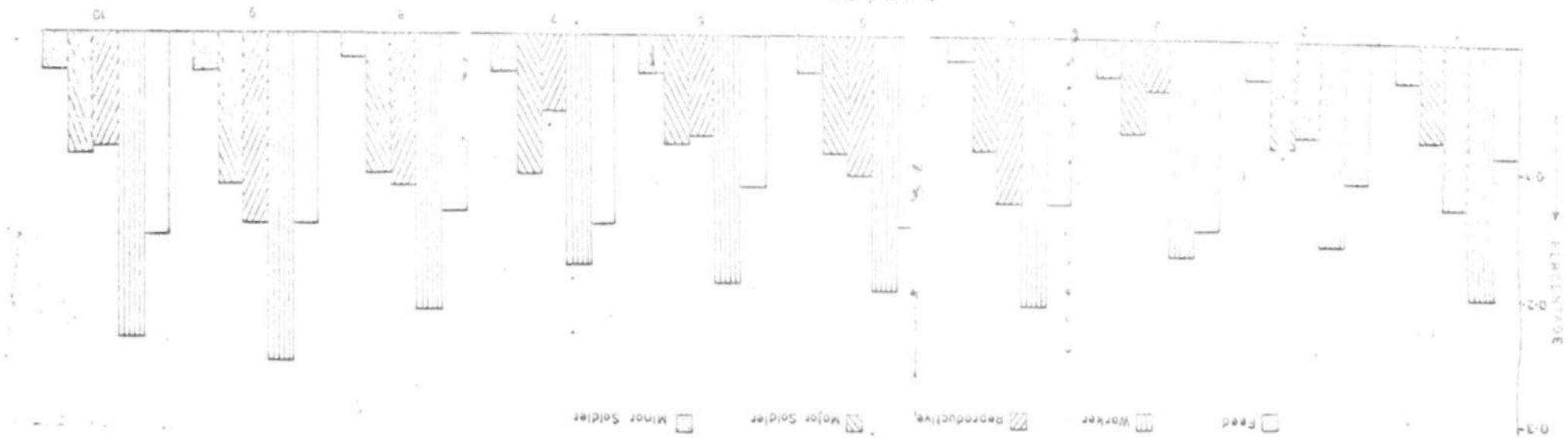


FIG. 8. HISTOGRAMS OF THE PERCENTAGE CONCENTRATION OF MAGNESIUM IN THE INSECT AND FEED

TABLE 10

Potassium concentration of termite and grass expressed as percentage of dry weight.

MOUNDS	PERCENTAGE CONCENTRATION				
	FEED	WORKER	REPROD.	MAJ. SOL	MIN. SOL
1	0.27	0.79	0.17	0.18	0.11
2	0.37	0.71	0.15	0.16	0.07
3	0.25	0.80	0.16	0.18	0.08
4	0.27	0.84	0.20	0.18	0.12
5	0.22	0.95	0.16	0.19	0.08
6	0.23	0.86	0.14	0.14	0.07
7	0.21	0.82	0.24	0.18	0.13
8	0.29	0.76	0.15	0.15	0.06
9	0.27	0.93	0.23	0.17	0.11
10	0.25	1.00	0.25	0.18	0.12
$\bar{x}$	0.27	0.83	0.19	0.17	0.10
S.E.	0.01	0.03	0.01	0.01	0.01

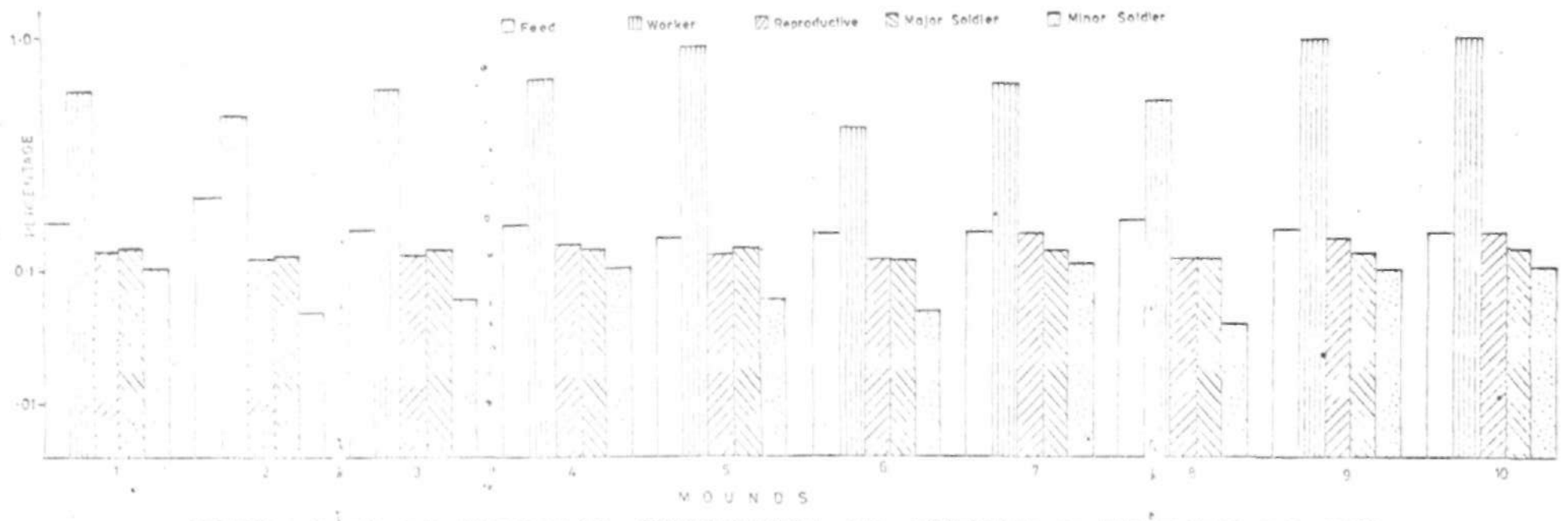


Fig. 9. HISTOGRAMS OF THE PERCENTAGE CONCENTRATION OF POTASSIUM IN THE INSECT AND FEED

TABLE 11

Phosphorus concentration of termite and grass expressed as percentage of dry weight.

MOUNDS	PERCENTAGE CONCENTRATION				
	FEED	WORKER	REPROD.	MAJ. SOL	M[illegible] SOL
1	0.14	0.5	0.35	0.16	0.[illegible]6
2	0.07	0.41	0.39	0.13	0.06
3	0.05	0.44	0.34	0.16	0.07
4	0.11	0.47	0.41	0.16	0.07
5	0.1	0.5	0.41	0.13	0.07
6	0.09	0.5	0.41	0.16	0.06
7	0.07	0.44	0.29	0.15	0.06
8	0.12	0.55	0.39	0.15	0.08
9	0.18	0.51	0.39	0.15	0.07
10	0.18	0.51	0.41	0.13	0.07
$\bar{X}$	0.11	0.48	0.38	0.15	0.07
S.E.	0.01	0.02	0.1	0.12	0.1

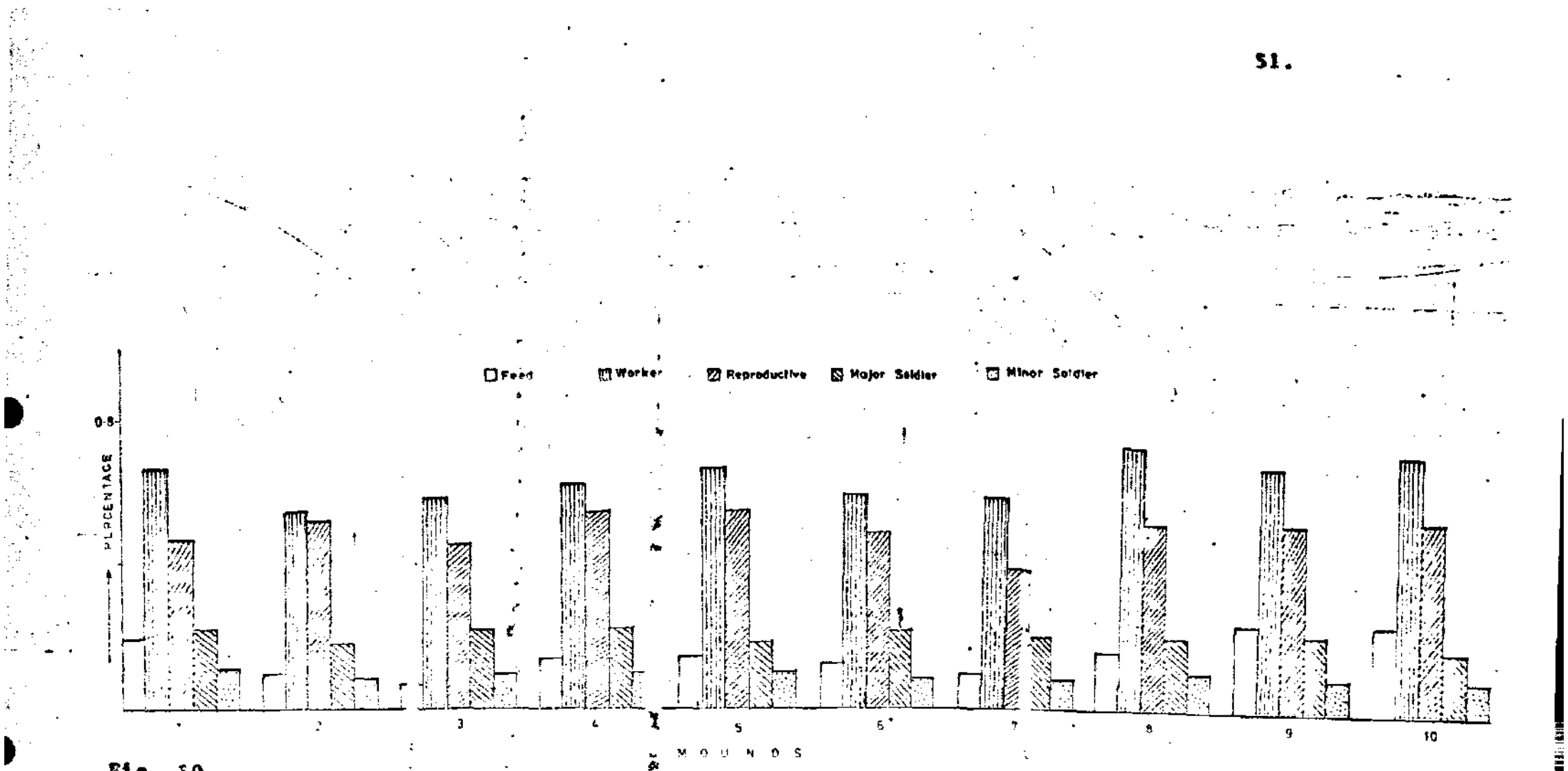


Fig. 10. HISTOGRAMS OF THE PERCENTAGE CONCENTRATION OF PHOSPHORUS IN THE INSECT AND FEED

TABLE 12

Zinc concentration of termite and grass expressed as percentage of dry weight.

MOUNDS	CONCENTRATION IN ppm.				
	FEED	WORKER	REPROD.	MAJ. SOL	MIN. SOL
1	3.8	101	30	31	11
2	4.0	95	29	24	13
3	8.0	92.5	34	22	12
4	10	96.0	37	26	9.0
5	5.9	89.0	38	23	12
6	6.9	80.5	29	14	13
7	2.0	112	29	19	12
8	4.8	100	27	17	9.0
9	5.0	122	36	33	8.0
10	4.4	110	38	52	11
$\bar{x}$	5.48	112.75	32.7	26.1	11.0
S.E.	0.75	5.86	1.37	3.42	0.56

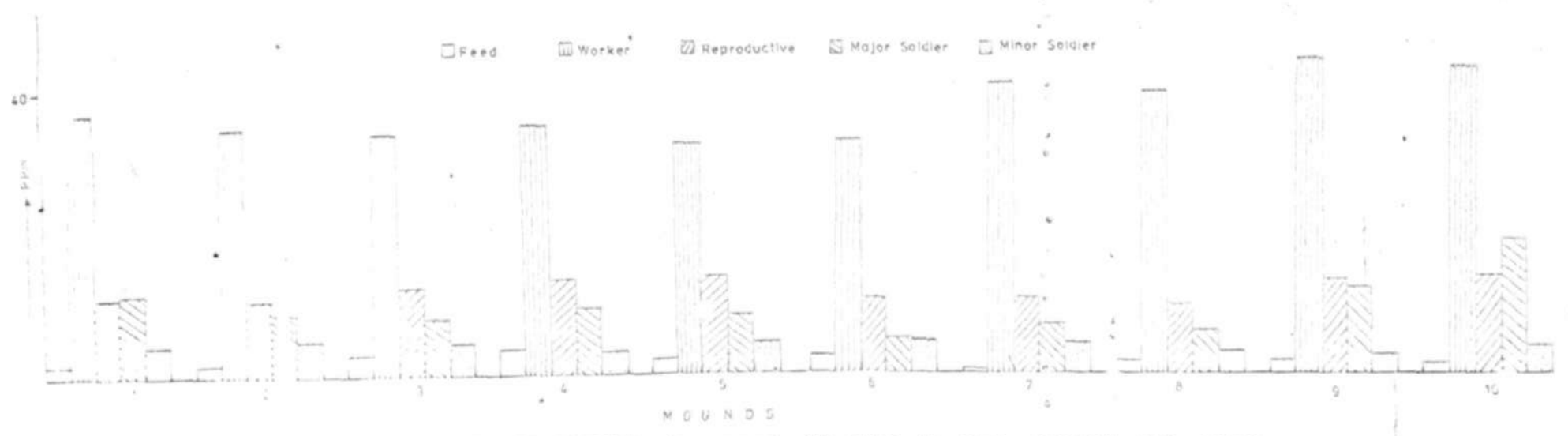
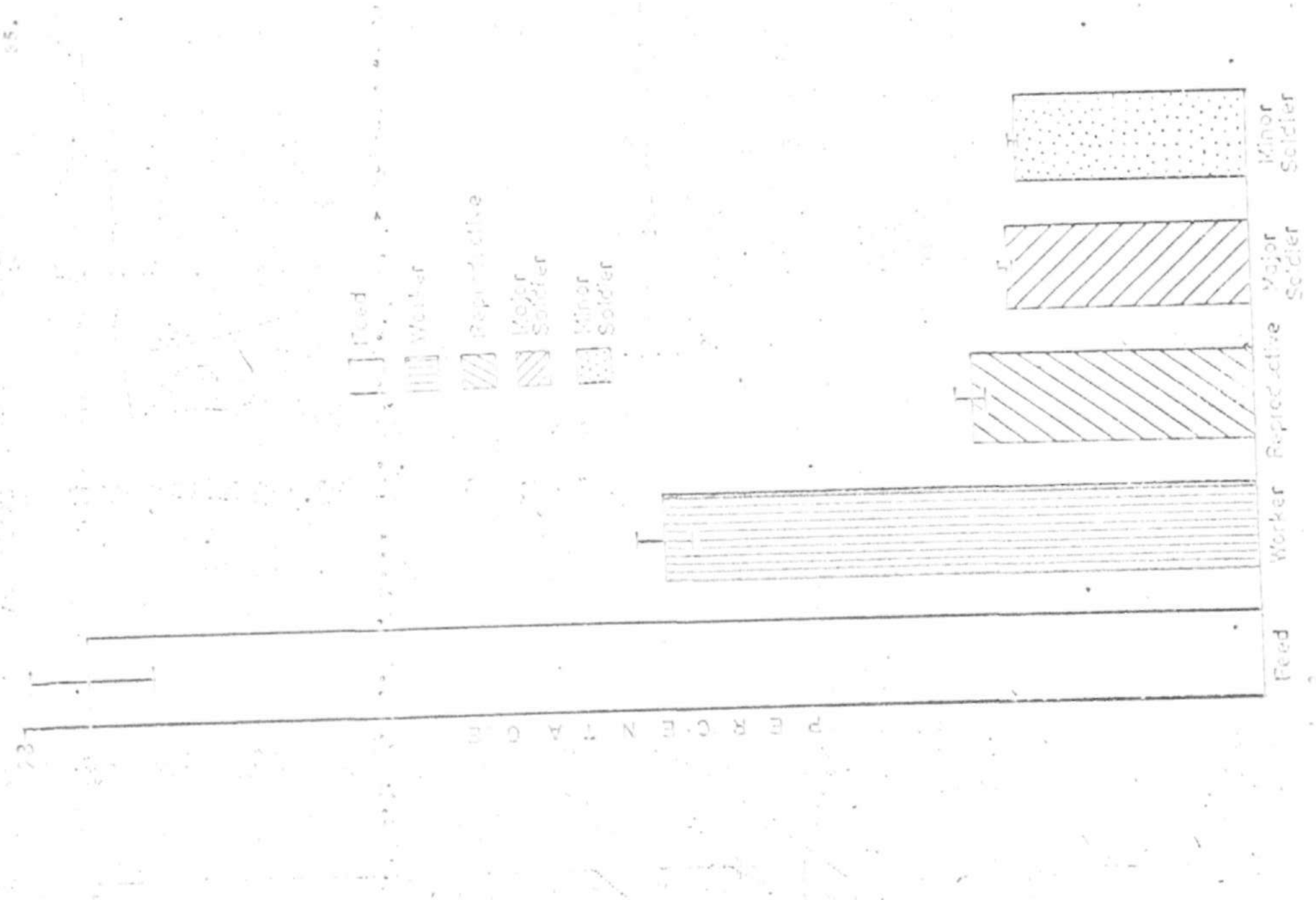


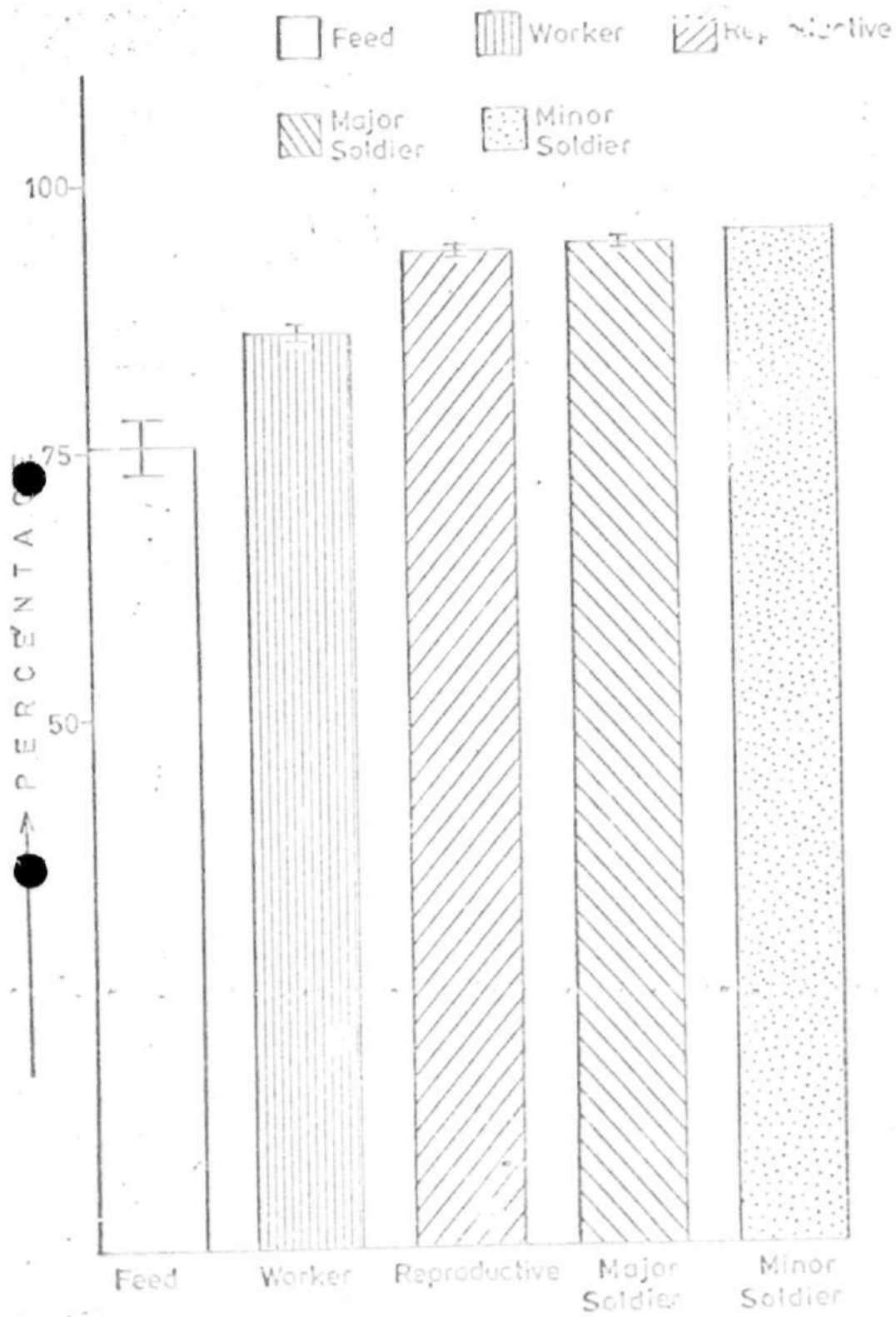
Fig. 11. HISTOGRAMS OF THE CONCENTRATION (in ppm) OF ZINC IN THE INSECT AND FEED

TABLE 13

Mean percentage concentration ± S.E. recorded for termite and grass.

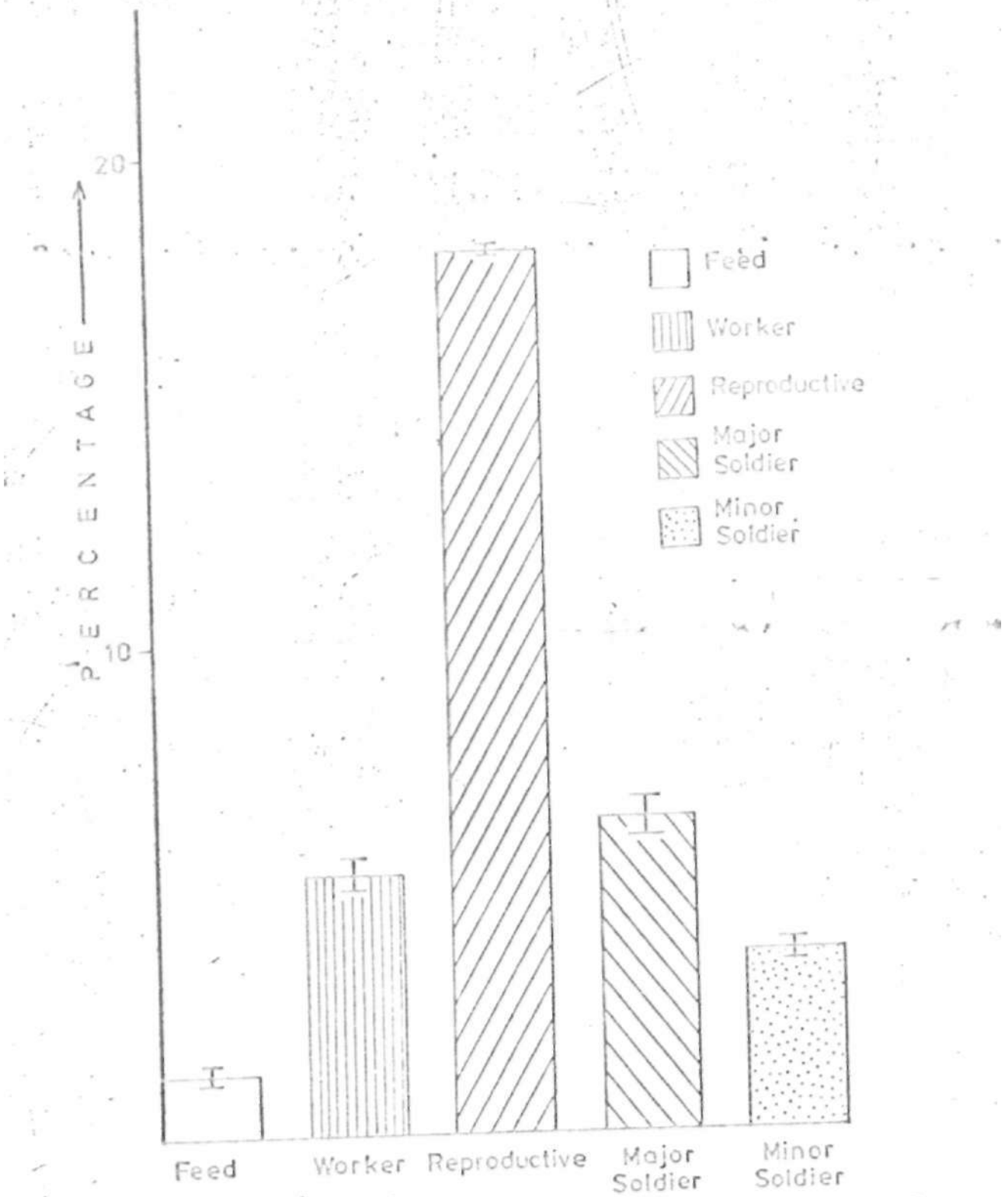
SUBSTANCE	MEAN ± S.E.				
	FEED	WORKER	REPROD	MAJ. SOL.	MIN. SOL.
	n = 10	n = 10	n = 10	n = 10	n = 10
ASH	26.36±1.46	13.96±0.65	6.64±0.31	5.68±0.18	5.39±0.15
ORG. MAT.	75.43±2.44	86.05±0.65	93.36±0.31	94.22±0.25	94.82±0.15
LIPID	1.3±0.23	5.26±0.34	18.06±0.12	6.41±0.46	3.63±0.22
PROTEIN	2.75±0.32	47.57±1.43	56.24±0.43	37.71±0.48	37.39±0.3
CARBOHYD.	71.55±2.64	35.28±1.76	19.47±0.49	50.68±1.22	53.62±0.31


Minor Soldier
Major Soldier
Reproductive
Worker
Feed
PERCENTAGE



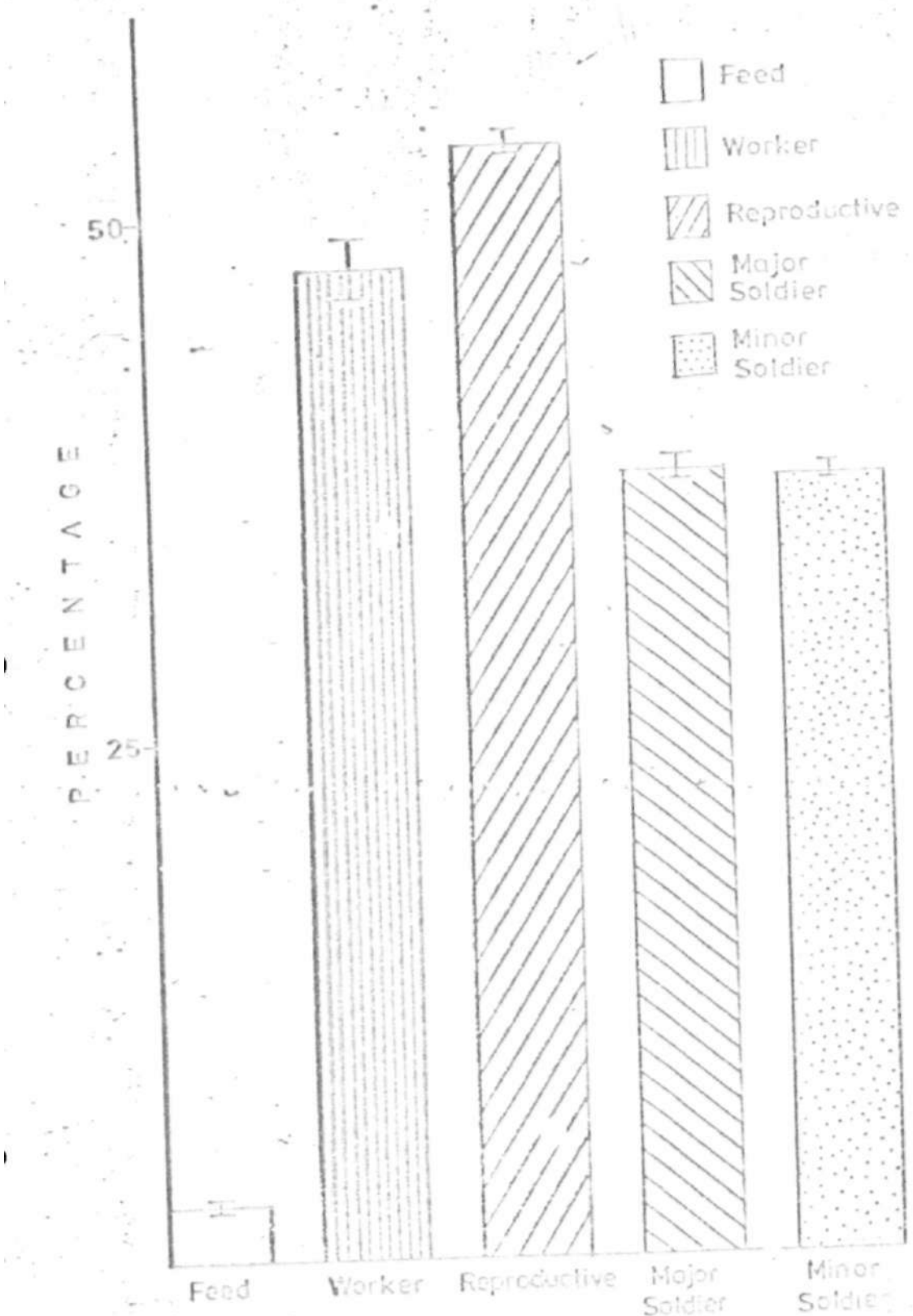
HISTOGRAMS OF THE PERCENTAGE COMPOSITION OF ORGANIC MATTER IN THE INSECT AND FEED (MEAN ± S.E)

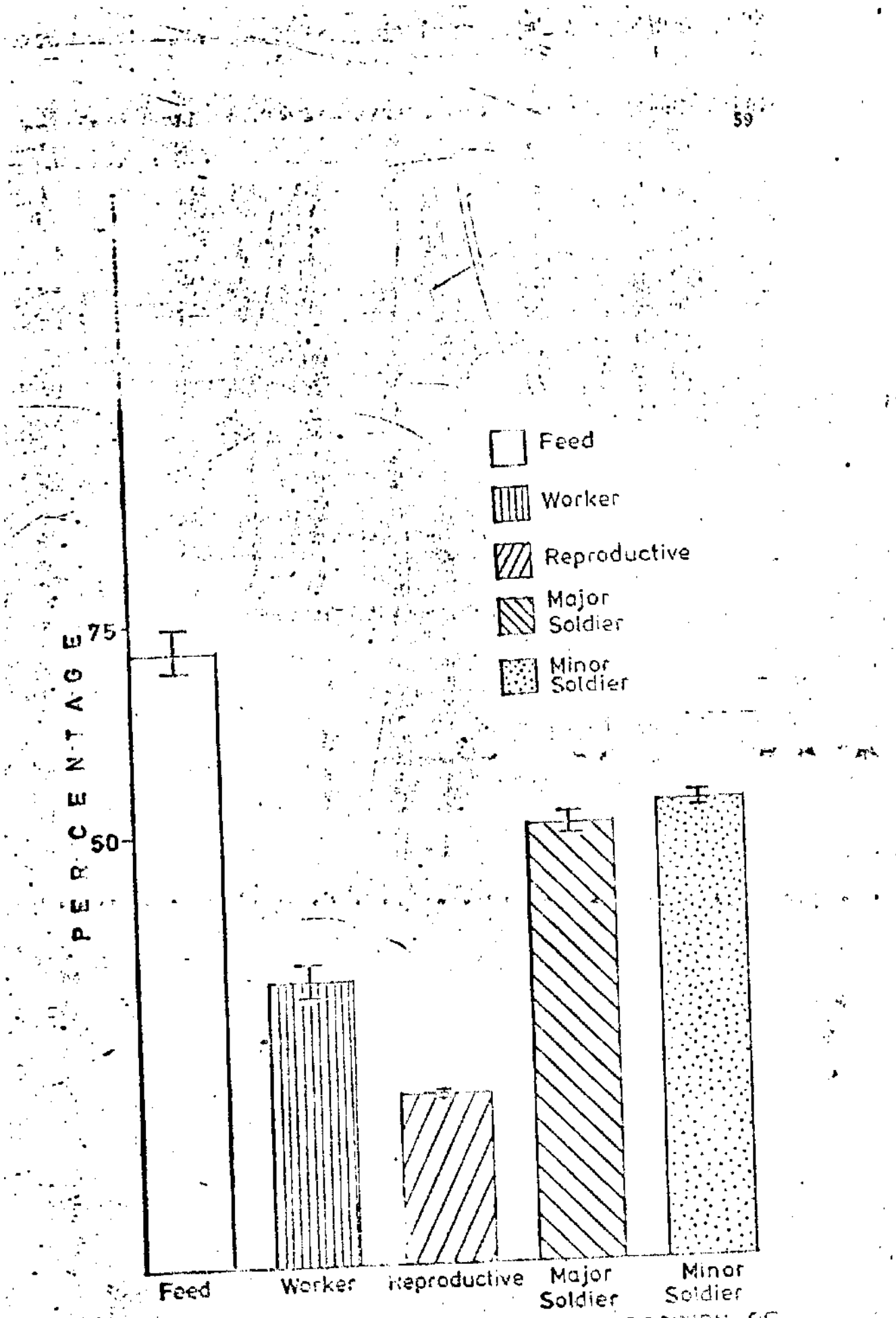
Fig. 13.



HISTOGRAMS OF THE PERCENTAGE COMPOSITION OF FAT IN THE INSECT AND FEED (MEAN ± S.E.)

Fig. 14.


Feed
Worker
Reproductive
Major Soldier
Minor Soldier
50
25
PERCENTAGE
Feed
Worker
Reproductive
Major Soldier
Minor Soldier



HISTOGRAMS OF THE PERCENTAGE COMPOSITION OF CARBONHYDRATE IN THE INSECT AND FEED(MEAN ±S.E)

TABLE 14

Ratio of the chemical concentration in the feed to the concentration in the termite castes.

	FEED	WORKER	REPROD.	MAJ. SOL.	MIN. SOL.
n	10	10	10	10	10
ASH	1	0.83	0.25	0.22	0.20
ORG. MATTER	1	1.13	1.2	1.25	1.26
LIPID	1	1.05	13.89	4.93	2.79
PROTEIN	1	17.24	20.38	13.66	13.55
CARBOHYD.	1	0.49	0.27	0.71	0.75

TABLE 15

Ratio of the chemical concentration of the termite castes.

	WORKER	REPROD.	MAJ. SOL	MIN. SOL
n	10	10	10	10
ASH	1	0.48	[illegible]	0.39
ORG. MATTER	1	1.03	[illegible]	1.10
LIPID	1	3.43	1.22	0.69
PROTEIN	1	1.18	0.79	0.79
CARBOHYD.	1	0.55	1.44	1.52

TABLE 16

The mean percentage (ppm for Iron and Zinc) concentrations ± S.E. for mineral elements for termite and grass.

ELEMENTS	MEAN ± S.E.				
	FEED	WORKER	REPROD.	MAJ. SOL.	MIN. SOL.
	n=10	n=10	n=10	n=10	n=10
CALCIUM	0.26±0.03	0.32±0.02	0.16±0.003	0.13±0.004	0.05±0.006
IRON	58.2±4.2	172.5±5.76	77.3±8.42	60.2±2.62	20.9±0.71
MAGNES.	0.13±0.007	0.21±0.01	0.11±0.013	0.09±0.005	0.03±0.001
POTASS.	0.27±0.01	0.83±0.03	0.19±0.01	0.17±0.01	0.1±0.01
PHOSPHD.	0.11±0.01	0.48±0.02	0.38±0.1	0.15±0.12	0.07±0.01
ZINC	5.48±0.73	109.5±5.85	32.7±1.37	26.1±3.42	11.0±0.56

TABLE 17

Ratio of the concentration of mineral elements in the termite and the grass.

	FEED	WORKER	REPROD.	MAJ. SOL.	MIN SOL.
n	10	10	10	10	10
CALCIUM	1	1.25	0.59	0.48	0.19
IRON	1	2.96	1.33	1.03	0.30
MAGNESIUM	1	1.82	0.85	0.69	0.23
POTASSIUM	1	3.27	0.70	0.63	0.37
PHOSPHORUS	1	4.36	3.45	1.35	0.64
ZINC	1	14.70	5.97	4.76	2.01

TABLE 18

Ratio of the concentration of mineral elements in the termite castes.

	WORKER	REPRODUCTIVE	MAJ. SOLDIER	MIN. SOLDIER
n	10	10	10	10
CALCIUM	1	0.5	0.41	0.16
IRON	1	0.45	0.35	0.12
MAGNESIUM	1	0.52	0.43	0.14
POTASSIUM	1	0.23	0.21	0.12
PHOSPHORUS	1	0.79	0.31	0.15
ZINC	1	0.32	0.25	0.11

CHAPTER FIVE

DISCUSSION

As shown in tables 2,13 and 15 Figs. 1 and 12, a higher percentage concentration of ash was recorded in the feed than in the different insect castes. However, the higher ash concentration did not represent a higher concentration of minerals analysed for, in the feed (Tables 16 and 17 Fig. 17). This situation may have arisen for the following reasons: certain mineral elements, as chlorine and macronutrients like silicon and sulfur are known to be abundant in plants (Salisbury and Ross, 1969), and silicon is particularly abundant in monocots, especially members of the grass family: also, carbon, carbonates and oxides of certain minerals persist during ashing (Obodo, 1982). Those undetected elements and compounds could have accounted for the high values recorded for ash concentration in the feed. Similar values have been reported by Adams (1975) and Oni (1979). Among the insect castes, the ash concentration was directly proportional to the concentration of mineral elements.

The distribution of concentration of the mineral elements follows the pattern given by Cunningham (1964), Gauch (1972), and Adams (1975) for forages and Ammerman *et.al.*, (1974) for animals. Potassium showed the highest concentration in the feed and all the insect castes, apart from the reproductives. This mineral element was found to be very highly concentrated in the workers (Table 17). In cells, potassium appears to exist as a free protoplasmic component and has

been reported to have a certain percentage bound to proteins as co-factors in some enzyme systems (Stout *et.al.*,1947), and also functions as a cell membrance component involved in the maintenance of ionic balance suitable for the activity of the living cells. Its high concentration in the worker, which was also observed for the other mineral element analysed for (Table 17), was probably due to accumulation, a phenomenon commonly occurring in animals (Rook and Balch, 1962; Rook and Storry, 1962;Jones and Pendrock, 1955; Cohen, 1973) The abundance of this element in plants and animals has been widely reported, although its essentiality in these organisms is not too well known (Gauch, 1972). The higher concentration of phosphorus in the reproductives is strongly linked to both their protein content and carbohydrate phosphorylation, which are fully discussed later. The results obtained are similar to those of several authors who have worked on forage (Cunningham, 1964; Haag *et.al.*,1967; Jacobson *et.al.*,1972; Jones *et.al.*, 1972; Comide, 1976; and Smartt, 1976) and animal samples (Cohen, 1973; Ammerman *et.al.*,1974).

Calcium was next to potassium in abundance in the feed (Tables 7 and 16; Fig. 9). In the insect, it was third, behind potassium and phosphorus. Calcium is a known component of the cell membrance and also an essential part of α- amylase, an enzyme to which it acts as an activator. Cell division is also affected by calcium where the element plays a part in the synthesis of the cell plate (Gauch, 1972).

The results obtained agree with those of Austin (1930),

Siegel *et.al.*, (1952), Adams (1975) and Ammerman *et.al.*, (1974).

Whereas magnesium is the third most abundant element in the feed, it is fourth in the insect (Table 9 and Fig. 8). This element is known to be very essential in photosynthetic activity as a part of the chlorophyll molecule. The element is also an activator for enolase, hexokinase and carboxylase. It also plays a role in the catabolism of adenosine di-and tri-phosphates to give off energy. These important metabolic roles account for the abundance of this macronutrient in both the feed and the insect castes. As discussed earlier, the very high concentration of the element in the worker is due more to accumulation than actual need. As obtained in this study, Bartha (1970), Long *et.al.*, 1972) and Adams (1975) have reported similar concentration for forages. Also, Ammerman *et.al.*, (1974) and De Sousa (1978) have reported the element to be the fourth most abundant in the tissue of animals.

Lower phosphorus levels occurred for the feed than the insects except the minor soldier (Tables 9 and 17 and Fig. 10). In animals and plants, phosphorus is a constituent of many compounds as nucleoproteins, phospholipids and certain coenzymes. As a component of nucleoproteins, phosphorus is involved in cell division and the transfer of hereditary characters by the chromosomes (McElroy and Glass, 1951,1952). The phospholipid, lecithin, is believed to be present in cell membrane and to be of universal occurrence in all living cells. Special hydrogen ion carriers, diphosphopyridine nucleotide (DPN or NADP) are concerned with hydrogen ion

transfers that occur as steps in the Krob's cycle, glycolysis and the pentose cycle. Phosphorus is a constituent of the unique, high energy compounds ADP and ATP. Unlike in plants, large amounts of carbohydrates are converted into lipids by phosphorylation and this may account for the additional requirement of the element in the insect. Again, in the reproductives, where lipids abound and where protein content is high (as reported earlier) due to gametogenesis, the concentration of phosphorus element exceeded that of potassium. These metabolic importance of phosphorus in the reproductives could account for its higher concentration and its uptake may have antagonized the absorption of potassium (Table 18). The concentration of the element obtained for the minor soldiers (Table 17) is linked with their carbohydrate and protein contents. The values obtained for the feed in this study are in accordance with those reported by Cunningham (1964), Bartha (1970), Adams (1975) and Kapu (1975). Values similar to those obtained for the insect have also been reported by Ammerman *et.al.*, (1974).

Concentration of iron was highest among the micronutrients (Tables 8 and 16 and Fig. 7) in both the insect and the feed. It has been established that iron is a constituent of enzymes as cytochrome oxidase which is involved in the terminal step of oxidation in the Krebs (Citric acid) cycle. Iron is also associated with chlorophyl synthesis in plants and is known to be a component of ferrodoxin, an electrontransferring protein (Burris, 1966). Requirements of iron in metabolism is only in small quantities as observed in

this study. The function of this element in enzyme activity and protein synthesis account for its greater abundance in the insects than in the feed. Among the insect its concentration in the worker is probably due to accumulation as alluded to earlier. Andreani *et.al.*,(1969), Comide *et.al.*,(1969) and Adams (1975) have reported on the concentration of iron in plants and the values reported tally with the results of this study. Reports by Cunha *et.al.*, (1969) and Ammerman *et.al.*,(1971) also indicated that animals require an iron level greater than that of the pasture as was observed for the insects. Zinc concentration was also lower in the feed than in the insects (Tables 12 and 17 and Fig. 11). Zinc is required in plants for the maintenance of auxin in an active state (Skoog, 1940) and the element is a prosthetic group in carbonic anhydrase and many respiratory enzymes. These latter functions and involvement in protein synthesis are the major roles played by the element in animals. These metabolic and biochemical involvements account for the trend observed in the study. The results agree with those of Andreani *et.al.*,(1969), Miller (1972), Adams (1975) and Ammerman *et.al.*,(1971).

Copper is a known constituent of some plant proteins and enzymes (Chuch, 1972), or regulates iron, as blood constitment, in invertebrates. However, the non detection of this element in this study could be due to the level of very low concentration in both the insects and the feed. Teixeira *et.al.*, (1971) reported equally low concentrations in fresh forages. Cunha *et.al.*,(1964) and Ammerman *et.al.*(1971) have reported fairly high tolerance in the tissue of animals. Cobalt has

been reported to be essential to legumes having nitrogen-fixing bacteria (Gauch, 1972). No demonstrable essentiality has been reported for animals. Like copper, cobalt was undetected in this study and this was probably as a result of its low concentration in both the insect and the feed. Fernandes and Carmago (1975) reported very low concentration in fresh forage plants, with a further drop occurring with age. Looney *et.al.*, (1975) have reported the rejection of cobalt by the tissues of sheep. Their conclusion that cobalt concentrations in plants may not indicate cobalt availability to animals clearly explains the non-detection of this element in the insect.

The organic matter content (Tables 3 and 14 and Fig. 13) show fairly low values for the feed. As explained earlier, this may be due to the loss of some organic carbon, that ... may have persisted in the ash (Obodo, 1982). There was no significant difference between the values obtained as organic matter content for the major and minor soldiers; this may be linked to their similar structure and role in the termite colony. Adams (1875) has reported compositions similar to those obtained for the feed in this study. Lipid composition was lowest in the feed. Energy substrates are mainly stored in plants as carbohydrates while in animals, a great quantity of the carbohydrate is phosphorylated into fatty acids. This possibly accounts for the disparity in lipid composition in the insects and feed. The reproductives contain significantly more lipids than the other castes. This is probably as a result of the limited mobility of this caste, as very little lipid is oxidised for the purpose of energy

utilization (Mathur and Yurkienicz, 1969). This high lipid concentration may also probably be related to the use of lipids in egg development (Ba'lev, 1975). The cephalic secretory glands in the soldiers may account for the increased index of lipids obtained for these castes. However, this quantity may have been too low in the minor soldiers to supercede that of the workers. Reports by Bartha (1970), and Obodo (1982) are similar to the findings of this study.

Carbohydrates are the main energy substrates in plants, but these are esterified into fatty acids in the insects. This carbohydrate conversion by esterification probably also accounts for the higher concentration of lipids in the insects than the feed and for the inverse lower concentration of carbohydrates in the insects as shown in tables 6 and 14 and figs 16. As obtained, the concentration of carbohydrates in the solders may be as a result of their possession of a higher frequency of the aminopolysaccharide (chitin), a vital exoskeleton component, to dry weight, than the other castes. The results of this study tally with the findings of Salisbury and Ross (1969), Bartha (1970), and Macleod and Minson (1974).

Reproductives possess a marginally ihigher concentration of protein than the other castes and the feed (Tables 5 and 14 and Fig. 15). This may be linked to the need for protein in gametogenesis and other essential systhesis related to reproduction. The low concentration in the feed may be associated with the interferrence of potassium and other ions in the uptake of nitrogen.(Jacobson *et.al.*,1972), an essential component of proteins. The results are similar to those

obtained by Butterworth (1967), Long et.al., (1964, Bartha (1970), and Adams (1975).

Generally the reproductives excelled in the concentration of proteins, lipids and, excluding the workers, all the mineral elements. This may be associated with their having a greater ability to metabolize these biomolecules and elements more efficiently than the other castes.

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APPENDIX I

SOLUTIONS: COMPOSITION AND CONCENTRATION

Determination of Crude Protein

Materials.

(i) Sulphuric acid; concenrated Sp. Gr. 1.84; Nitrogen free.

(ii) Sulphuric acid; 0.05M, Standardised.

(iii) Boric acid (H_3BO_3); 0.3M solution, prepared by disccolving of Boric acid in water and making the volume up to 100 cm^3.

(iv) Sodium Hydroxide Solution; 4M, prepared by disolving 160g of carbonate-free sodium hydroxide pellets in distilled water and making volume up to 1000cm^3.

(v) Kjeldahl Catalyst. 100g of Sodium Sulphate, 10g of Copper Sulphate and 1g of selenium powder, ground and mixed in a mortar.

(vi) Mixed indicator, prepared by mixing 1.25g of methyl red and 0.825g of Methyl blue and then dissolving in 1 litre absolute ethanol. For half litre, 0.625g M.R. and 0.412g M.B.

PHOSPHORUS

Vanadate-molybdate compsite reagents. Prepared by dissolving 70g of Ammonium molybdate in 400cm^3 of warm water; 1g of Ammonium vanadate in 300cm^3 of boiling distilled water, and cooling. Two hundred and forty millilitres of concentrated perchloric acid was gradually added, with stirring, to the vanadate

solution. Finally the molybdate solution was gradually added to the acid vanadate solution, with stirring, and then diluted to litre with distilled water.

APPENDIX 2

Determination of Standard Curves. The absorbance value (percentage transmission or optical density for phosphorus : for standard solutions containing known parts per million or microgram per gram (ppm) of inorganic elements to be monitored for (calcium, Magnesium, Iron, Copper, Chronium, Cobalt, Potassium, Phosphorus and Zinc) were determine for different ppm (Concentrations). Using a Perkin-Elmer Model 2908 atomic absorption spec rophotometer (Brush and Lamb Spectronic for Phosphorus). The values obtained gave the values for the Y-axis in the standard curves. See figs 18-26.

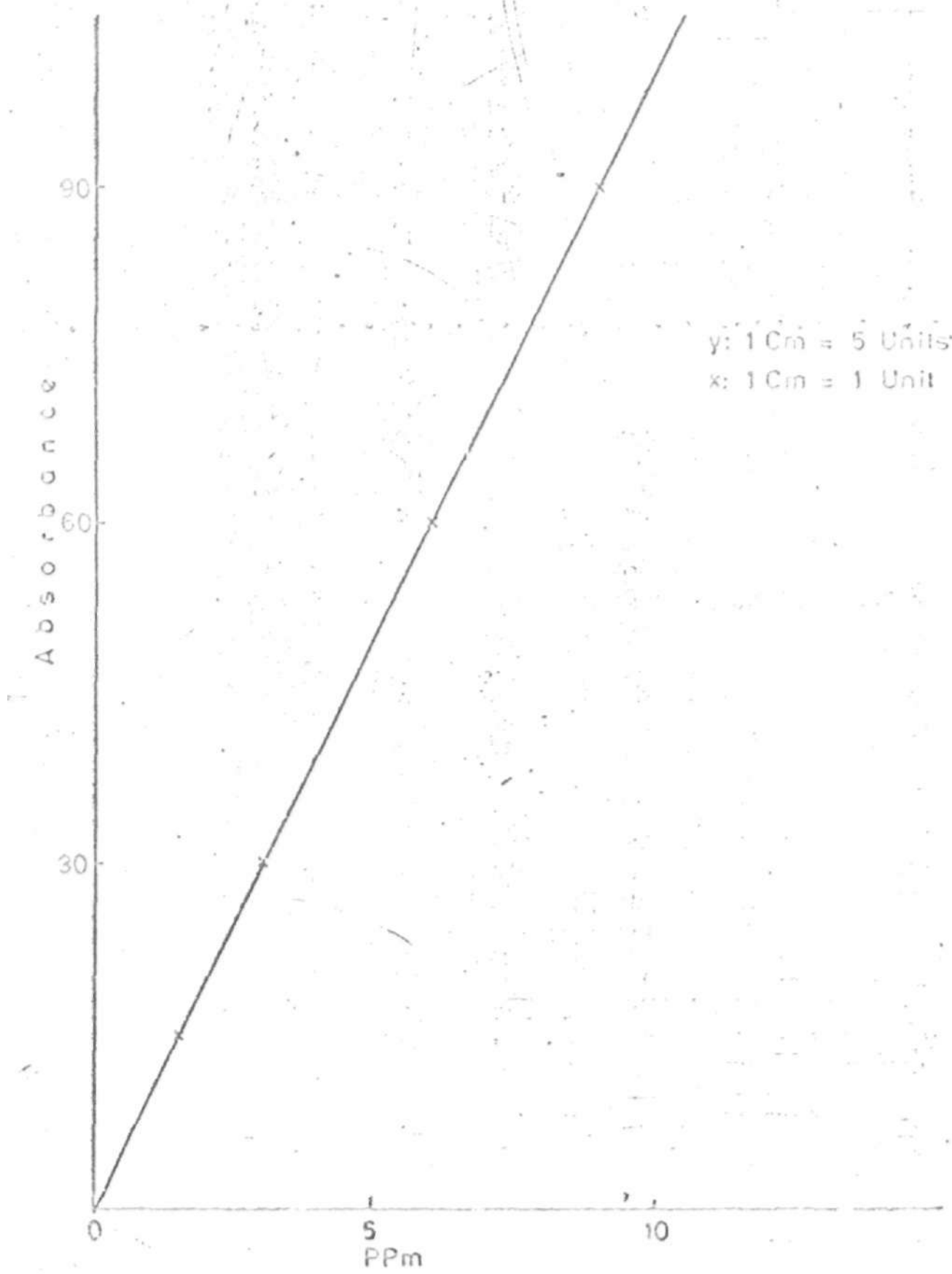


Fig.18 Standard Curve of Absorbance of Calcium

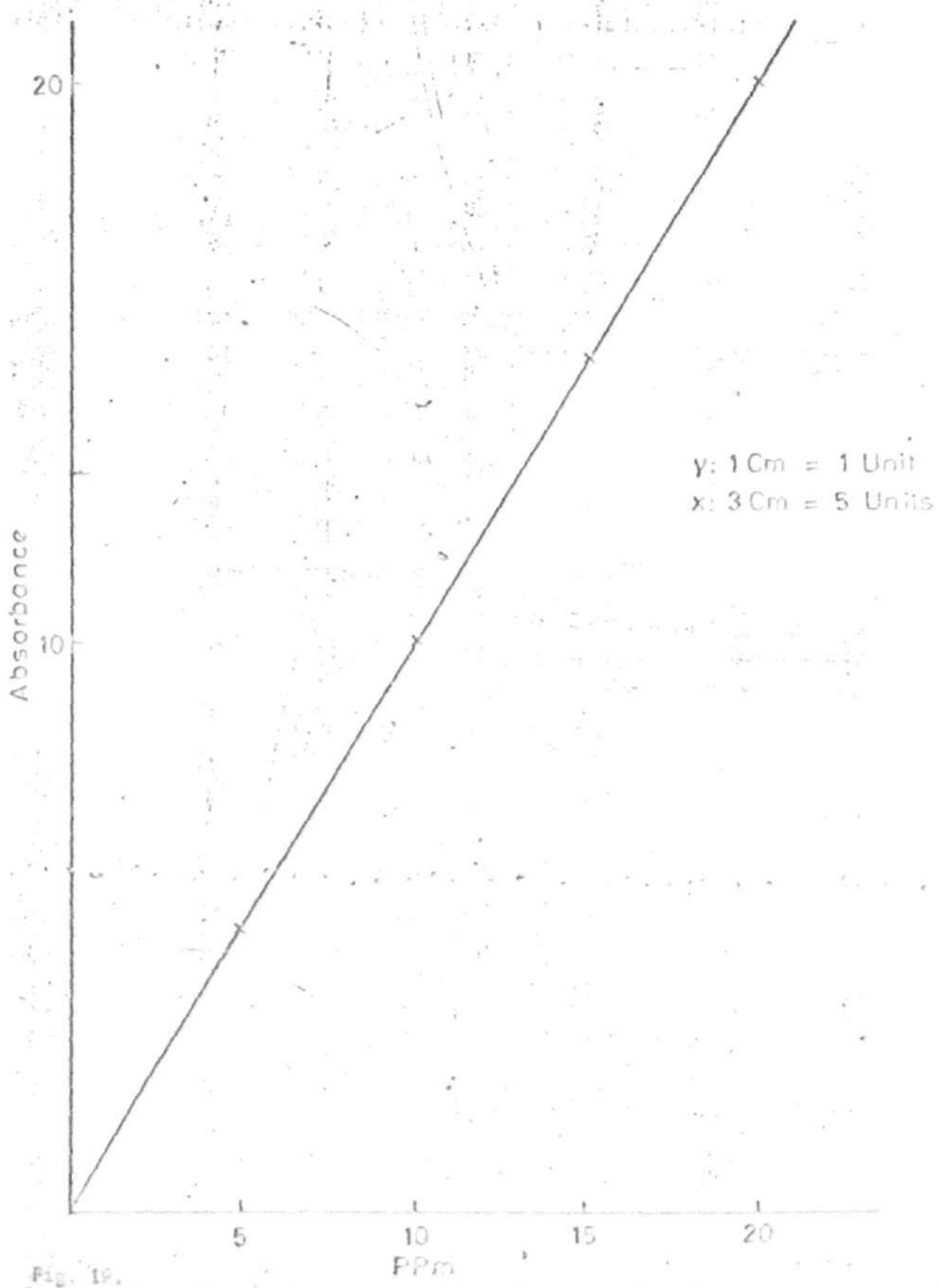


Fig. 19.
Standard Curve of Absorbance of Iro

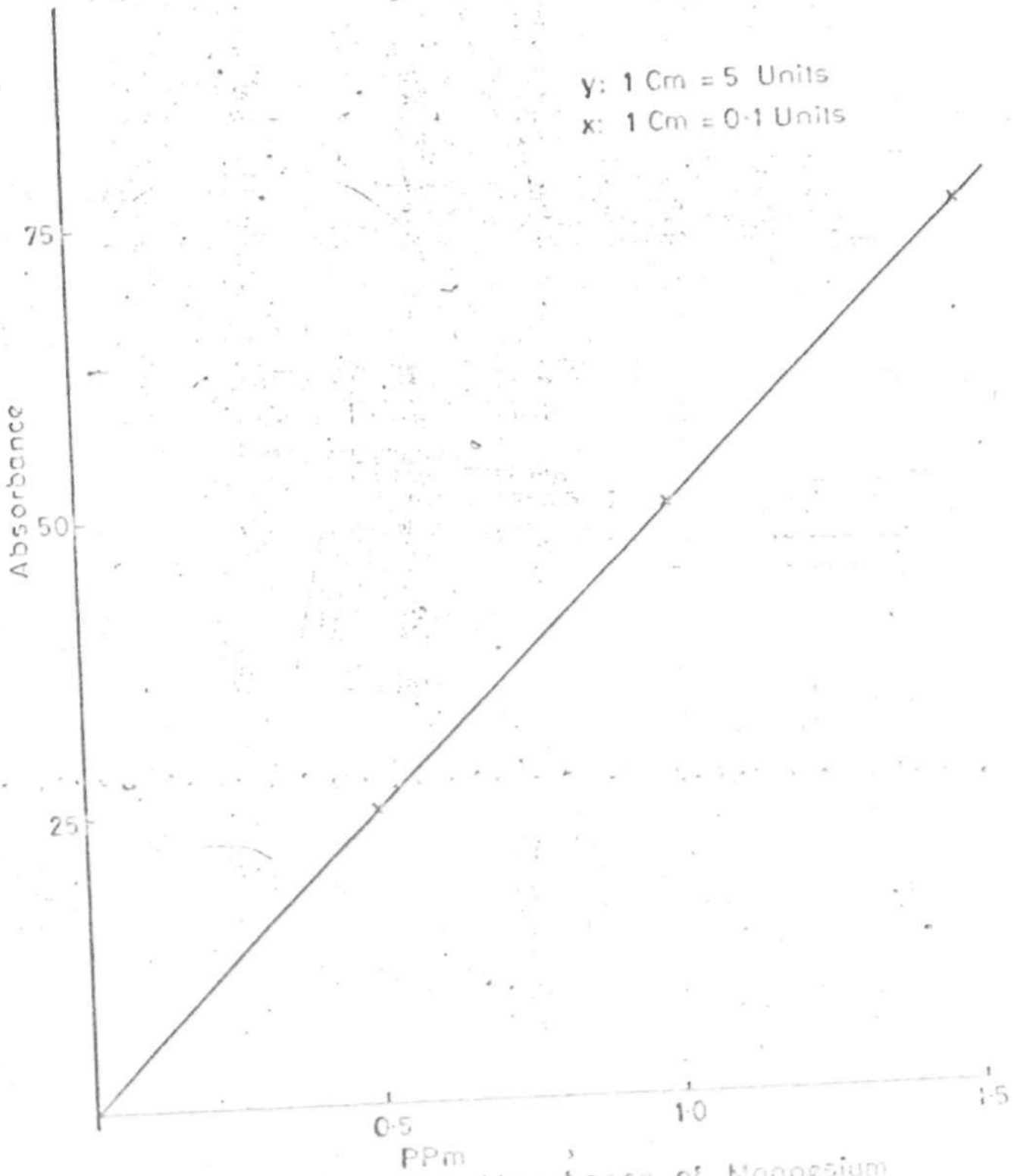


Fig. 20. Standard Curve of Absorbance of Magnesium

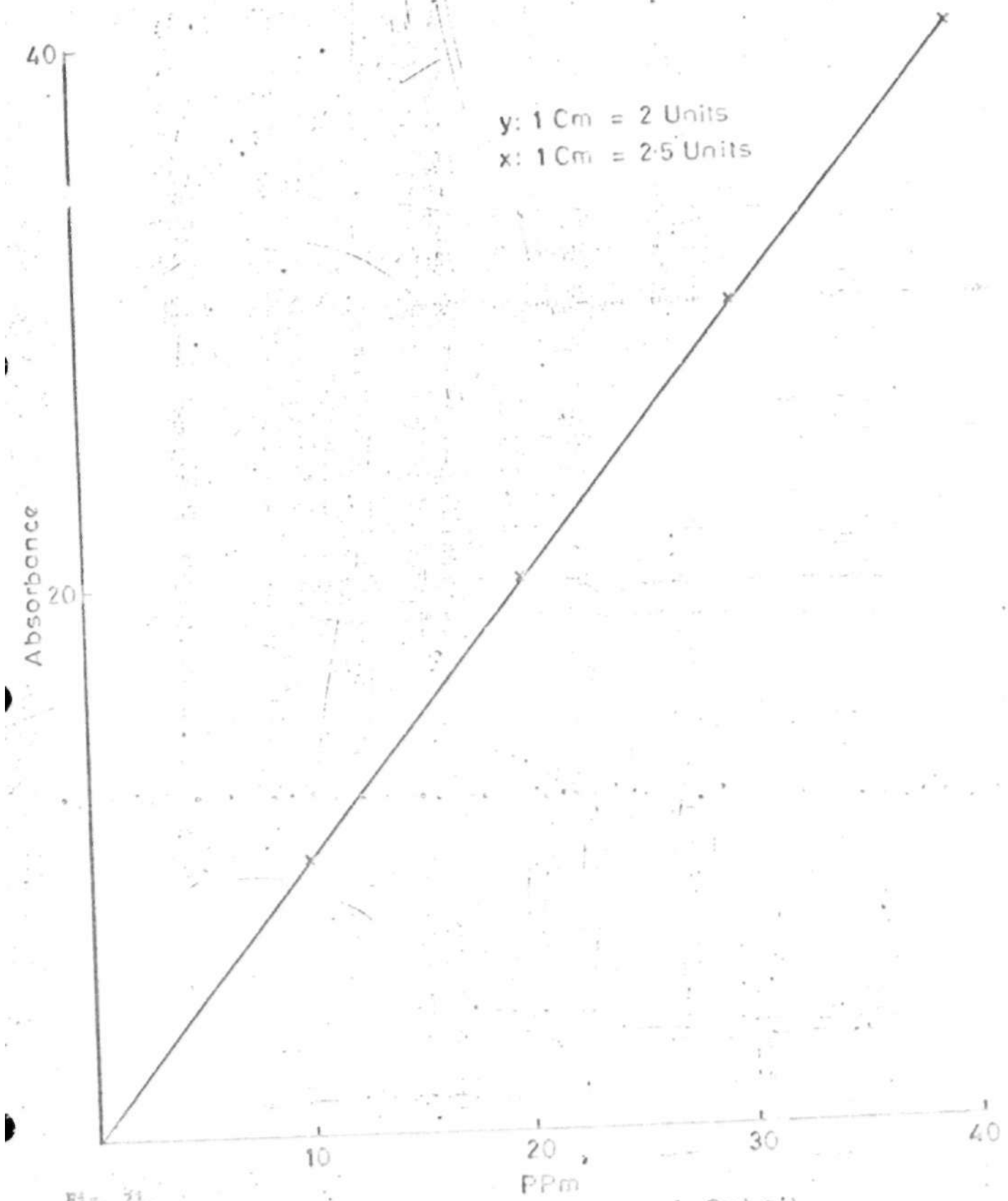


Fig. 21.
Standard Curve of Absorbance of Cobalt

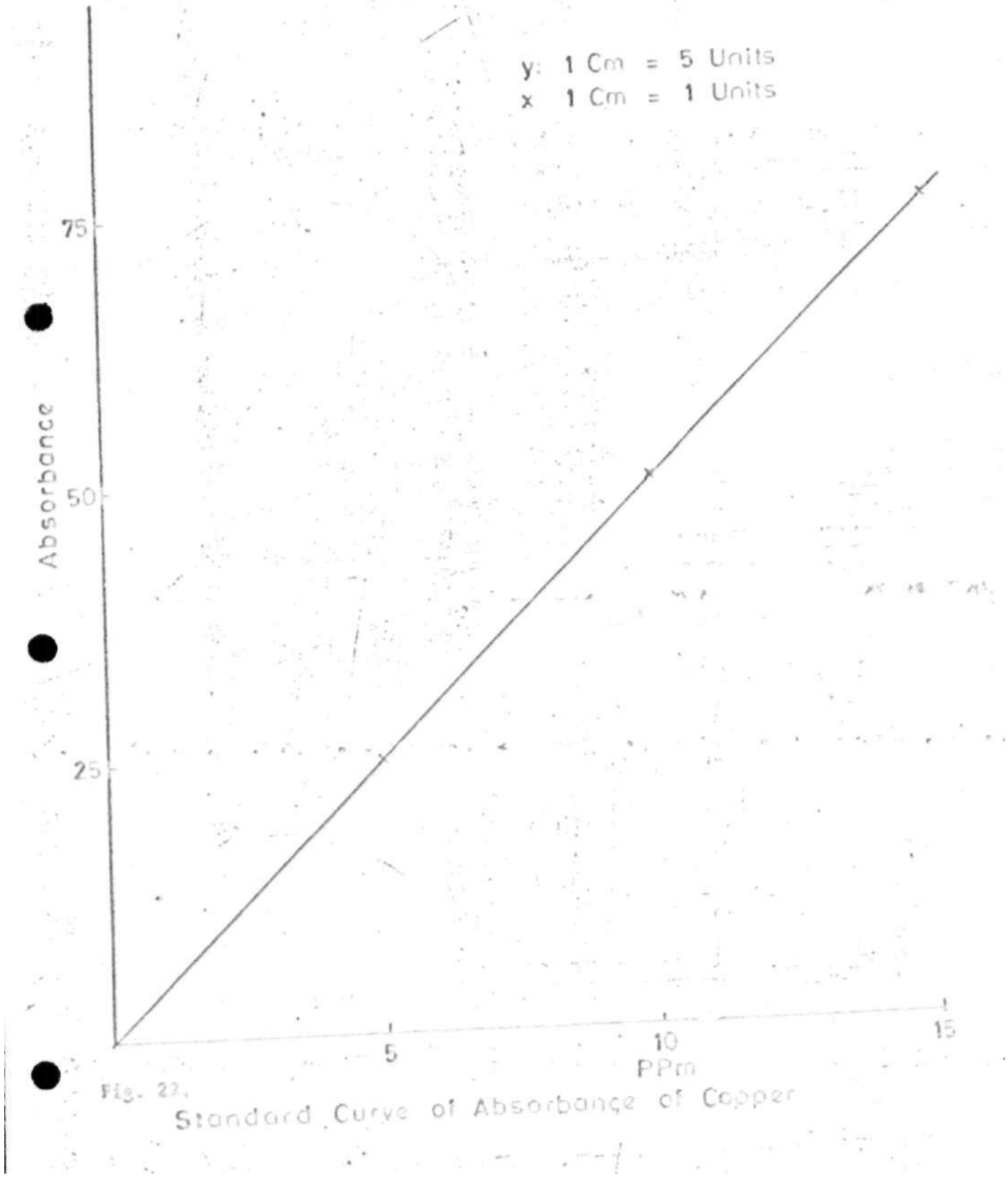


Fig. 22.
Standard Curve of Absorbance of Copper

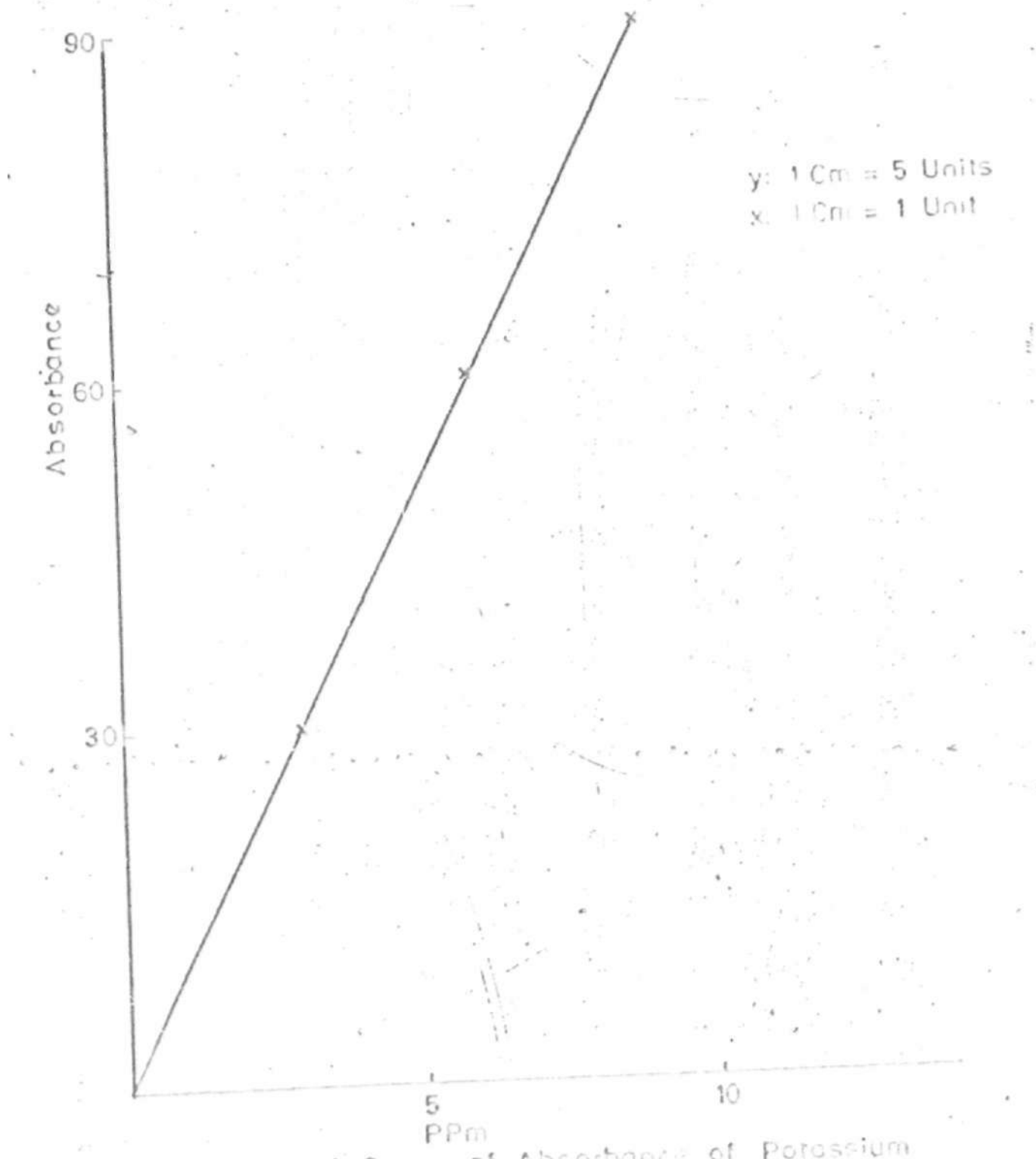


Fig. 23 Standard Curve of Absorbance of Potassium

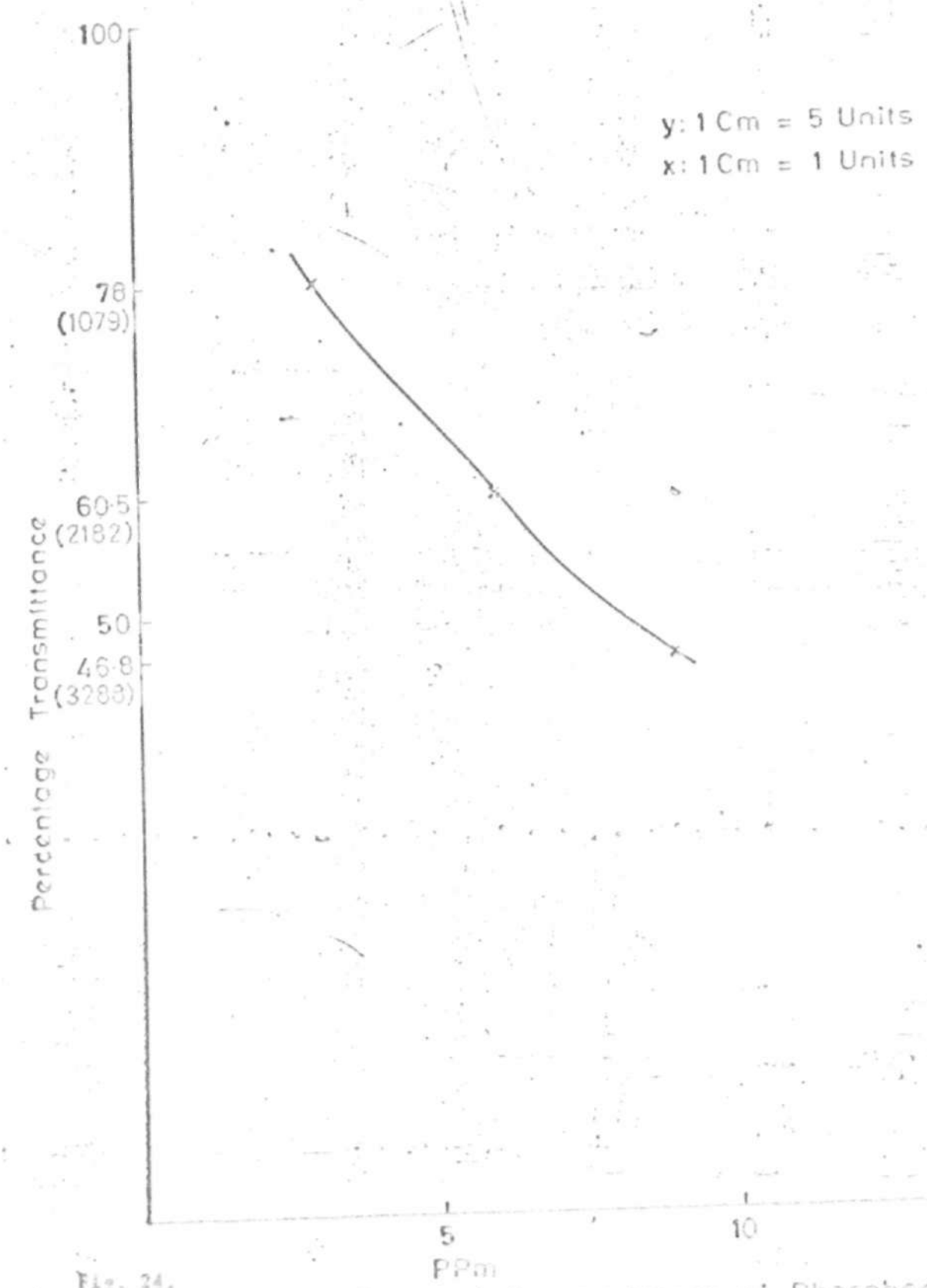


Fig. 24.
Standard Curve of Transmittance of Phosphorus

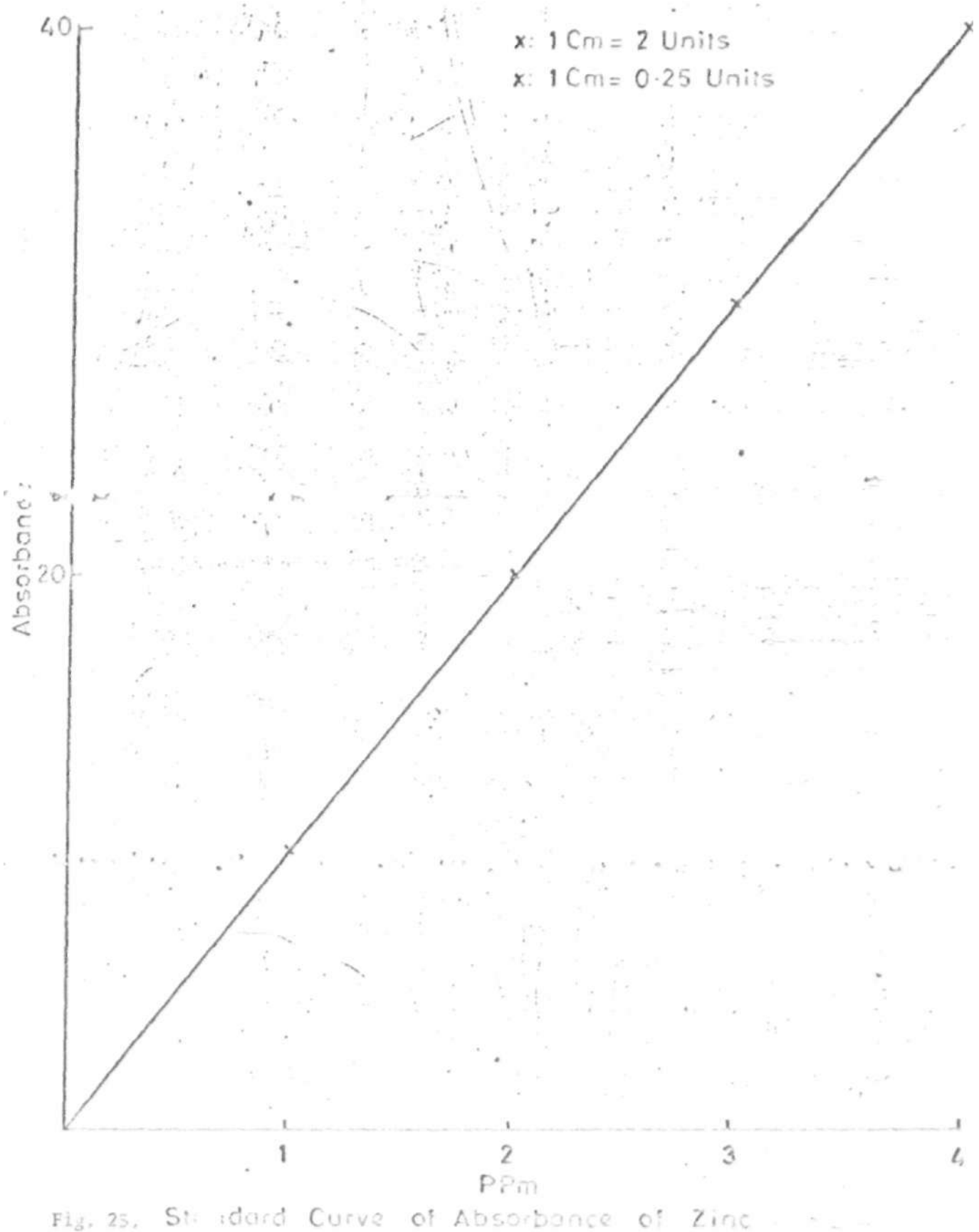


Fig. 25. Standard Curve of Absorbance of Zinc

APPENDIX 3

Estimation of mineral elements in inorganic material

(i) CALCIUM AND MAGNESSIUM

Five millilitre of diluted sample (see Chapter Two) were pipetted into a conital flask and made up to the 50ml-mark with de-ionised water. 1000 ppm strontium chloride were added to eliminate interference of other elements, eg. Aluminium and phosphorus. The absorbance values were separately read off for Calcium and Magnesium. From the values obtained were subtracted the values for the blank, i.e. control samples. The percentage of the element present was calculated using the simultaneous linear relationship obtained for the standard solutions. For Calcium, See Fig. 1[9].

If 6.0ppm Ca (Standard) has an absorbance of 60.0

then

$$X \text{ absorbance unit} = {}^{6}/_{60} \times {}^{x}/_{1} \times \frac{\text{dilution factor} \times \text{extraction volume}}{\text{wt. of sample used}}$$

$$= {}^{6}/_{60} \times \frac{x \times 10 \times 50}{100mg} \text{ ppm Ca}$$

$$\% \text{ Ca} = \frac{\text{ppm} \times 100}{10 \times 10^{6}} \%$$ since ppm is expressed in million.

$$= \frac{\text{ppm } \%}{10^{4}}$$

$$= \text{ppm} \times 10^{-4} \%.$$

Percentage magnesium was determined by simply substituting values obtained in Fig.23 for the standard constant relationship.

(ii) POTASSIUM

Five millilitres (5mls) of sample was diluted to 50mls with de-ionised water, as in (i) above. 0.01% lithium chloride was added to prevent ionization of the element in the hot acetylene flame. The absorbance for the sample was monitored and percentage of the element was calculated as in (i) above, but using a standard constant relationship obtained for potassium. See Fig. 24.

(iii) CHROMIUM, COBALT, COPPER, IRON AND ZINC

Absorbance values for the experiemental samples were monitored. No further dilution was necessary before monitoring i.e. part of solution diluted to 50mls after filteration (see (i) above) was directly introduced to the spectrophotometer for mineral detection. The calculation for estimation was similar to those described above. Standard constants from the relevant curves were used.

(iv) PHOSPHORUS

Ten millilitres (10mls) of solution containing 50gms of Ammonium molybdate in 600mls of water, 25gms of Ammonium vanadate in 500mls of water and 700mls of perchloric acid were added to 25mls of the diluted sample. The volume was made up to 50mls with deionised water. The solution was then allowed to stand for 10mins. for development. The percentage trasmittance of the phosphorus in a 10mm cell was recorded with a spectronic 20 (Bausch and Lamb) set at 440nm. The ppm phosphorus, x, was obtained by finding the

quotient of the log of percentage transmittance of a standard blank (I_o, taken as 100) and the log of percentage transmittance of the sample (I_1 read off from the Spectronic 20). Experimental blanks were also treated as I_1 and their value substracted from the value of sample experiments.

$$\log \frac{I_o}{I_1}$$

$$= \log I_o - \log I_1$$

$$= \log 100 - \log \% \text{ transmittance of sample}$$

$$x = 2 - \log \% \text{ transmittance } (\log 100 = 2)$$

Final value of x was calculated from equation in which optical density of standard solutions are known (see Fig. 25).

$$\frac{\text{Standard ppm}}{\text{Optical density}} \times \frac{x \times \text{dilution} \times \text{total sample volume}}{\text{wt. of sample used}}$$

From Fig. 25, for example,

$$\text{ppm} = \frac{3}{1079} \times \frac{x \times 2 \times 50}{100} \text{ ppm}^p$$

$$\%p = \frac{\text{ppm} \times 100}{10 \times 10^6}$$

$$= \text{ppm} \times 10^{-4}.$$

APPENDIX 4

ESTIMATION OF NITROGEN

Calculation:-

If 1ml of $0.05NH_2SO_4$ was required to react with hydrated ammonia to form $(NH_4)_2SO_4$ in the chemical reaction

$$2|NH_3 - H|^+ + 2H_2SO_4 \rightarrow 2|NH_4|^+ + |SO_4H|^- + SO_2 + 2|H|^+ + 2|O^=|$$

$$\rightarrow (NH_4)_2SO_4 + SO_2 + 2H_2O$$

then

$$1ml \text{ of } 0.05NH_2SO_4 \equiv \frac{0.025 \times 14}{1000} \text{ gm of N}$$

where 14 = atomic weight of ntrogen

$$\therefore x ml \text{ of } 0.05NH_2SO_4 \equiv \frac{0.05 \times 14 \times x \times \text{total Samp. Vol.}}{1000 \times \text{wt. of samp. used} \times \text{vol.}}$$

$$\equiv \frac{0.05 \times 14 \times x \times 50}{1000 \times 0.25 \times 2} \text{ gm of N}$$

$$\% N = \frac{0.05 \times 14 \times x \times 50}{1000 \times 0.25 \times 2} \times \frac{100}{1} \%$$

APPENDIX 5

Determination of Least Significant Difference (LSD)

1. Correction Factor (CF) = $\frac{\text{Grand Total}^2}{\text{Treatment(s) x No. of castes(I) x no of Mounds (M)}}$

$= \frac{GT^2}{S \times I \times M}$

2. Total Sum of squares (T.S.S.) = $X_1^2 + \ldots\ldots + X_n^2$ - C.F.

3. Insect sum of squares (I.S.S) = $\frac{W^2 + R^2 + MN^2 + MN^2}{S \times M}$ - C.F.

4. Mound sum of squares (M.S.S.) = $\frac{Z_1^2 + \ldots\ldots + Z_{10}^2}{I \times S}$ - C.F.

5. Experimental Error sum of squares

(E.E.S.S.) = $\frac{X_1^2 + \ldots\ldots + X_n^2}{S}$ - (CF+I.S.S.+M.S.S.)

6. Sampling Error sum of squares

(S.E.S.S) = T.S.S. - (I.S.S. + M.S.S. + Expt. E.S.S)

Analysis of Variance

Source	Degree of Freedom	sum of squares	$SS/D.F$ Mean Square	$M.S/M.S.$ Error F.
Insect (I-1)	= 3			
Mound (M-1)	= 9			
Expt. Err. (I-1)(M-1)	= 27			
Sampl. Err. I.M.(S-1)	= 40			
Pooled Error	= 67			

$$\text{L.S.D.} = \text{t/value for which F is significant}) \sqrt{\frac{2 \times \text{Error Mean Square (EMS)}}{\text{M.S.}}}$$

The value for the L.S.D. determin significance as the difference between the variables has to be greater than the L.S.D. to be signficantly different.

Determination of the significance of compositions and concentrations.

(a) Ash Composition

Mounds (M)		Percentage Composition					
		Worker (W)	Reprod. (R)	Major Soldier (MJ)	Minor Soldier	$\sum$	
1	S_1	11.45	5.63	5.47	5.4		
	S_2	11.49	5.71	5.47	5.52	56.11	Z_1
2	S_1	14.00	5.48	5.00	4.9		
	S_2	14.02	5.5	4.96	4.89	58.75	Z_2
3	S_1	16.74	6.1	5.1	5.0		
	S_2	16.72	6.07	5.14	5.0	65.87	Z_3
4	S_1	13.26	6.71	5.46	5.3		
	S_2	13.30	6.75	5.48	5.26	61.52	Z_4
5.	S_1	13.00	7.11	5.75	5.09		
	S_2	12.99	7.11	5.71	5.03	61.79	Z_5
6	S_1	12.3	5.45	5.2	4.96		
	S_2	12.31	5.45	5.16	5.02	55.85	Z_6
7	S_1	12.52	7.86	5.92	6.24		
	S_2	12.60	7.93	5.87	6.16	65.1	Z_7
8.	S_1	12.9	6.67	5.9	5.34		
	S_2	12.93	6.65	5.89	5.41	61.72	Z_8
9.	S_1	15.54	8.2	6.7	6.19		
	S_2	15.52	8.26	6.68	6.16	73.25	Z_9
10	S_1	17.76	7.06	6.42	5.46		
	S_2	18.04	6.98	6.43	5.38	73.53	Z_{10}
$\sum$		279.39	132.71	113.71	107.71	633.52	

ANALYSIS OF VARIANCE

Source	D.F.	S.S.	M.S.	F
Ins (I-1)	3	993.91	331.3	312.55
Mounds (M-1)	9	43.61	4.85	4.575
Expt.(I-1(M-1)	27	-2996.99	-111.00	
Samp(IxM)(S^I-1)	40	3068.03	76.7	
Pooled Error	67	71.04	1.06	

L.S.D. = t/at significance). If $\sqrt{\frac{2 \text{ EMS}}{M \times S}} = 20$

$2.576 \quad \frac{2.12}{20} = \sqrt{0.106} = 0.326$

$= 0.34.$

(b) Organic Matter Content.

Mounds	Percentage Composition				∑
	W	R	MJ	MN	
1	88.55	94.37	94.53	94.6	
	85.51	94.29	94.29	94.48	743.86
2	85.99	94.52	95.0	95.10	
	85.97	94.5	95.04	95.11	741.23
3	83.26	93.9	94.9	95.0	
	83.28	93.93	94.86	95.0	734.13
4	84.74	93.29	94.54	94.7	
	84.7	93.25	94.52	94.74	734.48
5	87.00	92.89	94.25	94.91	
	87.11	92.89	94.29	94.97	738.31
6	87.7	94.54	94.8	95.04	
	87.69	94.54	94.84	94.98	744.13
7	87.43	92.14	94.08	93.76	
	87.4	92.07	94.13	93.84	734.9
8	87.1	93.3	94.1	94.66	
	87.07	93.35	94.11	94.59	738.28
9	84.46	91.8	93.3	93.81	
	84.48	91.74	93.32	93.84	726.75
10	82.24	92.94	93.58	94.54	
	81.96	93.02	93.57	94.62	726.47
∑	1716.60	1867.27	1886.29	1892.29	7362.54

Organic Matter

Source	DF	SS	MS	F
Ins. (I-1)	3	1041.21	347.07	369.22
Mounds(M-1)	9	43.56	4.84	5.12
Expt. Err. (I-1)(M-1)	27	-339304.63	-12566.8	
Samp. IxM(s-1)	40	339367.58	8484.19	
Pooled Err.	67	62.95	0.94	

$$2.576 \sqrt{\frac{1.88}{20}} \qquad \sqrt{0.094} = 0.31$$

$$= \underline{0.79}.$$

(c) Lipid Composition

Mounds	Percentage Composition				∑
	W	R	MJ	MN	
1	5.63	17.8	4.8	3.62	
	6.7	17.88	5.1	3.59	66.12
2	5.22	18.23	5.4	4.0	
	5.15	18.19	5.36	4.0	65.55
3	3.5	18.07	3.75	2.64	
	3.56	18.03	3.8	2.69	56.04
4	5.1	17.7	8.0	3.17	
	5.04	17.76	7.6	3.1	67.47
5	6.48	18.0	7.34	4.53	
	6.42	18.0	7.3	4.47	72.54
6	6.63	18.1	8.5	3.66	
	6.77	18.04	8.56	3.74	74.0
7	4.66	18.92	5.98	5.0	
	4.58	18.88	5.98	4.82	68.82
8	4.72	18.44	6.48	3.75	
	4.63	18.36	6.44	3.7	66.57
9	4.16	17.45	6.02	2.98	
	4.16	17.5	6.14	3.02	61.43
10	5.5	17.94	7.5	0.31	
	5.46	17.89	7.49	3.08	67.96
∑	105.12	361.18	127.54	72.66	666.5

Lipid Composition

ANALYSIS OF VARIANCE

Source	DF	SS	MS	F
Insect (I-1)	3	2599.58	866.53	312.55
Mounds (M-1)	9	29.64	3.29	4.575
Expt. Err(I-1)(M-1)	27	-4070.61	-150.76	
Samp. Err.IxM(s-1)	40	[illegible].4	102.79	
Pooled Err.	67	+40.97	.61	

$$2.576 \sqrt{\frac{1.22}{20}} = \sqrt{0.061} = 0.25$$

$$= \underline{0.6}.$$

(d) Protein Content

Mounds	Percentage Composition				∑
	W	R	MJ	MN	
1	39.4	55.16	36.2	36.5	
	39.5	55.22	36.19	36.53	334.7
2	45.2	55.0	35.35	37.42	
	45.1	55.0	35.28	37.38	345.74
3	52.5	56.3	36.85	38.3	
	52.5	56.34	36.9	38.37	368.06
4	47.83	58.75	36.81	36.5	
	47.81	58,75	36.8	36.5	359.74
5	52.47	56.35	38.5	37.5	
	52.54	56.4	39.2	37.5	370.46
6	43.74	55.85	38.8	37.2	
	43.77	55.9	38.9	37.3	351.46
7	42.89	55.16	36.9	35.9	
	42.84	55.1	36.85	37.83	343.47
8	50.0	58.2	40.1	39	
	50.0	58.3	40.3	39	374.48
9	51.4	54.72	38.96	38.2	
	51.34	54.78	38.91	38.17	366.48
10	50.3	56.75	38.5	37.35	
	50.33	56.75	38.5	37.4	365.88
∑	951.46	1124.78	754.8	749.85	3580.89

ANALYSIS OF VARIANCE

Source	D.F	S.S.	M.S.	F
Ins. (I-1)	3	4835.55	1611.85	420.85
Monds (M-1)	9	203.26	22.58	5.9
Expt. (I-1)(M-1)	27	-82533.31	-3036.79	
Samp. (IxM)(S^I-1)	40	82790.17	2069.75.	
Pooled Error	67	256.86	3.83	

$$2.576 \sqrt{\frac{7.66}{20}} = \sqrt{0.0383} = 0.619$$

1.59.

(e) Carbohydrate Composition

Mounds	Percentage Composition				∑
	W	R	MJ	MN	
1	42.52	21.41	53.53	54.48	
	42.31	21.19	53.24	54.25	342.93
2	35.56	21.27	54.32	53.68	
	35.63	21.31	54.29	53.73	329.79
3	27.26	19.53	54.3	54.01	
	27.22	19.63	53.23	53.94	309.12
4	31.83	16.81	49.73	55.03	
	31.85	16.74	50.12	55.14	307.25
5	28.1	18.54	48.45	52.88	
	28.15	18.49	47.79	53.0	295.4
6	37.33	20.59	47.5	54.18	
	37.15	20.6	47.38	53.94	318.67
7	39.93	18.06	51.2	52.86	
	39.98	18.89	53.3	51.19	325.41
8	32.38	16.66	47.56	51.91	
	32.39	16.69	47.37	51.89	296.85
9	28.9	19.63	48.32	52.63	
	28.98	19.46	48.27	52.67	298.86
10	26.44	18.35	47.58	54.09	
	26.17	18.38	47.78	54.14	292.93
∑	660.08	382.23	1005.26	1069.64	3117.21

ANALYSIS OF VARIANCE

Source.	D.F.	S.S.	M.S.	F
Ins. (I-1)	3	15361.67	5120.56	740
Mounds(M-1)	9	321.12	35.68	5.16
Expt.Err.(I-1)(M-1)	27	-68340.75	-2531.14	
Samp. Err.(s-1)(1-M)	40	68804.51	1720.1	
Pooled Err.	67	463.76	6.9	

$$2.576 \sqrt{\frac{13.84}{20}} = \sqrt{0.692} = 0.83$$

$$= \underline{2.14}.$$

(f) Calcium Concentration.

Mounds	Percentage Concentration				∑
	W	R	MJ	MN	
1	0.32	0.16	0.15	0.05	
	0.26	0.14	0.15	0.05	1.28
2	0.32	0.16	0.12	0.05	
	0.34	0.16	0.14	0.05	1.34
3	0.27	0.16	0.13	0.05	
	0.31	0.19	0.15	0.05	1.31
4	0.40	0.19	0.16	0.05	
	0.37	0.17	0.16	0.05	1.55
5	0.25	0.16	0.12	0.04	
	0.25	0.16	0.14	0.04	1.16
6	0.28	0.17	0.15	0.05	
	0.2	0.14	0.11	0.04	1.14
7	0.32	0.17	0.12	0.05	
	0.26	0.15	0.12	0.05	1.24
8	0.44	0.18	0.12	0.06	
	0.46	0.16	0.12	0.07	1.61
9	0.31	0.15	0.12	0.06	
	0.35	0.18	0.16	0.06	1.39
10	0.40	0.17	0.12	0.07	
	0.38	0.17	0.13	0.07	1.51
∑	6.49	3.29	2.69	1.06	13.52

ANALYSIS OF VARIANCE

Source	D.F.	S.S.	M.S.	F
Ins. (I.1)	3	.775	0.26	260
Mound(M-1)	9	.03	.003	3
Expt.(I-1)(M-1)	27	-1.51	-0.056	
Samp. IxM(s-1)	40	1.58	0.0395	
Pooled Err.	67	.07	.001	

$$2.576 \sqrt{\frac{.002}{20}} = \sqrt{.0001} = 0.01$$

$$= \underline{0.026}.$$

(g) Iron Concentration

Mounds	Concentration in ppm				∑
	W	R	MJ	MN	
1	161	98	68	18	
	158	90	66	20	679
2	160	55	64	22	
	156	55	61	20	593
3	162	47	54	25	
	156	44	54	21	563
4	177	90	62	22	
	169	81	58	20	679
5	162	48	64	18	
	165	48	62	16	584
6	172	73	50	18	
	180	77	55	20	645
7	184	125	68	22	
	178	116	70	20	783
8	161	62	45	22	
	153	64	48	22	577
9	175	69	64	22	
	179	72	64	20	665
10	216	115	68	25	
	220	120	75	25	864
∑	3445	1549	1220	418	6632

ANALYSIS OF VARIANCE

Source	D.F.	S.S.	M.S.	F
Ins.(I-1)	3	246734.7	82244.9	546.77
Mounds(M-1)	9	10522.2	1169.13	7.77
Expt.(I-1(M-1)	27	-398485.7	-14758.73	
Samp. IxM(s-1)	40	408564	10214.1	
Pooled Err.	67	10078.3	150.42	

$$2.576 \sqrt{\frac{300.84}{20}} = \sqrt{15.042} = 3.8784$$

$$= 9.99.$$

(h) Magnesium Concentration

Mounds	Percentage Concentration				∑
	W	R	MJ	MN	
1	0.22	0.15	0.08	0.03	
	0.20	0.11	0.08	0.03	0.9
2	0.15	0.07	0.08	0.03	
	0.17	0.07	0.08	0.03	0.68
3	0.17	0.04	0.06	0.03	
	0.19	0.04	0.08	0.03	0.64
4	0.2	0.14	0.09	0.02	
	0.22	0.12	0.09	0.02	0.9
5	0.2	0.09	0.08	0.03	
	0.2	0.12	0.1	0.03	0.85
6	0.17	0.06	0.09	0.03	
	0.21	0.08	0.09	0.03	0.76
7	0.13	0.06	0.1	0.03	
	0.18	0.06	0.12	0.03	0.76
8	0.24	0.14	0.11	0.02	
	0.2	0.1	0.11	0.02	0.94
9	0.23	0.15	0.12	0.03	
	0.28	0.15	0.12	0.03	1.11
10	0.25	0.09	0.1	0.03	
	0.25	0.09	0.1	0.03	0.94
∑	4.11	1.93	1.88	0.56	8.48

ANALYSIS OF VARIANCE

Source	D.F.	S.S.	M.S.	F
Ins.(I-1)	3	.33	.11	-36.67
Monds(M-1)	9	.22	.024	-8
Expt.(I-1)(M-1)	27	-0.8114	-0.30	
Samp.(IxM)s^{I}-1)	40	0.6374	0.016	
Pooled Err.	67	-0.174	-.003	

$$2.576 \sqrt{\frac{0.006}{20}} = \sqrt{0.003} = 0.0173$$

$$= \underline{0.0446.}$$

(i) Potassium Concentration

Mounds	Percentage Concentration				∑
	W	R	MJ	MN	
1	0.76	0.16	0.18	0.09	
	0.82	0.18	0.18	0.12	2.49
2	0.72	0.15	0.15	0.07	
	0.70	0.15	0.17	0.07	2.18
3	0.8	0.16	0.18	0.08	
	0.8	0.16	0.18	0.08	2.44
4	0.86	0.22	0.18	0.14	
	0.82	0.18	0.18	0.1	2.68
5	0.95	0.17	0.2	0.08	
	0.95	0.15	0.18	0.08	2.76
6	0.70	0.14	0.14	0.07	
	0.62	0.14	0.14	0.07	2.02
7	0.78	0.22	0.18	0.14	
	0.86	0.26	0.18	0.12	2.74
8	0.78	0.15	0.15	0.06	
	0.72	0.15	0.15	0.06	2.22
9	0.95	0.22	0.18	0.1	
	1.03	0.24	0.16	0.12	3.0
10	1.0	0.25	0.2	0.12	
	1.0	0.25	0.18	0.12	3.12
∑	16.62	3.7	3.44	1.89	25.65

ANALYSIS OF VARIANCE

Source	D.F.	S.S.	M.S.	F
Ins.(I-1)	3	7.05	2.35	1175
Mounds(M-1)	9	.15	.017	8.5
Expt.(I-1)(M-1)	27	-7.63	-0.28	
Samp.(IxM)(s^I-1)	40	7.7849	0.195	
Pooled Err.	67	.1549	.002	

$$2.576 \sqrt{\frac{.004}{20}} = \sqrt{.0002} = 0.014$$

$$= \underline{0.36}.$$

(j) Phosphorus Concentration

Mounds	Percentage Concentration				Σ
	W	R	MJ	MN	
1	0.52	0.35	0.17	0.08	
	0.48	0.35	0.15	0.08	2.18
2	0.4	0.4	0.12	0.6	
	0.42	0.38	0.14	0.06	1.98
3	0.47	0.36	0.16	0.07	
	0.41	0.32	0.16	0.07	2.02
4	0.45	0.42	0.14	0.07	
	0.49	0.4	0.18	0.07	2.22
5	0.5	0.38	0.12	0.07	
	0.5	0.44	0.14	0.07	2.22
6	0.54	0.4	0.16	0.06	
	0.46	0.34	0.16	0.06	2.18
7	0.4	0.29	0.16	0.06	
	0.48	0.3	0.14	0.06	1.89
8	0.56	0.4	0.15	0.07	
	0.54	0.38	0.15	0.09	2.34
9	0.54	0.39	0.18	0.07	
	0.48	0.39	0.12	0.07	2.24
10	0.52	0.39	0.14	0.06	
	0.56	0.42	0.12	0.06	2.29
Σ	9.72	7.5	2.96	=.38	21.56

ANALYSIS OF VARIANCE

Source.	D.F.	S.S.	M.S.	F
Ins.(I-1)	3	2.26	0.75	750
Mounds(M-1)	9	.024	.0026	2.6
Expt.(I-1(M-1)	27	-0.41	-0.015	
Samp.IxM)(s^I-1)	40	476	0.012.	
Pooled Err.	67	.066	.001	

$$2.576 \sqrt{\frac{.002}{20}} = \sqrt{.0001} = .01$$

$$= \underline{0.026.}$$

(k) Zinc Concentration

Mounds	Concentration in ppm				∑
	W	R	MJ	MN	
1	104	32	31	10	
	98	28	30	12	345
2	95	28	24	14	
	95	30	24	12	322
3	94	35	24	12	
	91	33	20	12	321
4	94	36	25	10	
	98	38	27	8	336
5	92	40	26	12	
	86	36	21	12	325
6	89	32	14	12	
	90	26	14	13	290
7	116	30	20	12	
	108	28	18	12	344
8	104	24	15	9	
	114	30	20	9	325
9	124	39	32	8	
	120	37	34	8	402
10	116	40	48	10	
	122	36	54	12	438
∑	2050	658	521	219	3448

ANALYSIS OF VARIANCE

Source	D.F.	S.S.	M.S.	F.
Ins.(I-1)	3	99134.5	33044.8	681.9
Mounds(M-1)	9	2113.7	234.86	4.85
Expt.(I-1(M-1)	27	-123305	-4566.85	
Samp.(IxM)(s^I-1)	40	126552	3163.8	
Pooled Err.	67	3247	48.46	

$$2.576 \sqrt{\frac{96.92}{20}} = \sqrt{4.846} = 2.2$$

$$= \underline{5.67}.$$

ASPECTS OF THE CHEMICAL CONCENTRATION OF *Trinervitermes geminatus* WASMANN (ISOPTERA; TERMITIDAE; NASUTITERMITINAE) AND ITS FOOD MATERIAL

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1979