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A MORPHOMETRIC STUDY OF THE CASSAVA GREEN MITE, *MONONYCHELLUS* SPP. (ACARI: TETRANYCHIDAE) IN AFRICA

by

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D E C L A R A T I O N

I, Rosetta Bekinwari Bob-Manuel, hereby declare that, the work presented in this thesis is my own and has not been submitted for a degree in any other University; it is original except indicated otherwise and in which case full references are given.

R.B. Bob-Manuel

I certify that, this thesis has been supervised by me.

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D E D I C A T I O N

T O

INE-WARIGBANI WHYTE - FOR HER FOREBEARANCE

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A B S T R A C T

The study deals with investigations undertaken to assess and identify characters other than the dorso-central body setal lengths (D_1-D_3) in the adult females for better morphological understanding of the Mononychellus spp. in Africa. Twenty-seven characters were measured on 200 adult female specimens from 10 African countries. Fifteen characters each, on 150 immature stages (larva, protonymph and deutonymph) from Kenya were also examined. The ontogeny of body setae in all the instars was also studied.

Measured characters were subjected to principal components analysis (PCA), cluster analysis and other basic statistical analysis. Characters assessed, using the PCA were mostly intercorrelated. The few uncorrelated characters, such as all the ratios, particularly RL_2 in the adult, P_1,P_2,D_3 and D_5 in the larva and P_1, L_2 and D_4 in the protonymph could not effectively indicate indices of variation for classification. The pattern of the scatter plots of the "Operational Taxonomic Units" (OTUs) for all the instars and the results obtained from the cluster analysis of adult females inferred a single species. Location effect was significant for all the variables with analysis of variance (ANOVA) tests but the percentage variances due to location were very low (except for variable (RL_2) with 50%), suggesting in the non statistical sense, an insignificant role of geographical influence in the species distribution using the intercorrelated characters. Mean setal lengths for the instars were not all directly proportional to the increases in body sizes.

Setal counts on the life stages from both the laboratory cultures of immatures and preserved adult specimens showed a constant number of 13 pairs of setae on the dorsal idiosoma from larval to adult instars, while there was a progressive addition of setae on both the ventral idiosoma and leg segments.

Complete setal formulae for the leg segments for all the instars, including mean setal lengths and body sizes of the larva, protonymph and deutonymph are presented.

Finally, the results of the study, based on the variables used, indicated no real evidence for describing the species as more than a single species.

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1. GENERAL INTRODUCTION

Mites in general, are minute chelicerate arthropods. The adult size ranges from 150-700 um in length. They belong to the Acari (=Acarina), a subclass of the Arachnida. They have neither distinct body divisions nor segmentation, while chelicerae replace mandibles for mouthparts. They have four pairs of legs at nymphal and adult stages while the larval stages have three pairs of legs (except the Eriophyoidea with two pairs of legs all through the life stages).

Mites, though small as individuals, usually occur in large numbers which rank them among some of the most dangerous organisms attacking plants. Although systematic studies of the Acari began in the past century, it is probable that only a small portion of the fauna has been discovered. Inspite of this, studies of phytophagous mites in the families Tetranychidae (spider mites), Tenuipalpidae (false spider mites), Tuckerellidae (peacock mites) and Eriophyidae (gall mites) have made steady progress because of their agricultural importance. Among these, the spider mites are of particular interest because of their cosmopolitan nature as well as their abundance and damage done to many plant species of economic importance.

Identification of tetranychid mites to genus and species level has received considerable attention. Such studies have made use of morphological characters, including association of host plant species, feeding damage and geographical location, among others. Earlier works on tetranychid taxonomy include those of Pritchard and Baker (1955) and Tuttle and Baker (1968) to mention but a few.

In Africa, a key to the tetranychid mites of central Africa was compiled by Baker and Pritchard (1960).

Meyer (1974) published a revision of the Tetranychidae of Africa with a key to the genera of the world. Flechtmann (1977, 1982) published a series of papers on keys on the tetranychid pests found on cassava in South America. Mattysse (1980) published a paper on the phytophagous mites occurring in Nigeria which included several species often found on cassava. Meyer (1981) showed how phytophagous mites of agricultural crops in South Africa may be identified using feeding preference. Macfarlane (1984) has prepared a taxonomic key to the tetranychids found on cassava in Africa. Yaninek (1980, 1986, unpublished data) has formulated ecological keys to the tetranychid mites found on cassava in Africa in general and Nigeria in particular.

Most recent in the above series of studies are those in the tetranychid mites of the genus *Mononychellus* feeding on cassava plants in Africa. They are commonly referred to as "Cassava Green Spider Mites (CGM)".

The pest problems on cassava have increased with intensive cultivation and the CGM and other phytophagous mites are responsible for severe injuries to the plant itself and a heavy reduction in tuber yields. The CGM in Africa, first described as Mononychellus tanajoa (Bondar) is an exotic species from South America. It was first recorded from Uganda, in 1971. Since then it has been found in almost all the cassava growing countries of Africa. Doreste (1981) described Mononychellus progresivus (Doreste) in Venezuela which has also been reported in Africa (Flechtmann 1982, Macfarlane 1984).

The occurrence of both M. tanajoa and M. progresivus in Africa has raised some doubts (Yaninek and Herren, 1985). Their similarities in general morphology suggest a single species though with some variations (Rogo et al., 1987). This taxonomic issue is now the subject of a review study at the International Centre of Insect Physiology and Ecology (ICIPE) Nairobi, Kenya.

A preliminary review study of the CGM from their South American topotype and from several African countries indicates that, the dorso-central body setal lengths (D_1-D_3) as reported by Doreste (1981) are not reliable and stable diagnostic characters for separating the species. This is because of their wide variabilities in a continuous gradient (Rogo, *et al.*, 1987). Also, only one type of male aedeagus occurs in Africa, suggesting a single species (Rogo, pers. comm.). Meanwhile, the CGM in Africa is being referred to as "*Mononychellus tanajoa* (Bondar)" (Rogo, pers. comm.). Furthermore, crossing experiments on the Kenya population at ICIPE also showed some degree of sexual compatibility (Murega, pers. comm.). Finally the actual number of *Mononychellus* spp. in Africa requires clarification. This, therefore, calls for the examination of other taxonomic characters to determine their precise identity which may assist in the development of control strategies.

Presently in Africa, classical biological control methods are being emphasised. This is because both the pest and the host plants are exotic to Africa and biological control once established will be best for a subsistence crop like cassava. This is because the latter being a perennial crop, will in practice, provide food for both the pest and predator in all seasons and hopefully maintain the natural acosystems approximately in a state as occurring in their original countries. The requirements of an effective biological control programme include accurate identification of both the pest and its natural enemies. Misidentification of the pest may misdirect the search for natural enemies which may result in a waste of effort, or in neglect of search for potentially effective enemies (see Greathead, 1971 and Kumar, 1984 for references). In biological control studies in Africa, control of the Kenya coffee mealy bug, Planococcus Kenyae, was delayed due to the confusion on its identity (Greathead, 1971).

It was not until its exact identity and likely place of origin was established that an effective parasite was introduced for its control. Similarly, Compere (1961) reported that, attempts on biological control of the California red scale, *Aonidiella aurantii* (Maskell) had been handicapped and confused by the failure to find any morphological differences between this scale and the closely related yellow scale, *Aonidiella citrina* (Coquillett).

Although considerable work has been done on the identity of *Mononychellus* species in Africa a reliable description of the species is still lacking. The present research was therefore undertaken: (i) to investigate characters of the adult females other than those mentioned by Doreste (1981) which may be used for the identification of CGM; (ii) to examine and assess their suitability for correct identification of the species; and (iii) to identify the character(s) that best describe the species.

To accomplish these objectives a number of characters (see materials and methods - section 3.5 for details) both of adult females and immature stages were examined and subjected to statistical analysis. Studies on immature stages may be justified when one considers that not only structural characters but also data from other aspects of the organisms biology, including life history and immature stages could be used in the development of a classification scheme. Van Emden (1957) emphasized the taxonomic significance of the characters of immature insects. At this point of Mononychellus taxonomy, the necessity of obtaining information on the immature stages becomes apparent since there are problems in identifying ideal diagnostic characters on the adults.

Numerical taxonomic methods would be expected to be employed in handling the large quantitative data derived in this study. According to Sneath and Sokal (1962, 1973), numerical taxonomy is defined as the grouping, by means of numerical methods, of taxonomic units into taxa on the basis of their character states. This also involves the application of multivariate analyses. In this study, the principal components analysis (PCA), was used. This examines the interactions within variables by displaying the relationships between "Operational Taxonomic Units" (OTUs) in a multidimentional space. Thus finding which variable(s) mostly accounts for the variation among the distribution of the OTU's. This will determine the objective weightings of the variables in the construction of taxonomic indices. Furthermore, to test for evidence of groupings from the PCA results, the cluster analysis was used as well as other basic statistical methods such as the analysis of variance (ANOVA).

The objective of numerical approach is to rid taxonomy of its traditionally subjective nature and to provide objective and stable classification. Objective, in the sense that the analysis of the same set of organisms by the same sequence of numerical methods will provide the same classification; stable, in that the classification is repeatable and remains almost the same even under a wide variety of additions of organisms or of new characters. Usually, many published exercises in numerical taxonomy have been undertaken to test either the conlusions of an existing traditional classification or the numerical methods themselves. The former applies in this study. The classification of *Mononychellus* species has so far been based on the traditional taxonomic system.

Whether the objectives of numerical methods of classification are always met or not, it is convincingly clear that, there are some fields of taxonomy where numerical methods offer many advantages over the traditional approaches, especially where the traditional methods appear to be inefficient as it appears to be the case with *Mononychellus* taxonomy.

2. LITERATURE REVIEW

2.1 Historical background of Cassava Green Mites.

Prior to the discovery of CGM in Africa in the early 1970's, only one published paper was known on the description of the species. That, by Bondar (1938) being the original taxonomic description of CGM as _Tetranychus tanajoa_. In 1970, Flechtmann and Baker redescribed _T. tanajoa_ and designated it as _Mononychus tanajoa_, but because of the rule of priority _Mononychus_ was changed to _Mononychellus_ by Wainstein in 1971. In 1981, Doreste again redescribed the female of _Mononychellus tanajoa_ and also described for the first time the males. He also described two new species _Mononychellus progresivus_ and _Mononychellus manihoti_. In Africa, the first record of _Mononychellus_ was determined as _M. tanajoa_ (Bondar) (Lyon, 1973 and Flechtmann, 1977), but Flechtmann (1982) recognized two species, _M. tanajoa_ and _M. progresivus_ on cassava in Gabon and Nigeria.

Since then these two species have been reported from Africa by several other workers. In Kenya, both *M. tanajoa* and *M. progresivus* have been identified in major cassava growing areas (Murphy, 1984). MacFarlane (1984) also stated that the majority of recorded African species probably belong to *M. progresivus*.

2.2 Taxonomy of Cassava Green Mites.

The Cassava Green Mites are tetranychid mites in the subfamily Tetranychinae, tribe, Tetranychini. Tuttle and Baker (1968) and Meyer (1974) based the family distinction of female characters on the position of the dorso-central setae on the hysterosoma, chaetotaxy of the dorsum and empodium; number and position of duplex setae on tarsi 1 and 11 and patterns of striae on opisthosoma.

The genus *Mononychellus* is recognised from the other genera by the longitudinal striae between the third pair of dorso-central hysterosomal setae, and the setae being borne on weak tubercules. The presence of 2 pairs of para-anal setae; 2 pairs of duplex setae on tarsus I being adjacent, and empodium consisting of 3 pairs of proximo-ventral hairs (Meyer, 1974).

At species level, M. tanajoa and M. progresivus are separated on the bases of the lengths of the dorso-central body setae and shapes of their aedeagi (Doreste, 1981 and MacFarlane, 1984). M. tanajoa specimens are identified as those with short dorso-central body setae (D_1 - D_3) (Flechtmann and Baker, 1970). The aedeagus is strong, straight and ending in a bulge with two projections sharply directed forwards its basal part (Doreste, 1981). Those with long dorso-central body setae (D_1 - D_3) and aedeagus without strong ventral hook are termed M. progresivus (Doreste, 1981). M. tanajoa has 9 tactile setae and 1 slender solenidion on tibia 1 and 7 tactile setae on tibia 11. On tarsi 1 and 11 are 5 proximal tactile setae and 1 solenidion and 3 proximal tactile setae and 1 solenidion respectively (Flechtmann, 1977 and Nyiira, 1977). Doreste (1981) however redescribed M. tanajoa with 4 proximal tactile setae and 1 solenidion on tarsus 1 and 8 tactile setae and 1 solenidion on tibia 1. For M. progresivus he recorded 9 tactile setae and 1 solenidion on tibia 1. In re-examining these diagnostic characters, studies at ICIPE using the principal components analysis (PCA) indicated that, the group examined from different African countries including their South American topotypes, represents one species (Rogo, pers. comm.) but further analysis using the discriminant function, showed that the long, intermediate and the short setaed forms can be separated using the 3rd pair (D_3) of the dorso-central body setae (Nokoe, pers. comm.).

2.3 Economic significance of Cassava and Cassava Green Mites.

2.3.1 Cassava

According to Montaldo (1973), cassava (*Manihot esculenta* (Crantz) (family Euphorbiaceae) originated in the Venezuelan savannah. It was introduced in the delta of the Congo River by the Portuguese during the latter part of the sixteenth century and in the early nineteenth century in East Africa (IITA, 1986). Most cassava in Africa grows between latitude 15°N and 15°S of the equator (Jones, 1959). It is now extensively grown from the humid to semi-humid regions of tropical Africa, covering 80 million hectares in about 34 countries (IITA, 1985). Montaldo (1973) reported that, over nine million hectares are sown worldwide, the main producers being Brazil with more than two million hectares, followed by Indonesia and Nigeria with more than one million each.

Approximately 52% of the world area is under cassava cultivation (FAO, 1977, 1982). Africa produces 4.2×10^7 metric tons of cassava which constitutes 44% of global production.

Over 200,000 ha of cassava is planted in Nigeria with yields between 7 and 12 tons/ha (Zwankhvizen, 1962). In Ivory Coast, over 1200,000 ha of cassava are planted mainly for domestic consumption in rural areas (Naigon and Catrisse, 1978). In comparison, Toro (1979) reported that, in Colombia the average yield is 8 tons/ha and in some localities more than 20 tons/ha have been obtained. On the average, Africa's cassava tuber yield is 6.0 tons/ha as compared to the world average of 8.3 tons/ha. (IITA, 1985).

The crop is used for both food and industrial purposes. It is a staple carbohydrate food source of 300-500 million inhabitants of Africa (Byrne et al., 1983). Cassava is used in animal and food industries in place of cereals in some European countries (Doreste, 1984). The leaves serve as green vegetable in many areas and the protein content in flour from the leaves is also as high as 17% (Burger, 1952).

Cassava is also used as a raw material for the production of alcohol and adhesives in Brazil (Lima, 1977). Lii and Chang (1978) reported that the principal starch sources in Taiwan are sweet potato, cassava and arrow root (Maranta arundinacea L.). In Indonesia, it ranks second to rice in importance (Wang, 1980).

2.3.2 Cassava Green Mites

In Africa, the arthropod pest status on cassava was not considered to be of economic importance until the accidental introduction of cassava mealy bug and cassava green mite (Girling et al., 1977). Flechtmann (1977,1981) and Doreste (1981) stated that, there are about 40 different species of tetranychids on cassava all over the world. Out of these, the most frequent and most important being M. tanajoa (Bondar). The host range of CGM is also limited within the family Euphorbiaceae and is restricted almost entirely to the genus Manihot.

Nyiira (1977) reported that the mites feed and breed on *Manihot esculenta*, *M. glaziovii*, *M. dichotoma* and *M. pauyensi*. This narrow host range indicates specificity leading to high build up of pest populations to damaging levels.

Mononychellus spp. attack the ventral surface of young cassava plants, especially 2-8 months old leaves near the terminal shoots (Girling *et al.*, 1977). Byrne *et al.* (1983) described the feeding mechanism of *M. tanajoa* (Bondar). They feed by piercing individual cells of the leaf parenchymatous tissue with their elongated, paired, needle-like stylets, extracting cell contents. The damage symptom as a result of this is first observed as irregular whitish spots on the leaf surface which later become yellowish (chlorotic spots) due to chlorophyll depletion in the leaves. Complete chlorosis occurs, depending on the population of CGM feeding actively. Heavy infestation leads to stunted growth of the plant and leaf drop producing a "candlestick" symptom followed by complete defoliation particularly under drought stress condition. Nestel (1976) stated that, during this period it is difficult to differentiate between the symptoms of severe mite infestation and those of cassava mosaic virus. Although cassava is present all through the season in most African countries, peak CGM populations are known to occur during the dry season (Nyiira, 1972; Leuschner, 1980 and Akinlosotu, 1982). Many authors have also cited the importance of rainfall as a mortality factor of CGM populations (Nyiira, 1972; Lyon, 1974; Yaseen, 1975 and Samways, 1979).

There has been a decline in yield all over the world ever since the mite pest infestation on cassava became apparent. Root yield losses due to Mononychellus spp. have been estimated at 10-80% (Bondar, 1938 and Shukla, 1978). In experiments with treated and untreated plots, yield losses of 8% and 17% (Doreste and Aponte, 1979) were reported. Reductions in tuber weight due to mite attack have been variously estimated at 46% in Uganda (Nyiira, 1975), 50-80% in Tanzania (Shukla, 1978). Bellotti and Schoonhoven (1978) also recorded 15-20% tuber losses in Venezuela and 20-53% in Colombia. The value of annual losses of tubers due to mite infestation was estimated at 860 million U.S. dollars, which excludes the loss of leaf vegetable and planting materials (IITA, 1986).

2.4 Multivariate analysis

Systematic studies using numerical taxonomy has led to an increasing dependence on multivariate analyses. Such analyses include the popularly used multiple regression and others, such as the principal components analysis (PCA), Principal factor analysis (PFA), Cluster analysis, Discriminant and Canonical analyses.

Principal components analysis was first developed by Pearson (1901) and Frisch (1929) in problems of multivariate analysis. The statistical properties of PCA have been investigated in detail by Hotelling (1933), Anderson (1958), Seal (1964), Kendall (1968), Davis (1973), Dunn and Everitt (1982). Rao (1964) has provided various interpretations of PCA used in multiple measurements. It has been applied by many authors in taxonomic studies. Bailey (1956) studied the morphogenesis of mice using genetic and environmental characters subjected to PCA. Jolicoeur and Mosimann (1960) classified painted turtles _Chrysemys picta marginata_ collected from a stagnant pond in the St. Lawrence Valley, using carapace length, width and height measured on 24 males and 24 females. Patterns of growth in grasshoppers were distinguished with PCA (Blackith, 1960). Reyment (1961) used individual measurements of cranial lengths and breaths of mature species for the classification of European frog _Rana esculenta_. Rohlf (1967) determined the taxonomic status of 45 species of North American mosquitoes using 74 intercorrelated external morphological characters of pupae; cluster and factor analysis were also computed and compared using the same data set. Forty individual winged aphids were classified using measurements on 19 morphological characters (Jeffers, 1967). Prentice (1980) in Scotland used 47 characters and character states to compare the populations of red campion *Silene dioica* (L. Clairv). Species of two groups of termites "badius" and "tangaricus" were separated with 15 measured characters using the PCA (Bagine, 1986). The PCA and discriminant function analyses were used in determining the taxonomic status of *Mononychellus* spp. in Africa using 22 measured characters (Rogo, pers. comm.).

Factor analysis was developed by experimental psychologists in the 1930s and 1940s (Davis, 1973). Some of the documented utilizations are those of Burt and Banks (1947) in the analysis of body measurements for British adult males. Stroud (1953) applied factor analysis to the systematics of termites of the genus *Kalotermes*. Kraus and Choi (1958) used it in determining the pre-natal growth of the human skeleton. Sokal and Daly (1961) also extensively used factor analysis in the behavioural studies in insects.

The detailed account of cluster analysis can be found in the texts of Jardine and Sibson (1971) Sneath and Sokal (1973), and Everitt (1980). Carter and Jeffers (1966, unpublished data) used 3 methods of multivariate analyses namely PCA, Canonical and Cluster analyses to separate species groups of Alate (Adelgidae: Hemiptera), using 24 measured characters.

Discriminant function is a synonym of canonical analysis (Dunn and Everitt 1982). The use of discriminant analysis has been illustrated and discussed by Jolicoeur (1959). Fisher (1936) has made use of it in the study of some taxonomic problems. Blackith and Albrecht (1959) reported studies of four groups of "crowded laboratory breed" Red locust using weight, elytron length, compound eye height all subjected to canonical analysis. Stower et al. (1960) studied the morphological differences on eight locust populations using elytron length, femur length and head capsule. MacFie *et al.* (1978) have studied the chemical analysis of aerobic food spoilage bacteria using discriminant analysis. O'Donnel *et al.* (1980) also used the same technique in the separation of closely related species of *Bacillus*.

3. MATERIALS AND METHODS

3.1 Specimen collection

Adult specimens preserved in 70% ethanol were received from 10 cassava growing countries of Africa, covering East, Central and West Africa. The countries covered were, Burundi, Cameroon, Ghana, Kenya, Nigeria, Rwanda, Tanzania, Uganda, Zambia and Zanzibar (Table 1). Most collections were made in the dry season.

Adult males and female teleiochrysalis (virgin females) reared for immature stages were collected from infested cassava leaves in the field, from 5 cassava growing areas of Kenya namely: Embu, Homabay, Mbita Point Field Station, Mombasa and Rusinga Island (Fig. 1). Collection was carried out at every 15 kilometre (Km) interval along a transect. At every point, infested leaves (leaves 6-10) from the terminal shoot were collected into cellophane bags.

Table 1. Collection areas of adult female specimens of *Mononychellus* spp. in Africa

Country	No. of collection sites
Burundi	1
Cameroon	7
Ghana	6
Kenya	9
Nigeria	4
Rwanda	1
Tanzania	3
Uganda	3
Zambia	2
Zanzibar	1

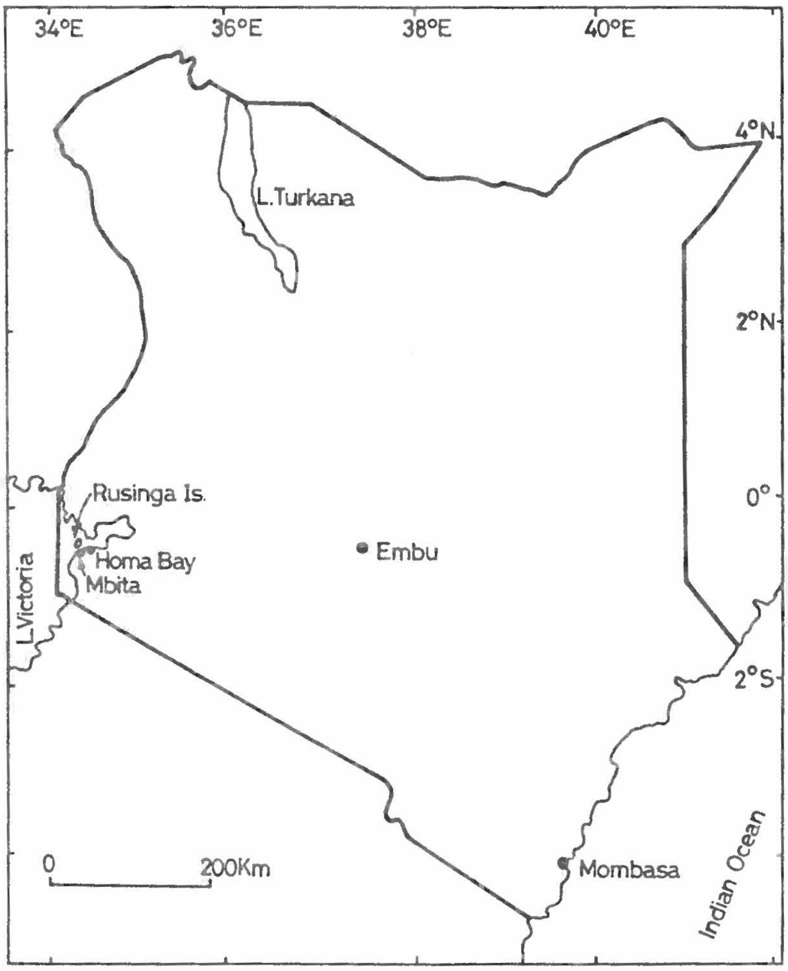

Fig. 1. Collection sites for adult males and female teleiochrysalis (virgin females) of Mononychellus spp. reared for immature stages in Kenya.

The largest number of CGM was usually present on these (Yaseen, 1975). Adult male and female mites were transferred with the aid of a fine camel hair brush with dampened bristles onto a leaf disk for rearing. Choice of collecting sites was based on earlier distribution studies of *Mononychellus* spp. in Kenya by Rogo (1986, unpublished manuscript).

3.2 Rearing

The leaf disk method described by Helle and Overmeer (1985) was employed. Disks were obtained from young fully developed cassava leaves using a cork borer. Contamination by alien species was avoided by washing and inspecting the leaves under the microscope before use. The leaves were changed within a maximum of 4 days to avoid fungal growths. Clean disks were placed with the upper surface down on a wad of wet cotton wool in a perforated plastic petridish of 90mm in diameter. The petri dishes were placed in a plastic tray (380mm x 230mm x 30mm in dimension) and a quarter filled with water to keep the disks moist (Fig. 2). The trays were in turn placed in a locally constructed growth chamber, which rested on a galvanised water trough, acting as a barrier to all crawling foreign agents for possible contamination. A 60W incandescent bulb illuminated the chamber and also provided the necessary warmth required. Temperature and relative humidity were regulated at 26° - 28°C and 65-75% R.H respectively by Mason's hygrometer fixed in the chamber (Yaseen and Bennett, 1975). Under these conditions, the mites mated and females oviposited. The eggs hatched into larvae and subsequently moulted into protonymphs, deutonymphs and adults. At each instar, enough specimens were removed for mounting and examination.

3.3 Mounting

CGM were mounted in Hoyer's medium as recommended by Pritchard and Baker (1955). The formulation is as follows: distilled water, 50mls; gum arabic, 30g; chloral hydrate, 200g; glycerol, 16mls; These were mixed sequenstially at room temperature,

Fig. 2. Leaf disk rearing technique for immature stages of <u>Mononychellus</u> spp. A = leaf disk; B = cotton wool; C = petridish; D = tray a quarter filled with water.

stirring occasionally until the ingredient went into solution in about 14 days.

A drop of the Hoyer's solution was placed at the centre of a clean microscope slide and individual adult and immatures were deposited in the medium and orientated dorso-ventrally with legs well spread out and covered with a cover slip. To expand and clear the specimen, it was gently heated over a spirit lamp and left to dry at 50°C for 5-7 days. Dried slides were ringed with glyceel or neutral nail polish and were labelled indicating the locality, host plant, date of collection, collectors name, specimen sex, reference number and then stored in slide boxes.

3.4 Measurements

The eye piece graticule used for measurement was calibrated in millimicron (μm). This was done using a stage graticule (micrometer) of 10mm in length and 0.1mm subunit. All measurements were made with a leitz phase contrast microscope at 40x objective and all illustrations made with leitz camera lucida.

Body lengths were taken excluding rostrum and the entire gnathosoma. Maximum body widths were measured at the level of the humeral setae. Lateral setal lengths and the distances between them and also, all the dorsal setal lengths were taken from the points of insertion. The portions of leg segments overlapping into adjacent segments were noted. Lengths of tarsal segments were taken up to the pretarsi excluding empodia and all ambulacral appendages. The nomenclature of the body parts and the different setae are illustrated in Fig. 3. Twenty replicates per location were used because greater degree of accuracy is expected with large sample sizes. With this, the total number of adult females examined were 200 from 10 countries. For the immature stages, based on the same consideration, 150 specimens were treated, 50 replicates for each instar and 10 from each locality. A total of 100 characters obtained from both measurements and setal counts were examined on the larval to the adult stage.

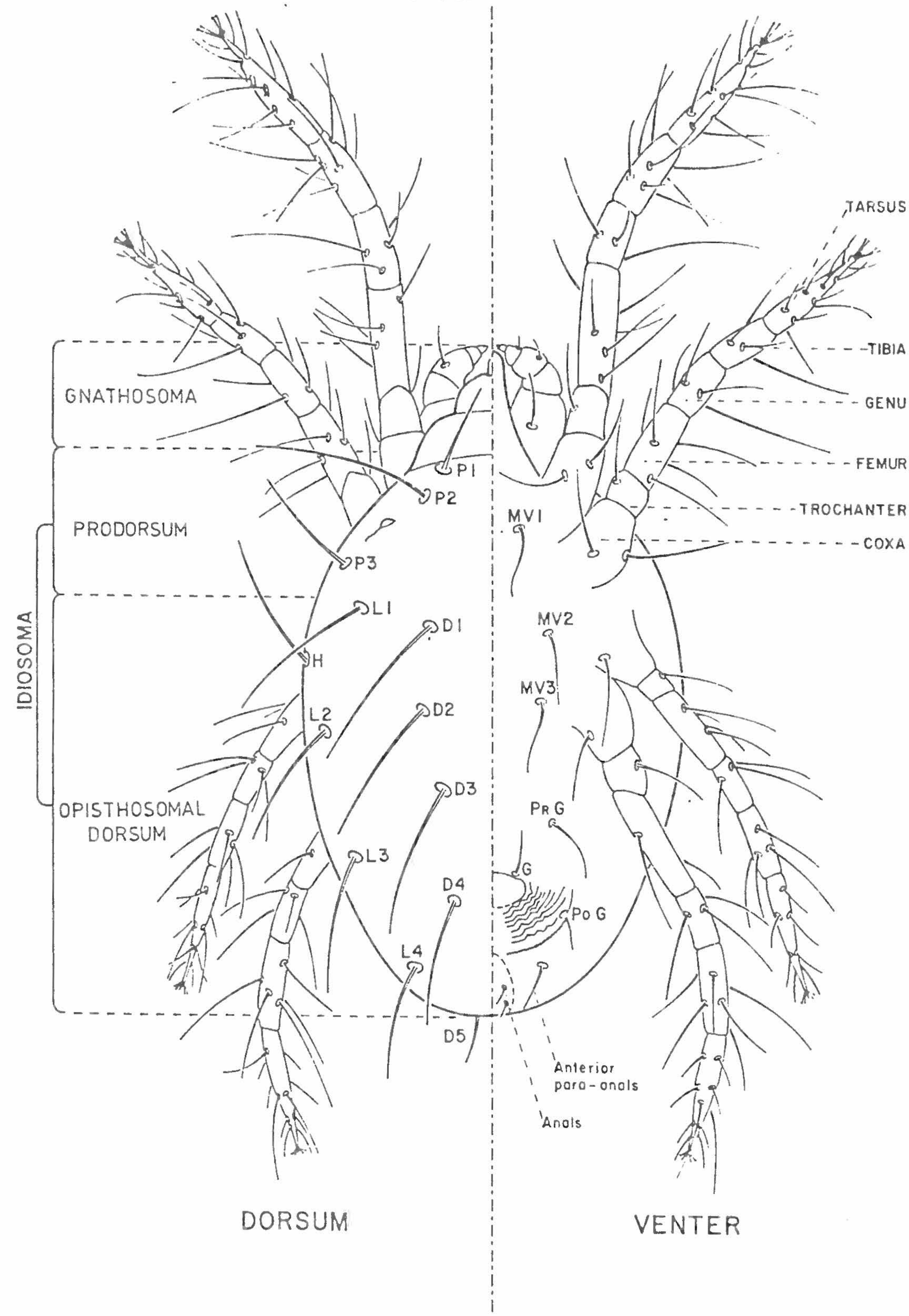

Fig. 3. A typical tetranychid mite (Tetranychus urticae Koch) showing the nomenclature of dorso-ventral aspects of body setae (after, Gutierrez, 1985).

3.5 Variables studied (see fig. 3).

The characters examined in this study were based on some general morphological characters often used in the identification of tetranychid mites.

Adults

1.	Length of	trochanter	segment,	leg	1	Trl
2.	" "	femur	"	"	"	Fm 1
3.	" "	genu	"	"	"	Gn 1
4.	" "	tibial	"	"	"	Tb 1
5.	" "	tarsal	"	"	"	Ts 1

Similar measurements were made on legs 11 - 1V for variables 6-20

21. Ratio of body length to the dorso-lateral setal length (L_1) RL_1

22. " " " " " " " " " " (L_2) RL_2

23. " " " " " " " " " " (L_3) RL_3

24. " " " " " " " " " " " (L_4) RL_4

25. Ratio of body length to the distances between the dorso-lateral setal length (L_1 and L_2) Rd_1

26. " " (L_2 and L_3) " " " " " Rd_2

27. " " (L_3 and L_4) " " " " " Rd_3

Setal scores

28.	Number of setae on coxisternal plate, leg 1	Cx 1
29.	" " " " trochanter segment, " "	Tr 1
30.	" " " " femur " " "	Fm 1
31.	" " " " genu " " "	Gn 1
32.	" " " " tibial " " "	Tb 1
33.	" " " " tarsal " " "	Ts 1

Similar scores were observed on legs 11 - 1V for variables 34-51

Immature stages

1.	Total body length (BL)	
2.	Maximum body width (BW)	
3.	Length of prodorsumal setae	P_1
4.	" " " " "	P_2
5.	" " " " "	P_3
6.	" " humeral "	H
7.	" " dorso-central "	D_1
8.	" " " " "	D_2
9.	" " " " "	D_3
10.	" " " " "	D_4
11.	" " " " "	D_5
12.	" " dorso-lateral "	L_1

Length of dorso-lateral setae

13. " " " " " L_2

14. " " " " " L_3

15. " " " " " L_4

Setal scores

16. Number of setae on idiosomal midventer Mv_1

17. " " " " " " Mv_2

18. " " " " " " Mv_3

19. Number of setae on opisthosomal venter PrG

20. " " " " " " G_1

21. " " " " " " G_2

22. " " " " " " A_1

23. " " " " " " A_2

24. " " " " " " PaA_1

25. " " " " " " PaA_2

26. " " " " Coxisternal plate leg 1 Cx 1

27. " " " " trochanter segment " " Tr 1

28. " " " " femur " " " Fm 1

29. " " " " genu " " " Gn 1

30. " " " " tibial " " " Tb 1

31. " " " " tarsal " " " Ts 1

The same scores were observed on legs 11-1V for variables 32-49

3.6 Techniques of principal components analysis (PCA) and cluster analysis

The mathematical account of PCA involves a reduction of the data set without much loss of information. The technique consists of transformation of the set of observed variables.

$$X_1, X_2 \dots X_p;$$

to a new set,

$$Y_1, Y_2 \dots Y_p;$$

such that each Y is a linear combination of the X's, that is

$$Y_1 = a_{1,1}X_1 + a_{1,2}X_2 + \dots + a_{1,p}X_p$$

$$Y_2 = a_{2,1}X_1 + a_{2,2}X_2 + \dots + a_{2,p}X_p$$

$$\vdots$$

$$Y_p = a_{p,1}X_1 + a_{p,2}X_2 + \dots + a_{p,p}X_p$$

Secondly, the coefficients defining each linear transformation (that is, the a's) are such that the sum of their squares is unity; that is,

$$\sum a_{ij}^2 = 1; \text{ for } i = 1, \dots, p$$

Furthermore, of all the possible transformation of this type, Y_1 has the greatest variance, also, of all the possible transformations of this type, which are uncorrelated with Y_1, Y_2 has the greatest variance, and so on, until the complete set of "P" transformed variables has been defined.

The PCA is expected to produce a set of "P" composite characters that are uncorrelated and are arranged in order of decreasing variance. If it is observed that the first few components account for most of the variation, it might be possible to use only these in subsequent analysis.

For the computation, the "R" type principal components analysis of correlation among variables as described by Sneath and Sokal (1962) was used, as it is appropriate for the quantitative data in this study. The data set was also standardized by substracting from each observation, the mean of the data set and dividing by the standard deviation. This technique converts the data to a form whereby all variables extend essentially over the same ranges with a mean of zero and a variance of unity.

Cluster analysis methods compare each OTU with every other one, in order to determine the degree of similarity based on the numerically coded characters. The resultant set of measured similarities can then be exhibited in the form of a ("t" x "t") matrix of OTUs. From this, OTUs can be arranged in clusters on the basis of the matrix of calculated similarities. The "single linkage cluster analysis" which defines the most similar (least dissimilar) pairs of OTUs was used. The PCA, as well as the cluster programs by Davis (1973) and mounted on WANG PC was used for the studies.

4. RESULTS

4.1 Measurements

4.1.1 Adult stage

Measurements on specimens from the different locations are given in appendices 1-10. The following subroutines were extracted from the PCA namely: correlation dispersion half-matrix (for standardized data), latent roots (eigenvalues), normalised eigenvectors (weightings), principal components scores and percentage variances.

Table 2 gives the coefficients of correlation between each of the 27 variables and their levels of significance. The high degree of intercorrelations between the variables are evident from the table except for variables 21-27 (ratios of measurements) which did not seem to correlate with anything. These variables might be of considerable taxonomic utility. To verify this, another set of PCA was computed using only the 7 ratios.

Table 2. Coefficients of correlation half-matrix for 27 Variables between adult female *Mononychellus* spp.

		TrI	FmI	GnI	TbI	TsI	TrII	FmII	GnII	TbII	TsII	TrIII	FmIII	GnIII	TbIII	TsIII	TrIV	FmIV	GnIV	TbIV	TsIV	RL1	RL2	RL3	RL4	Rd1	Rd2	Rd3
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
TrI	1	1.00	0.26**	0.27**	0.26**	0.01	0.39**	0.24*	0.25**	0.12	0.09	0.20*	0.07	0.22*	0.22*	0.12	0.12	0.18	0.23*	0.15	0.05	0.12	0.04	-0.02	0.00	0.12	0.08	0.04
FmI	2		1.00	0.34**	0.32**	0.26**	0.20*	0.34**	0.34**	0.34**	0.31**	0.10	0.27**	0.22*	0.30**	0.36**	0.06	0.20*	0.23*	0.22*	0.21*	0.03	0.05	0.07	-0.07	0.20*	0.16	0.10
GnI	3			1.00	0.46**	0.19	0.10	0.29**	0.47**	0.27**	0.17	0.24*	0.05	0.23*	0.36**	0.42**	0.35**	0.29**	0.31**	0.21*	0.36**	0.03	-0.11	-0.03	-0.07	0.03	-0:02	0.16
TnI	4				1.00	0.23*	0.19	0.22*	0.30**	0.22*	0.29**	0.19	0.13	0.25**	0.28**	0.35**	0.14	0.26**	0.33**	0.32**	0.36**	0.03	-0.07	-0.09	-0.09	-0.06	-0.07	0.08
TsI	5					1.00	-0.03	0.11	0.22*	0:25**	0.40**	0.16	0.05	0.09	0.14	0.36**	0.11	0.18	0.21*	0.22*	0.35**	0.06	-0.05	0.01	-0.07	0.04	0.00	-0.02
TrII	6						1.00	0.29**	0.10	0.13	0.02	0.33**	0.14	0.15	0.06	0.15	0.17	0.15	0.12	0.08	0.04	0.04	-0.05	-0.07	0.04	0.22*	0.15	0.04
FmII	7							1.00	0.22*	0.19	0.17	0.19	0.25**	0.20*	0.14	0.24*	0.15	0.22*	0.10	0.08	0.10	0.05	0.01	0.03	0.00	0.04	0.08	0.13
GnII	8								1.00	0.38**	0.15	0.22*	-0.03	0.23*	0.23*	0.32**	0.15	0.26**	0.26**	0.22*	0.33**	0.10	0.06	0.08	-0.07	0.06	0.05	0.08
TbII	9									1.00	0.14	0.13	0.07	0.19	0.17	0.30**	0.04	0.23*	0.23*	0.27**	0.19	-0.00	0.02	-0.03	-0.15	0.15	0.04	0.02
TsII	10										1.00	0.05	0.04	0.07	0.07	0.37**	0.05	0.16	0.15	0.13	0.35**	0.03	-0.09	-0.05	-0.12	-0.04	-0.08	0.15
TrIII	11											1.00	0.10	0.10	0.18	0.18	0.25**	0.16	0.16	0.13	0.10	0.03	-0.06	-0.10	-0.04	0.07	-0.01	0.12
FmIII	12												1.00	0.15	0.16	0.18	0.04	0.26**	0.17	0.14	0.10	-0.01	-0.02	-0.04	-0.05	0.05	0.12	0.06
GnIII	13													1.00	0.29**	0.39**	0.30**	0.12	0.14	0.17	0.17	0.07	0.05	-0.03	-0.09	0.02	0.09	0.07
TbIII	14														1.00	0.27**	0.14	0.21*	0.25**	0.39**	0.13	0.04	0.05	0.00	-0.08	-0.01	0.04	0.05
TsIII	15															1.00	0.27**	0.23*	0.17	0.32**	0.53**	0.04	0.01	-0.03	-0.19	-0.07	-0.09	0.05
TrIV	16																1.00	0.23*	0.03	0.16	0.26**	0.01	0.02	0.02	0.01	-0.17	-0.07	0.12
FmIV	17																	1.00	0.24*	0.29**	0.32**	0.09	-0.11	-0.08	-0.09	0.01	0.10	0.05
GnIV	18																		1.00	0.28**	0.20*	0.01	0.00	-0.02	-0.07	0.10	0.10	0.10
TbIV	19																			1.00	0.32**	0.01	0.13	0.02	-0.07	-0.03	-0.01	0.05
TsIV	20																				1.00	0.08	-0.00	-0.03	-0.13	-0.00	0.02	0.07
RL1	21																					1.00	0.04	-0.04	-0.02	-0.03	0.06	-0.12
RL2	22																						1.00	0.72**	0.10	0.02	0.14	0.15
RL3	23																							1.00	0.20*	0.04	0.13	0.11
RL4	24																								1.00	0.06	-0.02	0.04
Rd1	25																									1.00	0.46**	0.14
Rd2	26																										1.00	0.32**
Rd3	27																											1.00

** $r>0.254$ ($p<0.01$)

* $r>0.195$ ($p<0.05$)

Table 3 shows the correlation coefficients between the variables. The low degree of intercorrelation was expected except between the variables indicated in the table.

The latent roots for the best 5 components for 27 and 7 variables respectively were as follows:

Principal Components	27 Variables	7 Variables
1	5.17	1.96
2	2.13	1.46
3	1.80	1.06
4	1.50	1.06
5	1.26	0.96

These values were all significant considering an arbitrary value of 1.00 or greater as a practical significant level (Jeffers, 1967).

Tables 4 and 5 show the values of the normalised eigenvectors and percentage variances for the best 10 and 7 components of 27 and 7 variables respectively. The vectors being scaled so that the maximum weighting is +1, variables which have relatively high positive

Table 3. Coefficients of correlation half-matrix for 7 ratios between adult female *Mononychellus* spp.

	RL_1 1	RL_2 2	RL_3 3	RL_4 4	Rd_1 5	Rd_2 6	Rd_3 7
RL_1 1	1.00	0.04	-0.04	-0.02	-0.03	0.06	-0.12
RL_2 2		1.00	0.72**	0.10	0.02	0.14	0.15
RL_3 3			1.00	0.20*	0.04	0.13	0.11
RL_4 4				1.00	0.06	-0.02	0.04
Rd_1 5					1.00	0.46**	0.14
Rd_2 6						1.00	0.32**
Rd_3 7							1.00

** $r > 0.254$ ($P < 0.01$)

* $r > 0.195$ ($P < 0.05$)

Table 4. Normalised eigenvectors (weightings) and percentage variance explained by the best 10 principal components for 27 varialbles of adult female Mononychellus spp.

Variable	Principal components 1	2	3	4	5	6	7	8	9	10
Tr I	0.185	0.172	0.231	-0.232	-0.175	-0.219	0.106	-0.053	0.055	0.217
Fm I	0.264	0.153	0.077	0.188	-0.050	-0.016	0.253	-0.160	-0.207	0.127
Gn I	0.295	-0.055	-0.007	-0.130	0.070	-0.158	-0.267	-0.038	-0.102	0.239
Tb I	0.277	-0.107	0.012	-0.029	-0.054	-0.041	-0.051	-0.216	0.057	0.247
Ts I	0.199	-0.140	-0.180	0.306	0.101	-0.141	0.122	-0.032	0.182	-0.208
Tr II	0.144	0.199	0.378	-0.180	0.077	-0.122	0.207	-0.069	0.064	-0.267
Fm II	0.200	0.134	0.144	-0.110	0.211	-0.001	0.362	-0.144	-0.138	0.079
Gn II	0.261	0.049	-0.089	-0.006	-0.110	-0.364	-0.162	0.086	-0.126	-0.006
Tb II	0.219	0.029	-0.015	0.198	-0.211	-0.148	-0.035	-0.007	-0.291	-0.368
Ts II	0.188	-0.169	-0.127	0.301	0.299	-0.104	0.236	-0.163	0.075	0.218
Tr III	0.170	0.023	0.212	-0.226	0.162	-0.151	-0.147	-0.064	0.155	-0.437
Fm III	0.130	0.091	0.153	0.051	-0.005	0.599	0.310	-0.106	0.118	-0.059
Gn III	0.205	0.038	0.001	-0.216	-0.037	0.178	0.083	0.317	-0.381	0.099
Tb III	0.221	0.030	-0.040	-0.142	-0.337	0.225	-0.157	-0.069	-0.072	0.162
Ts III	0.296	-0.158	-0.162	0.004	0.133	0.065	0.172	0.109	0.177	-0.115
Tr IV	0.163	-0.078	-0.083	-0.434	0.341	0.090	-0.140	0.222	0.031	-0.121
Fm IV	0.227	-0.039	0.087	0.010	-0.008	0.205	-0.052	0.120	0.383	-0.087
Gn IV	0.213	0.060	0.042	0.122	-0.259	0.038	-0.242	-0.214	0.230	0.113
Tb IV	0.225	-0.021	-0.170	-0.023	-0.294	0.238	-0.144	-0.082	0.211	-0.184
Ts IV	0.253	-0.163	-0.201	0.135	0.183	-0.002	-0.045	0.209	0.200	-0.065
RL_1	0.043	-0.014	0.030	-0.051	-0.207	-0.245	0.314	0.552	0.389	0.270
RL_2	-0.006	0.398	-0.479	-0.143	-0.092	0.011	0.122	0.030	0.021	-0.110
RL_3	-0.019	0.396	-0.488	-0.106	0.003	-0.068	0.127	-0.087	0.042	-0.072
RL_4	-0.078	0.189	-0.056	-0.202	0.123	-0.167	0.041	-0.340	0.338	0.085
Rd_1	0.042	0.370	0.234	0.355	0.017	-0.132	-0.128	0.100	-0.027	-0.144
Rd_2	0.041	0.436	0.129	0.279	0.098	0.140	-0.151	0.362	0.066	0.092
Rd_3	0.079	0.268	-0.041	0.066	0.462	0.141	-0.353	-0.036	-0.022	0.267
Percentage variance	19.22	7.93	6.69	5.66	4.66	4.47	4.36	4.06	3.93	3.61
Cummulative % variance	19.22	27.15	33.84	39.50	44.16	48.63	52.99	57.05	60.98	64.59

Table 5. Normalised eigenvectors (weightings) and percentage variance explained by the best 7 principal components for 7 variables (ratios) of adult female <u>Mononychellus</u> spp.

Variable	Principal components 1	2	3	4	5	6	7
RL_1	-0.032	-0.028	0.892	0.153	0.377	0.172	0.083
RL_2	0.549	-0.380	0.124	-0.213	-0.085	0.104	-0.690
RL_3	0.557	-0.396	0.024	-0.075	-0.162	-0.008	0.707
RL_4	0.196	-0.184	-0.215	0.896	0.227	-0.126	-0.104
Rd_1	0.285	0.542	0.075	0.268	-0.480	0.564	0.002
Rd_2	0.396	0.527	0.186	-0.036	-0.014	-0.726	-0.038
Rd_3	0.333	0.304	-0.319	-0.221	0.737	0.314	0.068
Percentage variance	28.05	20.91	15.17	13.78	11.59	6.68	3.83
Cummulative % variance	28.05	48.96	64.13	77.91	89.50	96.18	100.01

or negative weightings (greater than 0.7) are said to constitute indices of distinction (Jeffers, 1967). There was no remarkably weighted character in Table 4. In Table 5, RL_1 weighted positively in component 3 but accounted for only 15% of the total variation. Similarly, RL_4 in component 4, Rd_3 in 5, Rd_2 in 6 and RL_2 and RL_3 in 7, weighted highly but all with low percentage variances out of the cummulative values. The first 3 components accounted for only 34% and 64% for the 27 and 7 variables respectively.

The eigenvectors were used to compute the various component scores as follows:

$$Y_1 = a_{1',1}Tr_1 + \cdots + a_{1',27}Rd_3$$

.

.

.

$$Y_{200} = a_{200',1}Tr_1 + \cdots + a_{200',27}Rd_3$$

$a_{1',1'} - a_{1'27}$ are the eigenvectors of the first principal component for the 27 variables; the second component follows the same computation and so on, While the Y_1-Y_{200} are the components scores (transformed variables) for the 200 OTUs. The computed values of the first three components for each of the OTUs were plotted as in figs. 4 and 5 for 27 variables and figs. 6, 7 and 8 for 7 ratios. The plotted data were all shown as clusters of the OTUs.

The results of the single linkage cluster analysis are given in Tables 6 and 7 for 27 and 7 variables respectively. The number of clusters and OTUs remaining unclustered at the different similarity levels are evident in the tables. Considering even the unclustered OTUs as a group, it was clear that majority of the OTUs out of 200 were in a group. This was an indication of very close similarities in the specimens. Detailed account of the analysis is given in appendices 14 and 15.

The "One-way" analysis of variance (ANOVA) and the Duncan's multiple range test results are shown in Tables 8 and 9. Location effect was significant ($P < 0.05$) but the percentage variances due to

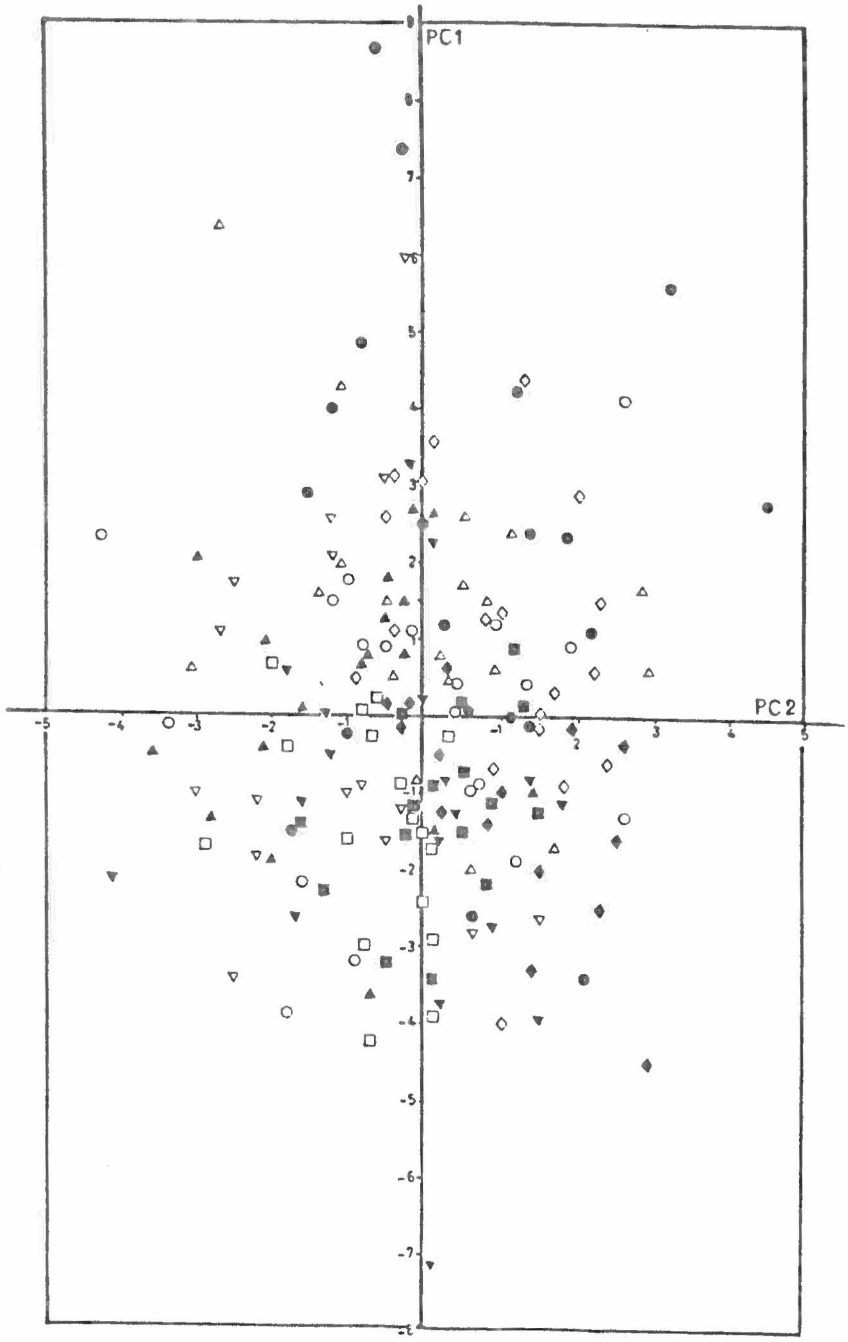

Fig. 4. First and second principal components plots for 27 variables of adult female, Mononychellus spp.

Key:

(▲▲) Burundi; (▼▼) Cameroon; (◇◇) Ghana;
(●●) Kenya; (○○) Nigeria; (□□) Rwanda;
(▽▽) Tanzania; (△△) Uganda; (■■) Zambia;
(◆◆) Zanzibar. PC = Principal component.

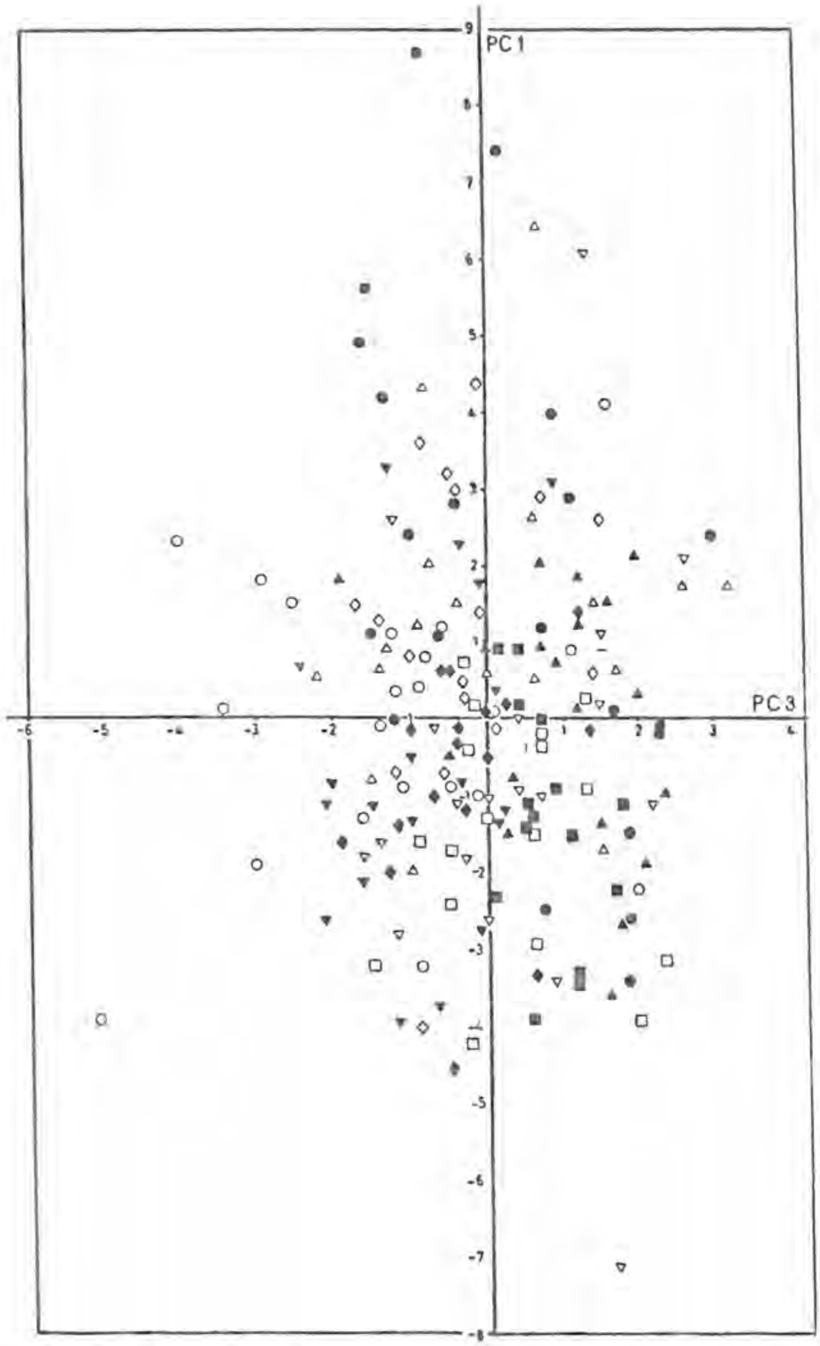

Fig. 5. First and third principal components plots for 27 variables of adult Mononychellus spp.

Key:

(▲▲) Burundi; (▼▼) Cameroon; (◇◇) Ghana; (●●) Kenya; (○○) Nigeria; (□□) Rwanda; (▽▽) Tanzania; (△△) Uganda; (■■) Zambia; (◆◆) Zanzibar. PC = Principal component.

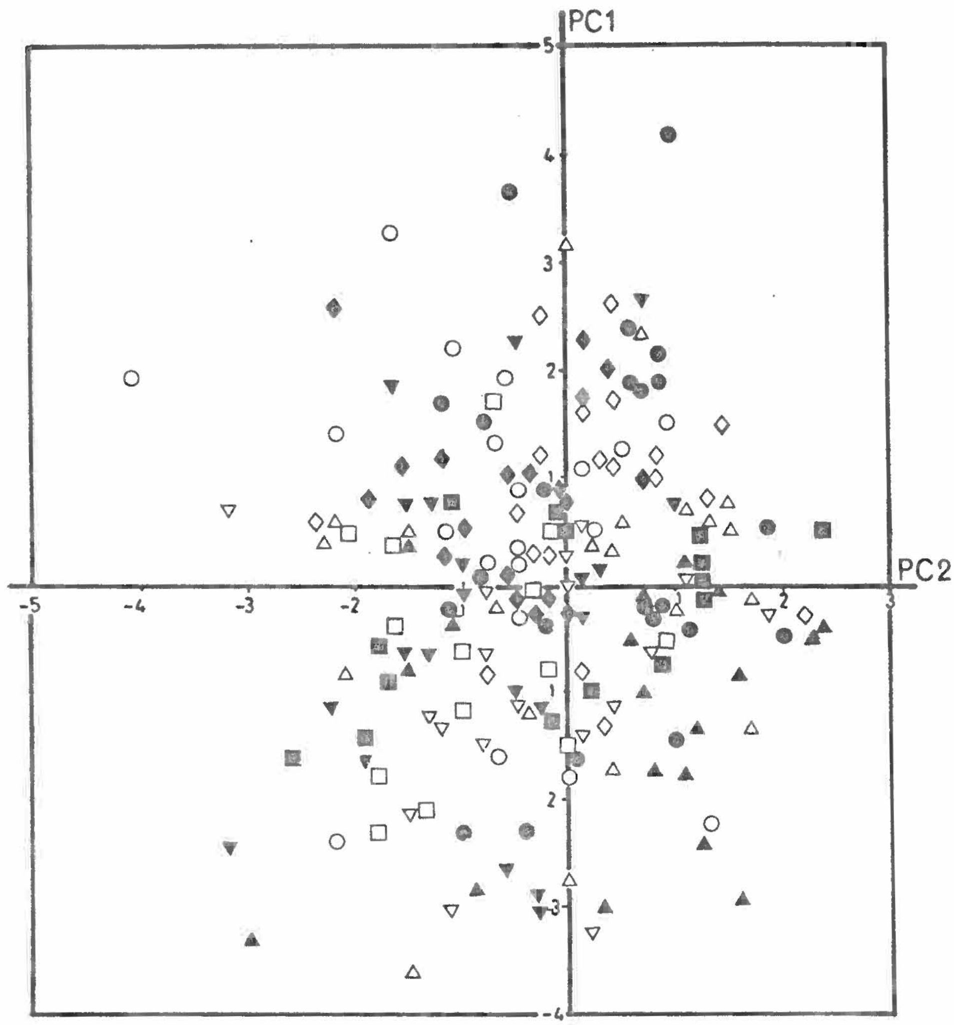

Fig. 6. First and second principal components plots for 7 ratios of adult female, Mononychellus spp.

Key:

(▲▲) Burundi; (▼▼) Cameroon; (◇◇) Ghana; (●●) Kenya; (○○) Nigeria; (□□) Rwanda; (▽▽) Tanzania; (△△) Uganda; (■■) Zambia; (◆◆) Zanzibar. PC = Principal component.

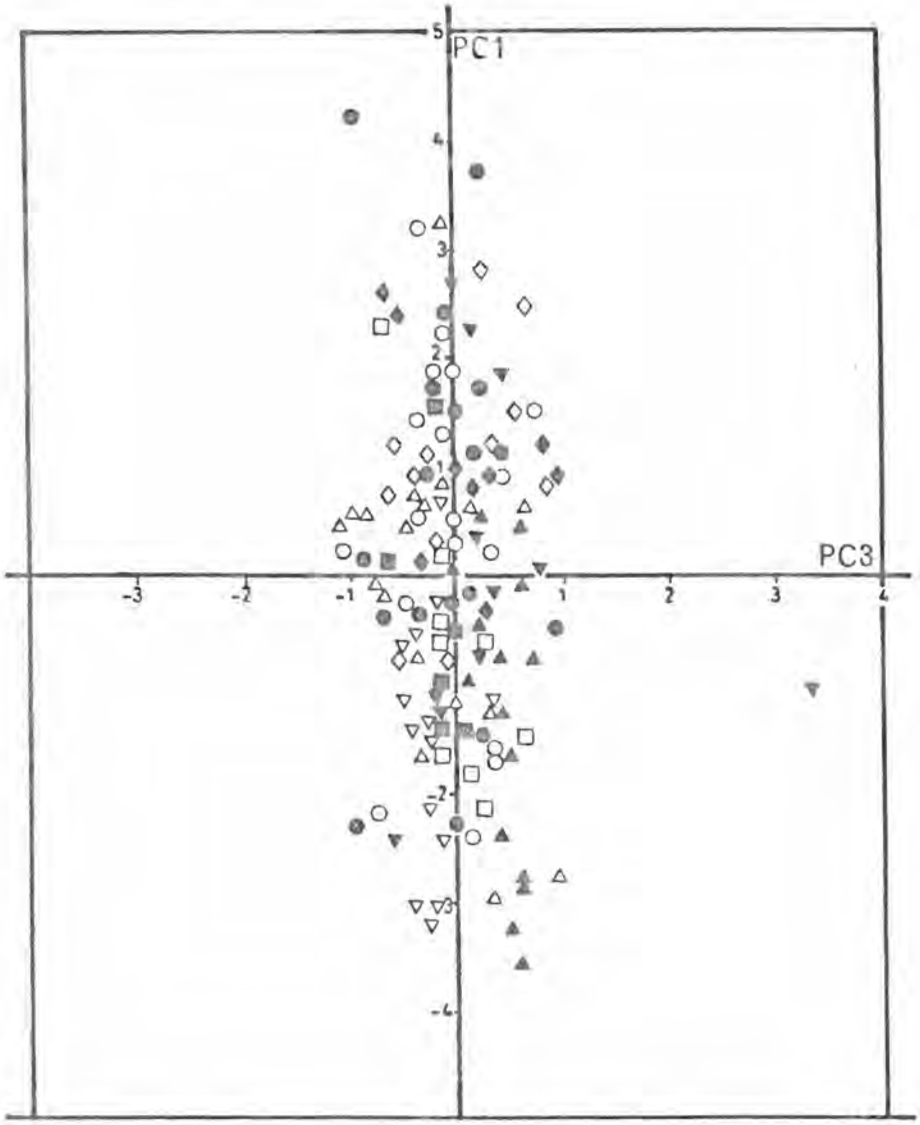

Fig. 7. First and third principal components plots for 7 ratios of adult female, Mononychellus spp.

Key:

(▲▲) Burundi; (▼▼) Cameroon; (◇◇) Ghana; (●●) Kenya; (○○) Nigeria; (□□) Rwanda; (▽▽) Tanzania; (△△) Uganda; (■■) Zambia; (◆◆) Zanzibar. PC = Principal component.

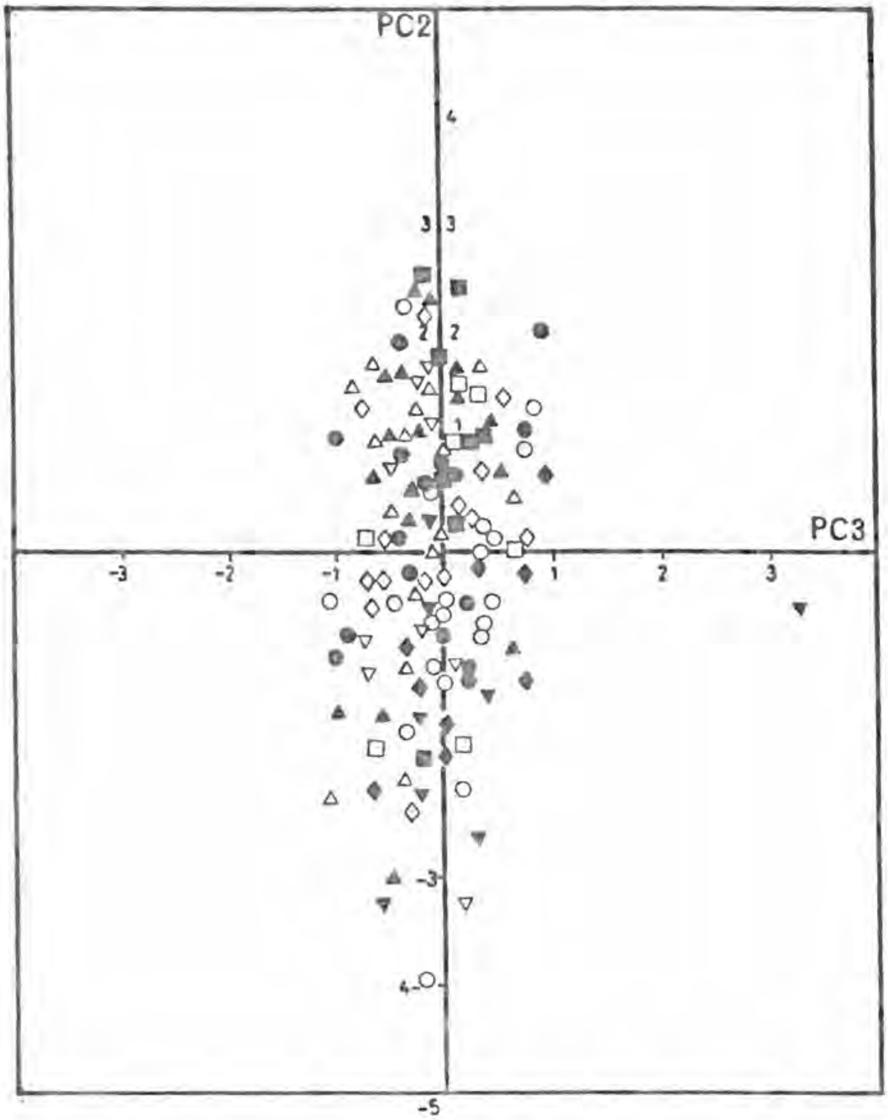

Fig. 8. Second and third principal components plots for 7 ratios of adult female, Mononychellus spp.

Key:

(▲▲) Burundi; (▼▼) Cameroon; (◇◇) Ghana; (●●) Kenya; (○○) Nigeria; (□□) Rwanda; (▽▽) Tanzania; (△△) Uganda; (■■) Zambia; (◆◆) Zanzibar. PC = principal component.

Tables 6. Cluster analysis for 20 variables of adult female *Mononychellus* spp.

Similarity level	No. of cluster	No. of OTU's out of 200 not clustered.
1.00	1	198
0.90	2	196
0.70	4	192
0.60	11	163
0.50	3	63
0.40	1	10
0.30	1	0

Table 7. Cluster analysis for 7 ratios of adult female *Mononychellus* spp.

Similarity level	No. of cluster	No. of OTU's out of 200 not clustered
0.57	2	195
0.37	15	167
0.27	21	55
0.07	1	0

Table 8. Analysis of variance (ANOVA) showing percentage variance due to location for 27 variables of adult female *Mononychellus* spp.

Variable	Mean Square Location 9df	Mean Square Error, 190df	F	Significance Level	Percentage Variance* due to location
Tr I	37.10	4.27	8.68	0.0000	27.75
Fm I	148.67	40.41	3.68	0.0003	11.81
Gn I	69.05	11.95	5.78	0.0000	19.28
Tb I	76.54	19.11	4.01	0.0001	13.06
Ts I	44.52	20.17	2.21	0.0232	5.70
Tr II	26.06	5.28	4.93	0.0000	16.43
Fm II	28.63	15.39	1.86	0.0599	4.12
Gn II	31.40	8.31	3.78	0.0002	12.21
Tb II	6.98	5.07	1.38	0.2001	1.86
Ts II	65.63	17.55	3.74	0.0003	12.05
Tr III	18.22	7.32	2.49	0.0105	6.93
Fm III	48.00	29.62	1.62	0.1113	3.00
Gn III	19.99	6.60	3.03	0.0022	9.22
Tb III	46.72	9.26	5.04	0.0000	16.82
Ts III	57.44	15.14	3.79	0.0002	12.26
Tr IV	13.75	6.86	2.00	0.0405	4.79
Fm IV	63.31	31.36	2.02	0.0391	4.85
Gn IV	23.91	6.31	3.79	0.0002	12.25
Tb IV	10.99	8.07	1.36	0.2074	1.78
Ts IV	43.85	13.94	3.15	0.0015	9.70
RL_1	6.18	7.98	1.03	0.4218	0.125
RL_2	0.012	0.0006	19.48	0.0000	50.00
RL_3	0.0037	0.0007	5.43	0.0000	13.04
RL_4	0.0005	0.0002	2.35	0.0155	6.17
Rd_1	0.0019	0.0007	2.78	0.0045	8.11
Rd_2	0.0023	0.0007	3.44	0.0006	10.88
Rd_3	0.0011	0.0006	1.82	0.0674	3.94

* The remainder of the variance component is due to error.

Table 9. Duncan's multiple range tests of location mean comparisons for 27 variables of adult female *Mononychellus* spp.

Location	Variable mean Tr I	 Fm I	 Gn I	 Tb I	 Ts I	 TrII	 Fm II
Burundi	a,bc 30.139	a 81.928	c,d 39.408	b,c 43.440	b 56.181	c,d,e 27.734	a 53.770
Cameroon	a,b 28.724	a 80.655	a,b 36.082	a,b 41.318	a,b 54.760	a,b 25.753	a 52.779
Ghana	c 30.564	b 85.281	b,c 38.478	b,c 43.582	b 56.175	d,e 27.946	b 56.604
Kenya	d 32.828	a,b 85.324	d 41.115	c,d 45.421	a,b 54.902	e 28.866	a,b 54.477
Nigeria	a,b,c 29.432	a 80.230	a,b,c 37.639	b,c 43.299	b 55.720	a,b,c 26.219	a 53.204
Rwanda	a 28.441	a 79.806	a 35.516	a 40.186	b 57.449	c,d,e 27.309	a 53.770
Tanzania	a,b 28.874	a 80.230	b,c 38.205	a,bc 43.016	a 52.213	a 25.328	a 52.638
Uganda	c 30.422	b 86.740	c,d 39.902	d 46.647	b 56.538	d,e 28.000	a,b 54.760
Zambia	a, 28.441	a 79.362	a,b 36.365	a,b 41.318	a,b 54.902	a,b,c 26.319	a,b 54.477
Zanzibar	b,c 29.998	a 81.645	a,b 36.507	a,b,c 42.450	a,b 54.236	b,c 27.168	a,b 53.911

Location	Variable mean GnII	 Tb II	 Ts II	 Tr III	 Fm III	 Gn III	 Tb III
Burundi	c 33.535	b 31.979	b,c 47.402	a,b,c 27.026	a 52.779	b 31.201	b 38.063
Cameroon	a,b,c 32.969	a,b 31.413	b,c 46.836	a,b,c 26.885	a,b 54.477	b 30.988	b 37.497
Ghana	c 33.394	a,b 31.554	c 47.827	b,c 28.441	a,b 54.338	b 31.837	b 38.912
Kenya	d 35.587	a,b 31.554	b,c 45.280	c 28.724	a,b 54.831	b 32.615	b 39.337
Nigeria	a,b,c 32.828	a,b 30.847	b,c 47.261.	a 26.036	a 53.628	b 32.836	b 38.913
Rwanda	a 31.130	a,b 30.988	c 47.827	a 26.177	a,b 56.600	a 29.290	a 34.234
Tanzania	a,b,c 32.262	a,b 41.413	a,b,c 44.855	a,b,c 27.309	a 53.062	b 31.712	b 39.054
Uganda	a,b,c 33.102	a,b 31.625	b,c 46.624	a 26.036	b 57.732	b 31.696	b 39.045
Zambia	a,b, 31.413	a 29.998	a,b 44.572	a,b 26.602	a,b 54.619	b 31.288	b 37.639
Zanzibar	a,b,c 32.686	a,b 31.347	a 42.308	a,b 26.743	a,b 54.194	b 31.696	b 37.639

Table 9. continued

Location	Ts III	Tr IV	Fm IV	Gn IV	Tb IV	Ts IV	RL_1
	b,c	b,c	a,b	a,b,c	a	a,b,c	a
Burundi	55.326	28.724	64.665	33.535	41.035	57.449	0.0880
	a,b,c	a,b	a	a,b,c	a,b	c	a
Cameroon	54.336	27.168	63.250	32.686	32.308	59.288	0.1328
	b,c	b,c	a,b	c,d	b	c	a
Ghana	55.892	28.866	64.241	34.384	43.299	59.152	0.1395
	b,c	c	a,b	d	a,b	c	a
Kenya	56.034	29.290	64.108	35.516	42.379	59.825	0.1148
	c	b,c	a	a,b	a,b	c	a
Nigeria	56.600	28.765	61.975	32.545	42.308	59.854	0.1402
	a,b	a	a	b,c,d	a	a,b,c	a
Rwanda	53.628	26.743	61.269	34.243	40.893	57.307	0.0940
	a	a,b,c	a,b	b,c,d	a,b	a,b	a
Tanzania	53.062	27.792	63.958	33.818	41.883	56.317	0.0909
	b,c	a,b,c	b	b,c,d	a,b	b,c	a
Uganda	55.750	28.158	67.635	34.172	32.308	59.005	0.1061
	a	a,b,c	a,b	a	a,b	a,b,c	a
Zambia	51.930	27.734	64.524	31.979	41.742	57.166	0.0920
	a	a,b,c	a	a,b,c	a,b	a	a
Zanzibar	52.355	28.300	62.684	32.828	42.025	56.034	0.1334

Variable mean

Location	RL_2	RL_3	RL_4	Rd_1	Rd_2	Rd_3
	a	a	a,b,c	a,b,c	a	a,b
Burundi	0.1077	0.1462	0.0931	0.2275	0.2150	0.2103
	d	c,d	a	a	a,b	a,b
Cameroon	0.1701	0.1776	0.0877	0.2099	0.2217	0.2066
	d	c,d	a,b	b,c	b,c	b
Ghana	0.1753	0.1800	0.0898	0.2299	0.2336	0.2239
	c	c,d	a,b,c	a,b,c	b,c	b
Kenya	0.1502	0.1728	0.0978	0.2284	0.2316	0.2191
	d	d	a,b	a,b	a	a,b
Nigeria	0.1721	0.1878	0.0895	0.2141	0.2198	0.2141
	b,c	b,c	a,b,c	a,b	a,b	a,b
Rwanda	0.1365	0.1638	0.0960	0.2213	0.2221	0.2074
	b,c	a,b	a,b,c	a	a	a,b
Tanzania	0.1312	0.1525	0.0937	0.2105	0.2120	0.2071
	b,c	c,d	b,c	a,b	b,c	b
Uganda	0.1408	0.1732	0.0998	0.2209	0.2330	0.2207
	b	b,c	c	c	c	a,b
Zambia	0.1255	0.1650	0.1034	0.2407	0.2446	0.2091
	d	d	a,b,c	a,b	b,c	a
Zanzibar	0.1766	0.1844	0.0981	0.2222	0.2390	0.2008

*Locations with the same letter (in each variable group) are not significantly different ($P > 0.05$).

location were low for all the variables except for RL_2 (50%). The results of the location mean comparisons were conflicting for almost all the variables but considering variable 22(RL_2) alone which indicated the highest ratio in the ANOVA result, showed that group "a" had only Burundi population, group "b" had Rwanda, Tanzania, Uganda and Zambia populations and in group "c" Kenyan population was included with those in group "b", while group "d" had Cameroon, Ghana, Nigeria and Zanzibar populations. This result indicated certain geographical influence in the distribution of the OTUs but, the results of the other variables could not sufficiently lead to reasonable inferences. This was because of the much intercorrelated nature of the variables.

4.1.2 Immature stages

The 15 measured variables considered as possible diagnostic characters on each instar of Mononychellus spp. were also subjected to PCA. Measurements on the larval, protonymphal and deutonymphal stages are given in appendices 11-13 respectively.

Table 10 shows the coefficients of correlation for the larval stage. Only a few of the variables were significantly intercorrelated. Variables P_1, P_2, D_3 and D_5 did not seem to be significantly correlated with any other variable. The normalised eigenvectors and percentage variance in Table 11 are also of insignificant values. None of the values were highly weighted and the percentage variance for the first 3 components accounted for only 53% of the total. The principal component plots for the first 3 components are shown in figs. 9, 10 and 11. An indistinctive cluster pattern of the OTUs was also evident.

Table 10. Coefficients of correlation half-matrix for 15 variables between larvae of *Mononychellus* spp.

	BL	BW	H	P_1	P_2	P_3	D_1	D_2	D_3	D_4	D_5	L_1	L_2	L_3	L_4
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
BL 1	1.000	0.354*	0.419**	0.062	0.023	0.376**	0.151	0.069	0.202	0.094	0.040	0.566**	0.279	0.319*	0.235
BW 2		1.000	−0.098	−0.284*	0.271	−0.102	−0.132	−0.299*	0.074	0.144	0.169	0.061	0.319*	0.611**	0.251
H 3			1.000	0.265	−0.031	0.316*	0.422**	0.438**	0.247	0.123	−0.252	0.551**	0.245	0.075	0.377**
P_1 4				1.000	−0.001	0.076	−0.082	0.207	0.206	0.256	−0.194	0.212	0.335*	−0.002	0.096
P_2 5					1.000	0.155	0.117	0.107	0.098	−0.023	0.137	0.196	0.191	0.349*	0.355*
P_3 5						1.000	0.192	0.324*	0.205	0.087	0.036	0.559**	0.278	0.015	0.185
D_1 7							1.000	0.458**	−0.009	−0.048	−0.230	0.367**	−0.030	0.106	0.046
D_2 8								1.000	0.207	0.108	−0.191	0.237	0.048	−0.068	0.200
D_3 9									1.000	0.300*	−0.039	0.134	0.426**	0.258	0.228
D_4 10										1.000	−0.196	0.043	0.442**	0.545**	0.395**
D_5 11											1.000	0.024	0.085	−0.048	0.052
L_1 12												1.000	0.298*	0.102	0.208
L_2 13													1.000	0.612**	0.409**
L_3 14														1.000	0.387**
L_4 15															1.000

** $r>0.363$ ($p<0.01$)

* $r>0.281$ ($p<0.04$)

Table 11. Normalised eigenvectors (weightings) and percentage variance explained by the best 10 principal components for 15 variables of larva of *Mononychellus* spp.

	Principal components									
Variable	1	2	3	4	5	6	7	8	9	10
BL	0.312	0.004	0.302	0.210	-0.430	-0.003	0.050	-0.115	-0.121	-0.460
BW	0.147	0.467	0.258	-0.139	-0.224	-0.017	-0.032	-0.178	-0.077	-0.202
H	0.326	-0.313	0.009	-0.044	-0.185	-0.058	0.333	-0.319	0.027	0.284
P_1	0.164	-0.157	-0.431	0.334	0.094	-0.556	-0.149	-0.172	0.142	-0.241
P_2	0.173	0.163	0.226	-0.244	0.600	-0.325	-0.279	-0.113	-0.272	-0.033
P_3	0.272	-0.211	0.219	0.281	0.143	0.209	-0.160	0.549	-0.341	0.091
D_1	0.167	-0.320	0.198	-0.506	-0.055	0.058	-0.190	0.029	0.453	0.182
D_2	0.201	-0.378	-0.085	-0.229	0.297	0.245	0.062	-0.120	0.121	-0.618
D_3	0.259	0.044	-0.236	0.175	0.108	0.603	-0.300	-0.492	-0.158	0.125
D_4	0.254	0.172	-0.448	-0.088	-0.091	0.111	0.155	0.489	0.054	-0.133
D_5	0.049	0.215	0.351	0.404	0.363	0.181	0.247	-0.008	0.583	-0.110
L_1	0.336	-0.214	0.314	0.202	-0.101	-0.246	-0.101	0.085	0.035	0.144
L_2	0.362	0.223	-0.164	0.199	0.049	-0.030	-0.164	0.056	0.321	0.304
L_3	0.308	0.389	-0.065	-0.282	-0.121	-0.028	-0.193	0.115	0.173	-0.053
L_4	0.320	0.136	-0.041	-0.132	0.267	-0.060	0.686	-0.055	-0.214	0.151
Percentage variance	25.48	16.48	11.21	8.44	7.64	5.45	5.05	4.70	4.11	3.11
Commulative % variance	25.48	41.95	53.16	61.60	69.24	74.69	79.74	84.44	88.44	91.66

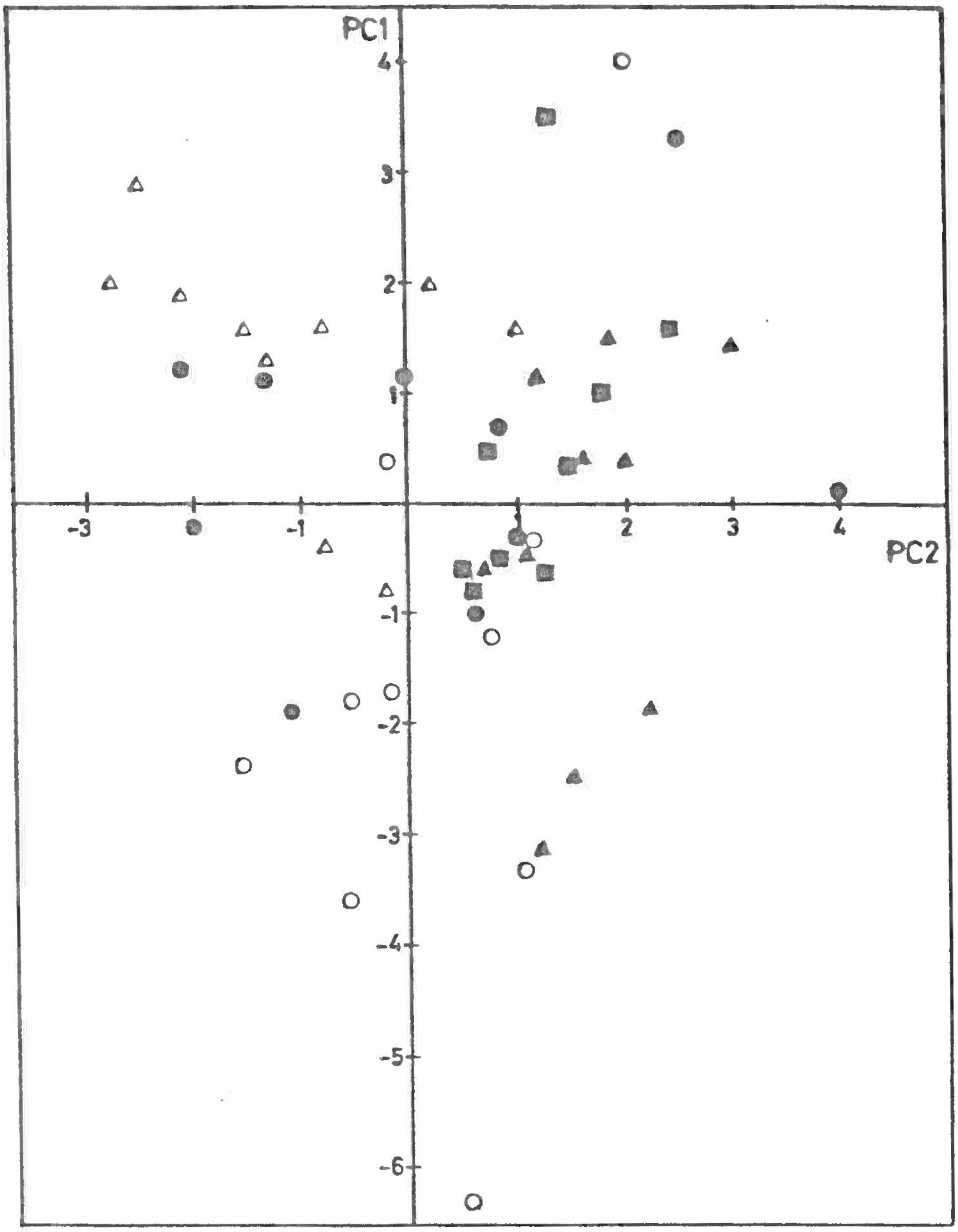

Fig. 9. First and second principal components plots for 15 variables of larva of Mononychellus spp.

Key:

(○○) Mbita Point Field Station; (●●) Rusinga Island; (△△) Mombasa; (▲▲) Homa-Bay; (■■) Embu.

PC = principal component.

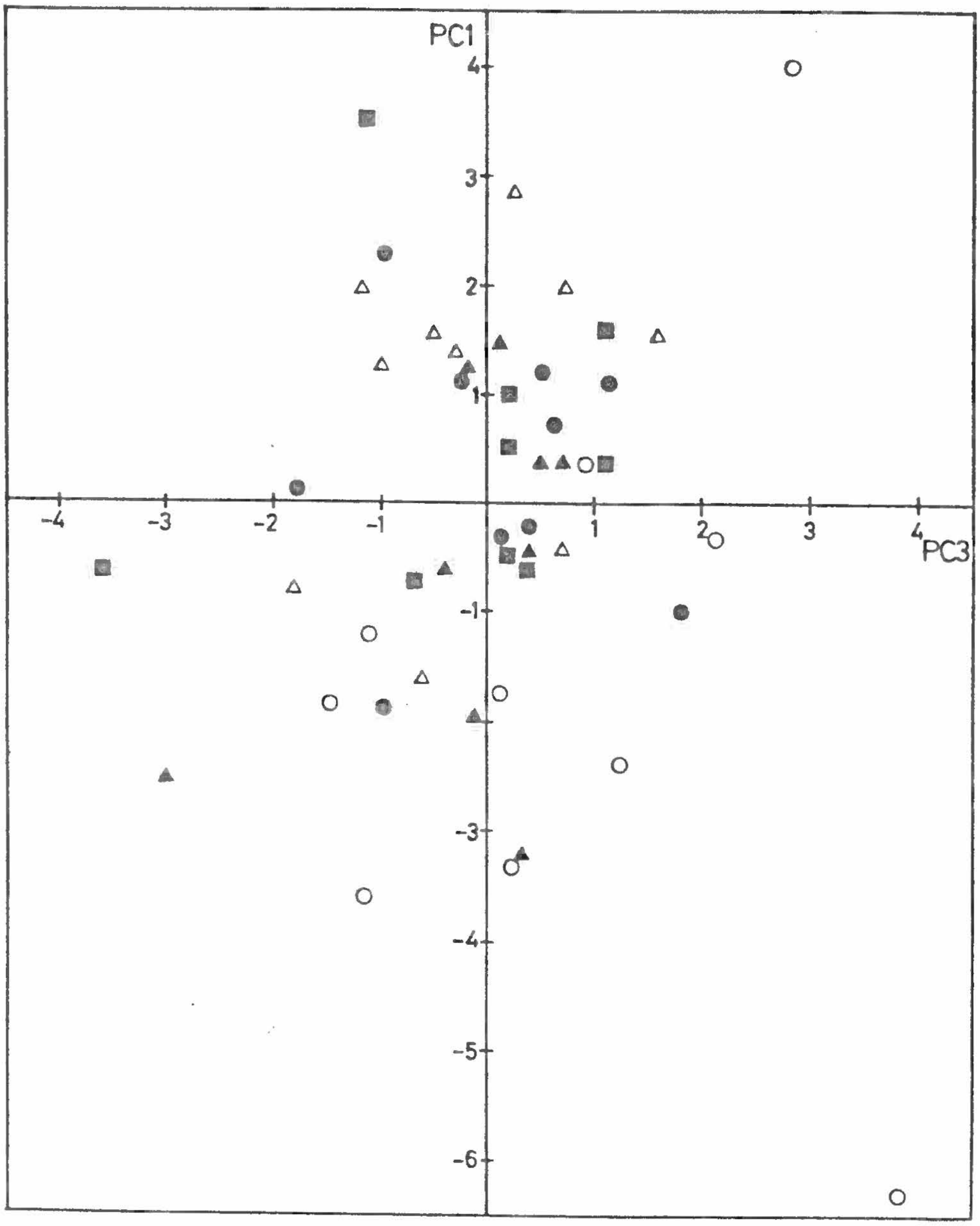

Fig. 10. First and third principal components plots for 15 variables of larva of *Mononychellus* spp.

Key:

(○○) Mbita Point Field Station; (●●) Rusinga Island; (△△) Mombasa; (▲▲) Homa-Bay; (■■) Embu.

PC = principal component.

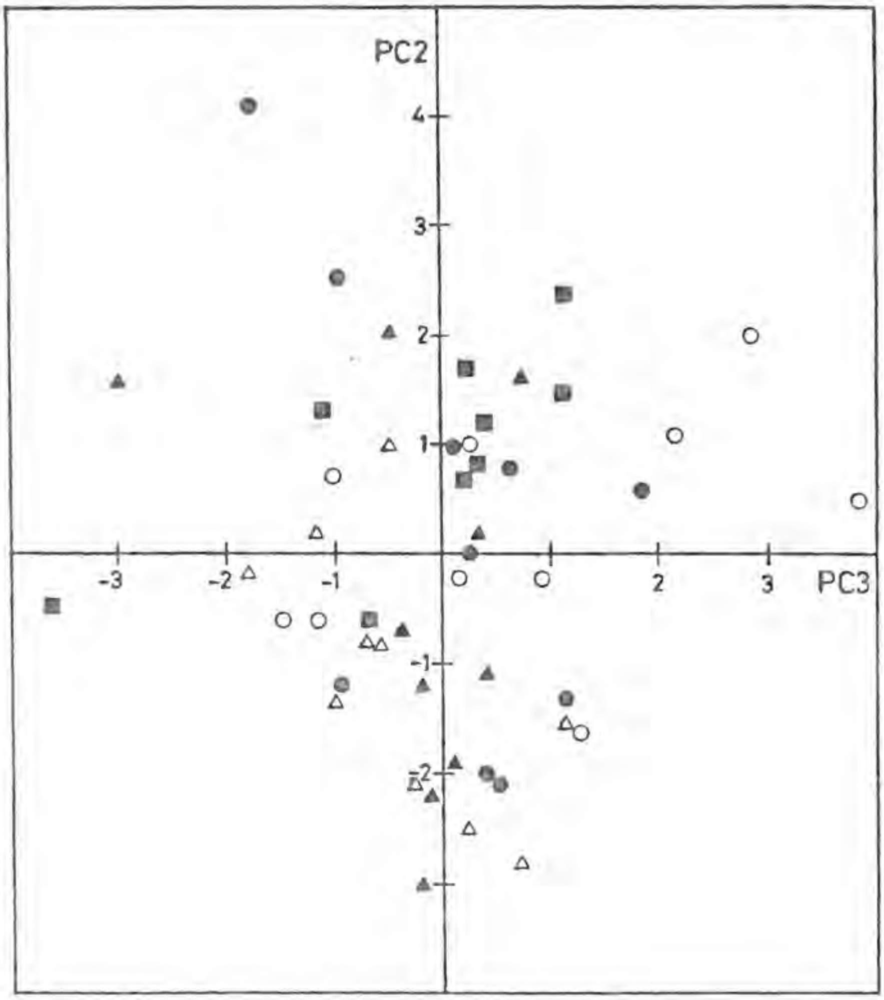

Fig. 11. Second and third principal components plots for 15 variables of larva of Mononychellus spp.

Key:

(○○) Mbita Point Field Station; (●●) Rusinga Island; (△△) Mombasa; (▲▲) Homa-Bay; (■■) Embu.
PC = principal component.

The coefficients of correlation matrix for the protonymphal stage is shown in Table 12. The situation was not different from that of the larval stage. Variables P_1, L_2 and D_4 had no significant correlation with other variables. Table 13 gives the values of the eigenvectors and the percentage variance. The first 3 components accounted for 59% of the total variance. In components 4 and 7, variables D_4 and P_1 showed high positive and negative weightings respectively. The percentages accounting for these weightings were however very low. Principal components plots of the OTUs for the first 3 components are given in figs. 12, 13 and 14. Figures 12 and 14 had a similar pattern of cluster, showing an elongated cluster along the direction of possibly the main axis constituting the highest variance.

Table 14 gives the coefficients of correlation of variables between the deutonymphs. High significant intercorrelation of almost all the variables was again evident.

Table 12. Coefficients of correlation half-matrix for 15 variables between protonymphs of *Mononychellus* spp.

	BL 1	BW 2	H 3	P_1 4	P_2 5	P_3 6	D_1 7	D_2 8	D_3 9	D_4 10	D_5 11	L_1 12	L_2 13	L_3 14	L_4 15
BL 1	1.000	0.544**	0.285*	0.209	0.350*	-0.050	0.547**	0.433**	0.400**	0.139	0.430**	0.366**	0.008	-0.013	-0.032
BN 2		1.000	-0.078	0.106	0.312*	0.027	0.302*	0.186	0.186	0.133	0.382**	0.274	-0.137	-0.140	-0.150
H 3			1.000	0.218	0.011	0.203	0.130	0.089	0.091	0.025	0.283*	0.408**	0.160	0.159	0.141
P_1 4				1.000	0.077	0.305*	0.133	-0.032	0.248	0.009	0.319*	0.213	0.123	0.123	0.109
P_2 5					1.000	0.087	0.475**	0.472**	0.350*	0.227	0.281*	0.394**	0.073	0.074	0.066
P_3 6						1.000	0.032	-0.182	0.027	0.009	0.310*	0.215	0.228	0.227	0.239
D_1 7							1.000	0.594**	0.647**	-0.084	0.364**	0.377**	0.077	0.051	0.044
D_2 8								1.000	0.581**	-0.043	0.229	0.434**	-0.068	-0.098	-0.102
D_3 9									1.000	-0.105	0.247	0.357**	0.024	-0.009	-0.040
D_4 10										1.000	-0.044	0.243	0.139	0.149	0.105
D_5 11											1.000	0.387**	-0.123	-0.121	-0.122
L_1 12												1,000	0.135	0.113	0.075
L_2 13													1.000	0.996**	0.990**
L_3 14														1.000	0.991**
L_4 15															1.000

** $r>0.363$ ($p<0.01$)

* $r>0.281$ ($p<0.05$)

Table 13. Normalised eigenvectors (weightings) and percentage variance explained by the best 10 principal components for 15 variables of Protonymph of *Mononychellus* spp.

	Principal components									
Variable	1	2	3	4	5	6	7	8	9	10
BL	0.375	-0.066	-0.010	0.150	-0.032	-0.515	-0.045	-0.077	-0.302	-0.088
BW	0.258	-0.138	0.061	0.397	-0.436	-0.321	0.163	0.336	0.199	-0.284
H	0.175	0.126	0.340	-0.150	0.641	-0.290	0.110	-0.150	-0.170	-0.313
P_1	0.176	0.098	0.421	-0.157	-0.218	-0.005	-0.733	-0.195	0.261	-0.109
P_2	0.323	-0.001	-0.190	0.232	-0.088	0.440	0.107	-0.590	0.073	-0.418
P_3	0.092	0.195	0.488	-0.070	-0.208	0.469	0.274	0.263	-0.393	-0.161
D_1	0.393	-0.036	-0.216	-0.212	-0.112	-0.006	0.055	-0.016	-0.359	0.079
D_2	0.338	-0.125	-0.358	-0.157	0.201	0.122	0.039	0.001	0.216	0.119
D_3	0.346	-0.059	-0.190	-0.340	-0.063	0.143	-0.320	0.338	-0.227	0.076
D_4	0.059	0.099	-0.007	0.714	0.248	0.178	-0.354	0.039	-0.339	0.318
D_5	0.308	-0.085	0.390	-0.023	-0.136	-0.049	0.304	-0.314	0.143	0.682
L_1	0.351	0.057	0.123	0.132	0.381	0.203	0.062	0.432	0.490	-0.014
L_2	0.062	0.538	-0.137	-0.012	-0.062	-0.090	0.025	0.034	0.054	0.057
L_3	0.050	0.541	-0.125	0.003	-0.068	-0.088	0.032	-0.007	0.063	0.055
L_4	0.038	0.539	-0.125	-0.017	-0.095	-0.087	0.072	-0.041	0.065	0.046
Percentage variance	26.29	21.58	10.68	8.64	6.87	5.89	5.11	3.44	3.20	2.75
Commulative % variance	26.29	47.87	58.55	67.19	74.06	79.95	85.06	88.50	91.70	94.45

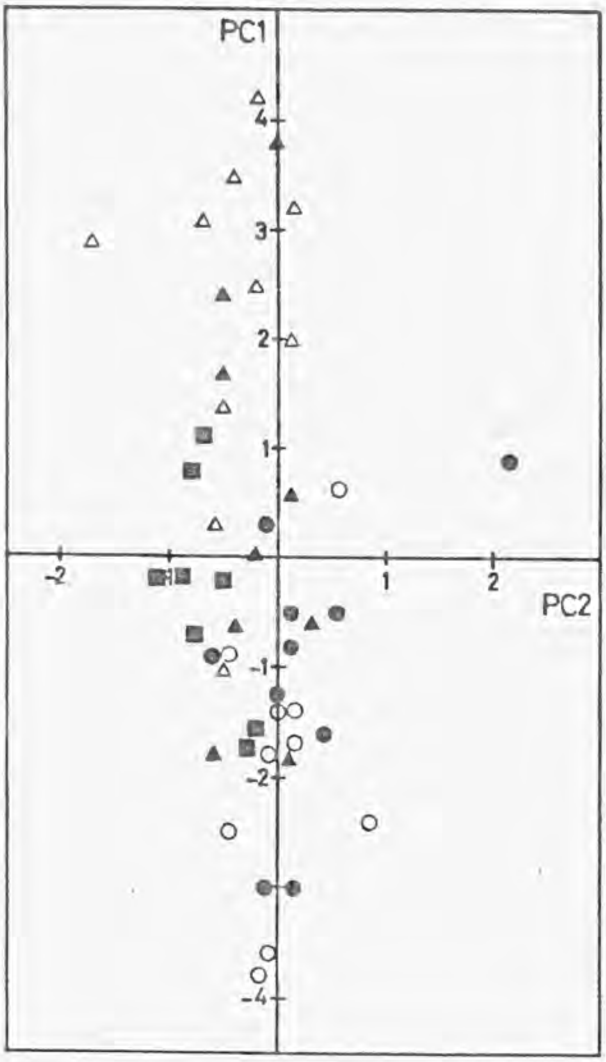

Fig. 12. First and second principal component plots for 15 variables of protonymph of Mononychellus spp.

Key:

(○○) Mbita Point Field Station; (●●) Rusinga Island; (△△) Mombasa; (▲▲) Homa-Bay; (■■) Embu.

PC = principal components.

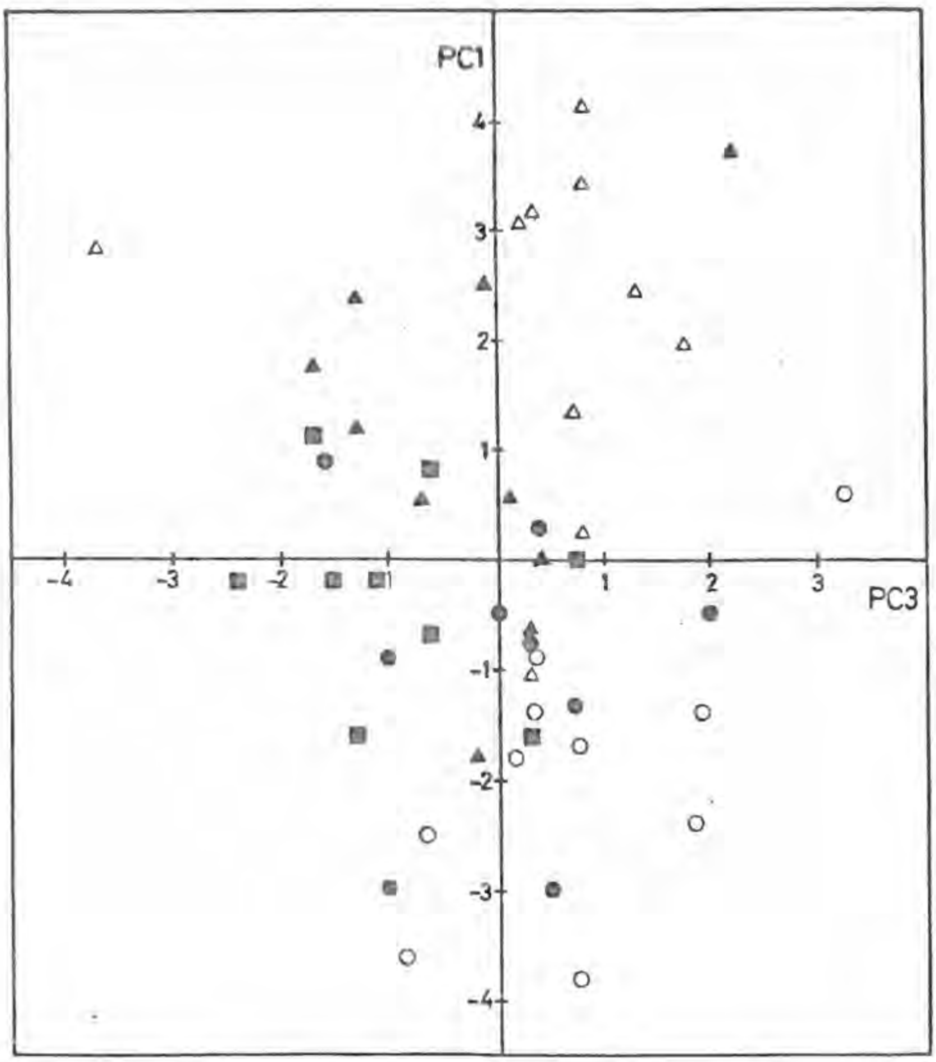

Fig. 13. First and third principal components plots for 15 variables of protonymph of Mononychellus spp.

Key:

(○○) Mbita Point Field Station; (●●) Rusinga Island; (△△) Mombasa; (▲▲) Homa-Bay; (■■) Embu.

PC = principal components.

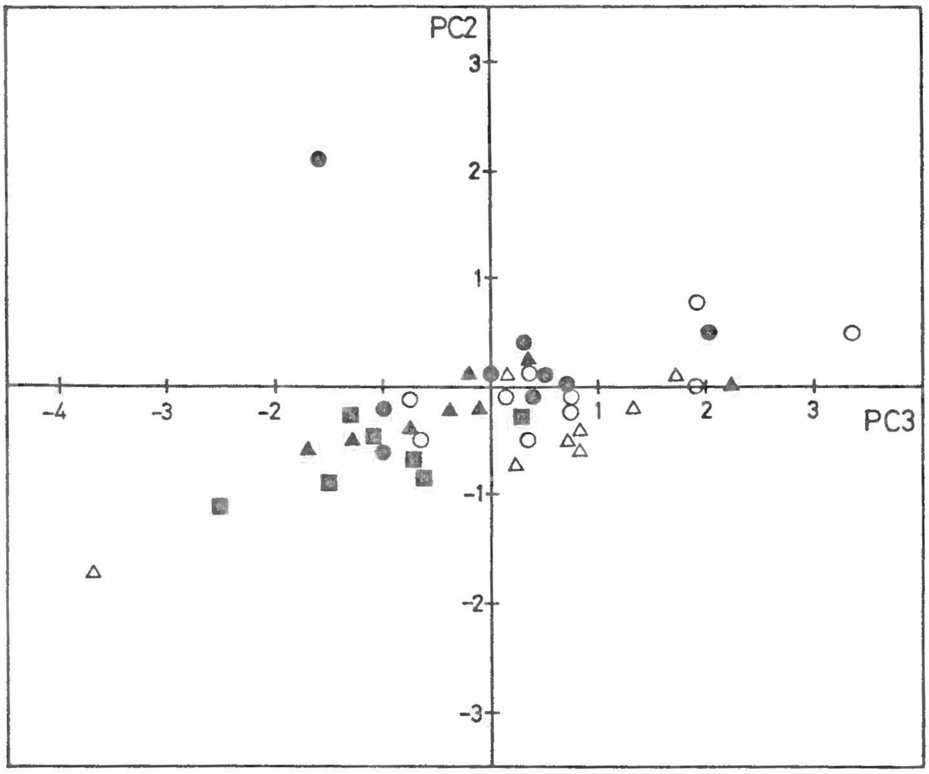

Fig. 14. Second and third principal components plots for 15 variables of protonymph of Mononychellus spp.

Key:

(○○) Mbita Point Field Station; (●●) Rusinga Island; (△△) Mombasa; (▲▲) Homa-Bay; (■■) Embu.

PC = principal component.

Table 14. Coefficents of correlation half-matrix for 15 variables between deutonymphs of <u>Mononychellus</u> spp.

	BL 1	BW 2	H 3	P_1 4	P_2 5	P_3 6	D_1 7	D_2 8	D_3 9	D_4 10	D_5 11	L_1 12	L_2 13	L_3 14	L_4 15
BL 1	1.000	0.786**	0.416**	0.335*	0.576**	0.529**	0.220	0.489**	0.236	0.657**	0.400**	0.584**	0.630**	0.696**	0.770**
BW 2		1.000	0.416**	0.364**	0.636**	0.540**	0.404**	0.520**	0.214	0.580**	0.447**	0.572**	0.434**	0.594**	0.711**
H 3			1.000	0.334*	0.534**	0.647**	0.236	0.382**	0.286*	0.500**	0.290*	0.555**	0.584**	0.580**	0.438**
P_1 4				1.000	0.320*	0.549**	0.082	0.259	-0.072	0.429**	0.250	0.433**	0.134	0.365**	0.504**
P_2 5					1.000	0.506**	0.552**	0.748**	0.394**	0.521**	0.260	0.651**	0.581**	0.604**	0.603**
P_3 6						1.000	0.222	0.403**	0.253	0.598**	0.267	0.633**	0.393**	0.569**	0.503**
D_1 7							1.000	0.678**	0.552**	0.065	0.399**	0.431**	0.324*	0.247	0.198
D_2 8								1.000	0.660**	0.285*	0.266	0.611**	0.549**	0.391**	0.441**
D_3 9									1.000	0.039	0.032	0.501**	0.486**	0.220	0.136
D_4 10										1.000	0.264	0.605**	0.490**	0.741**	0.761**
D_5 11											1.000	0.310*	0.142	0.309*	0.492**
L_1 12												1.000	0.636**	0.683**	0.513**
L_2 13													1.000	0.645**	0.474**
L_3 14														1.000	0.680**
L_4 15															1.000

** $r>0.363$ ($p<0.01$)

* $r>0.281$ ($p<0.05$)

The eigenvectors in Table 15 did not show any index of variation despite the moderately high percentage variance of the first 3 components which accounted for 71% of the total variance. The plotted principal components scores in figs. 15, 16 and 17 also showed clustering of the OTUs. In the three instars, particularly the protonymph and deutonymph, it was noted that, the Mombasa population showed a partial separation from the entire cluster. This was clearly illustrated in figs. 12 and 13 for protonymph and figs. 15 and 16 for deutonymph.

Table 16 shows the mean lengths of all the variables and the ranges of measurements. The progressive increase in body lengths and widths from larva to deutonymph was evident. Table 17 indicates the comparison of the mean lengths of the dorsal idiosomal setae in the instars. The least significant difference (LSD) test indicated that the humeral setae (H) increased progressively in all the instars. There was no significant difference in P_1-P_3 in the larva and protonymph

Table 15. Normalised eigenvectors (weightings) and percentage variance explained by the best 10 principal components for 15 variables of deutonymph of *Mononychellus* spp.

	Principal components									
Variable	1	2	3	4	5	6	7	8	9	10
BL	0.298	0.138	0.046	-0.370	-0.126	0.264	-0.195	0.225	-0.251	0.010
BW	0.291	0.079	0.254	-0.190	-0.176	0.004	-0.512	-0.046	-0.307	-0.046
H	0.252	0.034	-0.268	0.265	0.561	-0.310	0.188	0.319	-0.075	-0.056
P_1	0.182	0.293	0.129	0.602	-0.346	0.103	0.365	0.278	-0.205	-0.201
P_2	0.298	-0.152	0.015	-0.004	-0.216	-0.597	-0.032	-0.000	0.099	0.293
P_3	0.267	0.139	-0.136	0.439	0.079	0.184	-0.508	-0.147	0.039	-0.029
D_1	0.182	-0.458	0.365	0.110	0.057	-0.224	0.070	-0.317	-0.165	-0.442
D_2	0.262	-0.379	0.101	0.071	-0.279	-0.075	0.038	0.246	0.153	0.235
D_3	0.162	-0.527	-0.177	0.029	-0.014	0.509	-0.055	0.050	0.368	-0.225
D_4	0.273	0.317	-0.151	-0.123	-0.057	-0.061	0.103	-0.369	0.426	0.059
D_5	0.170	0.073	0.643	-0.022	0.564	0.187	0.178	0.061	0.080	0.241
L_1	0.305	-0.085	-0.142	0.157	-0.002	0.273	0.236	-0.395	-0.206	0.539
L_2	0.266	-0.145	-0.365	-0.272	0.167	0.010	0.296	0.335	-0.343	-0.006
L_3	0.298	0.151	-0.179	-0.165	0.122	-0.072	0.249	-0.351	-0.143	-0.416
L_4	0.292	0.241	0.171	-0.203	-0.143	0.022	0.123	0.227	0.479	-0.203
Percentage variance	50.03	13.29	7.86	6.35	4.74	3.24	3.01	2.73	2.19	1.64
Commulative % variance	50.03	63.32	71.18	77.53	82.27	85.51	88.52	91.25	93.44	95.08

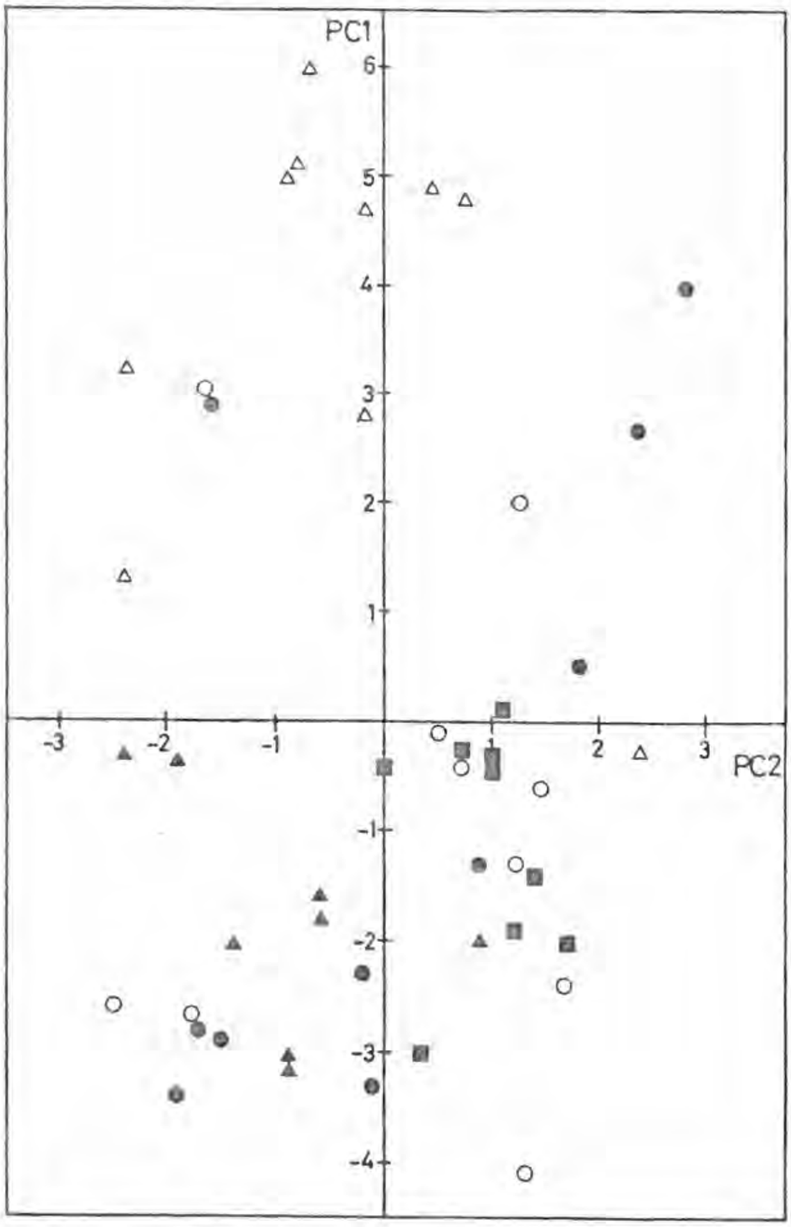

Fig. 15. First and second principal components plots for 15 variables of deutonymph of Mononychellus spp.

Key:

(○○) Mbita Point Field Station; (●●) Rusinga Island; (△△) Mombasa; (▲▲) Homa-Bay; (■■) Embu. PC = principal component.

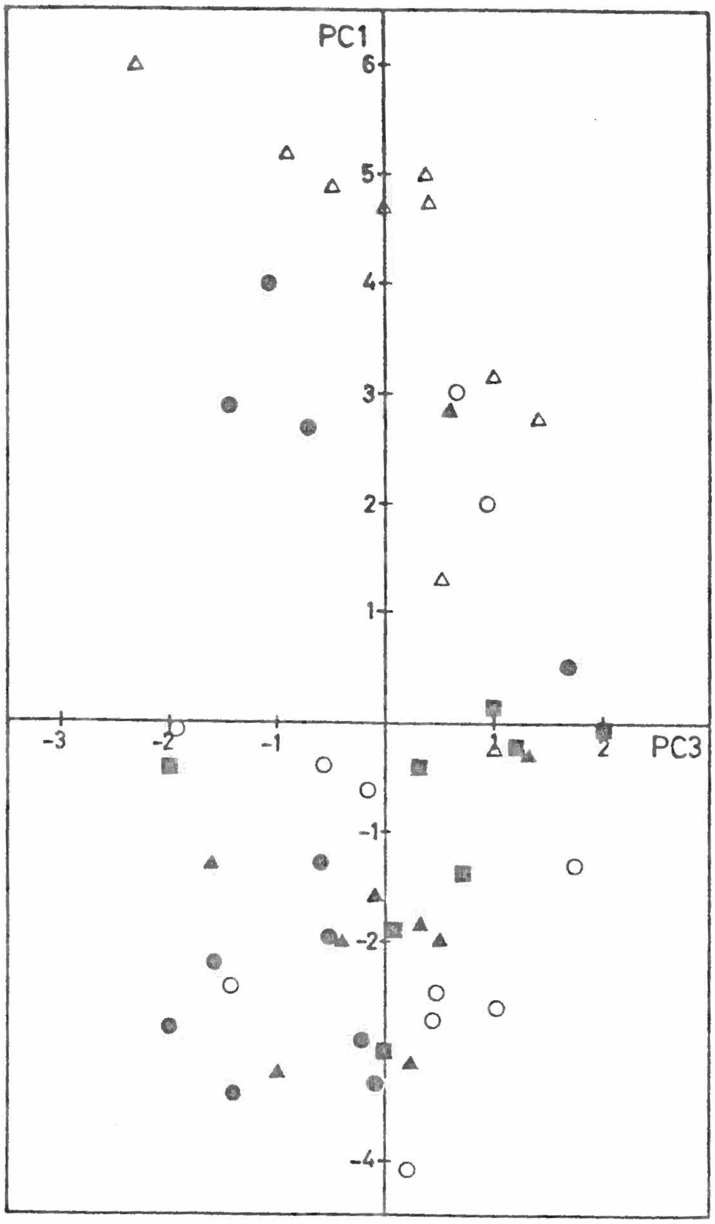

Fig. 16. First and third principal components plots for 15 variables of deutonymph of Mononychellus spp.

Key:

(○○) Mbita Point Field Station; (●●) Rusinga Island; (△△) Mombasa; (▲▲) Homa-Bay; (■■) Embu.

PC = principal component.

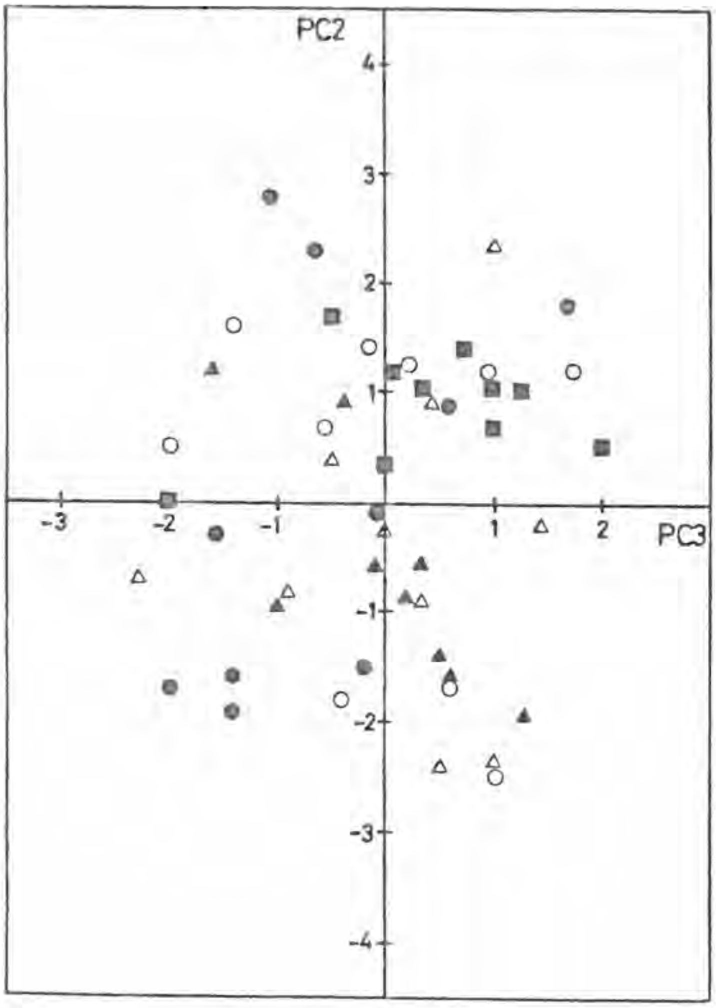

Fig. 17. Second and third principal components plots for 15 variables of deutonymph of Mononychellus spp.

Key:

(○○) Mbita Point Field Station; (●●) Rusinga Island; (△△) Mombasa; (▲▲) Homa-Bay; (■■) Embu.

PC = principal component.

Table 16. Measurements of body length, body width and dorsal idiosomal body setae of immature stages of Mononychellus spp.

Variable	Mean lengths/(Range)(um)		
	Larva	Protonymph	Deutonymph
Body length	129.81 (101.88-155.65)	174.72 (135.84-217.91)	229.08 (166.97-311.30)
Body width	115.84 (90.22-141.50)	146.65 (130.18-172.63)	180.77 (101.88-226.40)
Humeral (H) setae	30.39 (22.64-39-62)	33.34 (25.47-42.45)	39.93 (31.13-50.94)
Prodorsumal (P_1) setae	35.88 (25.47-48.11)	35.04 31.13-42.45	39.42 (31.13-50.94)
" (P_2)	42.20 (31.13-50.94)	43.93 (31-13-56.60)	47.60 (31.13-70.75)
" (P_3)	37.30 (25.47-53.77)	36.91 (31.13-53.77)	43.24 (28.30-56.60)
Dorso-central (D_1) setae	31.41 (22.64-42.45)	26.94 (16.98-36-79)	26.26 (19.81-36.79)
" (D_2)	33.96 (25.47-42.45	29.03 (19.81-36.79)	28.87 (19.81-45.28
" (D_3)	38.66 (28.30-50.94)	35.04 (19.81-48.11)	35.35 (22.64-50.94)
" (D_4)	34.36 (19.81-42.45)	41.29 28.30--52.36)	50.60 (39.62-62.26)
" (D_5)	11.35 (08.49-19.81	14.61 (09.91-22.64)	21.79 (14.15-31.13)
Dorso-lateral (L_1) Setae	36.39 (22.64-42.45)	39.48 (22.64-50.94)	41.46 (22.64-56.60)
" (L_2)	40.38 (31.13-48.11)	47.35 (22.64-58.02)	51.09 (36.79-70.75)
" (L_3)	39.08 (25.47-48.11)	46.95 (14.15-56.60)	55.78 (33.96-70.75)
" (L_4)	16.30 (05.66-25.47)	22.36 (14.15-33.96)	27.71 (19.81-33.96)

Table 17. Analysis of variance (ANOVA) and least significant difference (LSD) tests of immature stages of *Mononychellus* spp.

		Mean squares						
Source of Variance	df	H	P_1	P_2	P_3	D_1	D_2	D_3
INSTAR	2	1192.55**	325.91**	380.66**	630.00**	391.92**	413.35**	202.17**
ERROR	147	21.57	21.49	61.26	30.21	25.01	24.62	44.84
MEANS† LARVA		30.39a	35.88a	42.20a	37.30a	31.41a	33.96a	38.66a
PROTONYMPH		33.34b	35.04a	43.93a	36.91a	26.93b	29.09b	35.04b
DEUTONYMPH		39.93c	39.82b	47.60b	43.24b	26.26b	28.87b	35.35b
LSD (5%)		1.82	1.82	3.07	2.15	1.96	1.94	2.62

Source of Variance	df	D_4	D_5	L_1	L_2	L_3	L_4
INSTAR	2	3319.49**	1425.02**	326.55**	1476.08**	3488.70**	1627.90**
ERROR	147	40.35	14.11	51.29	47.03	36.72	15.35
LARVA		34.36a	11.35a	36.39a	40.38a	39.08a	16.30a
PROTONYMPH		41.29b	14.60b	39.48b	47.35b	46.95b	22.36b
DEUTONYMPH		50.60c	21.79c	41.46b	51.09c	55.78c	27.71c
LSD(5%)		2.49	1.47	2.81	2.69	2.37	1.54

** Significant ($P < 0.01$)

† Means with the same letter (within the same variable) are not significantly different ($P > 0.05$)

and was longest in deutonymph. D_1, D_2 and D_3 were longest in the larval stage and D_4 and D_5 were longest in the deutonymph. L_1 was shortest in the larva while L_2, L_3 and L_4 were longest in the deutonymph.

4.2 Setal scores

Changes during setal ontogeny involve changes in number, length, shape and position of the setae. Changes in length (measurements) have been treated earlier in 4.1. In this section, the remaining parameters were considered. It should be noted that in interpreting these changes, it was assummed that once a seta appeared it was always retained in the subsequent instars. The body setae under examination were classified as dorsal idiosomal, ventral idiosomal and setae on the leg segments. Using Pritchard and Baker (1955) notation, dorsal idiosomal setae comprise the prodorsumal and opisthosomal setae while opisthosomal is further differentiated as humeral, central and lateral setae.

4.2.1 Dorsal idiosomal setae

In the larval stage, 3 pairs of prodorsumal setae P_1,P_2 and P_3 were observed. These were observed without addition or reduction through the protonymph, deutonymph to adult stage. The opisthosomal dorsum showed 10 pairs of setae in the larva and again all through the life stages. These comprised a pair of humeral (H), 5 pairs of dorso-central (D_1-D_5) and 4 pairs of dorso-lateral (L_1-L_4) setae. Figures 18-21 illustrate their position, shape and the total number of 13 pairs. All the setae on this striated cuticle appeared similar in length, except the L_4 and D_5 series which were shorter and shortest respectively all through the stages. From larva to deutonymph, setae L_1 - L_4 and D_1 - D_5 were either longer or as long as the distances between their bases. In the adult, the above mentioned setae were shorter than the distances between their bases. All the setae were similar in shape showing serrations and non-tapered ends.

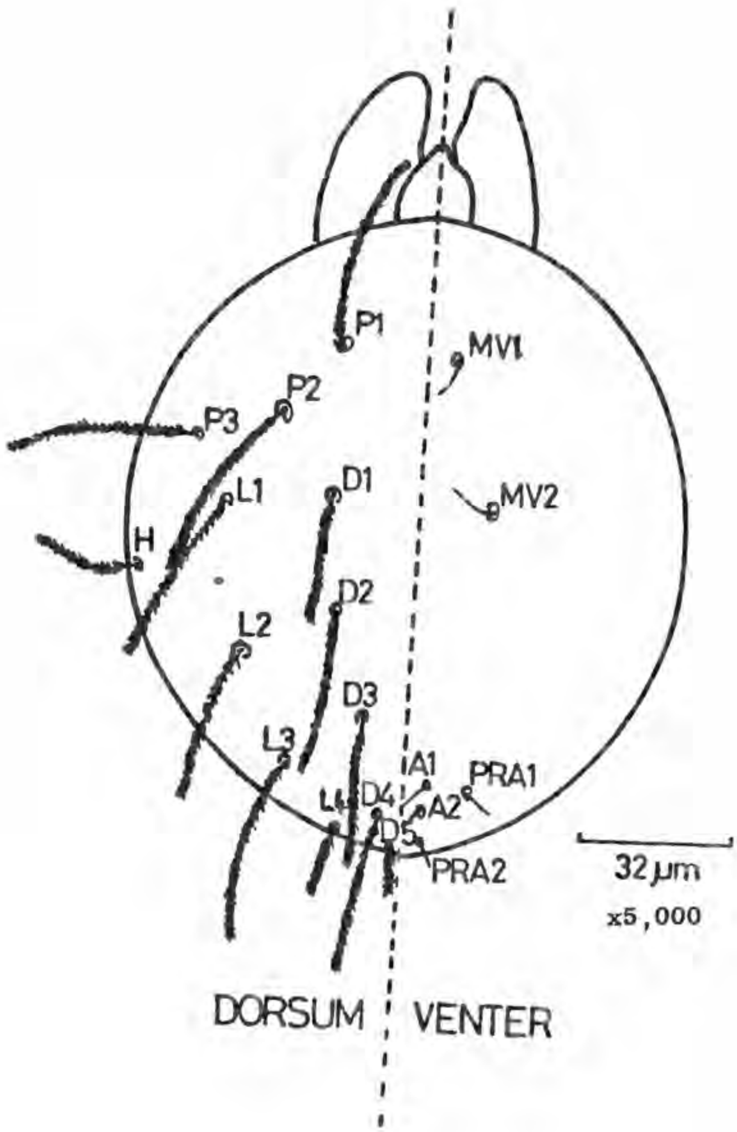

Fig. 18. Dorso-ventral aspect of larva of Mononychellus spp. showing idiosomal body setae. P1-3=Prodorsumal setae; H = Humeral seta; D1-5 = Dorso-central setae; L1-4 = Dorso-lateral setae; MV1-2 = Midventral setae; A1-2=Anal setae; PRA1-2 = Para-anal setae.

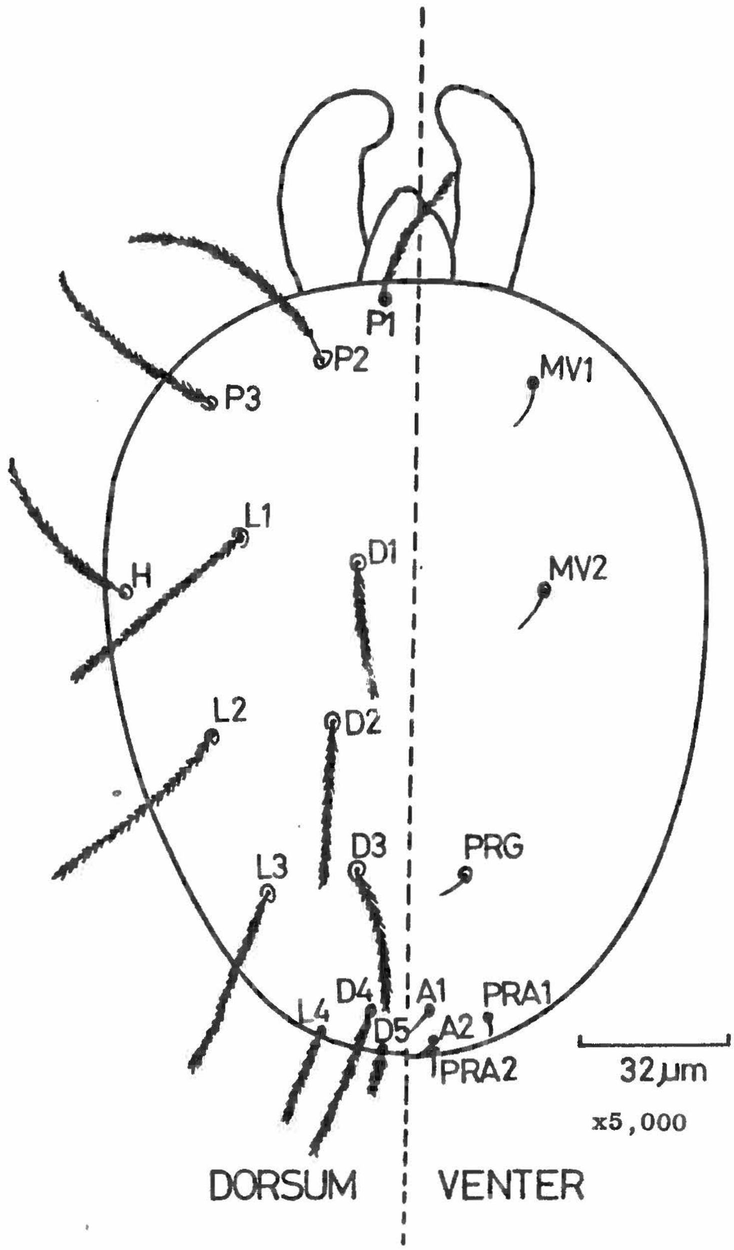

Fig. 19. Dorso-ventral aspect of protonymph of Mononychellus spp. showing idiosomal body setae. P1-3=Prodorsumal setae; H= Humeral seta; D1-5=Dorso-central setae; L1-4= Dorso-lateral setae; MV1-2=Mid-ventral setae; PRG = Pre-genital A1-2=Anal setae; PRA1-2=Para-anal setae.

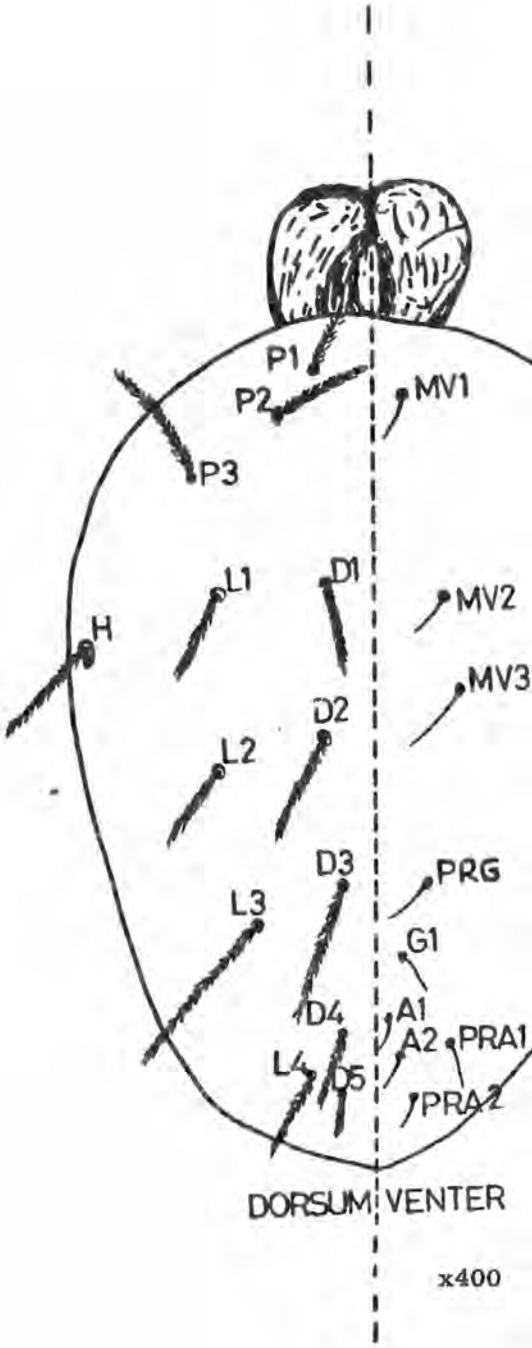

Fig. 20. Dorso-ventral aspect of deutonymph of Mononychellus spp. showing idiosomal body setae.
P1-3= Prodorsumal setae; H = Humeral seta; D1-5 = Dorso-central setae; L1-4 = Dorso-lateral setae; MV1-2= Midventral setae; PRG = Pre-genital seta; G1= Genital seta; A1-2 = Anal setae; PRA1-2 = Para-anal setae.

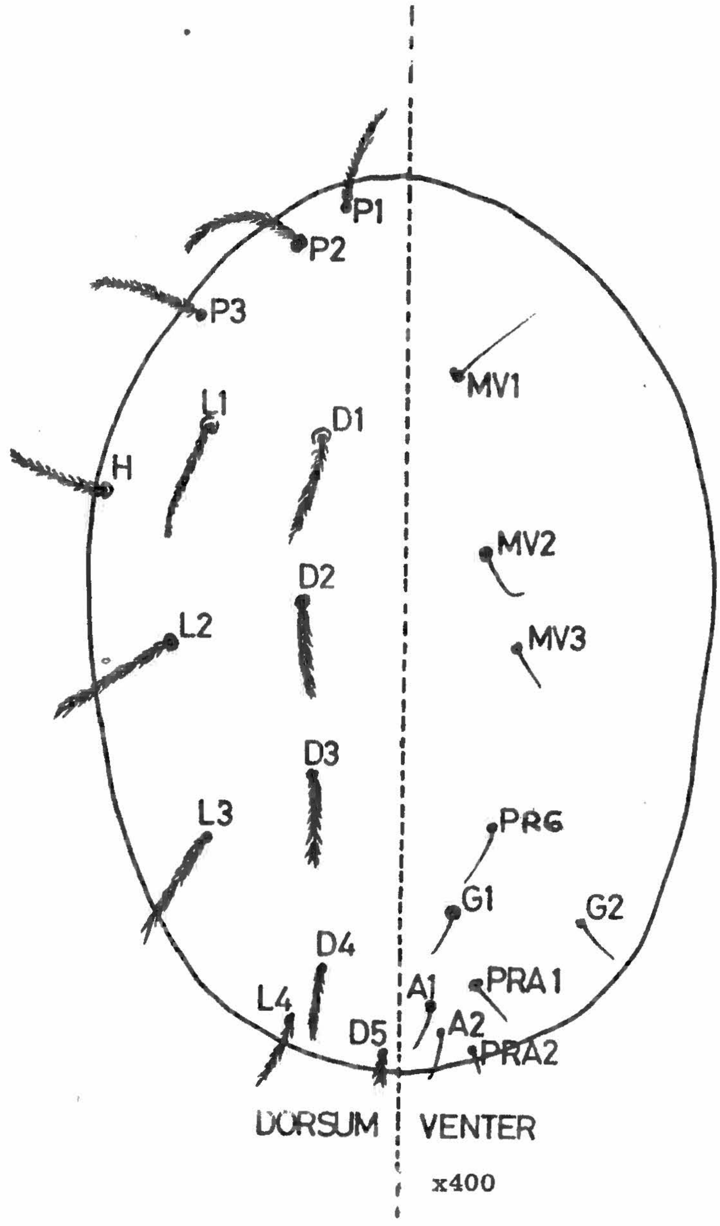

Fig. 21. Dorso-ventral aspect of adult female, of <u>Mononychellus</u> spp. showing idiosomal body setae. P1-3 = Prodorsumal setae; H = Humeral seta; D1-5= Dorso-central setae; L1-4=Dorso-lateral setae; MV1-3= Mid-ventral setae; PRG = Pregenital seta; G1-2= Genital setae; A1-2= Anal setae; PRA1-2= Para-anal setae.

4.2.2 Ventral idiosomal setae

Ventral idiosomal setae are distributed within the prodorsumal and opisthosomal ventral portions. In the larva, 2 pairs of setae, often referred to as mid-ventral setae Mv_1 and Mv_2 were observed (fig. 18). Protonymph retained this number (fig. 19), but in the deutonymph a third pair (Mv_3) was added (fig. 20). The deutonymphal number was retained in the adult stage (fig. 21). In the opisthosomal venter, 2 pairs of anal setae (A_1 and A_2) appeared around the anal opening in the larva, and also 2 pairs of para-anal setae (PaA_1 and PaA_2) (fig. 18). These numbers were retained in the protonymph with the addition of a pair of pregenital setae (PrG) (fig. 19). In the deutonymph a pair of genital setae (G_1) was added to the protonymphal number (fig. 20). At adult stage, a second pair of genital setae (G_2) was observed. A summary of the total number of ventral idiosomal setae for the instars is given in Table 18. Unlike the dorsal setae, the ventral setae were all short, smooth, slender and setiform on memberanous cuticle.

Table 18. Ontogeny of the ventral idiosomal body setae of *Mononychellus* spp.

INSTAR	Mv_1	Mv_2	Mv_3	PrG	G_1	G_2	A_1	A_2	PaA_1	PaA_2	TOTAL
Larva	+	+	–	–	–	–	+	+	+	+	6 pairs
Protonymph	+	+	–	+	–	–	+	+	+	+	7 "
Deutonymph	+	+	+	+	+	–	+	+	+	+	9 "
Adult	+	+	+	+	+	+	+	+	+	+	10 "

– = absence; + = presence.

4.2.3 Leg segments

In all active instars of Mononychellus spp. each leg had 5 articulating segments namely: trochanter, femur, genu, tibia, and tarsus. The trochanter attached basally to a coxisternal plate which was delimited laterally but not medially from the rest of the prodorsumal surface.

4.2.3.1 Coxisternal plate

In the larva, only a pair of setae appeared on plate 1, none on plates 11 and 111 and plate 1V was absent (fig. 22). In the protonymph, with the larval setae retained a pair was added to plate 1, bringing the number to 2 pairs and a pair each on plates 11 and 111. There was none on plate 1V (fig. 23). To the protonymphal number, a pair each was added to plates 11 and 1V in the deutonymph (figs. 24 and 25). The deutonymphal expression was retained in the adult stage (fig. 26 and 27). Table 19 gives the summary of numbers.

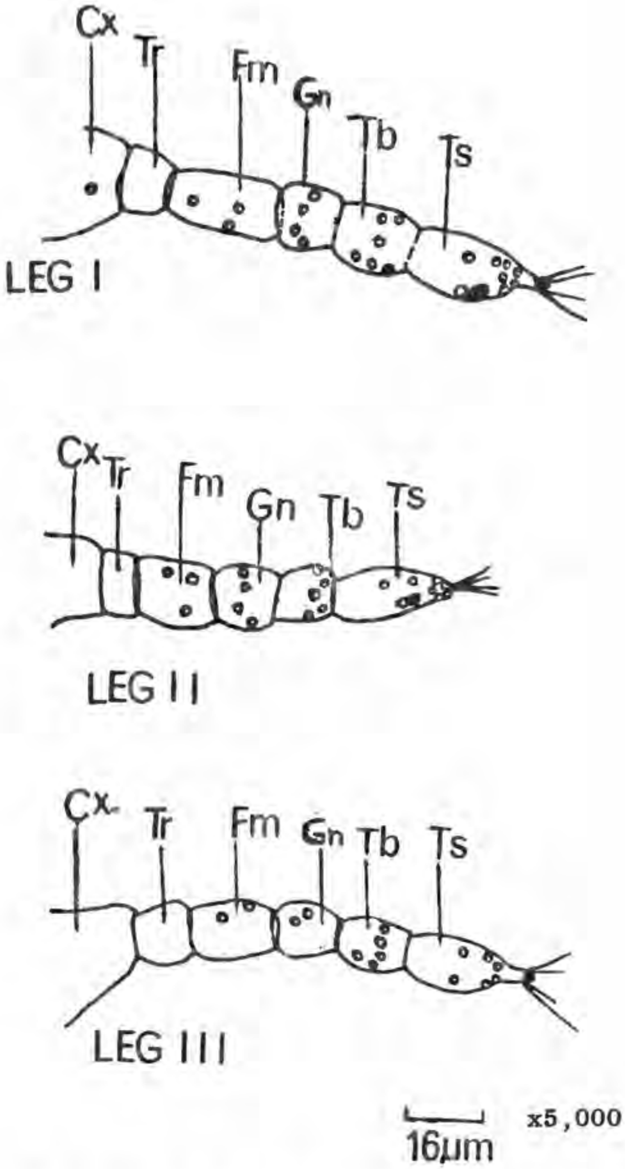

Fig. 22. The setation of legs I - III of larva of <u>Mononychellus</u> spp. Cx=Coxisternal plate; Tr=Trochanter; Fm=Femur; Gn=Genu; Tb=Tibia; Ts=Tarsus. (o) tactile setae; (•) sensory seta; (o•) duplex setae.

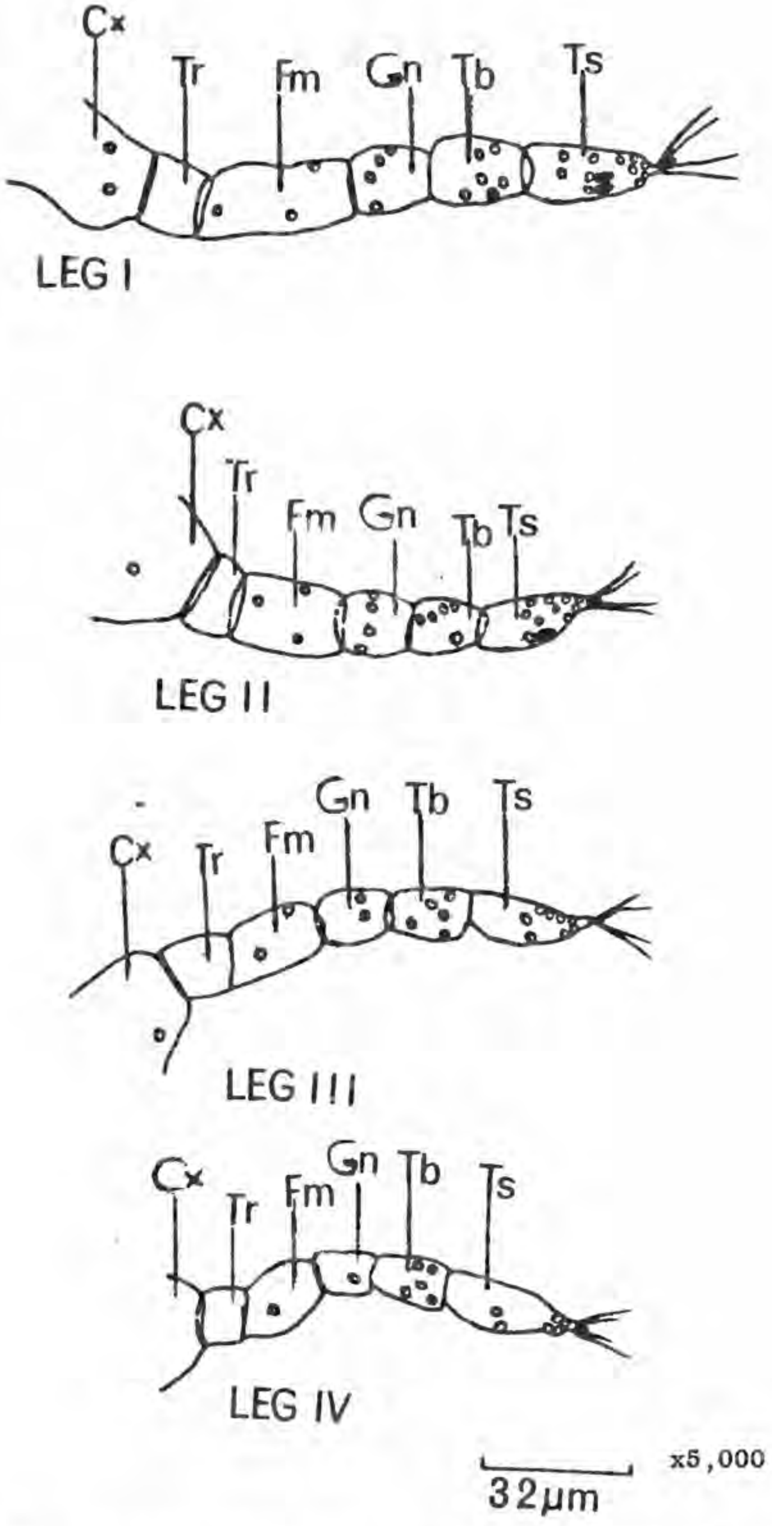

Fig. 23. The setation of Legs I - IV of protonymph of Mononychellus spp. Cx=Coxisternal plate; Tr=Trochanter; Fm=Femur; Gn=Genu; Tb=Tibia; Ts=Tarsus; (o) tactile setae; (•) sensory setae; (o•) duplex setae.

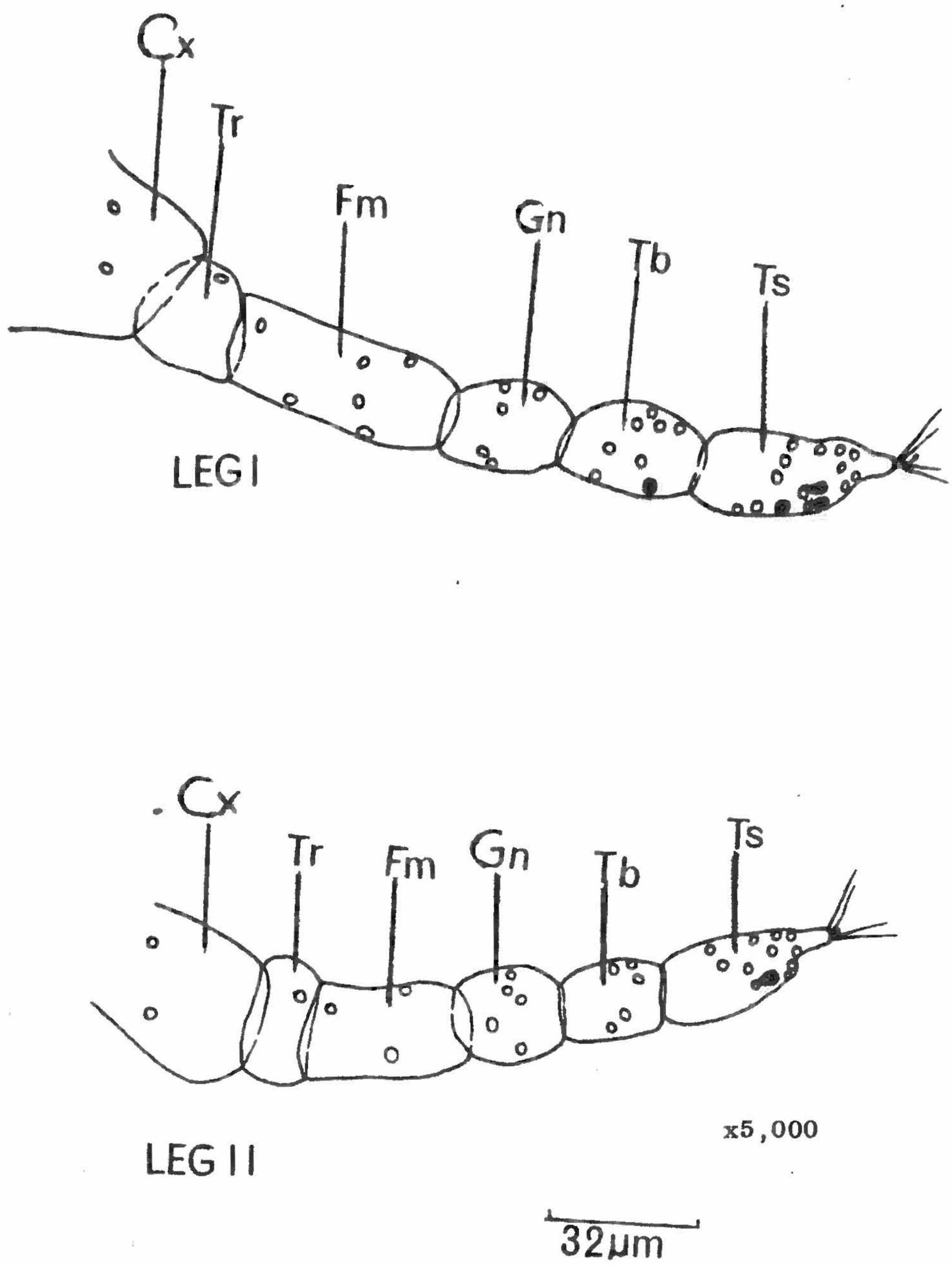

Fig. 24. The setation of Legs I and II of deutonymph of Mononychellus spp. Cx=Coxisternal plate; Tr=Trochanter; Fm=Femur; Gn=Genu; Tb=Tibia; Ts=Tarsus; (o) tactile setae; (•) sensory setae; (o•) duplex setae.

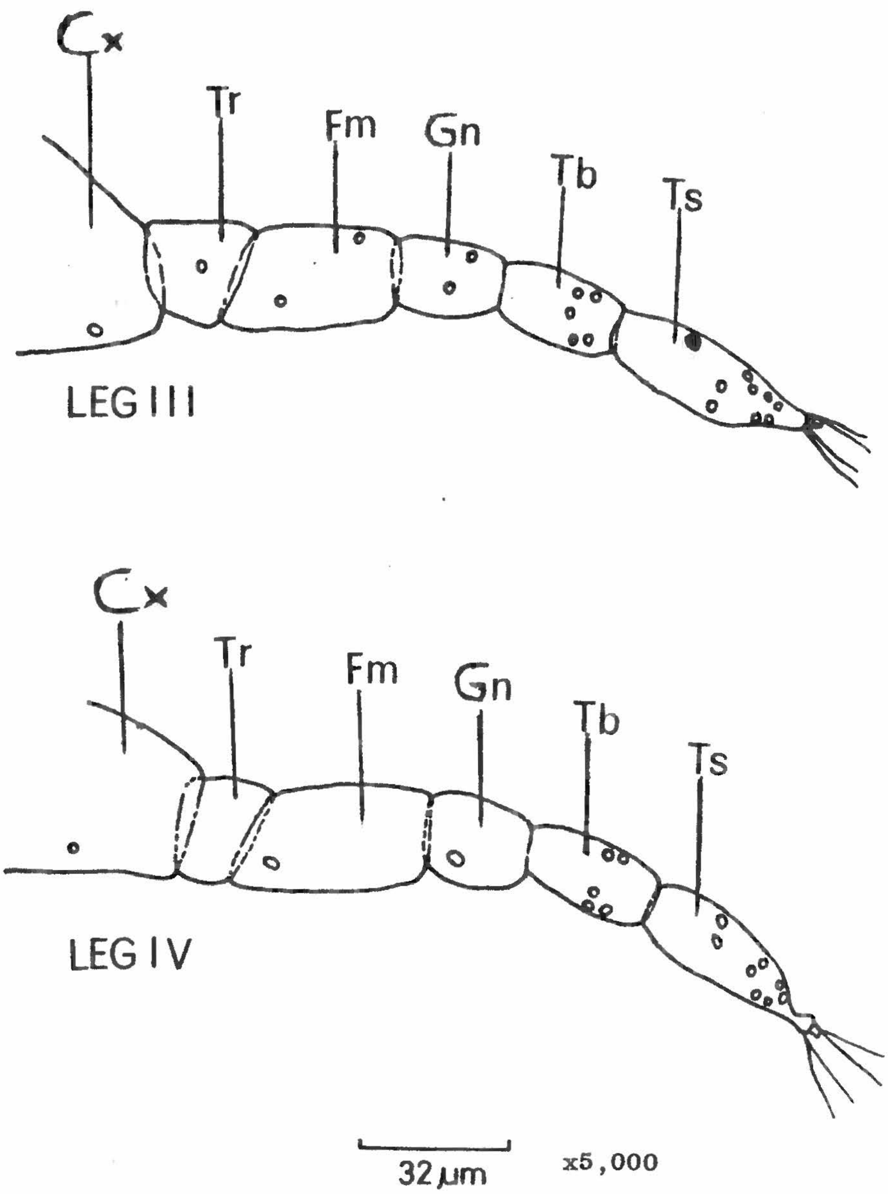

Fig. 25. The setation of Legs III and IV of deutonymph of Mononychellus spp. Cx=Coxisternal plate; Tr=Trochanter; Fm=Femur; Gn=Genu; Tb=Tibia; Ts=Tarsus; (o) tactile setae (●) sensory setae.

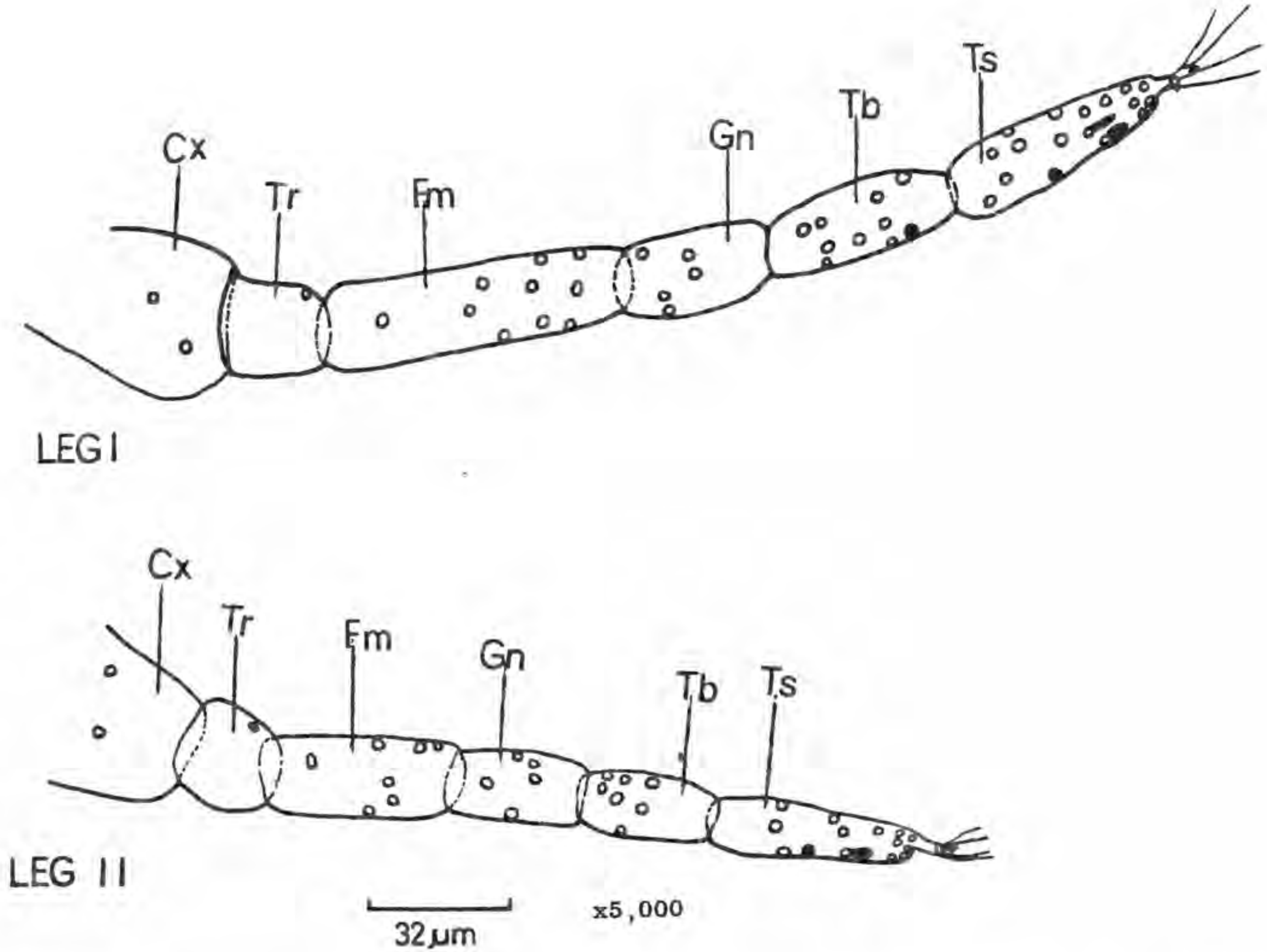

Fig. 26. The setation of Legs I and II of adult female; Mononychellus spp. Cx=Coxisternal plate; Tr=Trochanter; Fm=Femur; Gn=Genu; Tb=Tibia; Ts=Tarsus; (o) tactile setae; (•) sensory setae; (o●) duplex setae.

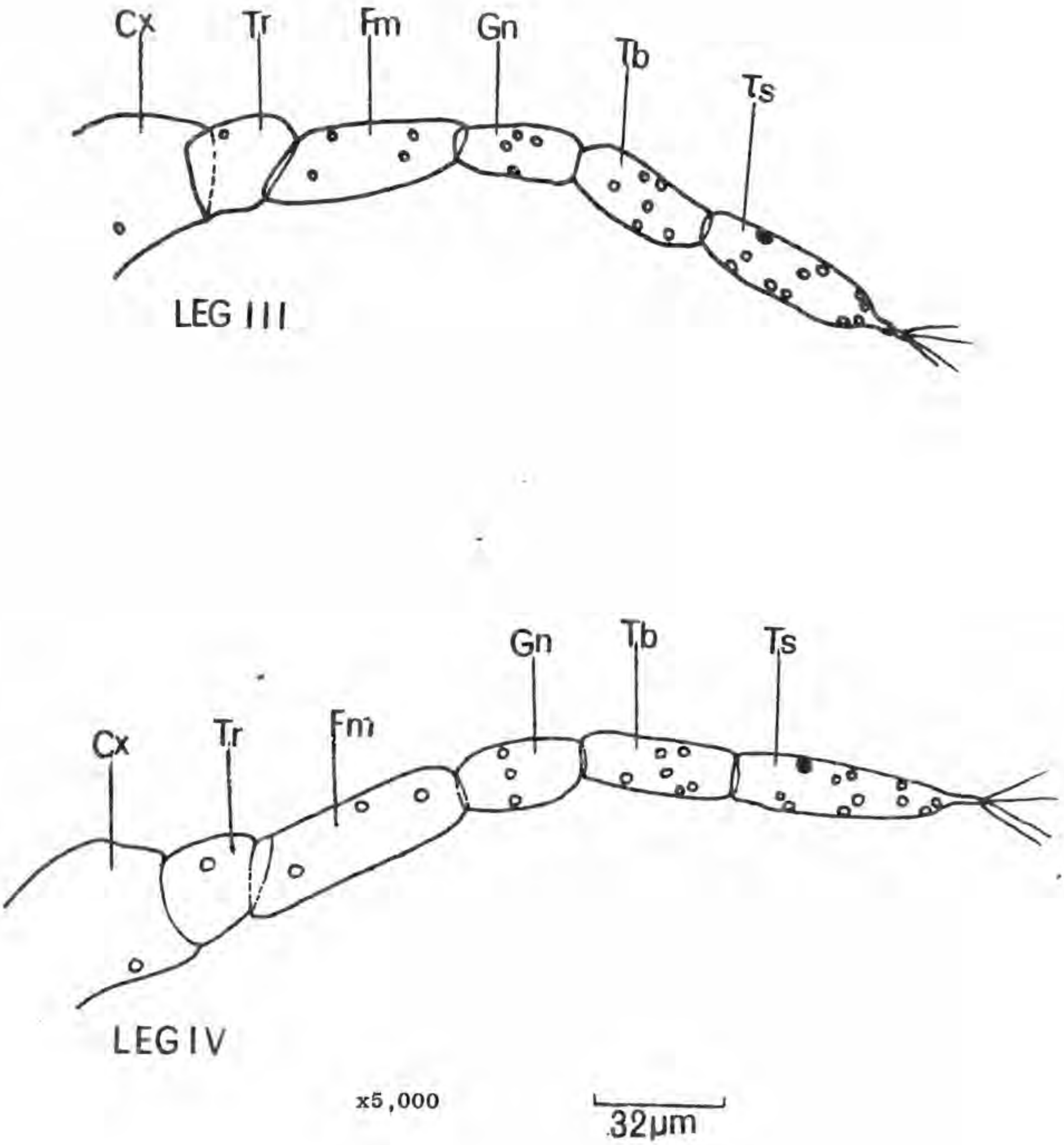

Fig. 27. The setation of Legs III and IV of adult female, Mononychellus spp. Cx=Coxisternal plate; Tr=Trochanter; Fm=Femur; Gn=Genu; Tb=Tibia; Ts=Tarsus; (o) tactile setae; (●) sensory setae.

Table 19. Ontogeny of setae on coxisternal plate of Mononychellus spp.

INSTAR	Leg 1	Leg II	Leg III	Leg IV
Larva	1	0	0	x
Protonymph	2	1	1	O
Deutonymph	2	2	1	1
Adult +	2	2	1	1

0 = seta absent; x = leg not in existence.

Table 20. Ontogeny of setae on trochanter segment of Mononychellus spp.

INSTAR	Leg I	Leg II	Leg III	Leg IV
Larva	0	0	0	x
Protonymph	0	0	0	0
Deutonymph	1	1	1	0
Adult	1	1	1	1

0 = seta absence; x = leg not in existence.

4.2.3.2 Trochanter segment

The setation on this segment was the simplest. No setae were observed on all the legs of both larva and protonymph (fig. 22 and 23). In the deutonymph, a pair each appeared on legs 1-111 none on leg 1V (figs. 24 and 25). The adult stage had the appearance of a pair on leg 1V in addition to the deutonymphal numbers (fig. 26 and 27). Table 20 gives the numbers of setae on this segment.

4.2.3.3 Femur segment

In the larva, 3 pairs of setae appeared on leg 1, 3 pairs on leg 11 and 2 pairs on leg 111. The protonymph had a pair on leg 1V (figs. 22 and 23). In the deutonymph, 3 more pairs were added to leg 1 only. The rest remained unchanged (figs. 24 and 25). At adult stage, there were additions all through the legs as follows, 4 pairs on leg 1, 4 pairs on leg 11, 2 pairs on leg 111 and 2 pairs on leg 1V. These brought the numbers to 10-7-4-3 (figs. 26 and 27). Table 21 shows the summary of femoral setation.

Table 21. Ontogeny of setae on femur segment of *Mononychellus* spp.

INSTAR	Leg I	Leg II	Leg III	Leg IV
Larva	3	3	2	x
Protonymph	3	3	2	1
Deutonymph	6	3	2	1
Adult +	10	7	4	3

x = leg not in existence.

Table 22. Ontogeny of setae on genu segment of *Mononychellus* spp.

INSTAR	Leg I	Leg II	Leg III	Leg IV
Larva	4	4	2	x
Protonymph	4	4	2	1
Deutonymph	5	5	2	1
Adult +	5	5	4	3

x = leg not in existence

4.2.3.4 Genu segment

The genual setal development in the larva was the appearance of 4 pairs of setae on leg 1, 4 pairs on leg 11 and 2 pairs on leg 111 (fig. 22). The protonymph had an additional pair of setae on leg 1V (fig. 23). In the deutonymph one set each was added to legs 1 and 11, none on legs 111 and 1V. The number was then increased to 5-5-2-1. In the adult stage additions were only on legs 111 and 1V (figs. 26 and 27), and the number increased to 5-5-4-2. A summary of the setal numbers on this segment is given in Table 22.

4.2.3.5 Tibial segment

In the larval and protonymphal stages, tibial setation on legs 1-1V were given as 5(+1 sensory) -5-5-5 (figs. 22 and 23). In the deutonymph, changes were only on leg 1 with the addition of 2 pairs of setae (figs. 24 and 25). There wes addition of setae all through the legs in the adult.

These brought the number to 9(+1 sensory)-7-6-6 (figs. 26 and 27). Ontogenetic changes in this segment are summarized in Table 23.

4.2.3.6. Tarsal segment

Larval setation in this segment was 7(+1 duplex)-7(+1 duplex)-6 (fig. 22). Protonymph had 9(+2 duplex)-9(+1 duplex)-8-6 (fig. 23). In the deutonymph, there were additions of both tactile and sensory setae all through the legs; the numbers then became 11(+1s+2 duplexes)-10(+1d)-8(+1s)-8. Adult expression was also increased to 14(+1s+2d) -12(+1s+1d)-10(+1s)-10(+1s). Full tarsal notation for the whole instars is given in Table 24. It was noted that, in this segment, the additions of setae were from the distal to the proximal end of the body.

The full complements of setal formulae for the legs of all the life stages are given in Tables 25-28.

Table 23. Ontogeny of setae on tibial segment of *Mononychellus* spp.

INSTAR	Leg 1	Leg II	Leg III	Leg IV
Larva	5t+1s	5	5	x
Protonymph	5t+1s	5	5	5
Deutonymph	7t+1s	5	5	5
Adult +	9t+1s	7	6	6

x = leg not in existence; t = tactile setae;
s = sensory seta.

Table 24. Ontogeny of setae on tarsal segment of *Mononychellus* spp.

INSTAR	Leg I	Leg II	Leg III	Leg IV
Larva	7t+1d	7t+1d	6	x
Protonmph	9t+2d	9t+1d	8	6
Deutonymph	11t+1s+2d	10t+1d	8t+1s	8
Adult +	14t+1s+2d	12t+1s+1d	10t+1s	10t+1s
	(5t+1s)*	(3t+1s)*	(2t+1s)*	(2t+1s)*

t = tactile setae; s = sensory setae
d = duplex setae; x = leg not in existence.
* = proximal setae

Table 25. Leg chaetotaxy in larva of *Mononychellus* spp.

LEG	Cx	Tr	Fm	Gn	Tb	Ts
1	1	0	3	4	5t+1s	7t+1d
II	0	0	3	4	5	7t+1d
III	0	0	2	2	5	6

t = tactile setae; s = sensory seta;
d = duplex setae; o = seta absent.

Table 26. Leg chaetotaxy in protonymph of *Mononychellus* spp.

LEG	Cx	Tr	Fm	Gn	Tb	Ts
1	2	0	3	4	5t+1s	9t+2d
II	I	0	3	4	5	9t+1d
III	1	0	2	2	5	8
IV	0	0	1	1	5	6

t = tactile setae; s = sensory seta;
d = duplex setae; o = seta absent.

Table 27. Leg chaetotaxy in deutonymph of _Mononychellus_ spp.

LEG	Cx	Tr	Fm	Gn	Tb	Ts
1	2	1	6	5	7ts+1s	11t+1s+2d
II	2	1	3	5	5	10t+1d
III	1	1	2	2	5	8t+1s
IV	1	0	1	1	5	8

t = tactile setae; s = sensory setae;
d = duplex setae; o = seta absent.

Table 28. Leg chaetotaxy in adult female _Mononychellus_ spp.

LEG	Cx	Tr	Fm	Gn	Tb	Ts
1	2	1	10	5	9t+1s	14t+1s+ 2d
II	2	1	7	5	7	12t+1s+1d
III	1	1	4	4	6	10t+1s
IV	1	1	3	3	6	10t+1s

t = tactile setae; s = sensory setae
d = duplex setae;

5. DISCUSSION

In this study, the characters assessed were found to be intercorrelated. Such characters usually offer little or no information for possible distinction of species types but could be used in defining the genus. This was explained by Pankhurst (1978) stating that, characters that vary within species and whose states overlap, are of very little use for distinguishing taxa. Rohlf (1967) on the other hand, stated that characters that show wide variation within an OTU are considered as most important for making distinction between species. In the present work, although some characters varied, the variation was not large enough within the OTUs to enable species distinction. Usually from PCA computation, such highly varied characters come out with high weightings and high percentage variances of about 80% in the first two components. This was illustrated in the studies of winged aphids by Jeffers (1967) where a percentage variance of over 80% in the first two components was used to separate the species into four groups. Similarly, Bagine (1986) separated two groups of the termite genus Odontotermes into distinct species. In his study, the first two components accounted for about 86% and 96% respectively in the groups considered. Unlike the studies mentioned above, the low percentage variances of 42%, 48%, 63% and (27% and 49%) for the larva, protonymph, deutonymph and adult respectively in the first two components recorded in this investigation were not effective in establishing more than a single taxon. The high intercorrelation between the variables and the low percentage variances in all the instars suggested that, the characters assessed are perhaps under the influence of a few similar genetic factors. Furthermore, those highly correlated characters indicated a proportional increase or decrease in the dimensions of the various leg segments in relation to the size of the body. For further investigation, perhaps only a few of the correlated characters such as TrI, TsI, TrII, TbII, TsII, and TrIII in the adult could be useful. Also, the uncorrelated characters such as the ratios, particularly RL_2 in the adult, P_1, P_2, D_3 and D_5 in the larva, and P_1, L_2 and D_4 in the protonymph would however be preferred in defining the morphological variations in the species.

The patterns exhibited by the OTUs in the scatter plots indicated single clusters of the OTUs for different instars. The Mombasa population showed aggregation at one end of the ellipsoidal cluster in the protonymph and deutonymph. Such undifferentiated clustering of OTUs as observed here was expected because as Rohlf (1967) explained, such groupings are expected of intercorrelated characters in PCA. The position of the Mombasa population in the scatter plots as observed in this study corresponds with previous studies of this nature. For example Rohlf (1967) noted that, species that are usually found at the ends of such elongated clusters are phenotypically distant from the populations in the centre of the cluster. This confirms the findings that the Mombasa population has mainly the long setaed form of the Mononychellus compared to other locations in Kenya having mainly the short form (Rogo, 1986; unpublished manuscript). It should be noted that Mombasa, by virtue of its geographical location, is known to experience an equatorial type of climate as do most countries in West Africa where nearly all of the CGM specimens are known to be long setaed (Rogo, pers. comm.).

Factor analysis was not tried in this investigation because, it would not have given different results from the PCA since both work on the same principle. Also, discriminant function which assumes prior groupings and seeks the pattern of variation and correlation between groups was not used because, the variables assessed in this study could not establish groups in the PCA. The result of cluster analysis which is a measure of similarity and dissimilarity among OTUs was as expected of such intercorrelated characters. The similarities exhibited by OTUs in this study agree with the general behaviour of OTUs in cluster analysis, as explained by Sneath and Sokal (1973) who reported that an OTU in a cluster has equal similarity to the cluster and to its closest member within the cluster. The OTUs examined in this study have however shown close similarity to each other and have indicated only a single taxon of the data set at all levels of similarity. A phenogram which usually gives a more explicit illustration of phenetic relationships in studies of this form could not be constructed for the 200 OTUs that appeared to be the same. Such a phenogram would only have indicated a branch, consisting of all the OTUs which would not be a significant information for possible species distinction but would rather, emphasise the closeness within the specimens. This however, goes futher to infer that one is apparently dealing with the same species.

It has been explained by Davis (1973) that the relative effectiveness of means of variables could be of significance in characterizing specimen types. The trial with analysis of variance (ANOVA) which investigated the variable means, did not show consistency in indicating populations that were closest together. The variabilities of setal lengths and body sizes in the specimen as included in this exercise might explain these observations. The mean lengths of the setae in the immatures also indicated that, they were not totally directly proportional to the progressive increases in body sizes. Variations in such character states as noted in this investigation is common in the study of mites. For example, Buryn and Usher (1986) reported similar observation in their work on cryptostigmatid mites in the maritime antarctic. Rogo et al. (1987) also observed such variations in a review study of Mononychellus species in Africa. Variable 22 (ratio of body length to the length of the dorso-lateral seta L_2) which also weighted highly in the PCA could perhaps be of importance in further studies. The result shown by this variable corresponds favourably with earlier findings of geographical influence in the species distribution in Africa. The long setaed forms are found in West Africa and the short forms in East Africa (Rogo, pers. comm.). These results indicated that, neither the comparative setal lengths nor the body sizes of the instars can be utilized as characters for separating the OTUs in this study.

These different analyses have given results that agree in general but differ somewhat in detail. They have also directed the choice of characters for further similar studies, to avoid a waste of time measuring variables which contribute relatively little to the study. Although it is not possible to give all the reasons for the variations observed in this study, it was however noted that the ecological conditions existing in the collecting sites within the various countries were not recorded. In addition, the ages of the immatures as well as the adults were also not defined. These can perhaps explain some of the variations. Rogo et al. (1987) in their study, also noted that the ages of adult females could also cause variations. The same authors further pointed out that variations could, in addition, stem from methods of specimen preservation.

Using setal numbers, shapes and positions for species distinction in the Tetranychidae, earlier authors such as Grandjean (1939, 1948), Wainstein (1958) to mention only a few, used several different descriptive terms especially for setae on the leg segments. For example, "Anisotropic phaneres" was used to mean ordinary setae and "Isotropic phaneres" for sensory setae or solenidia. Most authors presently use the nomenclature adopted by Pritchard and Baker (1955). This system uses the terms "sensory setae" for the isotropic phaneres and "tactile setae" for the anisotropic phaneres, including an additional term "duplex setae." In this study, Pritchard and Baker's (1955) notation was adopted.

The prodorsumal setal number of 3 pairs observed in all instars of Mononychellus spp. was not unsual. It was observed by Lindquist (1985) in his general work on spider mites that, a number of 3 pairs of setae throughout life was consistent. The 10 pairs evident on the opisthosomal dorsum were also within the range of numbers found in other tetranychid mites (Lindquist, 1985). The dorsal setal lengths of the adult were observed to be shorter than the distances between their bases. This conforms with one of the diagnostic features of females of M. tanajoa (Nyiira, 1977; Flechtmann, 1977 and MacFarlane, 1984). This however, could not separate the populations but rather strengthened the definition of the taxon. For the immatures, the original observation in the present work was that, all the setae appeared either longer or as long as the distances between their bases.

The setal numbers of 6,7,9, and 10 pairs for the larva, protonymph, deutonymph and adult female respectively on the ventral idiosoma also conform with those on other tetranychid mites (Lindquist, 1985). Among these, were 2 pairs of para-anal setae which were evident from larval to adult stage.

These have been described as unique features among the Tetranychidae and have been used as a diagnostic character of the genus (Nyiira, 1977 and Flechtmann, 1977). This character was also unable to separate the Mononychellus examined in this study.

The number of the ventrally placed short setae on the coxisternal plates of Mononychellus spp. as found in this investigation agrees with the maximum number observed in the family Tetranychidae for all the instars (Robaux and Gutrierrez, 1973 and Lindquist, 1985).

The ontogenetic pattern in the trochanter segment as observed in this study is common to the Tetranychidae, as was also observed by Lindquist (1985) who reported that, in the adult only a pair of setae are present on each leg. It was also noted that these setae were absent on all the legs in the larva and protonymph. In the deutonymph they were absent only on leg IV. This observation makes distinction easier between this instar and the protonymph of Mononychellus spp.

The pattern of setation observed in the femoral segment did not tally completely with those of other tetranychid mites. According to Quiros and Baker (1984) the correct notation in this segment in tetranychids had not been determined but in the adult, they observed that there are generally additions of about 4 pairs of setae each to the deutonymphal numbers on legs 1 and 11 and 3 pairs each on legs 111 and 1V. These additions were observed on legs 1 and 11 but only 2 pairs each were observed on legs 111 and 1V. Grandjean (1965) however stated that, generally, spider mites also show varying degrees of setal additions and reductions on this segment. This corresponds with such variations observed in this investigation, in the _Mononychellus_ spp. The femoral numbers of 10-7-4-3 on the four legs indicated additions on legs 1 and 11 and reductions on legs 111 and 1V. Meyer (1974) on the other hand, described _Mononychellus lippiae_ with reductions all through the legs except for leg 11 with the numbers given as 9-7-3-3. The present observation on legs 11 and 1V agrees with that of _M. lippiae_ of Meyer (1974).

Addition of setae in the genual segment of adult spider mites is also variable in the Tetranychinae. In this subfamily, generally, no setae are added on legs 1 and 11 (Lindquist, 1985). This is in agreement with the present findings in adult female Mononychellus spp. retaining the deutonymphal numbers of 5-5 on legs 1 and 11. There are usually additions and reductions on legs 111 and 1V of the adult. A reduction giving a formula of 5-5-3-2 in the adult was used in the description of M. lippiae (Meyer, 1974), while there was setal addition in this study giving a formula of 5-5-4-3. These conditions in different species of Mononychellus as described above could be influenced by some genetic factors which determine the species types.

The findings in this study of 9 tactile and 1 sensory setae and 7 tactile setae on tibiae 1 and 11 respectively tally with earlier observations by Nyiira (1977), Flechtmann (1977) and Rogo et al. (1987). These are already used as diagnostic features of M. tanajoa (Nyiira, 1977).

The present findings however, do not agree with Doreste's (1981) report of 8 tactile and 1 sensory setae on tibia 1 during his redescription of M. tanajoa.

The proximal setal numbers of 5 tactile and 1 sensory and 3 tactile and 1 sensory on tarsal segments 1 and 11 respectively agreed with earlier studies by Nyiira (1977) and Flechtmann (1977) but disagreed with the record of 4+1 on tarsus 1 by Doreste (1981). These were also diagnostic characters for M. tanajoa (Nyiira, 1977 and Flechtmann, 1977). The numbers earlier recorded on legs 1-1V for all the segments including the proximal setae of tarsi 1-1V (5+1; 3+1; 2+1 and 2+1) of the adult female, also agree with the observations of Freitez and Guillermo (1977, unpublished manuscript) for M. tanajoa. Other observations on the larva, protonymph and deutonymph for legs 1-1V and the distal tarsal setae in the adult female as indicated in Tables 25-28 (see pages 100 and 101) are original findings of the present study. Although these tibial and tarsal setal numbers could not separate the population in this study, they have previously been successfully utilized in species distinction by Paschoal (1970) who used them to separate adult females of *Mononychellus* (= *Mononychus*) *bondari* and *M. chemosetosus* of Brazilian fauna.

These uniform numbers of setae on different body parts such as the dorsum, venter and leg segments recorded on all the instars out of all the populations of *Mononychellus* spp. were complementary to the results on measurements which have collectively emphasised a single taxon.

S U M M A R Y

1. Adult characters of measurements of leg segments were intercorrelated.

2. Weightings of the characters were low. None constituted indices of distinction for possible classification of the OTUs.

3. Low percentage variances of less than 50% were recorded in the first two component. Groups could not be established within the OTUs.

4. Ratios of measurements (RL_1, RL_2, RL_3, RL_4, Rd_1, Rd_2 and Rd_3) did not significantly correlate.

5. Weightings were low and plotted data were shown as clusters of the OTUs.

6. With cluster analysis, majority of the OTUs out of 200 were in a group. A single species was inferred.

7. Location effect was significant. Percentage

variances due to location were however very low for all variables except variable RL_2 (ratio of body length to the length of the dorso-lateral setal length - L_2) with 50%.

8. Geographical influence in the distribution of the OTUs was partially indicated by variable RL_2. Most of the long setaed forms were observed in West Africa while the short forms were mainly in East Africa.

9. Variables P_1, P_2, D_3 and D_5 did not significantly correlate with other variables in the larva. These however, could not constitute indices of variation.

10. Eigenvectors in the larva were not significant for possible species distinction.

11. Percentage variance for the first 3 components accounted for only 53% of the total variance.

12. Principal components plots illustrated an

indistinctive cluster pattern of the OTUs.

13. In the protonymph, variables P_1, L_2 and D_4 had no significant correlation with other variables.

14. Values of the eigenvectors were insignificant in the protonymphal stage.

15. The first 3 components accounted for only 59% of the total variance. A low score in the protonymph.

16. Principal component plots indicated a single cluster of OTUs. Mombasa population of mainly long setaed forms partially isolated themselves from the entire population.

17. Variables assessed in the deutonymph were significantly intercorrelated.

18. Eigenvectors did not indicate indices of variation despite the moderately high percentage variance of 71% in the first 3 components in the deutonymph.

19. Plotted principal component scores were in clusters of OTUs. Mombasa populations were partially isolated.

20. Larva had a mean body length of 129.8µm; with a range of 101.9 - 155.7 µm.

21. Mean body length in protonymph was 174.7 µm; with a range of 135.8 - 217.9 µm.

22. Mean body length of deutonymph was 229.1 µm; with a range of 167.0 - 311.3 µm.

23. Mean body width in larva was 115.8 µm; with a range of 90.2 - 141.5 µm.

24. Mean body width in protonymph was 146.7 µm; with a range of 130.2 - 172.6 µm.

25. Mean body width in deutonymph was 180.8 µm; with a range of 101.9 - 226.4 µm.

26. In the idiosomal setal lengths, humeral setal lengths increased progressively in all the instars.

27. There was no significant difference in the lengths of P_1, P_2 and P_3 in the larva and protonymph. They were longest in the deutonymph.

28. The lengths of D_1, D_2 and D_3 were longest in the larva while D_4 and D_5 were longest in the deutonymph.

29. The length of L_1 was shortest in the larva while L_2, L_3 and L_4 were longest in the deutonymph.

30. Idiosomal setal number from larva to adult female was 13 pairs (3 pairs of prodorsumal, 1 pair of humeral, 4 pairs of dorso-lateral and 5 pairs of dorso-central setae).

31. Ventral idisomal setae in the larva were 6 pairs (Mv_1, Mv_2, A_1, A_2, PaA_1 and PaA_2).

32. In the protonymph there were 7 pairs (Mv_1, Mv_2, PrG, A_1, A_2, PaA_1 and PaA_2).

33. In the deutonymph there were 9 pairs (Mv_1, Mv_2, Mv_3, PrG, G_1, A_1, A_2, PaA_1 and PaA_2).

34. In adult female there were 10 pairs (Mv_1, Mv_2, Mv_3, PrG, G_1, G_2, A_1, A_2, PaA_1 and PaA_2).

35. The setal formulae for leg chaetotaxy in the larva were:

Coxisternal plate:			1-0-0
Trochanter segment:			0-0-0
Femur	"	:	3-3-2
Genu	"	:	4-4-2
Tibial	"	:	(5t+1s)-5-5
Tarsal	"	:	(7t+1d)-(7t+1d)-6

36. Setal formulae in the protonymph were:

Coxisternal plate:			2-1-1-0
Trochanter segment:			0-0-0-0
Femur	"	:	3-3-2-1
Genu	"	:	4-4-2-1
Tibial	"	:	(5t+1s)-5-5-5
Tarsal	"	:	(9t+2d)-(9t+1d)-8-6

37. Setal formulae in the deutonymph were:

Coxisternal plate:	2-2-1-1
Trochanter segment:	1-1-1-0
Femur " :	6-3-2-1
Genu " :	5-5-2-1
Tibial " :	(7t+1s)-5-5-5
Tarsal " :	(11t+1s+2d)-(10t+1d)-(8t+1s)-8

38. Setal formulae in adult female were:

Coxisternal plate:	2-2-1-1
Trochanter segment:	1-1-1-1
Femur " :	10-7-4-3
Genu " :	5-5-4-3
Tibial " :	(9t+1s)-7-6-6
Tarsal " :	(14t+1s+2d)-(12t+1s+1d)-(10t+1s)-(10t+1s).

CONCLUSION

Based on the characters investigated in this study and the findings of other workers on both morphological and genetical studies, one may conclude that there is perhaps only one species of Mononychellus in this region. However, there is still need for further research work involving the establishment of "pure lines" of the long and short forms for the re-examination of some of the uncorrelated characters identified in the study. Studies should also include other aspects of systematic biology. Otherwise, M. tanajoa should be redescribed to take account of some of the morphological variations so far observed in the various studies. In doing this, it would be worthwhile to include information obtained in this study particularly the complete setal formulae of the immature stages, the body sizes and setal lengths of the larval, protonymphal and deutonymphal stages. These characters have often been used in systematic studies of species in the Acari in general and Tetranychidae in particular.

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APPENDICES 1-10: Measurements (µm) on adult female <u>Mononychellus</u> spp. from 10 African countries

Appendix 1: BURUNDI

REPLICATE	TrI	FmI	GnI	TbI	TsI	TrII	FmII	GnII	TbII	TsII	TrIII	FmIII	GnIII	TbIII
1	1.00	33.96	79.24	36.79	42.45	59.43	28.30	56.60	33.96	33.96	48.11	28.30	33.96	39.62
2	2.00	33.96	82.07	39.62	45.28	59.43	25.47	50.94	28.30	28.30	48.11	28.30	31.13	39.62
3	3.00	28.30	76.41	45.28	33.96	53.77	28.30	56.60	31.13	31.13	45.28	25.47	31.13	39.62
4	4.00	28.30	82.07	39.62	39.62	56.30	28.30	50.94	36.79	36.79	48.11	31.13	28.30	39.62
5	5.00	28.30	84.90	42.45	48.11	56.60	28.30	53.77	31.13	31.13	50.94	28.30	31.13	39.62
6	6.00	31.13	79.24	39.62	42.45	48.11	25.47	50.94	28.30	28.30	42.45	28.30	31.13	39.62
7	7.00	31.13	76.41	36.79	42.45	53.77	28.30	53.77	31.13	31.13	39.62	25.47	32.55	36.79
8	8.00	31.13	79.24	39.62	45.28	56.60	28.30	56.60	31.13	31.13	48.11	25.47	33.96	39.62
9	9.00	31.13	82.07	39.62	45.28	59.43	28.30	53.77	33.96	33.96	48.11	25.47	31.13	39.62
10	10.00	28.30	84.90	39.62	45.28	56.60	25.47	56.60	31.13	31.13	48.11	25.47	33.96	39.62
11	11.00	28.30	82.07	36.79	45.28	53.77	28.30	50.94	31.13	31.13	48.11	25.47	28.30	39.62
12	12.00	28.30	87.73	42.45	48.11	56.60	28.30	53.77	36.79	36.79	48.11	28.30	31.13	33.96
13	13.00	28.30	79.24	39.62	42.45	56.60	28.30	50.94	31.13	31.13	48.11	25.47	31.13	36.79
14	14.00	31.13	79.24	39.62	45.28	59.43	28.30	53.77	31.13	31.13	50.94	25.47	33.96	36.79
15	15.00	25.47	82.07	36.79	42.45	56.60	28.30	53.77	33.96	33.96	45.28	28.30	31.13	36.79
16	16.00	25.47	82.07	32.55	36.79	53.77	28.30	48.11	28.30	28.30	48.11	25.47	31.13	36.79
17	17.00	31.13	82.07	42.45	45.28	59.43	25.47	53.77	33.96	33.96	45.28	28.30	31.13	31.13
18	18.00	33.96	84.90	39.62	45.28	56.60	28.30	56.60	31.13	31.13	48.11	25.47	31.13	36.79
19	19.00	31.13	84.90	36.79	42.45	53.77	28.30	56.60	31.13	31.13	45.28	28.30	28.30	42.45
20	20.00	33.96	87.73	42.45	45.28	56.60	28.30	56.60	33.96	33.96	53.77	28.30	28.30	36.79

REPLICATE	TsIII	TrIV	FmIV	GnIV	TbIV	TsIV	RL1	RL2	RL3	RL4	Rd1	Rd2	Rd3
1	53.77	31.13	67.92	33.96	42.45	56.60	0.106	0.106	0.152	0.083	0.205	0.205	0.136
2	56.60	28.30	59.43	33.96	42.45	56.60	0.117	0.126	0.165	0.097	0.243	0.204	0.223
3	62.26	31.13	62.26	31.13	42.45	56.60	0.087	0.104	0.167	0.113	0.139	0.165	0.157
4	56.60	33.96	73.58	31.13	48.11	59.43	0.206	0.137	0.206	0.118	0.216	0.186	0.206
5	59.43	28.30	73.58	33.96	39.62	62.26	0.070	0.076	0.102	0.078	0.211	0.204	0.242
6	45.28	28.30	62.26	33.96	42.45	53.77	0.079	0.086	0.118	0.079	0.200	0.193	0.200
7	56.60	28.30	59.43	33.96	39.62	56.60	0.065	0.101	0.129	0.105	0.218	0.121	0.170
8	56.60	28.30	67.92	33.96	39.62	59.43	0.067	0.096	0.141	0.096	0.230	0.230	0.244
9	53.77	28.30	62.26	33.96	39.62	62.26	0.079	0.105	0.158	0.098	0.233	0.233	0.203
10	59.43	28.30	65.09	33.96	42.45	53.77	0.088	0.106	0.168	0.106	0.230	0.230	0.230
11	53.77	25.47	53.77	31.13	39.62	56.60	0.098	0.140	0.157	0.091	0.256	0.223	0.223
12	56.60	28.30	67.92	36.79	39.62	62.26	0.087	0.134	0.161	0.094	0.260	0.244	0.209
13	56.60	28.30	59.43	31.13	36.79	59.43	0.079	0.122	0.157	0.096	0.226	0.226	0.209
14	56.60	28.30	67.92	39.62	42.45	56.60	0.072	0.115	0.144	0.079	0.251	0.259	0.223
15	59.43	28.30	67.92	33.96	42.45	59.43	0.092	0.085	0.162	0.096	0.246	0.231	0.223
16	45.28	28.30	59.43	31.13	36.79	53.77	0.088	0.099	0.138	0.092	0.233	0.217	0.217
17	53.77	28.30	67.92	31.13	39.62	56.60	0.071	0.079	0.121	0.093	0.221	0.207	0.207
18	53.77	28.30	65.09	36.79	42.45	62.26	0.062	0.097	0.145	0.083	0.214	0.214	0.228
19	53.77	25.47	62.26	31.13	39.62	45.28	0.073	0.118	0.164	0.091	0.264	0.255	0.209
20	56.60	31.13	67.92	33.96	42.45	59.43	0.074	0.123	0.131	0.082	0.254	0.254	0.238

Appendix 2: CAMEROON

REPLICATE	TrI	FmI	GnI	TbI	TsI	TrII	FmII	GnII	TbII	TsII	TrIII	FmIII	GnIII	TbIII
1	1.00	28.30	65.09	36.79	45.28	53.77	22.64	56.60	31.13	25.47	42.45	28.30	28.30	36.79
2	2.00	28.30	84.90	39.62	42.45	53.77	28.30	56.60	36.79	33.96	48.11	28.30	33.96	42.45
3	3.00	33.96	84.90	39.62	45.28	59.43	28.30	56.60	36.79	31.13	48.11	28.30	33.96	39.62
4	4.00	28.30	79.24	33.96	42.45	53.77	28.30	53.77	31.13	31.13	42.45	28.30	31.13	33.96
5	5.00	28.30	82.07	33.96	42.45	56.60	25.47	50.94	25.47	31.13	48.11	31.13	31.13	39.62
6	6.00	28.30	79.24	31.13	36.79	53.77	22.64	53.77	33.96	31.13	42.45	28.30	31.13	36.79
7	7.00	31.13	82.07	33.96	45.28	56.60	25.47	53.77	36.79	36.79	50.94	25.47	33.96	36.79
8	8.00	28.30	82.07	33.96	33.96	56.60	22.64	48.11	39.62	31.13	48.11	28.30	28.30	33.96
9	9.00	28.30	73.58	31.13	31.13	53.77	28.30	53.77	33.96	31.13	45.28	25.47	25.47	36.79
10	10.00	28.30	79.24	31.13	31.13	53.77	28.30	50.94	31.13	31.13	48.11	22.64	28.30	33.96
11	11.00	28.30	84.90	36.79	42.45	53.77	25.47	53.77	33.96	31.13	50.94	25.47	31.13	39.62
12	12.00	31.13	87.73	39.62	42.45	50.94	25.47	56.60	31.13	31.13	45.28	22.64	31.13	39.62
13	13.00	28.30	73.58	39.62	42.45	53.77	25.47	53.77	31.13	31.13	45.28	28.30	31.13	39.62
14	14.00	28.30	84.90	39.62	42.45	50.94	25.47	48.11	33.96	31.13	42.45	25.47	31.13	36.79
15	15.00	28.30	73.58	36.79	39.62	56.60	22.64	45.28	31.13	31.13	50.94	28.30	31.13	39.62
16	16.00	28.30	79.24	33.96	39.62	50.94	28.30	50.94	31.13	28.30	45.28	28.30	28.30	33.96
17	17.00	25.47	79.24	33.96	42.45	53.77	22.64	48.11	31.13	31.13	42.45	22.64	31.13	33.96
18	18.00	28.30	87.73	33.96	48.11	59.43	22.64	53.77	31.13	33.96	50.94	28.30	33.96	33.96
19	19.00	28.30	82.07	39.62	45.28	56.60	28.30	53.77	31.13	31.13	50.94	28.30	33.96	42.45
20	20.00	28.30	87.73	42.45	45.28	56.60	28.30	56.60	36.79	33.96	48.11	25.47	31.13	39.62

REPLICATE	TsIII	TrIV	FmIV	GnIV	TbIV	TsIV	RL1	RL2	RL3	RL4	Rd1	Rd2	Rd3
1	53.77	33.96	65.09	28.30	42.45	59.43	0.105	0.133	0.168	0.070	0.031	0.217	0.231
2	56.60	28.30	70.75	33.96	42.45	62.26	0.120	0.152	0.192	0.072	0.216	0.248	0.192
3	56.60	28.30	70.75	33.96	42.45	62.26	0.095	0.161	0.146	0.088	0.212	0.248	0.168
4	56.60	28.30	56.60	28.30	39.62	59.43	0.130	0.171	0.187	0.081	0.228	0.211	0.211
5	50.94	28.30	65.09	31.13	42.45	59.43	0.104	0.139	0.146	0.063	0.201	0.222	0.222
6	56.60	28.30	62.26	31.13	42.45	59.43	0.133	0.183	0.200	0.100	0.208	0.217	0.200
7	53.77	25.47	65.09	33.96	42.45	50.94	0.140	0.154	0.154	0.103	0.224	0.224	0.221
8	56.60	28.30	62.26	33.96	42.45	59.43	0.143	0.179	0.171	0.071	0.214	0.186	0.193
9	53.77	19.81	56.60	28.30	42.45	59.43	0.125	0.169	0.184	0.096	0.206	0.228	0.184
10	50.94	28.30	65.09	31.13	42.45	59.43	0.142	0.183	0.125	0.100	0.242	0.258	0.242
11	53.77	22.64	56.60	31.13	39.62	59.43	0.170	0.196	0.205	0.116	0.241	0.250	0.214
12	53.77	28.30	65.09	31.13	42.45	59.43	0.112	0.157	0.172	0.097	0.179	0.179	0.187
13	50.94	28.30	59.43	33.96	42.45	59.43	0.144	0.159	0.174	0.083	0.242	0.242	0.242
14	53.77	22.64	59.43	33.96	42.45	56.60	0.138	0.177	0.192	0.077	0.223	0.208	0.200
15	53.77	28.30	62.26	36.79	42.45	59.43	0.155	0.200	0.200	0.100	0.282	0.245	0.245
16	48.11	25.47	56.60	28.30	36.79	56.60	0.175	0.196	0.237	0.082	0.216	0.216	0.206
17	53.77	25.47	59.43	33.96	42.45	59.43	0.136	0.179	0.164	0.079	0.157	0.221	0.200
18	56.60	28.30	65.09	33.96	45.28	59.43	0.118	0.169	0.199	0.088	0.184	0.191	0.169
19	56.60	28.30	67.92	36.79	42.45	62.26	0.145	0.167	0.159	0.087	0.246	0.225	0.210
20	59.43	28.30	73.58	39.62	48.11	62.26	0.127	0.178	0.178	0.102	0.246	0.195	0.195

Appendix 3: GHANA

REPLICATE	TrI	FmI	GnI	TbI	TsI	TrII	FmII	GnII	TbII	TsII	TrIII	FmIII	GnIII	TbIII
1	1.00	33.96	90.56	42.45	48.11	59.43	31.13	59.43	31.13	31.13	48.11	31.13	31.13	42.45
2	2.00	28.30	79.24	39.62	48.11	56.60	28.30	59.43	36.79	31.13	53.77	42.45	28.30	36.79
3	3.00	28.30	84.90	45.28	42.45	59.43	24.06	62.26	33.96	31.13	48.11	31.13	33.96	42.45
4	4.00	28.30	84.90	42.45	45.28	59.43	25.47	53.77	33.96	31.13	45.28	28.30	33.96	39.62
5	5.00	33.96	90.56	36.79	48.11	59.43	28.30	59.43	36.79	31.13	48.11	28.30	33.96	36.79
6	6.00	36.79	87.73	36.79	42.45	50.94	31.13	62.26	39.62	31.13	48.11	31.13	33.96	39.62
7	7.00	31.13	82.07	45.28	48.11	56.60	31.13	53.77	33.96	33.96	45.28	28.30	31.13	39.62
8	8.00	31.13	90.56	45.28	45.28	59.43	31.13	56.60	36.79	33.96	53.77	36.79	33.96	42.45
9	9.00	31.13	79.24	39.42	45.28	56.60	28.30	56.60	31.13	31.13	45.28	25.47	28.30	42.45
10	10.00	28.30	93.39	42.45	42.45	50.94	25.47	56.60	33.96	31.13	45.28	25.47	28.30	39.62
11	11.00	33.96	82.07	31.13	45.28	56.60	25.47	48.11	31.13	33.96	50.94	25.47	33.96	36.79
12	12.00	28.30	82.07	33.96	39.62	53.77	33.96	56.60	31.13	33.96	45.28	28.30	33.96	36.79
13	13.00	28.30	82.07	39.62	39.62	48.11	28.30	59.43	31.13	33.96	48.11	25.47	31.13	36.79
14	14.00	31.13	82.07	33.96	39.62	56.60	25.47	50.94	31.13	31.13	48.11	25.47	31.13	42.45
15	15.00	28.30	82.07	36.79	42.45	53.77	28.30	56.60	33.96	31.13	45.28	28.30	31.13	39.62
16	16.00	31.13	87.73	36.79	42.45	59.43	28.30	50.94	33.96	31.13	48.11	25.47	33.96	39.62
17	17.00	31.13	90.56	36.79	42.45	62.26	25.47	59.43	31.13	31.13	48.11	28.30	33.96	39.62
18	18.00	31.13	87.73	36.79	45.28	53.77	28.30	53.77	31.13	28.30	48.11	25.47	31.13	36.79
19	19.00	28.30	76.41	33.96	36.79	53.77	25.47	56.60	33.96	28.30	48.11	22.64	28.30	25.47
20	20.00	28.30	87.73	33.96	42.45	56.60	25.47	59.43	31.13	31.13	45.28	25.47	31.13	42.45

REPLICATE	TsIII	TrIV	FmIV	GnIV	TbIV	TsIV	RL1	RL2	RL3	RL4	Rd1	Rd2	Rd3
1	59.43	36.79	70.75	31.13	42.45	62.26	0.165	0.198	0.198	0.099	0.198	0.182	0.207
2	62.26	31.13	59.43	36.79	42.45	65.09	0.128	0.168	0.176	0.100	0.216	0.200	0.248
3	56.60	39.62	70.75	33.96	39.62	59.43	0.128	0.149	0.138	0.085	0.199	0.199	0.255
4	56.60	25.47	67.92	33.96	42.45	59.43	0.122	0.176	0.160	0.092	0.214	0.221	0.229
5	56.60	31.13	67.92	33.96	42.45	62.26	0.120	0.133	0.133	0.120	0.247	0.220	0.160
6	56.60	28.30	59.43	33.96	45.28	62.26	0.126	0.170	0.178	0.096	0.215	0.226	0.244
7	59.43	33.96	70.75	33.96	45.28	59.43	0.138	0.163	0.174	0.101	0.210	0.239	0.210
8	56.60	28.30	59.43	36.79	48.11	56.60	0.140	0.184	0.176	0.103	0.221	0.210	0.265
9	53.77	28.30	67.92	31.13	48.11	56.60	0.122	0.165	0.165	0.083	0.201	0.201	0.209
10	53.77	22.64	59.43	33.96	42.45	56.60	0.137	0.161	0.170	0.097	0.242	0.242	0.242
11	53.77	25.47	59.43	33.96	42.45	53.77	0.143	0.183	0.175	0.087	0.230	0.230	0.254
12	56.60	28.30	73.58	33.96	39.62	56.60	0.157	0.182	0.182	0.074	0.256	0.264	0.231
13	53.77	28.30	56.60	31.13	42.45	56.60	0.148	0.209	0.217	0.078	0.235	0.261	0.217
14	53.77	28.30	70.75	42.45	48.11	62.26	0.144	0.192	0.216	0.088	0.248	0.256	0.240
15	53.77	28.30	65.09	33.96	42.45	59.43	0.142	0.165	0.197	0.094	0.244	0.252	0.205
16	59.43	28.30	59.43	33.96	45.28	59.43	0.136	0.184	0.188	0.072	0.224	0.260	0.216
17	53.77	28.30	62.26	33.96	42.45	59.43	0.157	0.174	0.174	0.074	0.256	0.256	0.198
18	53.77	25.47	62.26	33.96	45.28	59.43	0.142	0.183	0.175	0.092	0.242	0.258	0.225
19	53.77	25.47	59.43	31.13	31.13	59.43	0.140	0.175	0.211	0.079	0.246	0.237	0.228
20	53.77	25.47	62.26	39.62	48.11	56.60	0.156	0.193	0.197	0.082	0.254	0.254	0.197

Appendix 4: KENYA

REPLICATE	TrI	FmI	GnI	TbI	TsI	TrII	FmII	GnII	TbII	TsII	TrIII	FmIII	GnIII	TbIII
1	1.00	33.96	87.73	39.62	45.28	56.60	28.30	56.60	36.79	33.96	45.28	31.13	31.13	42.45
2	2.00	33.96	79.24	36.79	39.62	53.77	28.30	53.77	31.13	28.30	42.45	28.30	31.13	36.79
3	3.00	33.96	82.07	33.96	45.45	53.77	31.13	53.77	33.96	28.30	45.28	31.13	31.13	39.62
4	4.00	33.96	87.73	45.28	48.11	53.77	25.47	59.43	33.96	31.13	48.11	28.30	36.79	36.79
5	5.00	33.96	96.22	48.11	50.94	65.09	28.30	59.43	53.77	39.62	50.94	28.30	33.96	42.45
6	6.00	28.30	84.90	39.62	45.28	36.79	28.30	59.43	33.96	28.30	33.96	25.47	31.13	39.62
7	7.00	31.13	84.90	53.96	45.28	59.43	28.30	53.77	35.38	31.13	45.28	31.13	31.13	39.62
8	8.00	33.96	82.07	39.62	45.28	53.77	28.30	42.45	31.13	31.13	42.45	25.47	31.13	39.62
9	9.00	31.13	73.58	45.45	42.45	48.11	28.30	53.77	33.96	28.30	33.96	28.30	33.96	42.45
10	10.00	33.96	99.05	45.28	48.11	62.26	28.30	56.60	39.62	33.96	53.77	28.30	36.79	42.45
11	11.00	33.96	84.90	38.21	48.11	56.60	31.13	50.94	33.96	31.13	39.62	25.47	36.79	36.79
12	12.00	31.13	87.73	42.45	48.11	56.60	28.30	53.77	36.79	33.96	45.28	25.47	31.13	39.62
13	13.00	33.96	93.39	45.28	48.11	59.43	31.13	59.43	39.62	33.96	48.11	28.30	33.96	39.62
14	14.00	31.13	93.39	45.28	48.11	65.09	25.47	53.77	39.62	33.96	50.94	31.13	35.36	42.45
15	15.00	33.96	96.22	42.45	48.11	59.43	28.30	56.60	36.79	31.13	50.94	31.13	33.96	39.62
16	16.00	33.96	70.75	36.79	42.45	53.77	28.30	45.28	31.13	31.13	45.28	31.13	28.30	36.79
17	17.00	36.79	84.90	36.79	45.28	48.11	33.96	62.26	31.13	31.13	48.11	28.30	33.96	39.62
18	18.00	28.30	79.24	33.96	39.62	53.77	31.13	50.94	28.30	31.13	45.28	28.30	31.13	36.79
19	19.00	31.13	79.24	39.62	45.28	53.77	28.30	53.77	39.62	31.13	45.28	31.13	28.30	39.62
20	20.00	33.96	79.24	36.79	42.45	48.11	28.30	53.77	31.13	28.30	45.28	28.30	31.13	33.96

REPLICATE	TsIII	TrIV	FmIV	GnIV	TbIV	TsIV	RL1	RL2	RL3	RL4	Rd1	Rd2	Rd3
1	59.43	25.47	56.60	36.79	45.28	62.26	0.167	0.194	0.203	0.167	0.278	0.278	0.259
2	53.77	25.47	48.11	33.96	33.96	53.77	0.088	0.149	0.149	0.070	0.237	0.246	0.193
3	53.77	25.47	62.26	33.96	42.45	56.60	0.091	0.124	0.124	0.124	0.190	0.174	0.215
4	62.26	28.30	70.75	42.45	42.45	62.26	0.151	0.187	0.227	0.079	0.223	0.216	0.216
5	62.26	28.30	73.58	39.62	48.11	67.92	0.091	0.132	0.165	0.045	0.240	0.256	0.215
6	53.77	28.30	65.09	36.79	39.62	59.43	0.093	0.136	0.161	0.085	0.220	0.237	0.220
7	56.60	33.96	59.43	39.62	38.21	62.26	0.085	0.101	0.147	0.085	0.232	0.232	0.194
8	56.60	33.96	56.60	36.79	42.45	56.60	0.152	0.192	0.200	0.096	0.224	0.232	0.224
9	56.60	36.79	67.92	31.13	48.11	59.43	0.148	0.189	0.197	0.086	0.246	0.246	0.246
10	62.26	31.13	79.24	39.62	48.11	65.06	0.100	0.131	0.162	0.092	0.238	0.231	0.215
11	53.77	28.30	59.43	36.79	45.28	62.26	0.091	0.140	0.149	0.116	0.215	0.231	0.198
12	53.77	28.30	65.09	33.96	45.28	62.26	0.165	0.177	0.195	0.083	0.237	0.244	0.263
13	59.43	33.96	70.75	36.79	42.45	65.09	0.191	0.222	0.243	0.096	0.230	0.270	0.239
14	59.43	31.13	65.09	36.79	45.28	62.26	0.138	0.174	0.167	0.101	0.203	0.217	0.188
15	56.60	31.13	62.26	33.96	48.11	62.26	0.096	0.107	0.143	0.100	0.229	0.193	0.200
16	53.77	28.30	56.60	31.13	36.79	53.77	0.070	0.127	0.184	0.131	0.211	0.211	0.219
17	56.60	31.13	70.75	31.13	42.45	62.26	0.095	0.124	0.162	0.105	0.257	0.252	0.238
18	53.77	25.47	70.75	33.96	39.62	56.60	0.089	0.113	0.137	0.089	0.202	0.202	0.185
19	48.11	25.47	65.09	33.96	39.62	56.60	0.096	0.130	0.152	0.096	0.226	0.235	0.235
20	48.11	25.47	53.77	31.13	33.96	48.11	0.100	0.155	0.190	0.111	0.230	0.230	0.220

Appendix 5: NIGERIA

REPLICATE	TrI	FmI	GnI	TbI	TsI	TrII	FmII	GnII	TbII	TsII	TrIII	FmIII	GnIII	TbIII
1	1.00	28.30	84.90	42.45	45.28	59.43	16.98	56.60	39.62	33.96	53.77	16.98	33.96	41.04
2	2.00	25.47	73.58	33.96	42.45	62.26	14.15	45.28	28.30	25.47	53.77	19.81	28.30	36.79
3	3.00	28.30	84.90	39.62	45.28	56.60	25.47	53.77	33.96	31.13	45.28	28.30	31.13	39.62
4	4.00	25.47	79.24	39.62	42.45	59.43	28.30	48.11	33.96	31.13	45.28	28.30	33.96	48.11
5	5.00	28.30	62.26	39.62	45.28	53.77	25.47	48.11	33.96	31.13	50.94	25.47	33.96	36.79
6	6.00	25.47	73.58	31.13	36.79	50.94	28.30	48.11	31.13	28.30	39.62	25.47	42.45	28.30
7	7.00	28.30	70.75	33.96	42.45	56.60	28.30	53.77	28.30	31.13	45.28	28.30	28.30	33.96
8	8.00	28.30	87.73	36.79	42.45	56.60	25.47	59.43	31.13	31.13	53.77	16.98	36.79	39.62
9	9.00	28.30	87.73	42.45	45.28	62.26	25.47	50.94	33.96	33.96	50.94	25.47	33.96	39.62
10	10.00	31.13	87.73	33.96	45.28	59.43	28.30	56.60	31.13	28.30	53.77	28.30	31.13	39.62
11	11.00	33.96	84.90	36.79	39.62	48.11	28.30	56.60	28.30	33.96	45.28	25.47	31.13	45.28
12	12.00	28.30	76.41	36.79	45.28	56.60	28.30	53.77	33.96	31.13	45.28	28.30	33.96	45.45
13	13.00	28.30	76.41	39.62	39.62	48.11	28.30	56.60	31.13	28.30	42.45	28.30	28.30	39.62
14	14.00	31.13	79.24	42.45	48.11	53.77	25.47	48.11	36.79	31.13	45.28	28.30	31.13	42.45
15	15.00	33.96	87.73	42.45	48.11	59.43	31.13	65.09	36.79	31.13	45.28	31.13	33.96	42.45
16	16.00	31.13	76.41	33.96	42.45	53.77	28.30	50.94	31.13	31.13	45.28	28.30	31.13	35.38
17	17.00	31.13	82.07	36.79	39.62	50.94	25.47	53.77	31.13	31.13	45.28	25.47	33.96	36.79
18	18.00	31.13	82.07	36.79	45.28	59.43	28.30	50.94	33.96	31.13	45.28	28.30	31.13	36.79
19	19.00	31.13	82.07	36.79	42.45	53.77	28.30	56.60	33.96	31.13	48.11	28.30	33.96	36.79
20	20.00	31.13	84.90	36.79	42.45	53.77	28.30	50.94	33.96	31.13	45.28	25.47	31.13	36.79

REPLICATE	TsIII	TrIV	FmIV	GnIV	TbIV	TsIV	RL1	RL2	RL3	RL4	Rd1	Rd2	Rd3
1	65.09	25.47	67.92	31.13	42.45	67.92	0.123	0.126	0.168	0.081	0.174	0.171	0.171
2	48.11	28.30	59.43	31.13	42.45	65.09	0.156	0.174	0.211	0.101	0.220	0.229	0.220
3	56.60	28.30	65.09	33.96	39.62	59.43	0.136	0.161	0.204	0.102	0.225	0.255	0.195
4	65.09	28.30	53.77	33.96	42.45	65.09	0.091	0.171	0.188	0.077	0.222	0.214	0.205
5	59.43	31.13	70.75	31.13	39.62	65.09	0.125	0.147	0.154	0.066	0.199	0.199	0.191
6	59.43	33.96	48.11	28.30	39.62	59.43	0.107	0.157	0.151	0.099	0.190	0.223	0.231
7	56.60	25.47	50.94	33.96	42.45	53.77	0.104	0.117	0.117	0.065	0.240	0.227	0.175
8	59.43	28.30	53.77	31.13	42.45	59.43	0.144	0.189	0.216	0.108	0.189	0.207	0.216
9	59.43	31.13	53.77	33.96	42.45	62.26	0.150	0.167	0.200	0.083	0.192	0.225	0.217
10	59.43	28.30	59.43	33.96	42.45	59.43	0.149	0.157	0.165	0.099	0.182	0.207	0.273
11	56.60	25.47	70.75	33.96	45.28	59.43	0.120	0.139	0.139	0.073	0.209	0.206	0.190
12	56.60	31.13	65.09	36.79	42.45	56.60	0.130	0.183	0.183	0.078	0.226	0.243	0.252
13	50.94	33.96	67.92	31.13	42.45	56.60	0.150	0.230	0.230	0.120	0.230	0.220	0.240
14	56.60	25.47	59.43	31.13	48.11	59.43	0.150	0.167	0.183	0.067	0.217	0.238	0.225
15	59.43	28.30	73.58	36.79	42.45	53.77	0.145	0.205	0.171	0.085	0.256	0.256	0.214
16	53.77	28.30	62.26	31.13	42.45	59.43	0.155	0.177	0.200	0.064	0.227	0.227	0.227
17	50.94	31.13	59.43	31.13	39.62	56.60	0.200	0.232	0.253	0.116	0.200	0.174	0.189
18	53.77	28.30	65.09	31.13	42.45	62.26	0.167	0.193	0.211	0.105	0.237	0.228	0.219
19	53.77	28.30	70.75	33.96	42.45	59.43	0.136	0.202	0.219	0.105	0.219	0.228	0.228
20	50.94	28.30	62.26	31.13	42.45	56.60	0.167	0.149	0.193	0.096	0.228	0.219	0.202

Appendix 6: RWANDA

REPLICATE	TrI	FmI	GnI	TbI	TsI	TrII	FmII	GnII	TbII	TsII	TrIII	FmIII	GnIII	TbIII
1	1.00	28.30	79.24	28.30	33.96	59.43	22.64	45.28	31.13	31.13	42.45	25.47	28.30	42.45
2	2.00	28.30	84.90	28.30	36.79	50.94	28.30	48.11	31.13	31.13	45.28	25.47	28.30	33.96
3	3.00	28.30	87.73	36.79	36.79	59.43	25.47	53.77	28.30	33.96	42.45	28.30	28.30	28.30
4	4.00	28.30	90.56	39.62	45.28	59.43	28.30	59.43	28.30	31.13	53.77	25.47	28.30	36.79
5	5.00	28.30	84.90	36.79	39.62	59.43	28.30	59.43	33.96	28.30	45.28	28.30	28.30	31.13
6	6.00	28.30	76.41	42.45	45.28	56.60	25.47	50.94	33.96	28.30	45.28	25.47	28.30	31.13
7	7.00	28.30	84.90	28.30	33.96	53.77	28.30	53.77	31.13	28.30	45.28	28.30	28.30	31.13
8	8.00	31.13	84.90	36.79	42.45	59.43	31.13	53.77	31.13	31.13	50.94	25.47	31.13	33.96
9	9.00	31.13	76.41	33.96	39.62	53.77	28.30	53.77	28.30	31.13	53.77	28.30	31.13	33.96
10	10.00	25.47	76.41	36.79	33.96	59.43	28.30	48.11	28.30	31.13	45.28	25.47	31.13	39.62
11	11.00	28.30	82.07	36.79	39.62	56.60	22.64	45.28	33.96	28.30	48.11	25.47	25.47	36.79
12	12.00	31.13	87.73	42.45	45.28	56.60	28.30	59.43	31.13	33.96	48.11	25.47	31.13	33.96
13	13.00	28.30	76.41	36.79	42.45	53.77	25.47	50.94	31.13	31.13	53.77	22.64	31.13	33.96
14	14.00	25.47	70.75	36.79	42.45	50.94	25.47	56.60	31.13	31.13	48.11	25.47	28.30	33.96
15	15.00	28.30	79.24	36.79	39.62	62.26	28.30	62.26	31.13	31.13	59.43	28.30	31.13	36.79
16	16.00	28.30	65.09	36.79	42.45	56.60	28.30	53.77	31.13	28.30	45.28	28.30	28.30	36.62
17	17.00	28.30	62.26	33.96	39.62	56.60	28.30	50.94	31.13	28.30	42.45	25.47	28.30	31.13
18	18.00	28.30	79.24	33.96	42.45	59.43	28.30	56.60	33.96	33.96	45.28	25.47	28.30	33.96
19	19.00	28.30	84.90	33.96	42.45	62.26	28.30	56.60	31.13	33.96	48.11	25.47	31.13	31.13
20	20.00	28.30	82.07	33.96	39.62	62.26	28.30	56.60	31.13	33.96	50.94	25.47	31.13	33.96

REPLICATE	TsIII	TrIV	FmIV	GnIV	TbIV	TsIV	RL1	RL2	RL3	RL4	Rd1	Rd2	Rd3
1	50.94	22.64	59.43	33.96	39.62	53.77	0.090	0.130	0.160	0.080	0.240	0.220	0.220
2	50.94	25.47	65.09	33.96	42.45	50.94	0.068	0.093	0.127	0.085	0.233	0.229	0.191
3	56.60	25.47	62.26	28.30	42.45	62.26	0.083	0.149	0.157	0.074	0.248	0.240	0.240
4	50.94	25.47	59.43	36.79	33.96	59.43	0.100	0.136	0.182	0.095	0.227	0.227	0.209
5	56.60	28.30	65.09	33.96	42.45	62.26	0.092	0.101	0.165	0.119	0.211	0.229	0.211
6	53.77	28.30	62.26	31.13	39.62	62.26	0.092	0.160	0.160	0.109	0.227	0.210	0.210
7	53.77	28.30	59.43	31.13	31.13	56.60	0.088	0.124	0.159	0.097	0.247	0.257	0.204
8	53.77	31.13	56.60	33.96	45.28	56.60	0.097	0.105	0.161	0.081	0.242	0.234	0.194
9	53.77	28.30	56.60	36.79	42.45	56.60	0.092	0.124	0.158	0.083	0.233	0.242	0.208
10	59.43	25.47	62.26	31.13	42.45	56.60	0.094	0.137	0.128	0.094	0.248	0.256	0.239
11	42.45	22.64	59.43	39.62	39.62	53.77	0.120	0.190	0.190	0.110	0.180	0.270	0.230
12	56.60	25.47	59.43	31.13	36.79	56.60	0.081	0.113	0.169	0.081	0.242	0.210	0.161
13	50.94	28.30	59.43	33.96	39.62	50.94	0.083	0.139	0.167	0.120	0.222	0.231	0.231
14	56.60	28.30	62.26	33.96	42.45	56.60	0.100	0.127	0.155	0.091	0.173	0.164	0.209
15	56.60	28.30	70.75	31.13	42.45	56.60	0.088	0.124	0.161	0.088	0.204	0.204	0.190
16	48.11	28.30	59.43	39.62	45.28	56.60	0.120	0.160	0.210	0.120	0.200	0.200	0.200
17	50.94	22.64	59.43	33.96	39.62	56.60	0.110	0.160	0.180	0.110	0.220	0.190	0.180
18	56.60	25.47	62.26	36.79	42.45	59.43	0.094	0.162	0.154	0.094	0.205	0.171	0.171
19	59.43	28.30	59.43	36.79	45.28	62.26	0.088	0.159	0.168	0.088	0.221	0.230	0.221
20	53.77	28.30	65.09	36.79	42.45	59.43	0.101	0.138	0.165	0.101	0.202	0.229	0.229

Appendix 7: TANZANIA

REPLICATE	TrI	FmI	GnI	TbI	TsI	TrII	FmII	GnII	TbII	TsII	TrIII	FmIII	GnIII	TbIII
1	1.00	28.30	70.75	28.30	33.96	50.94	25.47	50.94	28.30	31.13	33.96	25.47	28.30	33.96
2	2.00	33.96	67.92	36.79	45.28	59.43	25.47	56.60	33.96	31.13	53.77	28.30	31.13	36.79
3	3.00	28.30	73.58	33.96	39.62	48.11	28.30	50.94	31.13	28.30	42.45	25.47	31.13	36.79
4	4.00	28.30	90.56	42.45	48.11	59.43	25.47	50.94	36.79	33.96	50.94	28.30	33.96	39.62
5	5.00	31.13	96.22	45.28	48.11	56.60	28.30	59.43	39.62	31.13	50.94	33.96	39.62	42.45
6	6.00	28.30	82.07	36.79	45.28	48.11	25.47	56.60	31.13	28.30	36.79	22.64	31.13	42.45
7	7.00	28.30	73.56	36.79	39.62	53.77	25.47	48.11	33.96	31.13	33.96	33.96	33.96	42.45
8	8.00	31.13	76.41	42.45	45.28	48.11	28.30	50.94	33.96	33.96	42.45	28.30	33.96	39.62
9	9.00	28.30	79.24	39.62	42.45	53.77	22.64	50.94	28.30	31.13	42.45	28.30	33.96	39.62
10	10.00	28.30	73.58	36.79	42.45	56.60	22.64	45.28	31.13	31.13	42.45	28.30	31.13	39.62
11	11.00	28.30	73.58	39.62	39.62	50.94	22.64	50.94	28.30	28.30	50.94	25.47	28.30	36.79
12	12.00	31.13	84.90	42.45	42.45	28.30	25.47	48.11	31.13	28.30	50.94	22.64	28.30	36.79
13	13.00	28.30	76.41	45.28	45.28	59.43	25.47	56.60	33.96	31.13	39.62	25.47	31.13	42.45
14	14.00	28.30	79.24	45.28	45.28	50.94	25.47	56.60	28.30	33.96	45.28	28.30	31.13	39.62
15	15.00	25.47	79.24	42.45	42.45	50.94	28.30	50.94	36.79	28.30	45.28	28.30	31.13	36.79
16	16.00	28.30	87.73	45.28	45.28	56.60	25.47	53.77	31.13	36.79	48.11	25.47	33.96	39.62
17	17.00	28.30	84.90	42.45	42.45	56.60	25.47	50.94	28.30	31.13	48.11	28.30	28.30	39.62
18	18.00	28.30	84.90	42.45	42.45	45.28	25.47	50.94	31.13	31.13	48.11	25.47	33.96	39.62
19	19.00	28.30	84.90	42.45	42.45	56.60	22.64	56.60	33.96	33.96	45.28	25.47	33.96	39.62
20	20.00	28.30	84.90	42.45	42.45	53.77	22.64	56.60	33.96	33.96	42.45	28.30	36.79	36.79

REPLICATE	TsIII	TrIV	FmIV	GnIV	TbIV	TsIV	RL1	RL2	RL3	RL4	Rd1	Rd2	Rd3
1	36.79	25.47	62.26	31.13	39.62	42.45	0.124	0.134	0.159	0.097	0.195	0.212	0.195
2	56.60	28.30	73.58	31.13	42.45	62.26	0.072	0.092	0.124	0.085	0.216	0.222	0.196
3	53.77	25.47	70.75	33.96	42.45	50.94	0.119	0.210	0.210	0.114	0.190	0.190	0.181
4	59.43	25.47	65.09	33.96	42.45	62.26	0.092	0.154	0.177	0.077	0.227	0.223	0.208
5	59.43	33.96	79.24	33.96	42.45	59.43	0.085	0.131	0.154	0.085	0.215	0.250	0.246
6	50.94	22.64	56.60	33.96	45.28	48.11	0.095	0.152	0.190	0.095	0.229	0.238	0.210
7	50.94	25.47	67.92	39.62	39.62	56.60	0.065	0.083	0.116	0.094	0.196	0.203	0.188
8	53.77	31.13	73.58	39.62	42.45	62.26	0.064	0.093	0.114	0.093	0.207	0.236	0.215
9	56.60	28.30	59.43	33.96	42.45	56.60	0.057	0.100	0.114	0.079	0.200	0.200	0.186
10	53.77	28.30	65.09	31.13	42.45	59.43	0.092	0.125	0.183	0.092	0.225	0.175	0.192
11	56.60	31.13	62.26	36.79	42.45	53.77	0.072	0.116	0.136	0.088	0.184	0.232	0.216
12	53.77	28.30	59.43	31.13	39.62	56.60	0.098	0.106	0.130	0.089	0.179	0.171	0.187
13	48.11	28.30	50.94	33.96	39.62	59.43	0.089	0.119	0.141	0.096	0.222	0.207	0.222
14	53.77	26.64	56.60	33.96	45.28	59.43	0.086	0.129	0.129	0.112	0.259	0.250	0.207
15	50.94	28.30	59.43	33.96	42.45	59.43	0.082	0.136	0.182	0.109	0.200	0.200	0.227
16	53.77	28.30	62.26	33.96	42.45	53.77	0.085	0.173	0.154	0.085	0.200	0.185	0.204
17	50.94	28.30	59.43	33.96	42.45	53.77	0.122	0.130	0.195	0.106	0.211	0.203	0.228
18	56.60	28.30	65.09	31.13	42.45	56.60	0.123	0.177	0.177	0.092	0.192	0.231	0.192
19	50.94	25.47	70.75	33.96	39.62	56.60	0.114	0.157	0.171	0.086	0.221	0.221	0.229
20	53.77	28.30	59.43	31.13	39.62	56.60	0.083	0.117	0.150	0.100	0.242	0.221	0.217

Appendix 8: UGANDA

REPLICATE	TrI	FmI	GnI	TbI	TsI	TrII	FmII	GnII	TbII	TsII	TrIII	FmIII	GnIII	TbIII
1	1.00	25.47	90.56	36.79	45.28	62.26	28.30	39.62	33.96	31.13	42.45	25.47	28.30	42.45
2	2.00	31.13	84.90	45.28	45.28	56.60	28.30	53.77	31.13	28.30	45.28	25.47	31.13	36.79
3	3.00	28.30	82.07	36.79	42.45	59.43	28.30	56.60	31.13	28.30	45.28	25.47	28.30	39.62
4	4.00	31.13	87.73	39.62	39.62	59.43	25.47	50.94	33.96	31.13	48.11	25.47	31.13	39.62
5	5.00	25.47	93.39	42.45	46.70	65.09	28.30	62.26	39.62	33.96	53.77	28.30	31.13	39.62
6	6.00	31.13	84.90	42.45	45.28	56.60	28.30	48.11	31.13	31.13	42.45	28.30	28.30	33.96
7	7.00	28.30	90.56	42.45	45.28	59.43	28.30	56.60	33.96	31.13	50.94	25.47	31.13	39.62
8	8.00	31.13	90.56	36.79	46.70	63.68	28.30	56.60	31.13	33.96	53.77	28.30	31.13	42.45
9	9.00	28.30	87.73	39.62	48.11	56.60	31.13	56.60	33.96	33.96	53.77	28.30	33.96	39.62
10	10.00	31.13	79.24	39.62	39.62	50.94	25.47	56.60	33.96	31.13	39.62	22.64	28.30	39.62
11	11.00	31.13	82.07	39.62	39.62	56.60	25.47	56.60	33.96	31.13	42.45	22.64	33.96	36.79
12	12.00	31.13	84.90	36.79	48.11	56.60	31.13	53.77	31.13	33.96	48.11	28.30	33.96	39.62
13	13.00	33.96	87.73	39.62	48.11	56.60	28.30	56.60	33.96	32.55	48.11	28.30	31.13	39.62
14	14.00	31.13	82.07	42.45	45.28	50.94	28.30	53.77	33.96	31.13	48.11	28.30	33.96	39.62
15	15.00	31.13	84.90	36.79	48.11	56.60	25.47	53.77	31.13	31.13	48.11	22.64	31.13	39.62
16	16.00	28.30	87.73	39.62	45.28	48.11	28.30	53.77	33.96	31.13	42.45	25.47	31.13	33.96
17	17.00	28.30	87.73	42.45	45.28	56.60	28.30	56.60	33.96	33.96	46.70	25.47	31.13	39.62
18	18.00	31.13	87.73	39.62	42.28	53.77	28.30	56.60	33.96	31.13	42.45	22.64	33.96	36.79
19	19.00	36.79	87.73	39.62	42.45	48.11	33.96	56.60	33.96	33.96	45.28	28.30	36.79	42.45
20	20.00	33.96	90.56	39.62	48.11	53.77	31.13	59.43	31.13	28.30	45.28	25.47	33.96	42.45

REPLICATE	TsIII	TrIV	FmIV	GnIV	TbIV	TsIV	RL1	RL2	RL3	RL4	Rd1	Rd2	Rd3
1	56.60	31.13	70.75	31.13	45.28	62.26	0.061	0.102	0.136	0.082	0.218	0.218	0.129
2	56.60	28.30	67.92	36.79	42.45	62.26	0.095	0.129	0.200	0.095	0.219	0.200	0.210
3	56.60	28.30	67.92	31.13	39.62	59.43	0.138	0.188	0.196	0.107	0.205	0.214	0.179
4	56.60	28.30	65.09	33.96	42.45	56.60	0.109	0.147	0.178	0.085	0.194	0.264	0.233
5	62.26	31.13	67.92	33.96	42.45	65.09	0.098	0.135	0.150	0.086	0.211	0.233	0.256
6	53.77	25.47	87.07	33.96	42.45	62.26	0.118	0.127	0.173	0.109	0.245	0.255	0.227
7	56.60	25.47	67.92	33.96	42.45	62.26	0.091	0.107	0.167	0.103	0.218	0.210	0.183
8	59.43	25.47	65.09	33.96	42.45	59.43	0.086	0.147	0.181	0.121	0.198	0.181	0.181
9	62.26	28.30	73.58	36.79	48.11	65.09	0.119	0.123	0.135	0.092	0.212	0.215	0.208
10	53.77	28.30	59.43	32.55	39.62	53.77	0.110	0.160	0.190	0.120	0.200	0.195	0.240
11	56.60	33.96	67.92	33.96	39.62	56.60	0.156	0.189	0.233	0.111	0.244	0.267	0.244
12	56.60	28.30	70.75	33.96	45.28	62.26	0.140	0.130	0.180	0.100	0.215	0.240	0.240
13	53.77	25.47	70.75	33.96	42.45	62.26	0.112	0.155	0.164	0.086	0.246	0.250	0.241
14	56.60	28.30	67.92	33.96	39.62	56.60	0.073	0.110	0.156	0.101	0.183	0.284	0.284
15	59.43	28.30	62.26	36.79	42.45	56.60	0.080	0.170	0.205	0.112	0.170	0.179	0.250
16	45.60	28.30	59.43	31.13	39.62	53.77	0.114	0.136	0.164	0.100	0.245	0.255	0.245
17	53.77	28.30	67.92	36.79	42.45	56.60	0.120	0.170	0.211	0.101	0.275	0.257	0.220
18	53.77	28.30	70.75	33.96	39.62	56.60	0.100	0.120	0.140	0.105	0.230	0.245	0.260
19	53.77	25.47	62.26	33.96	42.45	50.94	0.100	0.160	0.190	0.070	0.250	0.240	0.200
20	50.94	28.30	65.09	36.79	42.45	59.43	0.102	0.111	0.116	0.102	0.241	0.259	0.185

Appendix 9: ZAMBIA

REPLICATE	TrI	FmI	GnI	TbI	TsI	TrII	FmII	GnII	TbII	TsII	TrIII	FmIII	GnIII	TbIII
1	1.00	28.30	79.24	36.79	42.45	53.77	25.47	50.94	31.13	28.30	39.62	25.47	33.96	33.96
2	2.00	28.30	79.24	36.79	39.62	53.77	25.47	50.94	31.13	28.30	45.28	28.30	31.13	36.79
3	3.00	28.30	82.07	36.79	39.62	53.77	25.47	53.77	31.13	28.30	45.28	25.47	31.13	39.62
4	4.00	28.30	82.07	36.79	39.62	53.77	25.47	56.60	31.13	28.30	39.62	28.30	31.13	39.62
5	5.00	28.30	84.90	36.79	39.62	50.94	25.47	59.43	31.13	28.30	42.45	28.30	31.13	33.96
6	6.00	28.30	79.24	36.79	45.28	59.43	25.47	53.77	31.13	28.30	39.62	28.30	28.30	36.79
7	7.00	28.30	84.90	36.79	42.45	56.60	28.30	53.77	31.13	28.30	45.28	25.47	28.30	36.79
8	8.00	28.30	82.07	36.79	42.45	56.60	25.47	50.94	33.96	31.13	48.11	25.47	28.30	36.79
9	9.00	28.30	84.90	39.62	42.45	59.43	28.30	53.77	31.13	31.13	48.11	25.47	31.13	36.79
10	10.00	28.30	82.07	31.13	42.45	59.43	25.47	56.60	31.13	31.13	42.45	25.47	28.30	42.45
11	11.00	28.30	76.41	36.79	42.45	50.94	25.47	48.11	31.13	31.13	45.28	25.47	31.13	39.62
12	12.00	28.30	70.75	33.96	39.62	48.11	25.47	56.60	31.13	31.13	42.45	25.47	28.30	33.96
13	13.00	28.30	79.24	36.79	33.96	48.11	28.30	56.60	31.13	31.13	45.28	25.47	31.13	33.96
14	14.00	28.30	84.90	33.96	42.45	56.60	25.47	53.77	31.13	28.30	50.94	25.47	39.62	42.45
15	15.00	31.13	84.90	36.79	45.28	56.60	28.30	56.60	31.13	28.30	50.94	28.30	31.13	42.45
16	16.00	28.30	79.24	33.96	42.45	59.43	28.30	59.43	31.13	28.30	48.11	28.30	31.13	33.96
17	17.00	28.30	84.90	36.79	42.45	56.60	28.30	53.77	31.13	28.30	45.28	25.47	28.30	36.79
18	18.00	28.30	79.24	36.79	39.62	53.77	25.47	50.94	31.13	28.30	48.11	28.30	31.13	36.79
19	19.00	28.30	82.07	36.79	39.62	53.77	25.47	56.60	33.96	31.13	42.45	28.30	39.62	42.45
20	20.00	28.30	84.90	39.62	42.45	56.60	25.47	56.60	31.13	31.13	48.11	25.47	31.13	36.79

REPLICATE	TsIII	TrIV	FmIV	GnIV	TbIV	TsIV	RL1	RL2	RL3	RL4	Rd1	Rd2	Rd3
1	48.11	28.30	65.09	31.13	39.62	59.43	0.088	0.132	0.140	0.096	0.213	0.228	0.199
2	53.77	28.30	65.09	31.13	42.45	56.60	0.085	0.108	0.146	0.100	0.254	0.254	0.215
3	48.11	28.30	56.60	31.13	33.96	53.77	0.083	0.092	0.167	0.108	0.233	0.242	0.158
4	53.77	28.30	59.43	31.13	42.45	53.77	0.096	0.162	0.174	0.113	0.235	0.252	0.191
5	53.77	28.30	65.09	31.13	42.45	59.43	0.105	0.124	0.143	0.124	0.267	0.286	0.200
6	50.94	28.30	59.43	31.13	42.45	53.77	0.099	0.134	0.179	0.116	0.250	0.152	0.152
7	53.77	25.47	67.92	31.13	42.45	56.60	0.096	0.130	0.183	0.104	0.252	0.243	0.243
8	48.11	28.30	59.43	33.96	42.45	56.60	0.074	0.099	0.182	0.099	0.248	0.248	0.207
9	50.94	28.30	67.92	33.96	42.45	59.43	0.084	0.134	0.168	0.101	0.252	0.252	0.218
10	45.28	31.13	65.09	36.79	42.45	59.43	0.076	0.144	0.159	0.083	0.235	0.250	0.235
11	53.77	28.30	70.75	33.96	42.45	62.26	0.098	0.146	0.171	0.130	0.220	0.260	0.195
12	45.28	25.47	62.26	31.13	42.45	56.60	0.097	0.121	0.153	0.097	0.234	0.225	0.225
13	45.28	28.30	67.92	31.13	42.45	59.43	0.083	0.117	0.142	0.133	0.242	0.242	0.223
14	56.60	28.30	56.60	31.13	42.45	56.60	0.092	0.117	0.133	0.100	0.250	0.250	0.208
15	56.60	25.47	67.92	33.96	42.45	56.60	0.136	0.127	0.191	0.091	0.245	0.273	0.209
16	53.77	25.47	65.09	31.13	39.62	53.77	0.091	0.136	0.191	0.109	0.227	0.227	0.200
17	53.77	25.47	67.92	31.13	42.45	56.60	0.105	0.114	0.184	0.091	0.219	0.246	0.211
18	53.77	28.30	65.09	31.13	42.45	56.60	0.071	0.126	0.142	0.079	0.213	0.220	0.205
19	56.60	28.30	67.92	31.13	42.45	59.43	0.093	0.127	0.169	0.102	0.254	0.263	0.237
20	56.60	28.30	67.92	31.13	42.45	56.60	0.084	0.121	0.187	0.092	0.271	0.280	0.252

Appendix 10: ZANZIBAR

REPLICATE	TrI	FmI	GnI	TbI	TsI	TrII	FmII	GnII	TbII	TsII	TrIII	FmIII	GnIII	TbIII
1	1.00	31.13	79.24	33.96	39.62	48.11	28.30	48.11	31.13	28.30	42.45	25.47	28.30	33.96
2	2.00	31.13	79.24	39.62	45.28	53.77	25.47	56.60	33.96	31.13	42.45	28.30	31.13	39.62
3	3.00	31.13	82.07	36.79	48.11	59.43	28.30	56.60	33.96	31.13	48.11	25.47	31.13	39.62
4	4.00	31.13	84.90	39.62	45.28	53.77	25.47	53.77	33.96	31.13	42.45	28.30	31.13	39.62
5	5.00	28.30	76.41	36.79	39.62	45.28	25.47	50.94	33.96	31.13	36.79	22.64	31.13	33.96
6	6.00	31.13	79.24	36.79	45.28	50.94	28.30	50.94	31.13	31.13	39.62	22.64	31.13	39.62
7	7.00	28.30	82.07	36.79	48.11	59.43	28.30	50.94	31.13	31.13	48.11	28.30	31.13	36.79
8	8.00	31.13	84.90	39.62	45.28	59.43	28.30	56.60	33.96	28.30	39.62	31.13	33.96	39.62
9	9.00	28.30	82.07	36.79	39.62	53.77	25.47	56.60	36.79	31.13	42.45	22.64	33.96	39.62
10	10.00	28.30	79.24	38.21	39.62	48.11	28.30	56.60	31.13	28.30	39.62	31.13	31.13	36.79
11	11.00	33.96	76.41	36.79	39.62	56.60	28.30	48.11	33.96	31.13	39.62	22.64	31.13	39.62
12	12.00	31.13	73.58	36.79	39.62	56.60	25.47	56.60	33.96	31.13	39.62	28.30	31.13	36.79
13	13.00	28.30	84.90	38.21	45.28	56.60	25.47	59.43	31.13	31.13	45.28	28.30	31.13	39.62
14	14.00	28.30	79.24	33.96	42.45	53.77	25.47	53.77	31.13	31.13	42.45	25.47	31.13	36.79
15	15.00	31.13	84.90	39.62	45.28	59.43	28.30	56.60	33.96	33.96	42.45	28.30	33.96	39.62
16	16.00	31.13	79.24	33.96	42.45	48.11	28.30	53.77	33.96	31.13	42.45	28.30	31.13	33.96
17	17.00	28.30	84.90	33.96	45.28	53.77	28.30	50.94	31.13	31.13	42.45	25.47	31.13	31.13
18	18.00	31.13	87.73	33.96	36.79	56.60	25.47	53.77	31.13	31.13	42.45	25.47	33.96	36.79
19	19.00	28.30	84.90	33.96	39.62	56.60	28.30	53.77	31.13	31.13	39.62	28.30	33.96	39.62
20	20.00	28.30	87.73	33.96	36.79	56.60	28.30	53.77	31.13	31.13	48.11	28.30	31.13	39.62

REPLICATE	TsIII	TrIV	FmIV	GnIV	TbIV	TsIV	RL1	RL2	RL3	RL4	Rd1	Rd2	Rd3
1	48.11	28.30	65.09	33.96	36.79	56.60	0.139	0.189	0.172	0.098	0.246	0.230	0.205
2	53.77	28.30	62.26	31.13	45.28	56.60	0.104	0.162	0.169	0.085	0.223	0.215	0.208
3	50.94	28.30	67.92	33.96	42.45	56.60	0.136	0.176	0.176	0.096	0.184	0.248	0.192
4	56.60	28.30	56.60	31.13	42.45	56.60	0.114	0.159	0.174	0.091	0.197	0.227	0.189
5	45.28	25.47	56.60	31.13	39.62	48.11	0.170	0.205	0.196	0.098	0.259	0.232	0.241
6	53.77	25.47	59.43	33.96	42.45	62.26	0.132	0.157	0.198	0.099	0.223	0.240	0.207
7	50.94	28.30	65.09	31.13	45.28	59.43	0.151	0.184	0.175	0.111	0.198	0.222	0.222
8	56.60	31.13	59.43	33.96	42.45	50.94	0.118	0.185	0.210	0.101	0.202	0.210	0.202
9	50.94	28.30	56.60	31.13	39.62	48.11	0.125	0.188	0.205	0.107	0.205	0.232	0.196
10	53.77	28.30	62.26	33.96	39.62	56.60	0.102	0.161	0.178	0.093	0.229	0.262	0.220
11	56.60	28.30	67.92	33.96	45.28	62.26	0.151	0.167	0.175	0.103	0.246	0.278	0.167
12	53.77	31.13	65.09	33.96	45.28	53.77	0.128	0.176	0.152	0.096	0.224	0.224	0.200
13	53.77	28.30	62.26	31.13	42.45	59.43	0.098	0.165	0.165	0.083	0.211	0.226	0.211
14	53.77	25.47	62.26	33.96	42.45	59.43	0.162	0.179	0.197	0.094	0.231	0.231	0.197
15	50.94	28.30	67.92	36.79	42.45	53.77	0.096	0.139	0.165	0.104	0.235	0.226	0.226
16	42.45	28.30	62.26	33.96	39.62	53.77	0.138	0.198	0.198	0.103	0.233	0.241	0.172
17	56.60	28.30	56.60	33.96	42.45	59.43	0.128	0.168	0.168	0.080	0.232	0.232	0.184
18	50.94	28.30	70.75	31.13	39.62	53.77	0.160	0.220	0.250	0.100	0.220	0.240	0.180
19	53.77	28.30	70.75	33.96	42.45	56.60	0.179	0.188	0.196	0.107	0.205	0.232	0.196
20	53.77	31.13	56.60	28.30	42.45	56.60	0.137	0.169	0.169	0.113	0.242	0.242	0.202

Appendices 11-13: Measurements (µm) on immature stages of <u>Mononychellus</u> spp. from 5 localities in Kenya.

Appendix 11: Larva

REP	BL	BW	H	P1	P2	P3	D1	D2	D3	D4	D5	L1	L2	L3	L4
1	113.20	104.71	16.98	25.47	42.45	36.79	22.64	28.30	31.13	19.81	8.49	33.96	33.96	25.47	5.66
2	144.33	133.01	36.79	28.30	50.94	42.45	39.62	31.13	42.45	36.79	19.81	42.45	45.28	48.11	25.47
3	113.20	118.86	25.47	25.47	42.45	25.47	36.79	28.30	36.79	28.30	8.49	28.30	36.79	39.62	12.74
4	135.84	118.86	31.13	22.64	33.96	39.62	39.62	33.96	36.79	36.79	11.32	36.79	42.45	39.62	16.98
5	135.84	127.35	25.47	31.13	48.11	39.62	36.79	31.13	28.30	31.13	11.32	36.79	39.62	45.28	14.15
6	121.69	107.54	28.30	33.96	36.79	33.96	28.30	28.30	39.62	36.79	11.32	33.96	39.62	39.62	16.98
7	118.86	107.54	28.30	36.79	39.62	39.62	28.30	25.47	36.79	31.13	11.32	36.79	39.62	33.96	14.15
8	118.86	104.71	28.30	36.79	33.96	33.96	28.30	33.96	36.79	36.79	11.32	33.96	39.62	33.96	14.15
9	125.35	107.54	31.13	42.45	36.79	36.79	33.96	42.45	36.79	33.96	11.32	31.13	31.13	33.96	14.15
10	118.86	110.37	25.47	36.79	31.13	31.13	28.30	31.13	36.79	31.13	8.49	31.13	33.96	33.96	11.32
11	138.67	118.86	31.13	31.13	36.79	53.77	25.47	36.79	45.28	31.13	11.32	39.62	42.45	28.30	19.81
12	135.84	113.20	28.30	33.96	43.87	38.21	25.47	28.30	33.96	39.62	11.32	38.21	36.79	41.04	16.98
13	124.52	133.01	22.64	36.79	42.45	28.30	22.64	28.30	42.45	42.45	11.32	33.96	45.28	48.11	16.98
14	147.16	118.86	31.13	39.62	48.11	39.62	28.30	31.13	50.94	42.45	14.15	33.96	45.28	48.11	25.47
15	121.69	124.52	25.47	31.13	48.11	39.62	36.79	31.13	28.30	31.13	11.32	36.79	39.62	39.62	14.15
16	133.01	110.37	28.30	42.45	36.79	33.96	31.13	33.96	36.79	33.96	8.49	32.35	33.96	33.96	12.74
17	141.50	113.20	39.62	42.45	36.79	31.13	31.13	31.13	36.79	28.30	8.49	42.45	39.62	31.13	14.15
18	133.01	118.86	25.47	36.79	45.28	36.79	33.96	31.13	33.96	36.79	11.32	42.45	42.45	42.45	16.98
19	135.84	116.03	31.13	39.62	39.62	36.79	33.96	33.96	36.79	36.79	11.32	39.62	42.45	42.45	16.98
20	149.99	113.20	39.62	36.79	31.13	39.62	36.79	36.79	39.62	33.96	11.32	39.62	36.79	39.62	16.98
21	101.88	107.54	28.30	39.62	45.28	33.96	28.30	36.79	42.45	36.79	11.32	33.96	39.62	33.96	19.81
22	113.20	104.71	36.79	36.79	45.28	39.62	31.13	36.79	36.79	39.62	8.49	42.45	42.45	39.62	16.98
23	113.20	110.37	28.30	33.96	46.70	38.21	33.96	39.62	42.45	33.96	8.49	32.55	36.79	36.79	19.81
24	121.69	130.18	36.79	33.96	36.79	39.62	33.96	33.96	42.45	35.38	11.32	35.38	48.11	48.11	14.15
25	104.71	101.88	31.13	39.62	45.28	33.96	28.30	33.96	33.96	28.30	11.32	33.96	39.62	33.96	19.81
26	124.52	110.37	28.30	41.04	39.62	45.28	33.96	36.79	36.79	39.62	11.32	36.79	48.11	45.28	19.81
27	124.52	110.37	39.62	42.45	48.11	42.45	42.45	42.45	45.28	33.96	11.32	42.45	42.45	39.62	16.98
28	141.50	101.88	33.96	42.45	45.28	45.28	39.62	42.45	39.62	33.96	11.32	42.45	39.62	39.62	14.15
29	155.65	113.20	36.79	39.62	45.28	42.45	31.13	36.79	36.79	24.47	8.49	39.62	42.45	39.62	16.98
30	135.84	96.22	33.96	39.62	45.28	42.45	31.13	36.79	42.45	33.96	8.49	42.45	42.45	36.79	19.81
31	121.69	127.35	33.96	36.79	45.28	31.13	25.47	33.96	36.79	33.96	14.15	31.13	42.45	42.45	24.06
32	107.54	107.54	22.64	42.45	45.28	33.96	19.81	35.38	39.62	36.79	11.32	22.64	42.45	39.62	11.32
33	116.03	113.20	28.30	33.96	46.70	36.79	39.62	36.79	36.79	33.96	8.49	32.55	36.79	36.79	19.81
34	133.01	130.18	31.13	33.96	45.28	28.30	33.96	45.28	45.28	31.13	14.15	38.21	39.62	42.45	18.40
35	113.20	121.69	25.47	25.47	42.45	25.47	28.30	36.79	36.79	28.30	8.49	28.30	36.79	39.62	14.15
36	135.84	107.54	33.96	36.79	42.45	39.62	28.30	39.62	39.62	33.96	11.32	36.79	39.62	31.13	14.15
37	116.03	101.88	33.96	36.79	42.45	39.62	31.13	33.96	33.96	33.96	8.49	36.79	31.13	31.13	14.15
38	127.35	107.54	33.96	45.28	45.28	42.45	42.45	39.62	39.62	33.96	8.49	39.62	39.62	36.79	14.15
39	130.18	110.37	31.13	39.62	42.45	36.79	42.45	41.04	41.04	35.38	11.32	42.45	42.45	39.62	14.15
40	135.84	113.20	33.96	36.79	45.28	33.96	41.04	39.62	39.62	36.79	9.91	36.79	39.62	39.62	16.98
41	127.35	113.20	31.13	45.28	36.79	33.96	33.96	33.96	33.96	33.96	14.15	36.79	42.45	31.13	16.98
42	118.86	99.05	31.13	48.11	31.13	33.96	33.96	39.62	39.62	42.45	11.32	31.13	42.45	39.62	14.15
43	127.35	127.33	31.13	33.96	45.28	39.62	31.13	36.79	36.79	36.79	11.32	36.79	43.87	45.28	16.98
44	141.50	124.52	31.13	39.62	45.28	42.45	33.96	39.62	39.62	36.79	11.32	39.62	48.11	45.28	14.15
45	138.67	124.52	31.13	33.96	41.04	33.96	31.13	33.96	33.96	33.96	8.49	36.79	42.45	39.62	11.32
46	147.16	141.50	31.13	36.79	45.28	33.96	36.79	33.96	33.96	36.79	16.98	36.79	42.45	42.45	22.64
47	127.35	133.01	28.30	33.96	45.28	42.45	31.13	36.79	36.79	33.96	11.32	39.62	39.62	42.45	16.98
48	141.50	113.20	28.30	36.79	42.45	39.62	31.13	36.79	36.79	33.96	11.32	36.79	42.45	42.45	16.98
49	138.67	133.01	28.30	28.30	43.87	39.62	31.13	36.79	36.79	38.21	8.49	36.79	39.62	45.28	14.15
50	135.01	133.01	25.47	39.62	42.45	36.79	31.13	39.62	39.62	33.96	11.32	36.79	36.79	39.62	14.15

Appendix 12: Protonymph

REP	BL	BW	H	P1	P2	P3	D1	D2	D3	D4	D5	L1	L2	L3	L4
1	141.50	138.67	31.13	31.13	39.62	35.38	19.81	28.30	36.79	36.79	14.15	28.30	39.62	42.45	19.81
2	192.44	161.31	32.55	33.96	36.79	35.58	19.81	28.30	31.13	39.62	14.15	33.96	42.45	45.28	25.47
3	155.65	147.16	31.13	36.79	36.79	36.79	22.64	28.30	31.13	41.04	11.32	33.96	36.79	50.94	25.47
4	147.16	141.50	33.96	31.13	39.62	39.62	22.64	19.81	19.81	28.30	11.32	28.30	22.64	28.30	22.64
5	175.46	149.99	39.62	39.62	42.45	45.28	25.47	25.47	28.30	33.96	19.81	42.45	53.77	53.77	25.47
6	175.46	138.67	36.79	39.62	42.45	31.13	22.64	28.30	28.30	39.62	11.32	31.13	48.11	48.11	25.47
7	152.84	130.18	31.13	31.13	33.96	33.96	16.98	28.30	28.30	42.45	9.91	31.13	39.62	42.45	25.47
8	147.16	135.84	33.96	36.79	31.13	36.79	22.64	28.30	33.96	42.45	14.15	36.79	50.94	42.45	22.64
9	166.97	141.50	31.13	39.62	36.79	39.62	19.81	22.64	33.96	42.45	16.98	33.96	39.62	48.11	14.15
10	158.48	116.03	42.45	33.96	36.79	36.79	19.81	19.81	28.30	42.45	14.15	39.62	45.28	48.11	19.81
11	138.67	141.50	28.30	31.13	38.21	31.13	25.47	22.64	25.47	49.53	11.32	36.79	41.04	49.53	22.64
12	169.80	155.65	31.13	36.79	48.11	36.79	25.47	22.64	31.13	48.11	11.32	39.62	50.94	53.77	19.81
13	155.65	152.82	36.79	36.79	36.79	36.79	22.64	22.64	29.72	52.36	16.98	48.11	49.53	56.60	25.47
14	135.84	147.16	33.96	33.96	33.96	33.96	16.98	25.47	25.47	45.28	11.32	39.62	39.62	45.28	25.47
15	175.46	141.50	33.96	33.96	36.79	39.62	19.81	28.30	31.13	42.45	14.15	36.79	53.77	42.45	22.64
16	169.80	133.01	36.79	36.79	48.11	45.28	28.30	25.47	33.96	48.11	11.32	42.45	53.77	50.94	28.30
17	186.78	152.82	31.13	31.13	36.79	31.13	22.64	31.13	31.13	45.28	14.15	36.79	50.94	50.94	22.64
18	161.31	124.52	36.79	31.13	36.79	36.79	22.64	26.89	31.13	48.11	14.15	42.45	53.77	53.77	22.64
19	172.63	141.50	33.96	36.79	42.45	33.96	25.47	28.30	31.13	45.28	11.32	45.28	53.77	53.77	14.15
20	178.29	138.67	33.96	36.79	39.62	39.62	25.47	31.13	39.62	39.62	14.15	42.45	50.94	48.11	16.98
21	161.31	144.33	28.30	36.79	56.60	53.77	31.13	33.96	33.96	45.28	22.64	45.28	45.28	45.28	28.30
22	147.16	135.84	31.13	36.79	33.96	38.21	31.13	28.30	39.62	39.62	16.98	33.96	48.11	48.11	33.96
23	206.59	172.63	31.13	36.79	31.13	36.79	22.64	28.30	31.13	39.62	16.98	42.45	50.94	50.94	22.64
24	206.59	169.80	33.96	36.79	48.11	36.79	22.64	25.47	31.13	42.45	16.98	36.79	42.45	45.28	28.30
25	198.10	172.63	33.96	36.79	53.77	36.79	36.79	28.30	45.28	48.11	19.81	36.79	53.77	50.94	22.64
26	183.95	152.82	39.62	36.79	48.11	39.62	28.30	33.96	39.62	39.62	19.81	48.11	50.94	48.11	22.64
27	200.93	164.14	39.62	33.96	50.94	39.62	33.96	33.96	36.79	42.45	19.81	50.94	50.94	48.11	22.64
28	217.91	144.33	32.55	33.96	50.94	42.45	36.79	42.45	39.62	39.62	16.98	45.28	53.77	48.11	25.47
29	206.59	169.80	39.62	36.79	56.60	42.45	31.13	33.96	46.70	45.28	16.98	50.94	53.77	48.11	25.47
30	203.76	144.33	39.62	36.79	50.94	42.45	36.79	33.96	45.28	45.28	14.15	45.28	53.77	49.53	25.47
31	186.78	147.16	33.96	33.96	45.28	39.62	28.30	28.30	36.79	48.11	14.15	42.45	50.94	53.77	25.47
32	164.14	141.50	28.30	42.45	39.62	39.62	28.30	28.30	36.79	50.94	11.32	33.96	53.77	53.77	25.47
33	164.14	135.84	28.30	33.96	36.79	39.62	25.47	25.47	31.13	45.28	11.32	33.96	50.94	31.13	28.30
34	189.61	141.50	33.96	33.96	52.36	41.04	33.96	31.13	45.28	48.11	18.40	45.28	48.11	53.77	19.81
35	189.61	147.16	31.13	33.96	50.94	39.62	33.96	39.62	39.62	33.96	11.32	45.28	53.77	45.28	19.81
36	141.50	133.01	33.96	33.96	42.45	33.96	31.13	31.13	36.79	33.96	14.15	39.62	48.11	45.28	16.98
37	186.78	149.99	33.96	33.96	48.11	33.96	31.13	33.96	42.45	42.45	11.32	50.94	53.77	42.45	16.98
38	186.78	144.33	39.62	33.96	50.94	33.96	32.55	41.04	42.45	42.45	14.15	42.45	53.77	48.11	19.81
39	206.59	152.82	36.79	42.45	50.94	42.45	31.13	33.96	39.62	39.62	22.64	48.11	58.02	56.60	28.30
40	166.97	149.99	33.96	33.96	42.45	39.62	25.47	28.30	36.79	33.96	14.15	45.28	50.94	48.11	19.81
41	189.61	130.18	33.96	31.13	42.45	33.96	28.30	28.30	28.30	42.45	15.57	22.64	25.47	33.96	19.81
42	203.76	164.14	31.13	33.96	41.04	36.79	33.96	28.30	36.79	36.79	14.15	33.96	50.94	48.11	16.98
43	149.99	155.65	25.47	31.13	45.28	31.13	31.13	33.96	39.62	45.28	14.15	36.79	48.11	42.45	19.81
44	192.44	158.48	31.13	33.96	45.28	36.79	25.47	25.47	25.47	45.28	16.98	42.45	48.11	50.94	19.81
45	164.14	155.65	28.30	33.96	48.11	33.96	22.64	33.96	31.13	48.11	14.15	42.45	33.96	45.28	22.64
46	181.12	138.67	31.13	42.45	42.45	32.55	25.47	25.47	48.11	36.79	14.15	36.79	46.70	45.28	19.81
47	181.12	161.31	28.30	33.96	48.11	33.96	24.06	24.06	36.79	42.45	14.15	32.55	46.70	36.79	16.98
48	166.97	130.18	28.30	31.13	48.11	36.79	25.47	25.47	36.79	36.79	11.32	35.38	42.45	42.45	19.81
49	169.80	141.50	33.96	33.96	42.45	36.79	31.13	32.55	39.62	36.79	11.32	33.96	42.45	42.45	19.81
50	164.14	152.82	31.13	31.13	42.45	33.96	28.30	31.13	42.45	33.96	12.74	38.21	39.62	43.87	16.98

Appendix 13: Deutonymph

REP	BL	BW	H	P1	P2	P3	D1	D2	D3	D4	D5	L1	L2	L3	L4
1	311.30	220.74	39.62	39.62	50.94	42.45	31.13	39.62	46.70	50.94	22.64	49.51	59.43	59.43	31.13
2	215.08	175.45	45.28	39.62	42.45	48.11	25.47	25.47	28.30	50.94	22.64	38.21	56.60	53.77	25.47
3	294.32	220.74	45.28	42.45	45.28	48.11	25.47	28.30	36.79	53.77	25.47	50.94	42.45	56.60	31.13
4	203.76	189.61	42.45	42.45	48.11	45.28	25.47	25.47	25.47	45.28	25.47	31.13	36.79	48.11	28.30
5	189.61	175.46	33.96	50.94	48.11	45.28	25.47	28.30	33.96	53.77	14.15	48.11	36.79	56.60	28.30
6	217.91	166.97	42.45	39.62	48.11	50.94	25.47	25.47	33.96	56.60	14.15	39.62	53.77	56.60	25.47
7	198.10	141.50	36.79	39.62	42.45	33.96	25.47	31.13	39.62	42.45	22.64	36.79	56.60	33.96	25.47
8	217.91	101.88	39.62	42.45	39.62	45.28	19.81	22.64	28.30	48.11	19.81	31.13	48.11	59.43	25.47
9	175.46	147.16	33.96	42.45	36.79	39.62	31.13	36.79	42.45	39.62	19.81	33.96	42.45	45.28	22.64
10	198.10	141.50	31.13	36.79	39.62	28.30	19.81	19.81	28.30	50.94	19.81	22.64	42.45	50.94	28.30
11	302.81	212.25	50.94	48.11	45.28	49.53	22.64	28.30	31.13	59.43	24.06	48.11	67.92	70.75	33.96
12	204.89	198.10	41.04	39.62	48.11	45.28	25.47	25.47	22.64	56.60	31.13	50.94	42.45	56.60	29.72
13	166.97	135.84	39.62	33.96	43.87	36.79	25.47	25.47	28.30	50.94	19.81	31.13	39.62	48.11	25.47
14	192.44	152.82	36.79	31.13	31.13	39.62	25.47	25.47	45.28	45.28	14.15	36.79	48.11	45.28	22.64
15	209.42	164.14	33.96	36.79	36.79	36.79	25.47	22.64	42.45	36.79	19.81	39.62	50.94	50.94	22.64
16	186.78	149.99	39.62	39.62	42.45	42.45	22.64	25.47	33.96	48.11	16.98	42.45	53.77	50.94	19.81
17	189.61	141.50	39.62	31.13	45.28	33.96	22.64	28.30	39.62	45.28	14.15	39.62	50.94	53.77	22.64
18	240.55	186.78	45.28	36.79	59.43	50.94	28.30	31.13	50.94	53.77	22.64	59.43	62.26	62.26	28.30
19	297.15	200.93	48.11	45.28	45.28	48.11	22.64	28.30	31.13	59.43	22.64	48.11	56.60	59.43	33.96
20	234.89	198.10	39.62	39.62	48.11	45.28	28.47	25.47	28.30	50.94	19.81	31.13	39.62	48.11	25.47
21	220.74	186.78	39.62	36.79	53.77	39.62	33.96	33.96	48.11	48.11	22.64	39.62	56.60	62.26	31.13
22	288.66	209.42	43.87	42.45	62.26	50.94	25.47	45.28	50.94	62.26	22.64	56.60	62.26	65.09	33.96
23	266.02	198.10	42.45	43.87	65.09	39.62	31.13	33.96	28.30	48.11	28.30	53.77	59.43	62.26	31.13
24	266.02	200.93	50.94	42.45	62.26	48.11	28.30	36.79	45.28	59.43	28.30	56.60	56.60	67.92	33.96
25	198.10	175.40	39.62	48.11	33.96	48.11	22.64	25.47	28.30	53.77	28.30	48.11	42.45	56.60	28.30
26	280.10	212.25	50.94	45.28	70.75	56.60	31.13	38.21	45.28	62.26	14.15	59.43	70.75	65.09	33.96
27	308.47	226.40	39.62	42.45	62.26	53.77	28.30	36.79	33.96	59.43	25.47	56.60	62.26	65.09	33.96
28	268.85	200.93	45.28	36.79	59.43	42.45	36.79	36.79	42.45	50.94	28.30	50.94	62.26	62.26	28.30
29	297.15	220.74	48.11	42.45	62.26	50.94	28.30	31.13	42.45	59.43	25.47	53.77	65.09	67.92	33.96
30	302.81	212.25	48.11	42.45	65.09	50.94	31.13	36.79	48.11	59.43	28.30	56.60	59.43	62.26	31.13
31	203.76	169.80	39.62	38.21	45.28	39.62	25.47	28.30	33.96	45.28	21.23	39.62	48.11	53.77	22.64
32	203.76	175.46	33.96	36.79	42.45	36.79	19.81	28.30	38.21	39.62	14.15	33.96	48.11	48.11	22.64
33	198.10	189.61	39.62	39.62	53.77	39.62	33.96	33.96	36.79	45.28	22.64	33.96	48.11	53.77	25.47
34	178.29	155.65	42.45	39.62	33.96	36.79	25.47	19.81	31.13	53.77	22.64	39.62	48.11	56.60	25.47
35	169.80	158.48	45.28	39.62	45.28	50.94	25.47	28.30	36.79	39.62	22.64	31.13	39.62	48.11	25.47
36	209.42	178.29	33.96	36.79	36.79	42.45	28.30	25.47	42.45	42.45	22.64	39.62	48.11	50.94	22.64
37	234.89	172.63	45.28	36.79	45.28	42.45	19.81	25.47	25.47	48.11	16.98	31.13	53.77	59.43	25.47
38	263.19	186.18	39.62	42.45	59.43	45.28	33.96	35.96	42.45	53.77	25.47	56.60	59.43	59.43	28.30
39	209.42	149.99	36.79	36.79	36.79	42.45	25.47	25.47	33.96	39.62	22.64	35.38	45.28	48.11	19.81
40	198.10	189.61	39.62	39.62	53.77	39.62	33.96	33.96	36.79	45.28	22.64	33.96	48.11	53.77	25.47
41	220.74	169.80	38.21	36.79	42.45	42.45	25.47	25.47	33.96	53.77	14.15	50.94	56.60	62.26	25.47
42	251.87	178.29	33.96	36.79	41.04	36.79	22.64	24.06	25.47	50.94	19.81	31.13	50.94	53.77	28.30
43	237.72	183.95	31.13	39.62	48.11	39.62	19.81	25.47	22.64	53.77	14.15	36.79	42.45	53.77	25.47
44	260.36	200.93	39.62	39.62	45.28	45.28	25.47	25.47	35.38	53.77	25.47	28.30	48.11	53.77	31.13
45	254.70	186.78	28.30	39.62	45.28	45.28	28.30	31.13	31.13	53.77	25.47	39.62	42.45	53.77	31.13
46	271.68	178.29	33.96	41.04	42.45	43.87	25.47	25.47	33.96	48.11	25.47	39.62	45.28	56.60	31.13
47	212.25	178.29	33.96	39.62	48.11	36.79	22.64	25.47	28.30	42.45	14.15	31.13	39.62	48.11	25.47
48	226.40	181.12	33.96	39.62	45.28	36.79	22.64	25.47	25.47	50.94	22.64	28.30	53.77	52.36	31.13
49	260.36	198.10	36.79	36.79	42.45	42.45	28.30	25.47	28.30	53.77	25.47	36.79	48.11	59.43	25.47
50	257.53	192.44	36.79	33.96	42.45	39.62	22.64	24.06	33.96	53.77	25.47	33.96	52.36	59.43	31.13

<u>Key</u>:

1 - 10 Mbita Point Field Station; 11 - 20 Rusinga Island; 21 - 30 Mombasa;

31 - 40 Homa-Bay; 41 - 50 Embu.

Appendix 14. Cluster analysis based on variables and 200 OTUS

SIMILARITY LEVEL = 1.00 (1 cluster)

Cluster 1: 2 OTUS - 187 (ZAM), 197(ZAM).

Unclustered: 198 OTUS

SIMILARITY LEVEL = 0.90 (2 clusters)

Cluster 1: 2 OTUS - 182(ZAM); 198(ZAM).

" 2: 2 " - 187(ZAM); 197(ZAM).

Unclustersd: 196 "

SIMILARITY LEVEL 0.70 (4 clusters).

Cluster 1: 2 OTUS 102(ZAN); 104(ZAN).

" 2: " 130(TAN); 155(CAM).

" 3: " 182(ZAM); 198(ZAM).

" 4: " 187(ZAM); 197(ZAM).

Unclustered: 192 OTUS.

SIMILARITY LEVEL =0.60 (11 Clusters).

Cluster 1: 12 OTUS-3(NIG); 19(NIG); 70(BUR); 84(BUR); 95(GHA)
97(GHA); 102(ZAN); 104(ZAN);
113(ZAN); 130(TAN); 136(TAN)
155(CAM)

" 2: 2 OTUS - 18(NIG); 122(TAN).

" 3: 2 " - 54(UGA); 68(BUR).

" 4: 4 " - 73(BUR); 138(TAN); 189(ZAM); 200(ZAM).

" 5: 2 " - 74(BUR); 159(CAM).

" 6: 3 " - 78(BUR); 142(CAM); 143(CAM).

" 7: 2 " - 90(GHA); 154(CAM).

" 8: 2 " - 114(ZAN); 157(CAM).

" 9: 2 " - 119(ZAN); 120(ZAN).

" 10: 4 " - 175(RWA); 182(ZAM); 185(ZAM); 198(ZAM)

" 11: 2 " - 187(ZAM); 197(ZAM).

Unclustered: 164 OTUS.

SIMILARITY LEVEL = 0.50 (3 Clusters)

Cluster 1: 129 OTUS

" 2: 2 " - 9(NIG); 124(TAN).

" 3: 3 " - 101(ZAN); 156(CAM); 177(RWA).

Unclustered: 66 OTUS.

1(NIG)	25(KEN)	49(UGA)	82(GHA)	127(TAN)	162(RWA).
2 "	27 "	50 "	83 "	128 "	163 " .
4 "	29 "	53 "	88 "	131 "	164 " .
5 "	30 "	55 "	99 "	132 "	106 " .
6 "	31 "	59 "	105(ZAN)	134 "	171 " .
7 "	33 "	60 "	106 "	139 "	172 " .
11 "	34 "	64(BUR)	110 "	140 " .	
14 "	36 "	67 "	111 "	141(CAM).	
15 "	39 "	71 "	112 "	148 " .	
21(KEN)	41(UGA)	76 "	121(TAN)	149 " .	
23 "	45 "	80 "	125 "	158 " .	
24 "	46 "	81(GHA)	126 "	161(RWA).	

SIMILARITY LEVEL 0.40 (1 Cluster).

Cluster 1: 190 OTUS.

Unclustered: 10 OTUS -2(NIG); 6(NIG); 25(KEN); 29(KEN); 30(KEN); 34(KEN); 41(UGA); 125(TAN); 131(TAN); 163(RWA).

SIMILARITY LEVEL = 0.30 (1 Cluster).of 200 OTUS.

Appendix 15. Cluster analysis based on 7 ratios and 200 OTUS.

SIMILARITY LEVEL = 0.57 (2 Clusters).

Cluster 1: 3 OTUS - 43(UGA); 109(ZAN); 119(ZAN).

" 2: 2 " - 98(GHA); 150(CAM).

Unclustered: 195 OTUS.

SIMILARITY LEVEL 0.37 (15 Clusters).

Cluster 1: 2 OTUS - 42(UGA); 126(TAN).

" 2: 3 " - 43 " ; 109(GHA); 119(ZAN).

" 3; 2 " - 50 " ; 176(RWA).

" 4: 2 " - 70(BUR); 179 " .

" 5: 2 " - 80 " ; 100(GHA).

" 6: 2 " - 81(GHA); 106(ZAN).

" 7: 3 " - 89 " ; 113 " ; 165(RWA).

" 8: 3 " - 90 " ; 120 " ; 153(CAM).

" 9: 2 " - 92 " ; 97(GHA).

" 10: 2 " - 98 " ; 150(CAM).

" 11: 2 " - 121(TAN); 167(RWA).

" 12: 2 " - 125 " ; 136(TAN).

" 13: 2 " - 140 " ; 193(ZAM).

" 14: 2 " - 164(RWA); 196(RWA).

" 15: 2 " - 174 " ; 195 " .

Unclustered: 169 OTUS.

SIMILARITY LEVEL = 0.27 (21 Clusters).

Cluster 1: 86 OTUS.

" 2: 2 OTUS - 3(NIG); 160(CAM).

" 3: 2 " - 5 " ; 83(GHA).

" 4: 6 " - 6 " ; 6(NIG): 10(NIG); 81(GHA); 106(ZAN);

116(ZAN); 188(ZAM).

" 5: 6 " - 9(NIG); 14(NIG); 107(ZAN); 111(ZAN); 145(CAM); 159(CAM).

" 6: 3 " - 15(NIG); 92(GHA); 97(GHA).

" 7: 2 " - 18(NIG); 19(NIG).

" 8: 5 " - 27(KEN); 82(GHA); 117(ZAN); 125(TAN); 136(TAN).

" 9: 3 " - 29(KEN); 53(UGA); 101(ZAN).

" 10: 4 " - 30(KEN); 75(BUR); 130(TAN); 138(TAN).

" 11: 2 " - 36(KEN); 65(BUR).

" 12: 2 " - 42(UGA); 126(TAN).

" 13: 3 " - 43(UGA); 109(GHA); 119(ZAN).

" 14: 2 " - 49(UGA); 102(ZAN).

" 15: 2 " - 60(UGA); 127(TAN).

" 16: 2 " - 64(UGA); 156(CAM).

" 17: 5 " - 80(BUR); 95(GHA); 100(GHA); 114(ZAN); 182(ZAM).

" 18: 2 " - 84(GHA); 139(TAN).

" 19: 2 " - 131(TAN); 158(CAM).

" 20: 2 " - 132(TAN); 152(CAM).

" 21: 2 " - 149(CAM); 181(ZAM).

Unclustered: 55 OTUS.

4(NIG);	37(KEN);	63(BUR);	105(ZAN);	148(CAM);	192(ZAM);
7 " ;	38 " ;	67 " ;	110 " ;	151 " ;	197 " ;
11 " ;	41(UGA);	71 " ;	122(TAN);	154 " ;	198 " ;
17(NIG);	44(UGA);	72(BUR);	123(TAN);	161(RWA);	199(ZAM);
20 " ;	48 " ;	74 " ;	128 " ;	162 " ;	200 " ;
21(KEN);	51 " ;	77 " ;	134 " ;	173 " ;	
22 " ;	54 " ;	78 " ;	137 " ;	186(ZAM);	

24 " ;	55 " ;	93(GHA);	141(CAM);	189 " ;
31 " ;	61(BUR);	96 " ;	143 " ;	190 " ;
32 " ;	62 " ;	99 " ;	144 " ;	191 " .

SIMILARITY LEVEL = 0.07 (1 Cluster).

Cluster 1: 200 OTUS.

KEY:

BUR=Burundi; CAM=Cameroon; GHA=Ghana; KEN=Kenya; NIG=Nigeria;

RWA=Rwanda; TAN=Tanzania; UGA=Uganda; ZAM=Zambia;

ZAN=Zanzibar.