THE ECOLOGY AND BIOLOGY OF *OEDELEUS SENEGALENSIS* KRAUSS (1877) (ORTHOPTERA : ACRIDIDAE} IN NIGERIA

BY

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DEDICATION

To my dear wife

NGOZI

and my children

Adaora

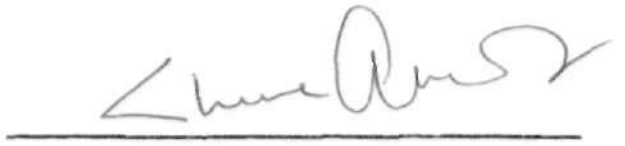
Jachinma

Chigozie

Kenechi

DECLARATION

I hereby declare that this thesis is a record of my own research. It has not been presented by me or anyone else in any previous application for a higher degree.



CHINENYE ANENE

20-2-89

DATE

CERTIFICATION

This thesis entitled "The Ecology of the Oedaleus senegalensis (Orthoptera : Acrididae) Krauss in Nigeria" by Chinenye Anene meets the regulations governing the award of the degree of Doctor of Philosophy of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

The distribution, ecology and biology of the grasshopper, Pedaleus senegalensis Krauss, in Nigeria were investigated. Results showed that the known distribution of 0. senegalensis in Nigeria has considerably increased, being extended and limited to areas North of Latitude 9°N. These areas comprised practically the Sahel, Sudan and northern one-third of the Guinea savanna ecological zones. Observations on the monthly fluctuations in the numbers of the grasshopper in three ecozones showed that the grasshopper was more abundant when rainfall was low, relative humidity low, and temperature high. The difference in occurrence and distribution of the grasshopper was a reflection of the variations in the climatic and vegetation conditions of the ecozones.

Seasonal population studies showed that the number of the brown morph exceeded the green in all the ecozones with an overall ratio of 3.4:1. The male grasshoppers out-numbered the females with a ratio of 1.23:1 which was significantly different from 1:1 at the 0.1% level.

Evidence from two peak populations observed over the years of this study showed that 0. senegalensis has two annual generations in Nigeria.

Migration of adult populations of 0. senegalensis suggested by the differences in numbers and stages of sexual maturity of the day and night populations was confirmed by morphometric analysis.

Adult female 0. senegalensis contained an average of 40.51 + 2.4 ovarioles. The mean number of eggs per pod of samples from the field and those laid in the laboratory were 26.86 + 2.2 and 27,42 + 2.2 respectively. The incubation period of the eggs ranged between 16.98 + 3.7 and 20.11 + 2.2 days.

The green and brown males, and green females were morphometrically homogenous. Significant morphometric differences existed between the green and brown dimorphic females. Day populations were morphometrically different from the night populations, indicating differences in their spatial origin and the existence of the 0. grasshopper in both solitaria and gregaria phases.

Three dipterous flies belonging to family Wemestrinidae and Sarcophagidae were common parasites of the nymphs and adults of 0. senegalensis. Numerous invertebrate and vertebrate predators preyed *on* the nymphs and the adults of the grasshopper. Birds were probably the most important and regular predators of the grasshopper. One insect parasite and eight species of insect predators were important enemies of the eggs of 0. senegalensis.

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CHAPTER ONE

INTRODUCTION

Cereal and other grain crops can be successfully produced in commercial quantities in the Sudan and Sahel Savanna ecological zones of Nigeria. In fact these crops form the main staple in the diets of the peoples of these areas. However, one of the major constraints to increased production of these crops is inadequate rainfall. Another major constraint is the incidence of pests especially grasshoppers which sporadically destroy farmers crops. Farmers in these areas have therefore regarded the incidence of grasshoppers and the destruction of their crops as a natural phenomenon, over which they have no control.

In recent years, acridoid grasshopper out-breaks have been reported in northern Nigeria and especially in the Sahel and drier parts of the Savanna zones (Oyidi 1975, 1977, 1982, and Hergert,1975). Oyidi (1974) estimated the damage by grasshoppers to cowpea and millet in Katsina and Daura Emirates at ₦208,000 (Two Hundred and Eight Thousand Naira). This estimate he explained, applied to only a very small fraction of cowpea and millet growing areas invaded by grasshoppers. In Kano State, records showed that whereas only four areas were attacked in 1973, fifteen areas were affected in 1975 (Hergert, 1975). In 1976, eight locations were affected by grasshoppers in Bauchi State,

while in Borno State, large areas of cowpea and millet were infested and destroyed by grasshopper (Anon, 1977).

Oyidi (1977) identified four major grasshopper outbreak areas in northern Nigeria and these cover the entire Sahel, the Sudan zone and some parts of the Guinea savanna zone.

Of the ninety-four species of the Acridoidea identified in the Sahel zone (Golding, 1948), Oedaleus senegalensis (Krauss) which invaded the northern parts of Nigeria in 1976 (Bindra, 1977), was the most important. Its preference for graminaceous crops makes it a potentially serious pest of cereal crops. This species also was the most important of some twenty other species of grasshoppers of economic importance recorded in the Sahel ecological zone of west Africa (Anon, 1977, Popov, 1980; Cheke, Fishpool and Ritchie, 1980). This investigation is therefore designed to study aspects of its ecology and biology with a view to evolving effective control strategies.

As Bhattia (1966) observed, the study of the life history of pests is not only important from the academic point of view, but is of practical values as it leads to the effective and economic control of the pests. For instance, it is important to know when and where oviposition is likely to occur so that emergence of hoppers can be reasonably anticipated

and warnings issued to adjoining areas. Secondly, surveillance of fledglings provides information on the migration of the young hoppers from breeding grounds preparatory to the invasion of other areas. In other words, bio-ecological studies are crucial in formulating rational pest control measures (Krebs), 1978). Atkinson (1931) suggested that for control of pests to be effective, cultural methods based on ecological study of the insect must be adopted. The importance of the ecological distribution of grasshoppers within large bio-geographical regions has been stressed (Uvarov, 1953; Roy, 1960). Uvarov (1951) has suggested that better knowledge of areas where locusts are able to exist permanently without undergoing complete phase transformation may help in understanding and preventing the development of outbreaks in known outbreak areas. Farrow (1974) is of the opinion that long term solution to the problem of locust outbreaks should be based on field management, rather than the continued dependence on insecticides.

It is interesting to note that although large scale control measures have been instituted against Oedaleus grasshopper (Anon, 1977), plagues continued to occur, inflicting serious widespread damages to crops annually. It is hoped therefore that this work will assist in providing solutions to the problems posed by O. senegalensis, as well as encourage detailed

studies along similar lines on other serious insect pests of crops in Nigeria.

The Objectives of this study were:

(a) To establish the limits of the distribution of Oedaleus senegalensis in Nigeria and the factors governing its distribution.

(b) To study the population density and its seasional fluctuation.

(c) To study the biology of this pest.

(d) To identify the natural enemies of the grasshopper.

CHAPTER TWO

LITERATURE REVIEW

The importance of Oedaleus senegalensis (Krauss) has in the past been overlooked owing in part to the attribution of the damages done to crops to other grasshopper species and its occurrence at very low densities (Batten, 1969; Hergert, 1975). During the last decade, however, the occurrence of large population of this grasshopper has been frequently reported throughout West African region, the Middle East, and the Indian subcontinent, causing severe damage to crops (Bindra 1977; Boys, 1978; Launois, 1978; Cheke, Fishpool and Forrest, 1980; Popov, 1980; Amatobi, 1982). Its preference for graminaceous crops has attracted considerable attention and observations. In this investigation, available literature on this grasshopper is reviewed under the following headings: General distribution, Habitat, Behaviour, Biology, damage and economic importance.

2.1 General Distribution

Oedaleus senegalensis has a wide but rather peculiar distribution, being found "almost everywhere" in favoured habitats with mean annual Isohyets of between 250 - 1000mm. Its distribution as shown by Batten (1969) and modified by Popov (1976) is detailed in Figure 1. These areas included the southern dry

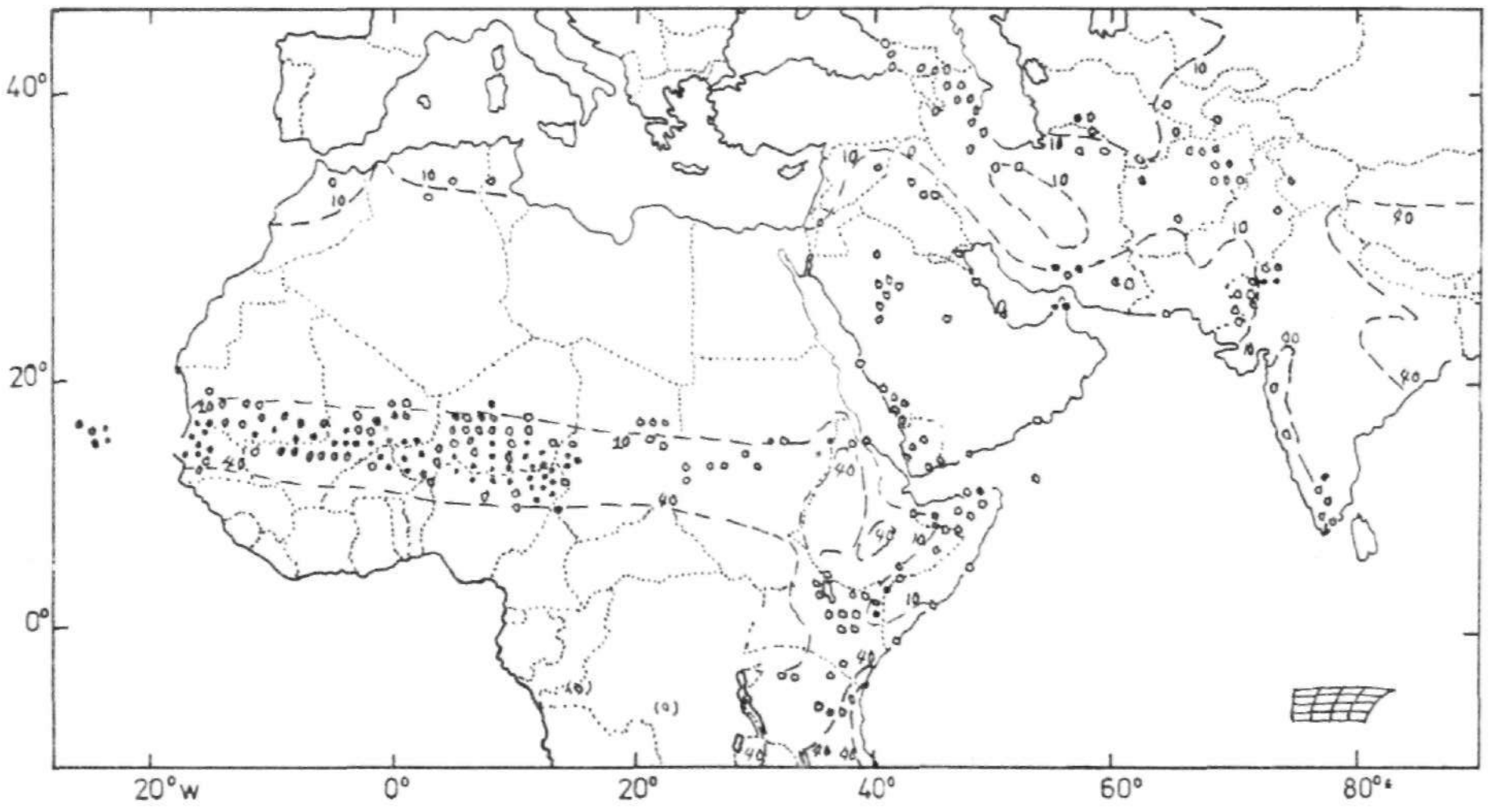


Fig.1. Distribution area of Oedaleus senegalensis o-Locality of occurrence ●-recorded gregarisation ---- mean annual Isohyet (in). (As per Batten 1969 and modified by Popov 1980).

tropical zone of the Sahara, approximately bordered by annual isohyet lines nearing 200 - 1000mm. In West Africa, the distribution zone is a band of territory between latitudes 10 and 20°N running approximately parallel to the equator, and in East Africa, it extends downwards to Kenya and Tanzania. The distribution area in the Arabian peninsula, Middle East and Indian Sub-continent is wide, although in an apparently patchy manner (Figure 1).

Batten(1969), indicates that O. senegalensis occurs widely throughout drier parts of West Africa. Mallamaire (1948), records that it is found "Un peu partout" (almost everywhere) from Senegal to Chad. Although Oedaleus has not been reported in the wetter countries of the northern half of Africa bordering the Gulph of Guinea, it has been found occurring in the wetter upland areas of Tibesti and Ahaggar (Chopard, 1943). Despite the wide distribution of this grasshopper throughout the Middle East, there are no records of its occurrence in Turkey, Israel or Lebanon (Batten, 1969). Chopard (1943) remarks that O. senegalensis appears not to be found in the Sahara as there are no records of it between latitudes 20° and 33°N . The few known records of occurrence in the north of the Sahara are from Tunisia, northern Algeria, Morocco and the Canary Islands (Rungs, 1949).

O. senegalensis occurs in all countries of the Arabian peninsula and in the middle East, species of the grasshopper have been found in Jordan, Syria and Iraq (Weidner, 1962). In Iran, O. senegalensis is described as having a general distribution (Bei-Bienko and Richter, 1960; Frarahbakhsh, 1961; Descamps and Donskoff, 1965) and in India O. senegalensis is said to be endemic. (Sardar Singh and Bhatia, 1965; Bhatia and Ahluwalia, 1966). Froggatt (1910) and Zacher (1925) observed the occurrence of O. senegalensis in Australia, although in a later work (Zacher, 1949), suggested that O. australis is conspecific with O. senegalensis.

The distribution of O. senegalensis in the USSR includes all republics of Transcaucasia, and from the Turkmen, Uzbeck and Tadzhik republics of Soviet Central Asia (Mishchenko, 1949).

O. senegalensis has been recorded in most countries of Eastern Africa. Miller (1929), recorded it in Tanzania, and Kevan and Knipper (1955), reported its occurrence in Central and north-eastern Kenya.

The presence of O. senegalensis in Nigeria is not a recent phenomenon. Golding (1934) observed that the adults were present in northern Nigeria between 23 May and 24 October, 1931. Equally, Golding (1948) observed that O. senegalensis occurs most frequently on farmlands and are distributed everywhere "in the

inland habitats" of Nigeria north of 11°N. Popov (1970), in his preliminary report on the northern states of Nigeria, reported the presence of O. senegalensis in parts of the North-West and North-Eastern states of Nigeria. That was confirmed by Jago(1971), who recorded it as a crop pest in northern Nigeria.

Broadly, much of the distribution areas of the O. senegalensis lie either in the warm tropical rainfall areas of West Africa, the Sudan, Tanzania and North West India, or the cooler tropical and Sub-tropical rainfall areas of North Africa and the Middle East (Batten, 1969).

2.2 Habitat

Records of the habitats of O. senegalensis indicate that it tends to favour semi-arid areas, and has a preference for ovipositing in light or sandy soils (Batten Loc cit.).

In Mali, O. senegalensis was referred to as being distributed throughout the 'drier habitats' (Davey, Descamps and Damange, 1959), while Descamps (1965), indicated that it was found in the comparatively dry Sudan-Sahel vegetation zone and none occurred in the slightly wetter zones to the south with Sudan - xerophile and Sudan - mesophile vegetation. The

preference for dry habitats is also seen in northern Cameroon where O. senegalensis was more common in the drier areas than in the wetter zones of the Benue valley (Descamps, 1953).

The distribution of O. senegalensis was found to follow a well defined ecological zonation in Trucial Oman (Batten, 1969). Adults were found most common on the silty parts of the Jiri plain, while on the gravelly foot stretches of the plain and on the foot hills, the densities were lower; and on the sand, adults were rare or absent.

Joyce (1952), observed that O. senegalensis occurs most abundantly on light dry soil and very commonly in short grass areas in the Sudan, and in cage experiments O. senegalensis was observed to show a definite preference for 'light' soils, where it laid eggs on the sides of the cages if no such soils were available, although some laying did occur in clay soil (Joyce Loc. cit).

Descriptions of the habitats in which O. senegalensis has been found in the more temperate latitudes are few. Weidner (1962) indicated that it was recorded in Iraq on arable lands and in areas with steppe vegetation while in Iran, Descamps and Donskoff (1965) and Bei-Bienko and Richter (1960) recorded the grasshopper as occurring frequently on 'Saline terrain' and on slopes in sandy localities generally covered with

scrub and 'low' vegetation respectively. Kobakhidze (1963) observed that adults occurred on grassland massifs in Georgia, and Mishchenko (1949) described them as being frequent on dry steppe land with 40% ephemeral vegetation cover in the USSR.

In West Africa (Anon, 1978), the habitats in which O. senegalensis is found is described as being mildly or not wooded, ephemeral steppe or grassland which develop on sandy soils, trimmed perennial or annual graminaceous plants. Chopard and Villiers (1950) indicated that in Niger, O. senegalensis was found along the edges of wadis on sandy ground often covered by grass tussocks, including Cymbopogon proximus and Panicum turgidum. Boys (1978) observed that Oedaleus occurs freely in the natural grassland sites and cultivated millet fields in Niger. In Somalia, adults were shown to be found on almost bare sand dunes and in very dry grass-steppe areas whereas in Kenya they were found in vegetation cover described as desert scrub, desert grass or thorn bush (Kevan and Knipper, 1961). Bhatia and Ahluwalia (1966) indicate that adults were found on generally sandy areas and light soil was stated to be preferred for oviposition. Similarly in the Cape Verde Island laying was observed to occur most frequently in sandy areas of the coastal plains (Saravia,1962).

In Nigeria Golding (1948), states that 0. seneqalensis is found most frequently on farmlands while Bindra (1977) observed the distribution and oviposition habitats of this grasshopper on fallow lands, grazing fields and cropped fields,, Amatobi (1982) observed that £. seneqalensis prefers areas that have less than 40% vegetation cover and are found on bare ground, scanty or low vegetation and shows definite preference for ovipositing on tops and sides of ridges.

The most comprehensive description of the habitats in which £. seneqalensis is found is by Popov (1980). He states as follows: "Ecologically, the egg fields of 0.. Senegal ensis are associated with sandy soils and open steppe vegetation with predominance of grasses such as the perennial Aristida pallida and the annual Cenchrus biflorus$_t$ and sometimes a scatter of trees and/or shrubs. The laying habitats comprise some of the most common communities of the Sahel and the majority are associated with shifting cultivation of millet (Pennisetum americanum), which is the most common rainfed subsistence cereal crop of the Sahel. The laying habitats of 0. seneqalensis range from clean-weeded to unweeded fields and fallows at all stages of regeneration. _0. seneqalensis is one of the rare grasshopper species that readily uses millet fields *as* oviposition sites, millet being one of its preferred food plants".

Historical evidence corrobroates the general concensus of workers that O. senegalensis has a preference for semi-arid areas, and for ovipositing in well-drained 'light' or sandy soils. Such conditions may often occur on land recently turned fallow, thus the expansion of cultivated areas particularly in the drier tropical countries where crops are likely to be mainly graminaceous may create suitable and extensive habitats for breeding by this species.

2.3 Behaviour

Extensive studies have been carried out on the behaviour of O. senegalensis. These studies are reviewed under the following headings: Gregarisation, Swarming and Migration, Mating and Oviposition behaviour, Diurnal activities.

2.3.1 Gregarisation, Swarming and Migration:

Available literature indicatesthat Oedaleus nymphs could aggregate and march in bands, and that swarming adults could migrate over some distances. Saravia (1962) observed loose swarms, each estimated at half a million insects and small concentrations of hoppers in Cape Verde Islands. In the Sudan (Joyce, 1952), noticed concentrations of hoppers in June near Kassala and in July in the Gash delta where small groups of marching hoppers covered a total area of over ½km^2. Kevan and Knipper (1955), recorded a loose flight at Wajir in

Kenya. Batten (1969) observed that an upsurge of the grasshopper occurred in Morocco in the summer of 1949, and a thin swarmlet was recorded in southern Mauritania in September, 1961.

In India, in 1962, the nymphs were found marching in bands and adults flying in a swarm of about nine square kilometers at a height of 1 to 2 metres above the ground (Bhatia and Ahluwalia, 1962). Again in 1964, the upsurge was described as being in 'epidemic proportions', (Sardar Singh and Bhatia, 1965). Batten (1969) is of the opinion that although the terms band and swarm have been used to describe nymphal and adult groupings of O. senegalensis there is no evidence to suggest that this species forms swarms comparable in size to the large swarms of the major plague locusts, but it may be assumed that the use of these terms is an indication of gregarious behaviour. In Mali, Popov (1976), indicates that gregarious adults make up loose swarms which fly sometimes during the day but more often during the night. This was confirmed by Riley and Reynolds (1983) who established that O. senegalensis fly together at up to 600-700m above ground level and are capable of covering more than 100km in just one night.

Popov (1975) and Jago (1977) have asserted that O. senegalensis migrates from the south at the beginning of the wet season with the northward progression of the

Inter-continental convergence zone and return with the retreat, and in confirmation of this, Lecoq (1978), described how a population of O. senegalensis changed during the course of a season and how numerous adults disappeared from his study areas in Upper Volta. He concluded that their departure was part of an adaptive migration which is related to the movements of the Intercontinental Convergence Zones.

The large numbers of O. senegalensis recorded in Nigeria in 1976 (Bindra 1977), were the immigrants from the Maradi and Zinder regions of Niger which were reported moving south as part of an end-of-season migration, induced by a combination of very high populations of locally bred insects, and an unusually early cessation of the rain (Cheke, Fishpool and Forrest, 1980).

2.3.2 Mating and Oviposition Behaviour:

The behaviour of O. senegalensis of flickering their legs, when sexually excited is of interest. Cheke, Fishpool and Forrest (Loc. cit.) observed that before mating male and female grasshoppers make displays by thrusting and flexing their hindlegs. This action is more prominent in males. The male then walks towards the female, slows down as it approaches closer, and holds its body at an angle of 30 degrees to the females' orientation. When the female flexes legs, the male advances rapidly before jumping up and landing on the

female's back. The female then twists her abdomen to her right and the male remaining mounted on the female then moves his abdomen to effect copulation. Bhatia and Ahluwalia (1966), and Page (1977), indicate that copulation can be maintained either with the males on top of the females, or with the sexes pointing in opposite directions.

O. senegalensis has preference for ovipositing in light and sandy soil (Saravia, 1962; Bhatia and Ahluwalia, 1966; Batten, 1969; Bindra, 1977; Popov, 1980). O. senegalensis lays preferentially on or near slopes which may be an adaption associated with properties of water retention characteristics of sandly slopes (Cheke, Fishpool and Ritchie, 1980; Amatobi, 1985). The process of oviposition has been described by Cheke, Fishpool and Ritchie (Loc. cit.). They observed that laying which could last at least 1 hour 45 minutes takes place even at mid-day under strong sunshine and away from any vegetation in areas devoid of shade. On the contrary, Popov (1980) believes that laying mostly takes place during the night. The ovipositing females stand with their antennae pointing upwards at an angle of 60 degrees to the ground, the hind legs were often raised up above the soil, the abdomen throbbed continually and the insects slowly moved their bodies horizontally from side to side. After the pod was completed, the females retracted their abdomens and rested over the site for 30 seconds or more before starting to cover the pods with sand.

The distribution of the O. senegalensis egg pods (Popov,1980; Cheke, Fishpool and Ritchie (Loc. cit.) has been shown not to be a result of aggregation or interactions between laying females but merely the consequence of a succession of individuals, selecting similar but suitable ovipositing sites.

2.3.3 Diurnal Behaviour:

Observations on O. senegalensis indicate that the activities of adults and nymphs increased with increase in temperature. Uvarov (1977), observed that the grasshoppers were more active in the late afternoon than early in the day.

Overnight, adults and older nymphs of O. senegalensis roost on the ground and the younger nymphs roost on vegetation. The differences in the roosting position could perhaps be explained on the basis of their geophilus or phytophilous adaptation, (Amatobi, 1982). The period spent in the roost in the morning was generally shorter on warm days than on cool days. It has been indicated that the basking behaviour is probably associated with body temperature regulation since the temperature of basking locusts are known to be affected by the insects position relative to heat sources (Volkonsky, 1939). Alternatively, it is possible that the behaviour is a means by which the insects obtain directional information for local movements or for use in later disperasive flights (Uvarov, 1977).

2.4 Biology

Very few studies have been carried out on the biology and life cycle of O. senegalensis. The insect spends the dry season which usually runs from November to June in egg-diapause; embryonic development recommencing following the onset of the first rains (Launois, 1978; Popov, 1980; Fishpool, 1982). However, laboratory studies on the hatching sequences of O. senegalensis egg pods showed that not all eggs respond to the first wetting (i.e. simulated rainfall) and indeed, that eclosion of eggs from a single pod could be staggered over a considerable period of time (Cheke, Fishpool and Forrest, 1980). Joyce (1952) had observed in the Sudan that eggs laid during mid-October hatched in June and July the following year. Saravia (1962) stated that the entire egg stage may last for only 8-10 days (in hot and dry summer) or may lie in the soil for as long as 5 years.

Venkatesh, Ahluwalia and Harjai (1971), working on the influence of rainfall on the egg diapause of Oedaleus pointed out that an egg diapause of 6 to 13 months is usual and that rain is the main factor in terminating the diapause.

The eggs of O. senegalensis are known to be subject to attack by various predators, (Cheke, Fishpool and Ritchie, 1980; Popov, 1980). Thirteen bird species have been recorded preying on the adults

of O. senegalensis (Cheke, Fishpool and Forrest, 1980). Among the invertebrate predators of the adult grasshopper, are Asilids and Solifugids. Bhatia and Ahluwalia (1966), recorded similar range of predators in India.

The feeding ecology of O. senegalensis has been investigated and results show that it favours graminaceous crops especially Pennisetum millet (Launois, 1976; Boys, 1978).

Colour change in the males and females of the two morphs (Green and Brown) of O. senegalensis has been studied. Abushama and El-Khider (1973), found that the green colour was not affected by temperature or humidity and can persist at relative humidities ranging between 0-37% and temperatures between 30 and 48°C. They observed that grasshoppers changed from green to brown after exposure to light for 48 hours, but the green colour was not restored even after keeping the insects in complete darkness for more than seven days.

2.5 Recent Studies on O. senegalensis in Nigeria

Although the presence of O. senegalensis in Nigeria is not a recent phenomenon (Golding, 1934) its importance was not recognized until 1976 when migrant swarms invaded northern parts of the country from Niger Republic (Bindra, 1977) causing much damage to graminaceous crops. Preliminary investigations on the population dynamics and aspects of the biology of this grasshopper were consequently initiated (Anon, 1977).

Anene (1980), studied the anatomy and physiology of the reproductive organs of the green and brown dimorphic females occurring during the dry and wet seasons. Amatobi (1982), in his study of the ecology of the grasshoppers in the Gumel area of northern Nigeria, investigated the following aspects of the O. senegalensis ecology: Population of O. senegalensis in various habitats; the population of O. senegalensis in relation to vegetation of the habitats; location of oviposition sites of O. senegalensis; the effect of mulching on egg-pod deposition and hatching of the eggs of O. senegalensis; and the diurnal activities of this grasshopper. In his study of oviposition preference and the influence of cultivation on egg hatching, he observed that O. senegalensis preferentially laid eggs on ridges and ridge slopes.

A survey of the insect enemies of the egg pods of O. senegalensis (Anene and Vajime, 1988a) and an extensive observations on the parasites and predators of the nymphs and adults of O. senegalensis (Anene and Vajime, 1988b) have been carried out in northern Nigeria.

2.6 Damage and Economic Importance

Oedaleus senegalensis feeds on a wide variety of plants including many annual herbs. In addition to wild plants, it has been recorded as feeding on, and showing preference for many crops of economic importance (Batten, 1969). O. senegalensis is graminivorous and shows particular preference for

Pennisetum millet (Mallamaire, 1948; Joyce, 1952; Saravia, 1962; Bhatia and Ahluwalia, 1966 Batten, 1969; Hergert, 1975; Popov, 1976; Bindra, 1977; Launois, 1976; Boys, 1978; Cheke, Fishpool and Forest, 1980; Amatobi, 1982). Apart from millet, other cereals such as maize, sorghum, rice, wheat and barely are attacked. Damages done on cotton, groundnuts, melon , potatoes and beans have equally been documented (Darling, 1946; Golding, 1946, 1948; Hargreaves, 1948; Farahbakhsh, 1961; Joyce, 1952; Hergert, 1975; Launois, 1976; Bindra, 1977). Numerous examples of damages inflicted on pasture have been reported,and in most of the cases, the damages have not been quantified (Saravia, 1962; Bhatia and Ahluwalia, 1966; Boys, 1978; Anon, 1982).

The physical damage by O. senegalensis on crops consists of total consumption of the young shoots (seedlings), defoliation of older plants, and attacks on the seeds and fruits. During large scale outbreaks and invasions, attack on cultivated agricultural crops results in complete destruction especially by the hopper stage of the grasshopper (Mallamaire, 1948). It has been observed that in general, damage on graminaceous crops especially millet and sorghum, occurs during the seedling stage and often makes replanting necessary (Mallamaire Loc. cit., Risbec and Mallamaire, 1949, Saravia, 1962). Serious damage equally occurs at the

milky stage of cereals when the grasshoppers, especially the females feed on the soft ripening grains (Popov, 1976; McAleer, 1977; Bindra, 1977; Cheke, Fishpool and Forrest, 1980). The third period of damage occurs when the crops are fully matured with the grains eaten up by the dispersing and migrating adults during serious plague (Cheke, Fishpool and Forrest, Loc. cit.).

The level and distribution of infestation and the damages by O. senegalensis vary from year to year. Available literature indicate that the worst attack and the most widespread was the upsurge of 1974, which affected all the Sudan-Sahelian countries (Anon, 1978).

There is a dearth of information on the evaluation of the losses caused by O. senegalensis. Mallamaire (1948) states that one million hectares of Pennisetum typhoideum were destroyed in Senegal and Niger in 1947. In 1977, the grasshoppers were said to have caused the greatest damage in the Watagouna-Ansongo sector of the Niger valley where 20-40% loss was recorded on millet, rice, and sorghum. Again in 1980, Niger Republic experienced another serious plague, resulting in the infestation of over 400,000 hectares by the grasshoppers (Anon, 1978).

In Nigeria, Bindra (1977), estimated the damages caused by O. senegalensis to crops in northern states of the country at three million dollars ($3,000,000).

During the general invasion of Senegal by the grasshoppers in 1974, agricultural losses were total in particular areas. An evaluation of 30% deficit was made and this represented an important global deficit in the production of millet (Anon, Loc. cit.).

In Mali, the loss sustained over an area of 9,000 hectares of rice and millet among others was estimated at three million CFA ($10,000) (Anon,1982).

2.7 The Study Area

2.7.1 Choice of site:

Nigeria has been divided into seven zones according to the types of vegetation (Keay, 1959; Walter, 1968). These zones follow the climatic conditions closely and include the Sahel, Sudan, Guinea Savanna, derived Savanna, the rain forest, the fresh water swamp and the Mangrove swamp (Figure 2).

From the general preliminary reconnaisance along a North-South transect through Nigeria; it would appear that C. senegalensis did not occur beyond south of latitude 9° North. Consequently it was decided that the studies would be limited to the areas north of latitude 9°N and this roughly covers the Sahel, Sudan and greater parts of the Guinea Savanna zones.

2.7.2 General Description of the study areas:

2.7.3 Biogeography:

The study areas consist of the three vegetational zones of the northern parts of Nigeria which is bounded

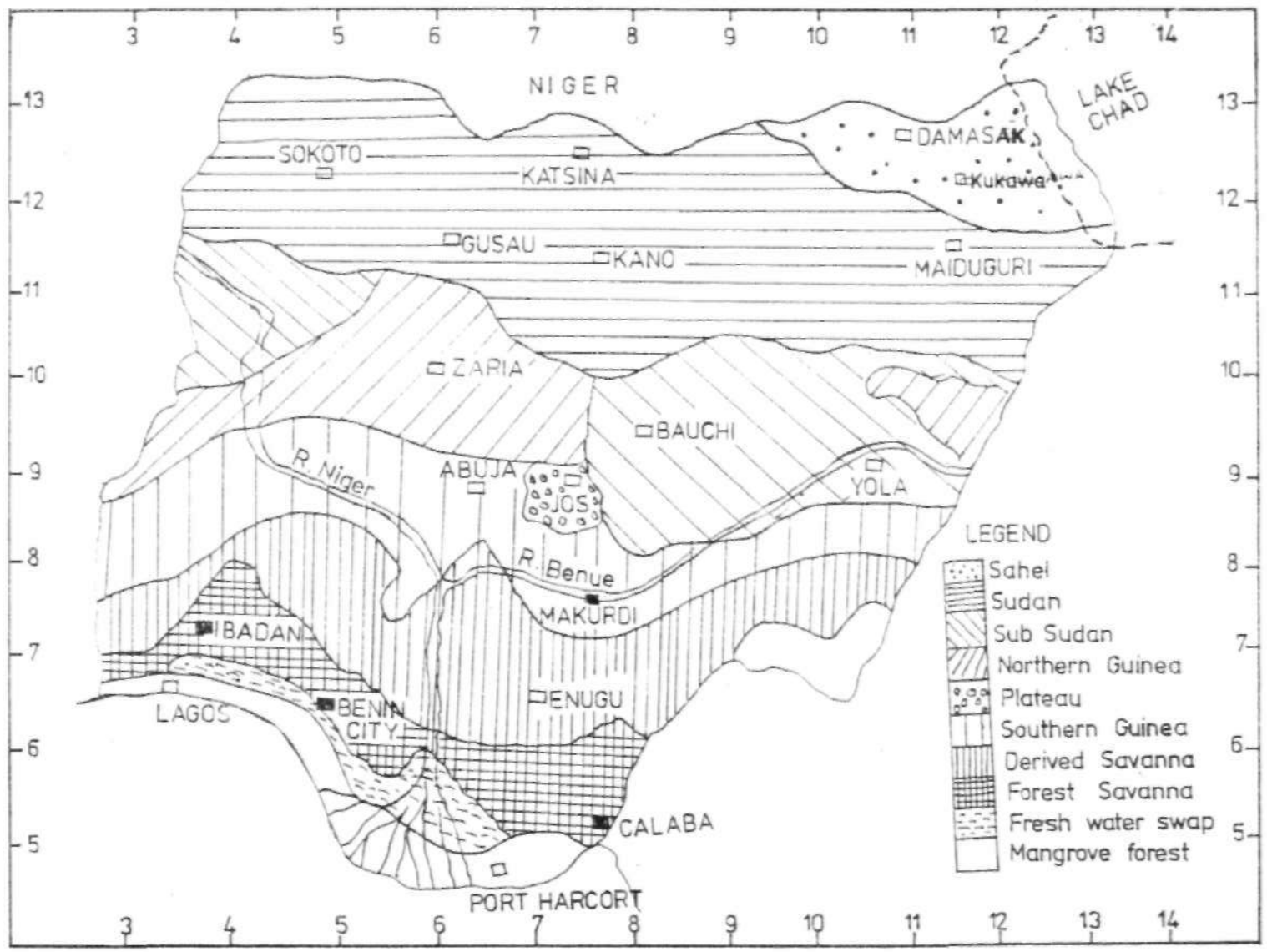


Fig.2. Map showing vegetation of Nigeria (after Keay 1953 and Clayton 1957)

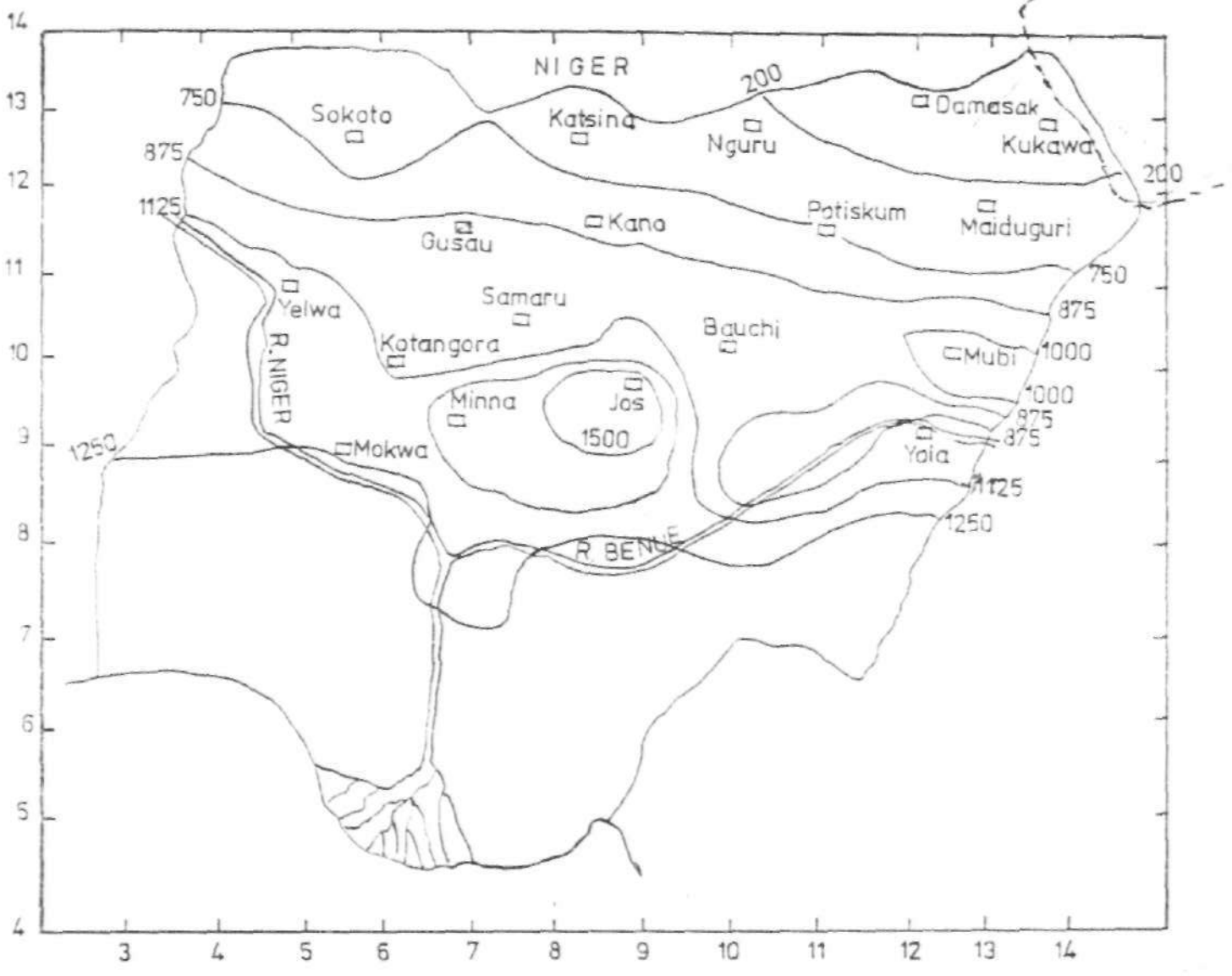


Fig. 3. Mean annual isohyets (mm)

approximately by latitudes 9° and 14° North and longitudes 4° and 14° East and roughly fall within 300-1,500mm rainfall isohyet (Figure 3). Biogeographyically, the study areas fall between two major regions or domains, the Saharan in the north and the tropical in the south. The southern boundary of the areas lie some 250-300km from the Atlantic coast and is demarcated roughly by the lowlands of the Niger-Benue valley.

North of the Niger and Benue rivers, the country rises irregularly to rolling or gently undulating plains often referred to as the high plains of Hausalands. The flat landscape is occasionally interrupted by groups of granite iselbergs. In the North east, the plain descends into the inland drainage basin of Lake Chad; the great plains slope down very gradually from Katsina, Kano and Bauchi to Lake Chad. In the North West, the plain descends into the Niger valley (Clayton, 1957).

2.7.4 Weather:

The weather and rainfall regimes of the study areas are the result of the general circulation of two air masses: the continental dry air mass in the north which has a long history of desert track before reaching the study areas as a North-easterly wind, and the maritime moist air in the South which also was a long tracking over the South Atlantic ocean and reaches the study area as the South westerly wind (Ilesanmi, 1970).

The two meet along a zone of convergence known as the Inter-Tropical Convergence Zone (ITCZ). In winter the pressure is high over the Sahara, the dominant wind being the harmattan blowing from the North and East, and the ITCZ retreats southwards. In summer, the surface of the desert is heated, the pressure drops and the ITCZ advances northwards. The ITCZ oscillates slowly and irregularly during the years. The annual motion over Nigeria is northwards between February and August, and southwards from September to January (Kowal and Knabe, 1969).

The study areas are considered under the three major climatic indices of rainfall, temperature and relative humidity; vegetation and land use.

2.7.5 The Sahel Zone

The climate of the Sahel zone is of the arid type (Keay, 1959) characterised by a short rainy season lasting 3-4 months followed by a dry season lasting 7-8 months. Practically all the rains fall during late July-August and September, with a mean annual precipitation ranging between 226 and 230mm (Keay Loc. cit.). Meigs (1953) defines this zone as one in which the rainfall is not adequate for the production of crops.

In Appendix 1, the average weather conditions for representative stations within the Sahel zone is shown. The annual temperature regime is characteristic

of the arid zone and there are seasonal and diurnal fluctuations. The maximum temperatures vary between 40 and 45°C and the minimum from 11 to 18°C, the coldest months of the year generally being December and January.

The humidity is generally very low throughout the area except during and for a short time after periods of rainy weather. The average relative humidities recorded during the drier months were in the order of 8-12% and during the humid months 32-67%. The typical vegetation of this zone is open thorn-tree Savanna with Acacia and Commphora spp dorminant (Kowal and Knabe, 1969). There is little cultivation of millet and groundnuts. Several irrigation schemes have been introduced for production of maize, wheat and rice.

2.7.6 The Sudan Zone:

Appendix 2 provides the weather data for this zone. The mean annual rainfall ranges between 200-1,125mm occurring from May to September with the remaining months receiving less than 25mm in a month. The maximum temperature exceeds 40°C from March to May and the minimum temperature ranges between 12-14°C from December to January. The mean relative humidity is low (13 - 18%) from November to April and is high (34 - 76%) for the rest of the year. Large areas in this zone are almost continuously cultivated and little trace remains of the natural vegetation (Kowal and Knabe, 1969). The vegetation is generally

characteristised by the presence of Guiera senegalensis, Combretum glutinosum, Piliostigma reticulata and Hyphaene thebeica (Keay, 1949). On fine textured soils towards the eastern part (Maiduguri) open woodland comprising Acacia arabica, A. seyel, and Combretum aculeatum occur. The most common grasses are Pennisetum pedicellatum, Andropogon gayanus and Cymbopogon giaganteus.

The main crops are groundnuts, millet, maize and cowpea. Wheat is grown with irrigation in the dry season. This zone provides the most favourable conditions for the production of grains and livestock.

2.7.7 Northern Guinea Zone:

This zone is characterised by mean annual rainfall range of 1,000 - 1,125mm with 4-6 months of dry season. Minimum temperatures range between 13-15^{o}C during the period of November to February while the maximum temperature reaches 37^{o}C in March. The relative humidity is low (12 to 23%) from November to March and increases gradually to its maximum (77-82%) during May and August (Appendix 3).

The vegetation in this zone is more luxuriant than in the Sudan zone. It is characterised by the prevalence of trees such as Isoberlinia doka, Monotes kerstingii, Uapaca togoensis (Anon, 1971). The herbaceous layer is covered mainly by Andropogon and Hyparrhenia grass species (Keay, 1959; Kowal and Knabe, 1969). The main crops of this zone are maize, sorghum, millet, groundnuts,

cowpeas, and cotton. Small amounts of yam, rice and sugar are also grown.

2.7.8 The Southern Guinea Zone:

The climatological data for this zone is presented in Appendix 4. The mean annual rainfall ranges from 1,200 to 1,350mm with 3-4 months of dry season. The minimum temperature from November to January ranges from 14°C to 19°C, while the maximum from November to April ranges from 34°C to 38°C. The relative humidity from November to March ranges between 31-55% while the rest of the year has monthly mean ranging from 55 to 86%.

This zone has a complex type of vegetation due to the effect of extensive seasonal burning and cultivation (Keay, 1959). Numerous vegetation communities were recognized including closed woodland, and shrub woodland (Clayton, 1957). The vegetation consists of thick-barked trees up to 40-50 feet high e.g. Daniellia oliveri, with tall grasses (5-10 feet high) growing in tussocks,e.g. Andropogon tectorum. The major crops in this area are yams, guinea corn, cassava, cotton, tobacco, locust beans and soya beans (Oyenuga, 1967).

2.7.9 Soil Types:

The distribution of soil types in northern Nigeria has been described by Klinkenberg and Higgins (1968). More than half of northern Nigeria is covered by Ferruginous tropical soils considered to be the zonal soils developed under the prevailing climatic conditions with

appreciable but seasonal rainfall (Kowal and Knabe, 1969). They are highly weathered soils and markedly laterised by the loss of silica. The soil aggregates are usually very small or very unstable, particularly in wet conditions.

The total content of available plant nutrients in these soils is very small because of leaching, run-off, and soil erosion.

In the southern part, where leaching is more intense, most soils are classed as ferralitic. Ironstone gravel in the profile is more common and the influence of parent material and slope on the soil profile is much more pronounced (Kowal and Knabe Loc. cit.).

North of the ferruginous tropical soils, in a much drier zone, the brown and reddish brown soil group occurs. These soils have little profile morphology and texturally can be described as sands and sandy loams, (KlinKenberg and Higgins, 1968).

CHAPTER THREE

MATERIALS AND METHODS

3.1 The Distribution of O. senegalensis, the weather conditions and vegetative composition of the distribution areas

Observations were commenced at the end of May 1983 and continued till December 1985. Extensive field studies involving regular seasonal surveys to record the grasshopper presence were undertaken.

In view of the vastness of the study area and the difficulties entailed in long range travels, a number of stations were selected to represent the range of ecological conditions existing across the study area. The selected stations included Kukawa (Lat. 12° 20'N) and Damask (Lat. 13° 17'N) in the Sahel zone, Maiduguri (Lat. 11°51'N), Sokoto (Lat. 13°1'N), Bauchi, Kano (Lat. 12°3'N) and Yola in the Sudan zone, Kotangora (Lat. 10°22'N), Samaru (Lat.11°11'N) Minna (Lat. 9°37'N) and Mokwa (Lat. 9°18'N) in the Guinea Savanna zone and Jos in the Plateau. Because of the size of the area involved, the timing of the survey and the routes followed had to be determined in such a way as to maximise the probability of obtaining the best return of the grasshopper information. The road survey network covered the area reasonably comprehensively, and the routes did not seem to have unduely favoured any particular vegetational zone (Fig. 4).

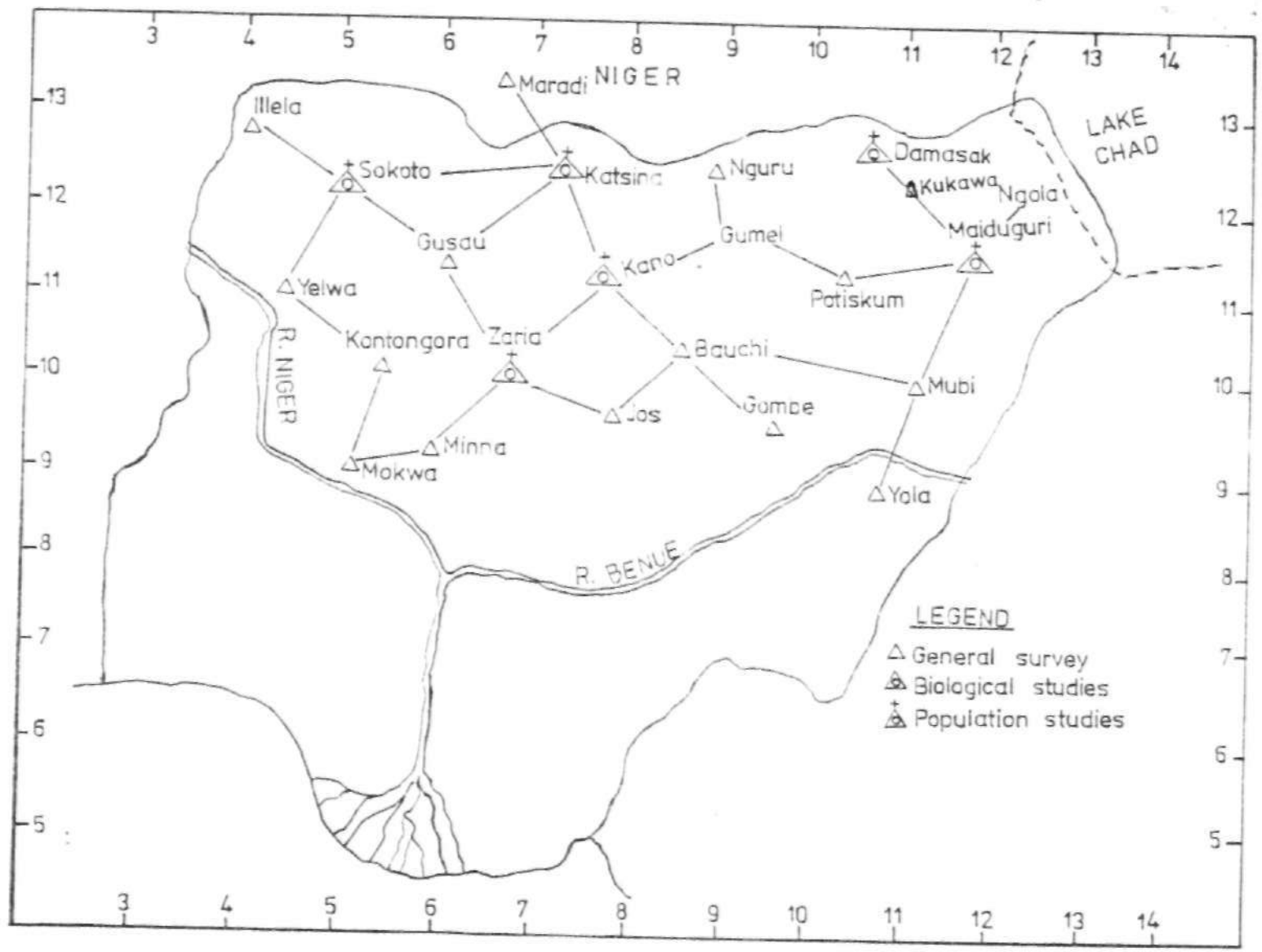


Fig. 4. General map of the study area showing the sampling axis and sites used in the survey.

3.1.1 Methods of survey and sampling:

Two methods of survey and sampling were used to establish the grasshopper presence and density: (a) use of light traps, and (b) the use of sweep nets.

3.1.2 Light traps:

At each station a multidirectional round metal light trap (3m in diameter) was used to establish the presence and density of O. senegalensis, and a uni-directional light trap was used to investigate the direction of migration of the grasshoppers. Prior to migrational investigations, day samples were taken from the light trap sites and later the catches compared with the light trap catches. Through this method, migrational movements and displacement were studied. Where electricity was available, a 150 watt white-light electric lamp was used as the source of light, and in other areas a gas lamp was used. The light traps were run for 2-3 hours after dusk each day during the sampling periods. Every morning, all the trapped Oedaleus grasshoppers were recorded and preserved for further studies.

3.1.3 Sweep-net Method:

At each station, habitats in which O. senegalensis are known to occur were selected for sampling. These habitats included fallow lands, roadsides, grazing fields, land with scanty vegetation, sorghum and millet fields (Bindra, 1977; Amatobi, 1982). Catches were

made for 2-3 hours using a hand sweep net, and all the O. senegalensis within the sample were sorted out and recorded.

Records of the nymphs encountered at each location were also kept. This would give an idea of local breeding.

3.1.4 Weather Records:

At the stations where meteorological services were not available, rain guages and thermometers were provided to record the various climatic indices which included rainfall, temperature and relative humidity.

3.1.5 Vegetation:

The vegetation cover and composition of selected habitats at each station was studied. The classification into vegetative types was based mainly on the criterion of species dorminance and abundance.

Three plots each measuring 50 x 25m were marked out at random in the selected habitats. The grass and herb components were sampled with a one-meter square wire quadrat which was thrown at random. On each of the three plots, three samples were taken each season. The plant species were identified and counted. The percentage vegetation cover and percentage bare ground were estimated by comparing the bare ground and the vegetation cover in each quadrat. The estimation of the percentage cover and percentage bare ground was based on the principle that both are equal to 100% (Southwood, 1966; Amatobi, 1982).

The study of the vegetation and bare ground were undertaken because they were considered important in roosting, feeding and oviposition of grasshoppers (Uvarov, 1957).

3.2 Seasonal Population Density and Fluctuations

The grasshopper seasonal population densities and the changes within them were investigated qualitatively and quantitatively from May 1984 to December 1986, in the three ecological zones by means of sampling and counting. The samples of adults were recorded according to (a) colour types since *O. senegalensis* occurs in both green and brown forms, (b) sex, (male and females), and (c) the stage of sexual maturity. The reproductive maturity of the females were assessed according to the condition of the ovaries (Albrecht, 1956). The samples were then reserved for morphometric analysis.

3.2.1 Methods for sampling adult:

Three methods used in the quantitative estimation of adult populations were: (a) flushing method, (b) the method of sweep net catches, and (c) light trap catches.

3.2.2 Flushing method:

In each of the habitats in which *O. senegalensis* is known to occur, plots measuring 50 x 25m were marked out. In each of the plots an area of 50 x 1m was marked out and demarcated by means of ribbons. The ribbons

were set out in the morning of the day preceding the flushing day so as to allow thorough spread of grasshopper population . Amatobi (1982, found this method very effective. The marked area was then approached cautiously and walked through and the number of O. senegalensis adults that flew out of it were recorded. Three habitats were usually sampled each time on weekly basis and the average record of the number of grasshoppersflushed was calculated.

3.2.3 Sweep net method:

A standard net was used and in each of the habitats, catches were made for 2-3 hours along a predetermined transect (after Joyce, 1952). Sampling was done weekly. At each light trap site, sweep net catches were made so that the relationships between population levels observed during the day, and light trap catches could be compared.

For the flushing and sweep net methods, sampling began at 10 a.m. (0900 GMT) when the grasshoppers were active, usually at an ambient temperature above 27^{o}C.

3.2.4 Light trap Catches:

At each station, adult insects were collected using a multi-directional light trap run for 2-3 hours after dusk on weekly basis. Light trap catches enabled studies on the night population to be carried out and at same time the comparison with day population . Furthermore, catches recorded on dark and moon-light

nights in various sites were compared and would give indication of migrational activities.

3.2.5 Methods of Sampling Nymphs:

Hopper populations were estimated by counting the numbers in one-metre metal square quadrats. The quadrats were laid down early in the mornings in a random manner at the selected habitats each sampling day. This enables thorough and undisturbed spread of the hoppers before sampling. Counting of the hoppers within the quadrats was done at 0900 hours using binoculars. Sampling was done on weekly basis and weekly mean numbers were calculated per square meter.

3.3 Studies on the Biology of O. senegalensis

3.3.1 Field Observations:

As a preamble to the investigation on the life history of O. senegalensis, field observations were carried out on the timing of some relevant aspects of the grasshoppers biology in 1983 and 1984. Observations were commenced soon after the first rains of each year to monitor the occurrence of the various stages of the grasshopper and to record the timing of the major events of the life cycle, viz: when the eggs hatched, nymphal activities, commencement of mating and egg laying, the periods of the occurrence of the nymphs and the adults in the field. These observations were made at Maiduguri, Kano and Samaru representing the Sudan and the Guinea Savanna ecological zones.

3.3.2 Investigations of Aspects of the Life Cycle:

Experiments were carried out between July and October, 1984 to 1986 in Maiduguri, Samaru and Kano to investigate the following aspects of the life cycle:

- the number of egg pods per female
- the number of eggs per pod
- the incubation period
- the number and duration of the nymphal instars
- the effect of food plants on egg production
- the effect of food plants on the rate of development of the nymphs.
- adult longevity
- fecundity and fertility

3.3.3 The number of egg pods per female, the number of egg per pod and the effect of food plants on egg production of O. senegalensis.

Groups of insects comprising five freshly fledged adult females and five males were kept in field cages measuring 2m x 2m x 2m each. Five of such cages were set up. Potted millet plants at various growing stages served as the insect food in the first cage while Digitaria, Sorghum and Cenchrus biflorus served as food in cage 2, 3, and 4 respectively. The insects in cage 5 were fed on a combination of all the food items mentioned above. These plant materials are the known preferred food by O. senegalensis (Boys, 1978; Popov, 1980; Amatobi, 1982). Cages 1 to 4 were used to investigate the effect of food plants on egg production, while

cage 5 was used to ascertain the number of egg pods per female and the number of eggs per pod, and adult longevity. All the cages were sited in areas with partial shade. The cages had false floors with two apertures into which were inserted two plastic containers 10cm high, 9cm in diameter and about 500cc capacity, containing sand moistened with 15% water by volume (after Popov, 1980).

Isolated grasshoppers were kept in breeding cages 30cm x 30cm and 45cm high, one male and one female in each cage (Appendix 6). A false floor was provided and appropriately holed for the insertion of aluminium tubes 10cm high and 4cm in diameter for egg laying. Five of these cages were set up and the food plants provided were as described for crowded rearing above.

When egg laying commenced, the soil tubes were changed on daily basis and the number of egg pods in them recorded.

For the egg pods collected from cage 5, some of them were opened and the number of eggs counted per pod, while the rest were reserved for further investigation.

Cage 5 in both the crowded and isolated rearing was maintained as long as the insects were alive and longevity data were collected from them.

These investigations were replicated and were carried out in Kano and Maiduguri between July and September, 1984 and 1985 respectively.

3.3.4 The Incubation period, the duration of nymphal instars, and the effect of food plants on the rate of development of the nymphs.

3.3.5 Incubation Period in the field:

On 25th July, 1986 in Samaru, field cages 1m x 1m x 1m were built over three spots where females of the O. senegalensis were observed ovipositing. Two to three egg pods laid on the same day were covered by each cage. There were three of such caged spots. Daily observations were made and the dates of the first hatching of the eggs were recorded.

3.3.6 Incubation Period in the laboratory:

The egg pods used in laboratory experiments were laid in field cages in 4 aluminium tubes 10cm high and 4cm diameter at Samaru on August 4, 1986. They were placed in the incubator at 32°C. About three to 4 days before the eggs were due to hatch, each tube was placed separately in a glass jar closed with a perforated metal lid. The jars were left in the incubator for 2 to 3 hours after hatching occurred to allow time for the hoppers to harden before they were weighed in bulk.

3.3.7 Duration of nymphal instars and the effect of food on the rate of development:

Soon after weighing, the hoppers were placed in rearing cages in groups of five. The rearing conditions and methods of Hunter-Jones (1966) were followed. Food

consisted of millet, Cenchrus, Digitaria and Sorghum plants which were put in a jar with water. The hoppers in each cage were fed on one particular food plant. Daily, fresh food was supplied. In this way it was ensured that the insects had plenty of fresh food available at all times.

3.3.8 Number of Instars:

It was easy to determine the number of nymphal instars by counting the number of exuviae on the floor of the cages. A small corked glass tube was kept inside the cage with all the exuviae in it. The length of each instar was recorded.

Fledgings were weighed 5 to 6 hours after they became adults and before they had an opportunity to feed.

3.3.9 Morphometrics:

Adult insects comprising day population caught by the sweep net method and the night population represented by light trap catches were used in this investigation. Measurements of the morphometric characters E (elytron length), F (hind femur length) and C (head capsule width) provided independent information on the phase status of the population . The measurements were carried out using vernier cellipers as described by Dirsh (1953).

3.3.10 Fecundity and Fertility:

Samples of mature females from day and night populations were dissected. The number of ovarioles in each ovary was counted, as well as the number of mature eggs.

The mean number of ovarioles per insect was related to the number of eggs found in the egg pods laid in the laboratory and those collected from the fields.

3.4 Parasites and Predators of O. senegalensis

The survey, sampling and observations on the parasites and the predators of the eggs, nymphs and adults of O. senegalensis was conducted during May to December of 1984 - 1986. The survey and sampling was sited along several main axes: Zaria-Funtua-Gusau-Zuru-Sokoto, Birnin Kebbi-Illela-Zinder, Zaria-Kano, Jibiya-Katsina Maradi; Kano-Azare, Bauchi-Gombe-Jos-Yola; Gombe-Potiskum-Bama-Maiduguri-Ngala, Damasak-Nguru-Hadeja-Gumel; Zaria-Funtua-Birnin Gwari-Kotangora-Mokwa-Minna-Abuja. All these areas fall within the Sahel, Sudan and northern guinea vegetation zones and lie north of latitude $9^{o}N$ (Figure 4).

Although this study was carried out at the same time as the other aspects of the ecology of the O. senegalensis, the timing of the survey and the routes

followed were determined in such a way as to reflect the varied ecological conditions of the large biogeographical area involved in the study. A wide spectrum of habitats in which the nymphs and adults of O. senegalensis were known to occur were surveyed and sampled. These included millet fields, road sides, fallow lands with low vegetation, grazing fields, grounds with less than 40% vegetation cover, egg laying and hatching sites (Popov, 1980; Amatobi, 1982).

3.4.1 Invertebrate Parasites and Predators of the Nymphs and adults:

Adult grasshoppers caught by the light trap and sweep net methods and the nymphs of various instars were examined externally, and later dissected for internal examination. Records were kept of infesting parasites. Grasshoppers found to be infested were brought to the laboratory to enable the infesting parasites complete their life cycles for easy identification.

Other arthropods especially the large ones found within the vicinity of the grasshoppers were watched if they attacked or fed on the grasshoppers.

3.4.2 Vertebrate enemies of O. senegalensis:

Observations on the vertebrate enemies of the nymphs and adults were made between 0900 - 1400 hours when the grasshoppers were active and when most predators came out to feed. Night sampling was between 1900 - 2200 hours.

The vertebrates were watched to see if they fed on the nymphs or the adults of the grasshopper.

Supplementary information was sought from local farmers and nomads on the occurrence of vertebrates which they suspected preyed on grasshoppers. Several of such vertebrates were caught (by the aid of local hunters) and were dissected to confirm the presence of Oedaleus grasshopper in their guts.

The vertebrates which were observed feeding on O. senegalensis were noted and on several occasions, those that could not be identified immediately were caught or shot and brought back to Ahmadu Bello University (A.B.U.) Zaria for identification.

3.4.3 Parasites and Predators of the Eggs:

The choice of sampling sites was based on its ecological value in oviposition of O. senegalensis. A typical laying habitat was a sandy terrain, flat, or undulating with open, predominantly graminaceous steppe vegetation (Popov, 1980; Cheke, Fishpool and Ritchie, 1980; Amatobi, 1982). Such habitats cover vast parts of the Sahel, the Sudan and northern 1/3 of the Guinea savanna zones.

The oviposition sites were located and marked out during the laying periods. This was made possible by the presence of laying females. These sites were located at Katsina, Maiduguri, Kano, Damask, Zaria, Sokoto and Kotangora.

The ground at the oviposition sites were scraped 8-10cm deep using a folding spade. The soil was sifted through a coarse sieve and the egg pods sorted out. The egg pods were then examined, some in situ, others preserved in the original soil for further examination and experimental rearing at A.B.U. Zaria. Parameters used were the total number of eggs pods, the number of eggs per pod, the number of intact pods and also those attacked by various predators, the biotic factors and their identity.

The predators were frequently inside the egg pods usually as larvae and were preserved. An attempt was made to rear them to the adult stage in the laboratory for complete identification.

The insect parasites and predators were identified at the insect museum of the Ahmadu Bello University Crop Protection Department while the vertebrate predators were identified at the Department of Biological Sciences of Ahmadu Bello University by a wildlife expert.

CHAPTER FOUR

R E S U L T S

4.1 General Geographical Distribution of O. senegalensis in Nigeria

The area in which the occurrence of O. senegalensis was recorded during this study is wide and comprised practically the whole Sahel, Sudan and the northern Guinea savanna zones. In the Plateau and southern Guinea zones, the grasshopper appeared to occur only at their borders with the Sudan and the northern Guinea zone respectively. Table 1 represents the geographical occurrence of the grasshopper as recorded by light trap and sweep net catches. Hopper records are included in this table and indicate that the localities given are therefore those where normally, or at certain seasons of the year, depending on wheather, the habitats are occupied permanently or only seasonally, populations of O. senegalensis may be found.

The distributional data (Table 2) and Figure 5 show the limits of geographical distribution of O. senegalensis in Nigeria.

Table 1: Geographical Occurrence of *O. senegalensis* in Nigeria as indicated by Light trap and sweep net catches.

Locality	Years of Collection	Abundance	Stage
Damasak	1983, 1985	xxx	AH
Kukawa	1983, 1985	xxx	AH
Ngala	1983, 1984, 1985	xxx	AH
Maiduguri	1983, 1984, 1985	xxx	AH
Marte	1983, 1984	xxx	AH
Nguru	1984, 1986	xxx	AH
Damaturu	1983, 1984, 1985	xxx	AH
Potiskum	1983, 1984, 1985	xxx	AH
Kari	1984, 1986	xxx	AH
Sokoto	1983, 1984, 1985	xxx	AH
Yelwa	1984, 1985	xxx	AH
Zuru	1985	xxx	AH
Gusau	1985, 1986	xxx	AH
Katsina	1983, 1984, 1985, 1986	xxx	AH
Funtua	1983, 1984,1985	xxx	AH
Samaru	1983, 1984, 1985, 1986	xxx	AH
Kaduna	1984, 1985	xx	AH
Kotangora	1983, 1984, 1986	xx	AH
Mokwa	1983, 1984, 1985	o	o
Minna	1983, 1984, 1985	x	A
Abuja	1983, 1986	o	o
Kachia	1984, 1987	o	o
Kano	1983, 1984, 1985, 1986	xxx	AH

Table 1 (cont'd).

Locality	Years of collection	Abundance	Stage
Gumel	1984, 1985	xxx	AH
Wudil	1984, 1985	xxx	AH
Hadejia	1985, 1986	xxx	AH
Dambata	1984, 1987	xxx	AH
Azare	1986, 1987	xxx	AH
Darazo	1985, 1986	xxx	AH
Bauchi	1983, 1985, 1986	xxx	AH
Gombe	1985, 1986	xxx	AH
Billri	1983, 1985	xx	AH
Mubi	1983, 1984	xx	A
Biu	1983, 1984	x	A
Jalingo	1983, 1984	x	A
Yola	1983, 1984, 1985	x	A
Nimbia	1983, 1984, 1985	x	A
Jos	1983, 1984, 1985, 1987	x	A

Legend

xxx High populations recorded

xx Low populations recorded

x Few individuals especially adults

o No catches

A Adults

H Hoppers

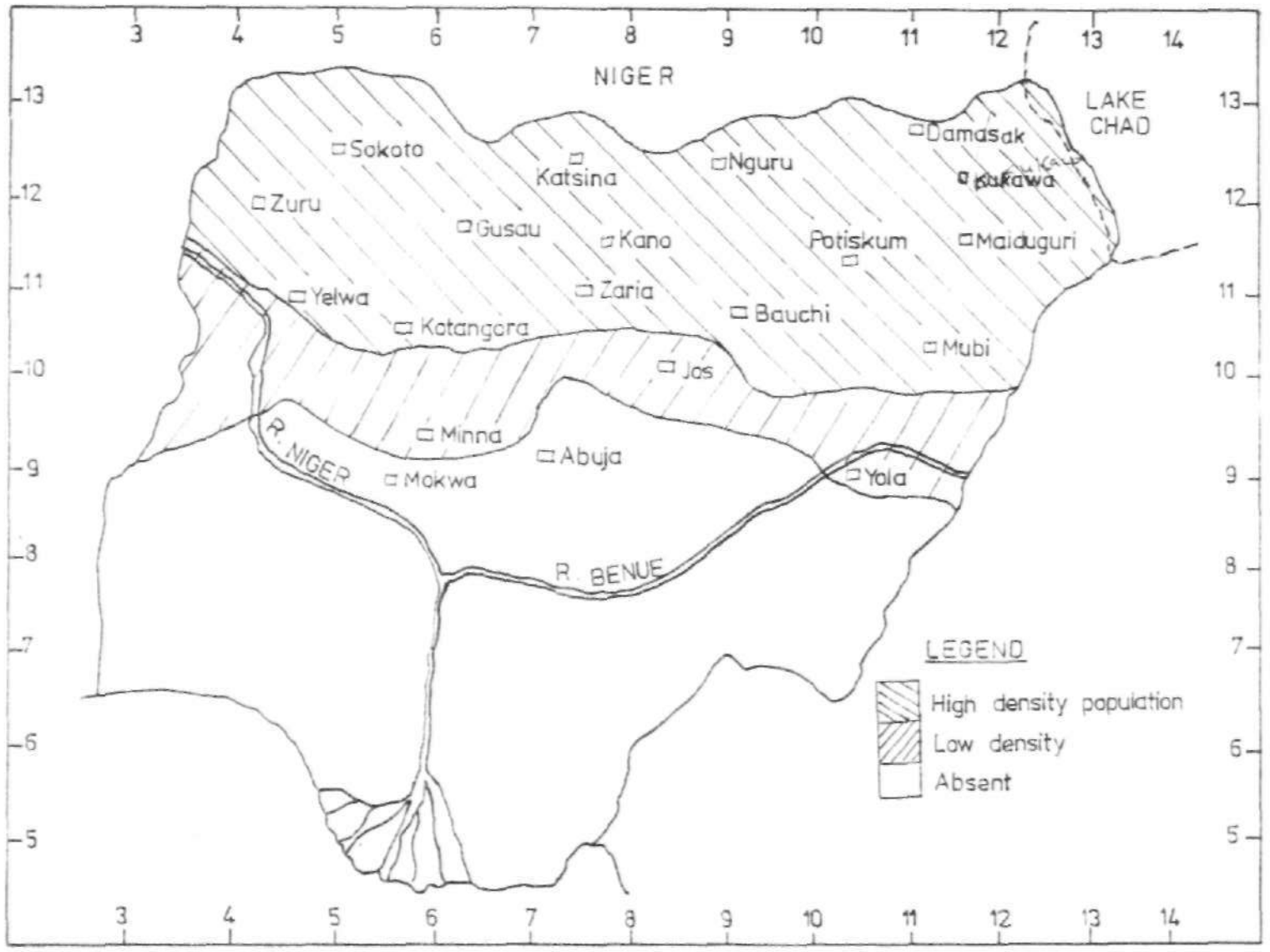


Figure 5. Distrubution map of Oedaleus Senegalensis in Nigeria.

Table 2: Geographical distribution of Oedaleus senegalensis in Nigeria.

Locality	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Damasak**	0	0	3	12	27	156	457	17	0	689
Kukawa**	0	0	3	20	29	211	373	24	0	660
Ngala*	0	0	2	27	24	131	188	11	0	383
Maiduguri**	0	0	13	44	62	207	499	52	6	883
Marte*	0	0	0	21	47	89	147	16	0	320
Nguru*	0	0	2	13	40	93	119	21	0	288
Damaturu*	0	0	0	7	37	124	203	13	0	384
Potiskum*	0	0	6	24	43	147	201	1	0	438
Kari*	0	0	13	35	54	164	121	13	4	404
Sokoto**	0	0	19	41	103	489	337	49	14	1052
Yelwa*	0	0	12	36	54	158	103	82	4	449
Zuru*	0	0	8	13	61	84	67	13	0	246
Gusau*	0	0	11	51	73	139	107	18	0	399
Katsina**	0	0	18	43	117	513	347	23	0	1061
Funtua*	0	4	14	42	87	127	112	27	3	416
Samaru**	0	10	33	98	131	377	185	13	7	854
Kaduna*	0	0	0	15	21	88	14	0	0	138
Kotangora**	0	0	0	16	27	143	23	4	0	213
Mokwa**	0	0	0	0	0	0	0	0	0	0
Minna**	0	0	0	0	0	13	25	2	0	40
Abuja*	0	0	0	0	0	0	0	7	0	7
Kachia**	0	0	0	0	0	0	0	0	0	0
Kano	0	0	12	42	93	187	433	67	9	843
Gumel*	0	0	6	37	47	78	101	37	0	306
Wudil*	0	0	8	29	32	83	127	16	0	295

Table 2 (contd):

Locality	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Hadejia*	0	0	4	21	37	69	93	34	0	258
Dambata*	0	0	0	18	31	47	67	28	0	191
Azare*	0	0	3	17	43	73	36	3	0	175
Darazo*	0	0	0	11	28	59	43	0	0	141
Bauchi**	0	0	18	31	57	113	36	13	0	268
Gombe*	0	0	0	16	31	47	17	5	0	116
Biliri*	0	0	0	6	34	76	11	17	0	144
Mubi*	0	0	0	14	27	49	43	0	0	133
Biu*	0	0	0	0	9	13	16	0	0	38
Jalingo**	0	0	0	0	0	7	15	27	0	49
Yola**	0	0	0	0	0	14	24	3	0	41
Nimbia**	0	0	0	0	0	0	18	2	0	20
Jos**	0	0	0	0	0	0	23	3	0	29

**Light trap catches

*Sweepnet catches

The catch data for O. senegalensis at different sites in the Sahel, Sudan, Guinea savanna and the Plateau highlands are presented in Table 3 and Figure 6. The results clearly establish the occurrence of O. senegalensis in high densities in the Sahel, Sudan and Guinea savanna ecozones and the relatively low numbers of the grasshopper in the Plateau and southern Guinea savanna zones and the areas south of latitude 10° North.

4.1.2 Weather Records during the Study Period:

The weather records for five years 1983 - 1987 for the representative stations of three ecozones are given in Tables 4-8. These Tables show that the climates of these areas differ greatly with a prolonged dry season in the Sahel and Sudan zones and a relatively long rainy season in the Guinea savanna. The rainy and dry seasons therefore constitute the main differences between different times of the year.

In the Sahel and Sudan zones the rains begin in May with a few showers. The showers increase in intensity until August which is normally the wettest month with average figuresof more than 85mm and 146mm respectively (Tables 4 and 5). From August onwards, there is a steady decline until October when the rains normally cease with annual mean precipitations of 228.2mm for the Sahel zone and 467.5mm for the Sudan

Table 3: The number of O. senegalensis caught in the ecological zones in 1983 - 1985.

Ecological zones	Number of Grasshoppers		
	Total	Lighttrap	Sweepnet
Sahel zone			
Damasak	689	423	266
Kukawa	660	387	273
		(405)	(268)
Sudan zone			
Maiduguri	883	641	242
Sokoto	1052	732	320
Kano	843	511	332
Bauchi	268	143	125
		(506.8)	(254.8)
Northern Guinea zone			
Samaru	854	637	217
Kotangora	213	124	89
		(308.5)	(153)
Southern Guinea zone			
Mokwa	0	0	0
Minna	40	40	0
		(20)	(0)
Plateau Highlands			
Jos	29	27	2
Nimbia	20	20	0
		(23.5)	(1)
Total	5553	3685	1868
		66.4%	33.6%

Numbers in brackets represent means.

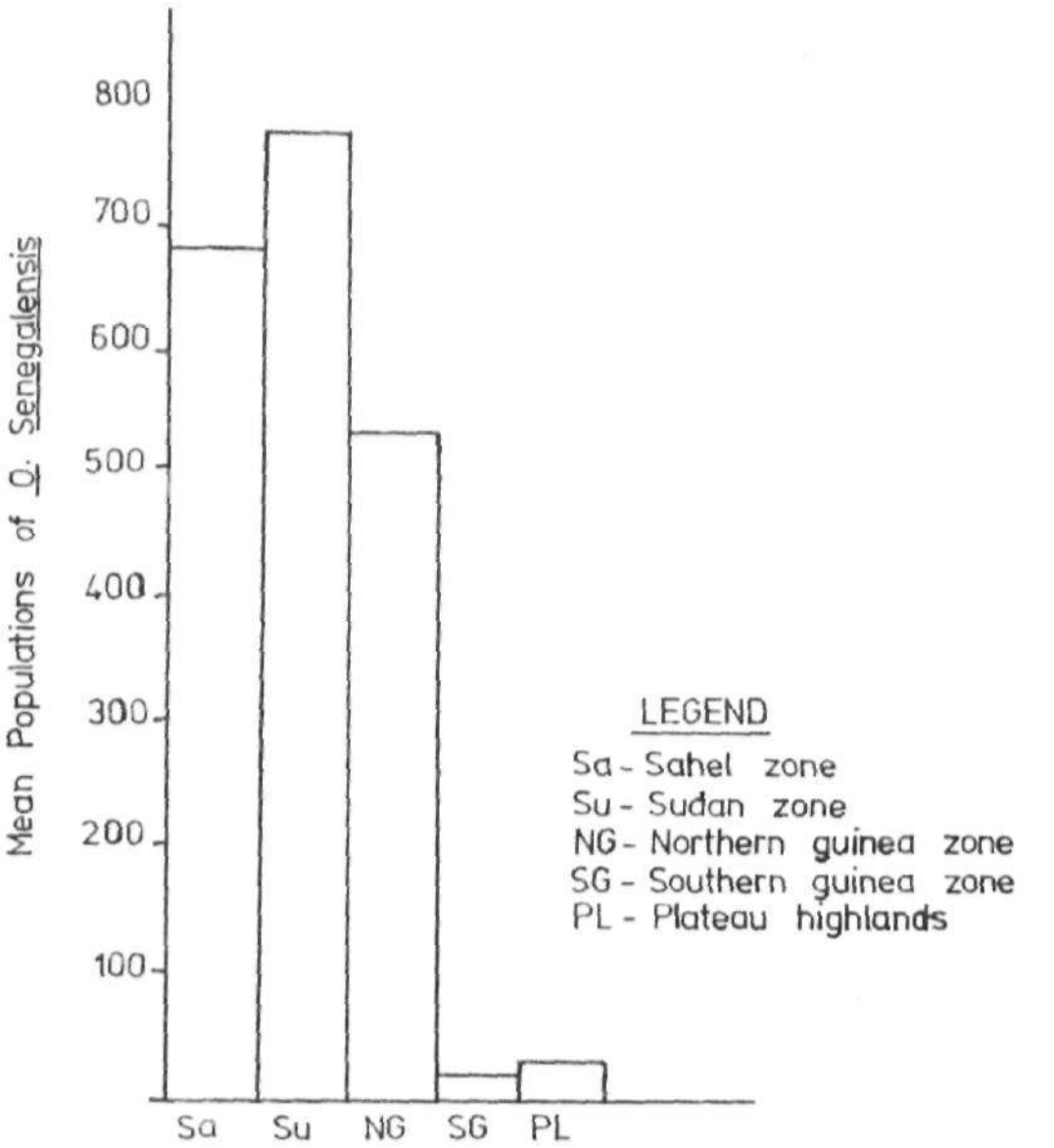


Figure 6. Histrogram of mean populations of O. Senegalensis at the various ecozones.

Table 4: SUMMARY OF FIVE YEAR (1983-1987)CLIMATOLOGICAL DATA MEANS FOR THE REPRESENTATIVE SITES OF THE SAHEL ZONE (KUKAWA LAT. 12° 20'N) AND DAMASK (LAT 13° 7'N)

Site	'Jan.	'Feb.	'Mar.	'Apr.	'May	'June	'Jul.	'Aug.	'Sept.	'Oct.	'Nov.	'Dec.	'Annual Total Mean	Mean (1983 - 1987
						Total Monthly Rainfall (mm)								
Kukawa	0.0	0.0	0.0	0.0	5.6	26.39	62.1	90.35	32.35	10.	0.0	0.0	226.79	19.9
Damasak	0.0	0.0	0.0	0.0	6.5	26.6	66.65	94.1	38.4	7.4	0.0	0.0	229.65	19.1
						Relative Humidity (%)								
Kukawa	10.8	12.4	11.4	9.4	24.	43.	60.4	66.2	53.	31.2	18.4	14.6		28.7%
Damasak	10.6	12.6	10.8	9.8	20.4	45.8	60.6	66.6	50.4	31.2	31.2	17.		30.6%
						Maximum Temperature (°C)								
Kukawa	31.6	34.	36.4	43.4	39.8	39.2	35.8	34.4	33.2	34.6	32.6	30.6		35.5
Damasak	31.4	33.8	36.	43.6	43.6	38.6	35.4	34.4	32.8	34.	31.8	30.		35.5
						Minimum Temperature(°C)								
Kukawa	12.	15.2	20.8	22.6	26.	23.4	22.4	21.4	20.2	21.	16.6	13.6		19.6
Damasak	11.4	14.6	20.4	24.2	26.2	23.4	22.	21.8	19.8	21.2	15.	13.		19.4

Table 5: SUMMARY OF FIVE YEAR (1983 - 1987) CLIMATOLOGICAL DATA MEANS FOR THE SUDAN ZONE MAIDUGURI (LAT 11° 51'N) SOKOTO (LAT 13° 1'N) KANO (LAT 12° 3'N).

Site	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Total	Mean 1983-87
						Rainfall (mm)								
Maiduguri	0.0	0.0	0.0	0.0	37.0	77.0	124.5	163.0	72.0	3.5	0.0	0.0	467.5	39.
Sokoto	0.0	0.0	0.0	0.0	30.5	73.3	70.1	120.9	53.1	4.1	0.0	0.0	371.5	30.9
Kano	0.0	0.0	0.0	0.0	7.1	33.2	91.5	251.4	115.3	3.1	0.0	0.0	563.4	46.9
						Relative Humidity %								
Maiduguri	17.	13.0	10.2	15.	43.0	60.0	73.1	75.2	65.0	35.1	19.	18.0		35.2
Sokoto	16.	11.	11.	17.	36.5	55.0	70.1	76.6	62.	30.	15.	16.		35.0
Kano	10.	13.1	13.1	23.	45.0	49.0	71.2	79.1	71.0	33.1	27.1	23.2		40.0
						Maximum Temperature °C								
Maiduguri	33.0	34.0	37.2	38.	37.6	34.1	31.	32.2	33.	34.	33.2	32.2		33.7
Sokoto	32.	34.1	37.1	38.1	37.1	37.	33.	31.0	33.1	34.0	37.1	32.0		34.7
Kano	33.1	34.0	38.0	37.	36.	34.1	30.0	30.0	32.	37.	37.	33.		33.6
						Minimum Temperature °C								
Maiduguri	18.4	15.0	20.1	23.1	24.0	23.6	20.0	20.3	21.	21.0	15.1	13.0		19.
Sokoto	14.	16.0	21.0	23.0	25.1	26.2	24.0	24.	23.	22.	17.0	14.		21.
Kano	13.	16.	20.2	22.	24.1	27.6	20.1	20.0	23.1	21.0	16.6	13.0		19.

zone (Table 9). The dry season lasts from October till May the following year.

Tables 6, 7 and 8 show that the rains start as early as February with frequent showers in northern Guinea, Southern Guinea and Plateau zones. By March the mean precipitations have reached 9.4, 22.1 and 31.9mm respectively and maximum precipitations are registered in August. Although there are showers during the months of November to February the monthly means do not exceed 4mm. The mean annual precipitations are in the order of 989.5mm for the northern guinea, 1296.5mm for the Southern Guinea and 1503.25mm for the Plateau zone (Table 9).

The dry period in these zones lasts from November to March.

The temperature regimes of the respective ecozones vary greatly at different seasons. The lowest temperatures of the year occur from November to February. After the harmattan ceases, the temperature rises steadily until May when most of the ecozones experience very high temperatures. The advent of the rains causes a fall in temperature until October, when a second rise begins and lasts until the harmattan sets in again (Tables 4 - 8).

The relative humidity is related to rainfall. In the study zones, the relative humidity falls sharply at the end of rains with the onset of the dry season and harmattan in November. The minimum is reached in February, March or April, and then increases gradually with the rains. The relative humidity at various ecological

Table 6: SUMMARY OF FIVE YEAR (1983 - 1987) CLIMATOLOGICAL DATA MEANS FOR NORTHERN GUINEA SAVANNA SAMARU (LAT. 11° 11'N) KOTANGORA (LAT. 10° 22'N).

Site	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Total	Mean (1983 - 1987)
							Rain Fall (mm)							
Samaru	0.0	0.0	7.6	7.2	101.4	99.6	167.	232.6	150.8	44.8	0.0	0.0	831.	69.3
Kotangora	1.6	1.7	11.2	47.3	112.8	149.7	200.3	260.2	260.2	96.9	5.5	.1	1148.1	95.7
							Relative Humidity (%)							
Samaru	17.6	12.4	20.8	27.	51.	65.	77.	75.	71.	45.	23.4	21.4		42.
Kotangora	23.1	24.4	29.6	55.6	70.4	76.5	81.6	82.4	79.6	66.7	33.3	23.9		53.1
							Maximum Temp. (°C)							
Samaru	28.8	32.2	35.6	36.4	34.4	31.	29.	29.	29.6	31.2	31.8	28.8		33.4
Kotangora	34.8	37.2	37.6	35.8	33.7	31.5	30.2	29.5	30.3	32.1	34.1	34.4		31.4
							Minimum Temp. (°C)							
Samaru	13.4	15.8	19.6	21.4	21.8	20.4	19.8	19.6	19.	17.	13.4	13.1		18.
Kotangora	15.5	19.	23.3	24.1	23.3	22.1	21.7	21.7	21.4	21.2	18.2	15.8		20.6

Table 7: Summary of five Year (1983 - 1987) Climatological Data Means For Southern Guinea Savanna (Minna and Nokwa).

Site	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Mean
9° 37'						Rain Fall (mm)								
Minna	2.2	6.4	62.7	59.2	122.2	165.2	231.6	251.7	281.5	121.6	0.1	2.9	1269.1	105.3
9° 19'														
Nokwa	2.0	4.4	31.5	69.8	141.2	170.2	263.6	289.2	228.7	119.0	2.7	1.1	1323.4	110.3
						Relative Humidity								
Minna	35.2	31.7	40.4	55.2	73.6	78.2	77.	78.	76.	66.	49.	43.3		58.2
Nokwa	39.7	36.4	52.8	70.9	81.6	84.9	81.6	82.4	86.	76.	65.7	34.9		65.3
						Max Temp. (°C)								
Minna	34.3	36.4	36.9	34.8	32.5	30.2	29.0	28.4	29.6	31.4	34.2	34.9		32.7
Nokwa	35.1	37.4	37.8	37.4	33.9	32.3	30.8	30.0	31.1	31.5	34.0	34.1		33.8
						Min. Temp. (°C)								
Minna	19.9	21.2	24.1	24.4	23.3	22.2	21.3	21.7	21.4	21.3	19.2	19.1		21.7
Nokwa	15.0	19.0	23.2	24.3	23.1	22.6	22.2	22.0	21.9	21.3	17.3	14.3		20.6

Table 8: Summary of Five Year (1983 - 1987) Climatological Data Means for the Plateau Highlands (Jos, Miango)

Site	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Mean 1983 - 1987
							Rainfall (mm)							
Jos	1.4	4.	41.	99.9	148.7	174.1	334.8	329.2	222.8	90.6	2.8	0.0	1448.8	120.7
Miango	0.0	6.7	22.7	55.8	220.8	267.	328.1	342.7	239.8	74.1	0.0	0.0	1557.7	129.8
							Relative Humidity (%)							
Jos	39.7	36.4	54.8	70.2	81.6	94.9	98.2	97.6	93.6	76.0	55.7	45.9		70.2
Miango	35.2	31.7	40.4	55.9	73.9	68.2	81.4	79.6	77.3	66.9	39.6	34.9		57.1
							Maximum Temp. °C							
Jos	28.6	30.8	31.0	32.5	28.8	26.5	24.1	25.9	28.7	30.5	26.4	27.5		28.4
Miango	28.2	29.9	30.5	30.3	27.3	25.3	23.4	22.7	24.2	25.5	26.7	26.6		26.7
							Minimum Temp. °C							
Jos	11.3	14.3	15.8	16.	13.1	13.8	13.	13.	12.9	13.5	7.9	8.5		12.8
Miango	10.6	12.8	14.1	15.9	14.7	14.	12.8	12.8	12.7	12.8	10.8	9.9		12.8

Table 9: Annual Mean rainfall records for Sahel, Sudan, Guinea and Plateau zones; 1983 - 1987.

Ecozones	Yearly Mean Rainfall (mm)
Sahel	228.2
Sudan	467.5
Northern Guinea	989.5
Southern Guinea	1296.25
Plateau Highlands	1503.25

zones for the years 1983 - 1987 is recorded in Tables 4 - 8.

4.1.3 Grasshopper Populations in Relation to Climate:

Figure 7 shows the monthly fluctuation in the populations of the adults of O. senegalensis in relation to rainfall, temperature and relative humidity. The grasshopper appeared to be more abundant when the maximum temperature was high, the relative humidity low and precipitation low. These were the prevailing conditions towards the end of rains in September and October. Low populations of the grasshopper were recorded when the temperature was low, high relative humidity and high precipitations.

4.1.4 Vegetational Changes during the Study Period:

Although Keay (1953, 1959) mapped and described the vegetation of Nigeria over the years human activities such as cultivation, bush burning, grazing and tree felling for fuel and other uses, have greatly modified the vegetation. The results of the seasonal sampling survey of the three ecological zones under study are given below. A list of all the plant species encountered is presented in Appendix 3.

4.1.4.1 Southern Guinea Zone:

Since very few migrant adult Oedaleus grasshoppers were found in the southern Guinea and Plateau zones, no habitats were studied in any detail with respect to vegetation cover and composition. However, in order to

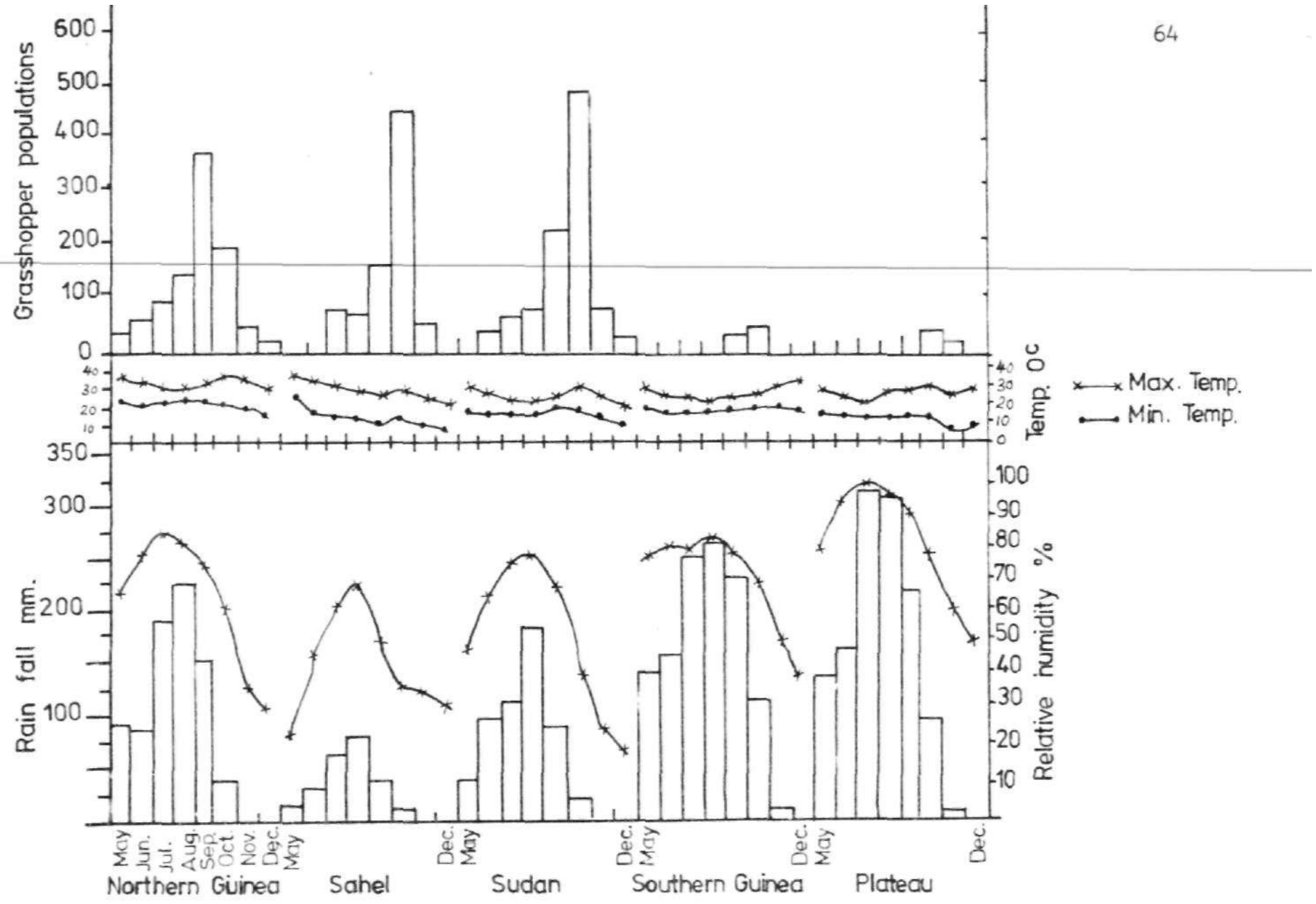


Figure 7. Monthly populations of O. Senegalensis in relation to the various climatic indices (means of the representative stations of different zones 1983 - 1984).

present a complete picture, a brief description is given of a habitat where the grasshoppers were recorded in September to October 1984. A two-year fallow land about five hectares which served as grazing field for cattle was studied.

The vegetation types and their distribution reflected the degree of human interference. It consisted of short trees and shrubs with herbaceous species and Gramineae underlayers representing fallow regrowth in different stages of successional development.

The dominant tree and shrub species were Daniellia oliveri, Annona senegalensis, Combretum hypopilinum, C. ghasalense, Detarium macrocarpum, Terminalia macropectra, Bridelia ferruginea, Entada africana, Sterculia setigera, Gardenia erubescens, Piliostigma thonningii, Crossopteryx febrifuga, Burkea africana, and Parinari curatellifolia.

Of the herbaceous species, the most commonly found are Urena lobata, Crotolaria confusa, Tridax procumbens, Sida urens, Spigelia anthelmia, Pandiaka involucrata, Desmodium velotinum, Crotolaria senegalensis, Indigofera bracteolata, Amaranthus spinosus, Ipomoae aquatica, Solanum nodiflorum, Veronia nigritana, Cassia tora, Sida linefolia, Cassia mimosoides and Borreria radiata.

The dominant gramineae species found are Loudetia simplex, Brachiaria jubata, Adropogon pseudapricus, Kyllinga squamulata, Pennisetum pedicellatum, Sporobolus pyramidalis, Chloris pilosa, Panicum flaviicola,

Michrochloa indica, Setaria anceps, Andropogon gayanus, Eragrostis tremula, E. aspera and Imperata cylindrica.

The rains started in March and by July the grass and herbaceous layers were at various stages of growth. The vegetation cover was 90-100%. In September the plants were fully grown and flowering. In November, the grasses and herbs started to dry and lodge while the shrubs e.g. Cassia tora and C. mimosoides started flowering. By January, the vegetation cover decreased to 50%. This condition was maintained till the first showers of rain came in February and March.

4.1.4.2 Northern Guinea Zone:

The northern Guinea zone presented similar floral species composition as the southern guinea zone. As a result of human interference, the tree and shrub components have been drastically reduced, leaving large expanses of open grasslands.

The dominant tree and shrub species included Isoberlinia doka, Uapaca togonensis, Terminalia macropectra, Dachrostachys glomerata, Piliostigma thonningii, Gardenia erubescens, Terminalia avicennioides, Monotes kerstingii and Swartzia madagascarensis.

The prevalent herbaceous plants were Urena lobata, Crotolalia confusa, Tridax procumbens, Sida lineafolia, Spigelia anthelmia, Pandiaka involucrata, Amaranthus spinosus, Solanum nodiflorum, Crotolaria senegalensis, Euphorbia convolvuloides, Menechma ciliatum, Ipomoae aquatica and Vicoa letoclada.

The dominant Gramineae association of the Northern guinea zone were Pennisetum pedicellatum, Schizachyrum brevifolium, Andropogon pseudapricus, Sporobolus pyramidalis, Brachiaria jubata, Panicum maximum, Ctenium newtonii, Avistida kerstingii, Chloris pilosa, Hyparrhenia rufa, Eragrostis ciliaris, Digitaria homblei, Imperata cylindrica, Setaria flaviicola and Cyperus pustulatus.

The seasonal vegetation changes is dependent on rainfall. In the Zaria area of the northern Guinea savanna, the rains start in April and by May the ephemeral plant species dominated by Brachiaria sand Pandiaka provided the initial vegetation cover of 10-20% in the fallow lands and grazing fields. This growth was restricted to depressions and small gullies. In the farm lands, the ephemeral plant species were found more in the furrows and less on ridge tops. In July about 30 - 40% of the vegetative cover has been achieved by the arrival of other colonizers which included herbaceous Tridax and Monechma species.

In August, the ephemeral vegetative cover and height had increased rapidly attaining full growth and a 70 - 100% cover.

When the rains stopped in October, the grasses began to dry up and by December the ephemeral vegetation had dried out providing very little cover. In January, the effect of the harmattan resulted in intensitve drying up and fragmentation of the plants, leaving the ground bare until the arrival of the rains.

Southern parts of the northern Guinea zone presented somewhat different aspect in the duration of vegetation, which by virtue of the early start and late stopping of rainfall, flush growth of vegetation was maintained virtually throughout the year. The ephemeral vegetation cover range between 50 - 80% from March till October. Between November and February, it was 20-30%.

4.1.4.3 Sudan Zone:

The distinct feature of the Sudan zone is the patchiness of the vegetation. Essentially, it is an area of short grass, especially in the northern stretches. Rainfall in this zone is extremely unreliable and in some areas may virtually fail.

Trees are scarce and the dominant species include Acacia albida, A. arabica, Azadirachta indica, Cassia singuana, Commiphora africana, Acacia seyel, Lannea microcarpa, Guiera senegalensis and Combretum glutinosum.

The dominant herbs included Hibiscus asper, Indigofera secundiflora, Acanthosperum hispidium, Cassia mimosoides, Commelina benghalensis, Crotolaria macrocalyx, Euphorbia hirta, Triumpheta dubia, and Zonia glachidiata.

The Sudan zone has a complex of ephemeral Gramineae species. The prevalent plants included Andropogon gayanus, Pennisetum pedicellatum, Aristida adsenscionis, Brachiaria kotschyna, Cenchrus biflorus, Cynodon dactylon, Digitaria longiflora and Eragrostis ciliaris.

Like the habitats in the other ecozones, a flush of vegetative growth followed the rain in June. In July the ephemeral vegetation provided 30% cover. In August, the vegetative cover increased to about 80% and the grass cover was about 50% of the total vegetative cover. Blooming and fruiting by the ephemeral plants occurred in September.

The percentage bare ground got increased as the ephemeral plant species began to wither as the rain stopped. In November and December, the drying up and death of the vegetation was accelerated with the harmattan. The vegetative cover was 20%. Owing to the pressure of grazing the disintegration of the scanty dry ephemeral vegetation proceeded at a much faster rate.

From January to May, the ground was virtually bare and dotted by the stumps of grasses.

4.1.4.4 The Sahel Zone:

Semi-desert conditions prevail in the Sahel zone. Rainfall is very scanty and starts in June.

The vegetation is characterised by two tree species, Acacia seyel and Commiphora africana. The commonest grammineae were sparse steppe tussock grasses which included Panicum turgidium, Lasiurus hirsutus, Aristida scutiflora.

Through out the year, vast expanses remain completely bare, but became populated for some time after rains by Fagoma arabica, Neurada procumbens and Aristida scutiflora but chiefly by Tribulus alatus.

4.2 Observations on the Grasshopper Population

4.2.1 Seasonal Sequence of events in the life stages of O. senegalensis:

Table 10 represents the occurrence of the life stages of O. senegalensis observed during 1983-87.

Hatching of eggs was observed usually after the first rains. In the northern Guinea zone the rains started early (Table 6) and hatching of diapausing eggs in the field were noticed early May whereas in the Sudan and Sahel zones where rains started late, (Tables4 and 5) hatching were observed in June.

Nymphs were recorded in the fields in the northern Guinea zone as early as May during the second week (Table 11) while in the Sudan and Sahel zones they were recorded during the second and fourth weeks of June respectively (Table 12 and 13). With the appearance of the nymphs in the field, the population fluctuations were low. In the three ecological zones, peak populations were reached in August. The Nymphs were observed in the fields until September.

Adults were observed in the fields during the last week of May in the northern Guinea zone, the last week of June in the Sudan zone and first week of July in the Sahel zone. Adults persisted until November when they disappeared from the fields.

Copulation and mating were observed from July to October. Egg laying was seen from July to October. Very few laying individuals were observed in July. The highest and most frequent laying period occurred in August and September and this was less frequent in October in the

Table 10: The occurrence and relative abundance of the life stages of O. senegalensis during the various months.

Months of the Year	Grasshopper Stages		
	Eggs	Nymphs	Adults
January	xxx		
February	xxx		
March	xxx		
April	xxx		
May	xx	x	
June	x	xx	x
July	x	xx	x
August	x	xxx	xx
September	xxx	xx	xxx
October	xxx		xxx
November	xxx		x
December	xxx		

x = Low population

xx = High Population

xxx = Very High Population

Table 11: Seasonal Populations of O. senegalensis in the Northern Guinea (Samaru) Zone during 1986/87

Date	Green			Brown			Total	
	Males	Females	Total	Males	Females	Total	B + G	Nymphs
May								
24	0	0		0	0			3
31	0	1	1	0	0		1	4
June								
1	0	0		0	2	2	2	0
8	3	2	5	0	0		5	7
15	2	2	4	1	0	1	4	3
22	0	2	2	0	1	1	3	0
29	3	0	3	0	3	3	6	0
July								
6	0	0		2	3	5	5	5
13	4	2	6	0	7	7	13	7
20	0	1	1	4	4	8	9	10
27	4	3	7	1	7	8	15	4
August								
3	0	4	4	4	5	9	13	2
10	0	17	17	0	14	14	31	8
17	21	31	52	3	11	14	66	16
24	5	27	32	6	10	16	48	7
31	3	4	7	14	5	19	26	4
Sept.								
1	0	2	2	4	7	11	13	10
8	0	0		6	4	10	10	4
15	1	3	4	3	6	9	13	6
22	0	0		8	14	22	32	2
29	0	0		52	81	133	133	4
Oct.								
1				18	44	62	62	
8				3	16	19	19	
15				0	2	2	2	
22				5	4	9	9	
29				0	0			
Nov.								
5				0	3	3	3	
12					3	3	3	
Total	46	101	147	134	256	390	537	

Table 12: Seasonal Populations of O. senegalensis in the Sudan zone (Maidiguri) during 1984/85.

Date	Green			Brown			Total B + G	Nymphs
	Males	Females	Total	Males	Females	Total		
June								
15	2	0	2	0	0		2	6
22	0	0		0	0			3
29	0	0		2	7	9	9	5
July								
6	0	0		0	0		0	0
13	0	1	1	2	4	6	7	0
20	3	4	7	0	0		7	6
27	0	0		0	0			3
August								
3	2	3	5	0	2	2	7	2
10	2	0	2	2	2	2	4	4
17	0	0		0	6	6	6	7
24	2	4	6	3	4	7	13	8
31	7	9	16	8	3	11	27	10
Sept.								
2	33	21	44	6	1	7	51	4
9	13	17	30	4	12	16	46	3
16	2	4	6	12	8	20	26	3
23	2	0	2	9	6	15	17	
30	0	0		13	14	27	27	
Oct.								
7	0	0		17	21	38	38	
14	0	0		63	74	137	137	
21	0	0		29	87	116	116	
29				8	12	20	20	
Nov.								
5				0	14	14	14	
12				1	10	11	11	
17				0	0			
Total	58	63	121	187	277	464	585	

Table 13: Seasonal Populations of O. senegalensis in the Sahel Zone (Damask) during 1984/85.

Date	Green			Brown			Total G + B	Nymphs
	Males	Females	Total	Males	Females	Total		
June								
23	0	0		0	0			
30	0	0		0	0			
July								
8	0	0		3	1	4	4	0
14	2	0	2	1	2	3	5	2
22	0	0		0	0			0
28	0	0		0	0			3
August								
5	0	2	2	3	0	3	5	5
11	0	0		0	4	4	4	10
18	0	0		0	0			3
25	1	0	1	0	3	3	4	4
Sept.								
1	0	0		7	2	9	9	7
8	0	0		4	8	12	12	2
15	0	0		4	3	7	7	
22	2	0	2	9	6	15	17	
29	4	10	14	12	15	27	41	
Oct.								
6	8	12	20	9	13	22	42	
15	11	17	28	53	41	94	122	
22	5	9	14	49	42	91	105	
30	0	0		13	19	32	32	
Nov.								
6	0	0			5	5	5	
13	0	0		2	2	4	4	
18	0	0		0	0			
Total	33	50	83	169	166	335	418	

Sudan and Sahel zones, and extended to November in the northern Guinea zone. The grasshoppers were observed laying in groups.

The eggs laid from September remained in the soil throughout the dry period until the arrival of rains the following year.

4.2.2 Seasonal Population density and fluctuation:

Tables 11, 12 and 13 show the monthly populations of the adults and nymphs of Oedaleus grasshopper in the Guinea, Sudan and Sahel zones respectively. Relatively low populations were recorded in all the zones during the first three months corresponding with the start of the rains. Then, there was a gradual population build-up which eventually culminated in a peak at the various zones, as reflected by the number of sweep-net and light trap catches. The decline in population was rapid.

In the northern Guinea zone, young nymphs were taken in the samples in May. There was a gradual increase in population until Mid-June when there was a decline as the nymphs turned to adults (Fig. 8). In August, the numbers of nymphs increased reaching a peak in the middle of the month and later decreased towards the end of the month. In early September another peak was noticed.

Adult grasshoppers maintained similar populations during May to July. In August there was a relatively rapid population build-up reaching a peak in the fourth week.

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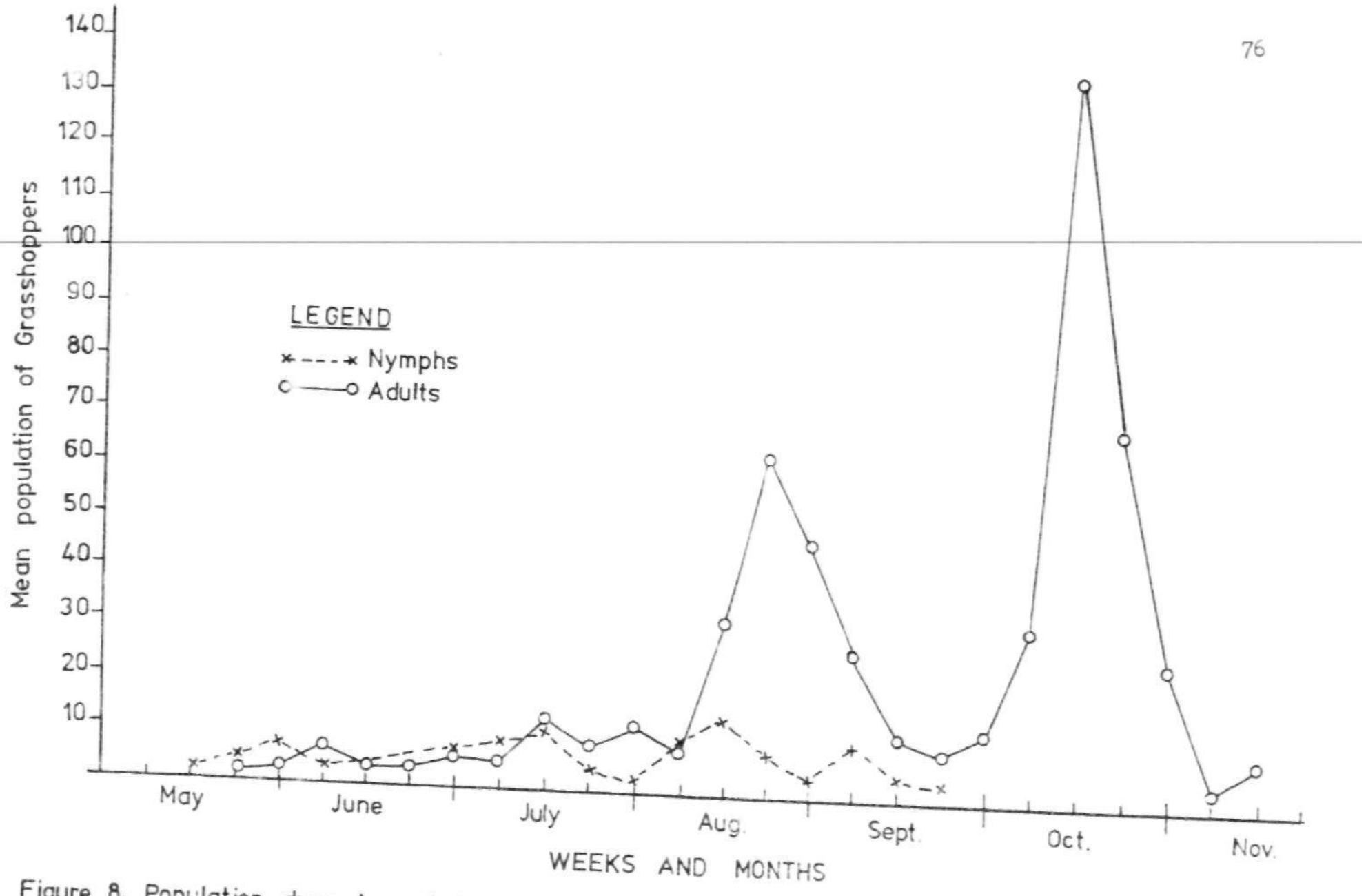


Figure 8. Population dynamics of Q. Senegalensis in the Guinea Savanna zone in 1984/85.

The numbers dropped drastically in September. In October, the highest population was recorded. The peak was reached in the second week. Thereafter, there was a very rapid decline in population by the end of the month.

The two major peaks of adult and nymph population (Fig. 8) suggest that there are probably two generations in a year in the northern Guinea savanna ecozone.

Figure 9 represents the dynamics of population fluctuations of the nymphs and adults of O. senegalensis in the Sudan ecological zone. The numbers of the nymphs were low until August and September when peak population were recorded. Throughout June, July and August, low and uniform adult populations were observed. By the last week of August, there was a gradual increase which culminated in a peak in the second week of September, and a decline at the end of the month. In October, the population fluctuation was high. The peak was recorded in the third week followed by a decline in November.

From the two peak populations recorded for the nymphs and adults, there is likely to be two generations of the grasshoppers in a year in the Sudan zone.

The nymphs were taken in the samples in July in the Sahel zone. The population remained low until August when an appreciable increase in numbers reached a peak during the second week. Then, the numbers dropped progressively until September when they disappeared from the field.

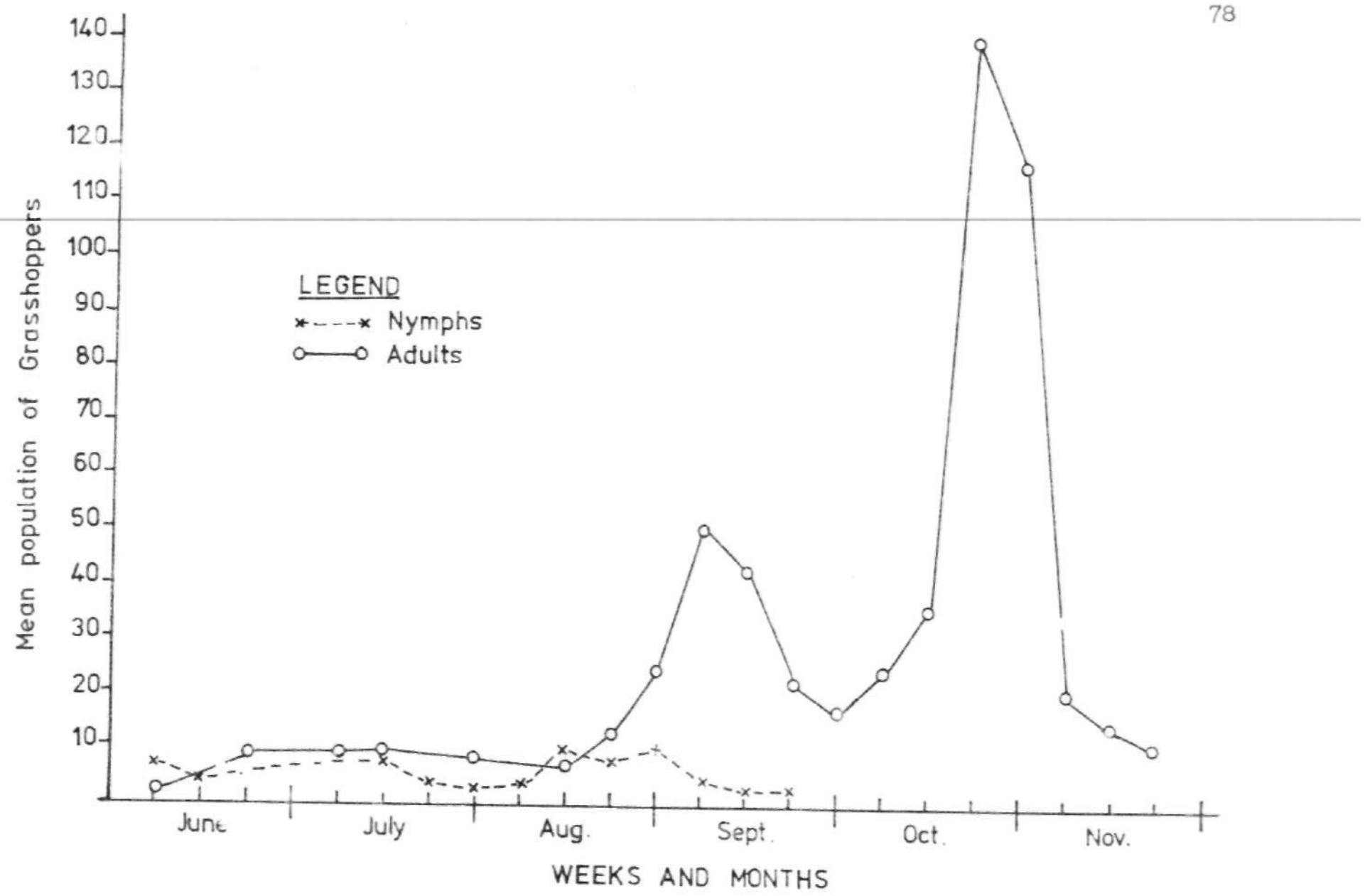


Figure 9. Population dynamics of O. Senegalensis in the Sudan zone in 1984/85.

The adults of the grasshopper were taken in the samples in July after which there was no major fluctuations in their populations (Fig. 10). From the fourth week of August, a noticeable increase in numbers occurred, in September and rising sharply in October, reaching the peak in the fourth week. Decline in population followed in November when the dry weather became severe.

In the Sahel zone, the adults and nymphs attained single peak populations indicating the possibility of only one generation in the year.

The fluctuations in the population of O. senegalensis in all the ecological zones were clearly associated with and related to the major climatic indices (ref. Fig. 7).

4.2.3 Green-Brown Polymorphism:

The mean weekly populations of each colour morph, for both sexes of O. senegalensis recorded in the ecological zones are given in Tables 11, 12 and 13. These tables show that a higher proportion of females than males were green. In all the ecozones the brown and the green forms maintained similar population levels. As the season progressed, substantial numbers of green forms predominated, reaching their peak populations in August, September and October respectively in the Guinea, Sudan and Sahel zones. They became progressively rare as the season developed. Thereafter, there was preponderance of the brown forms (Figures 11, 12 and 13).

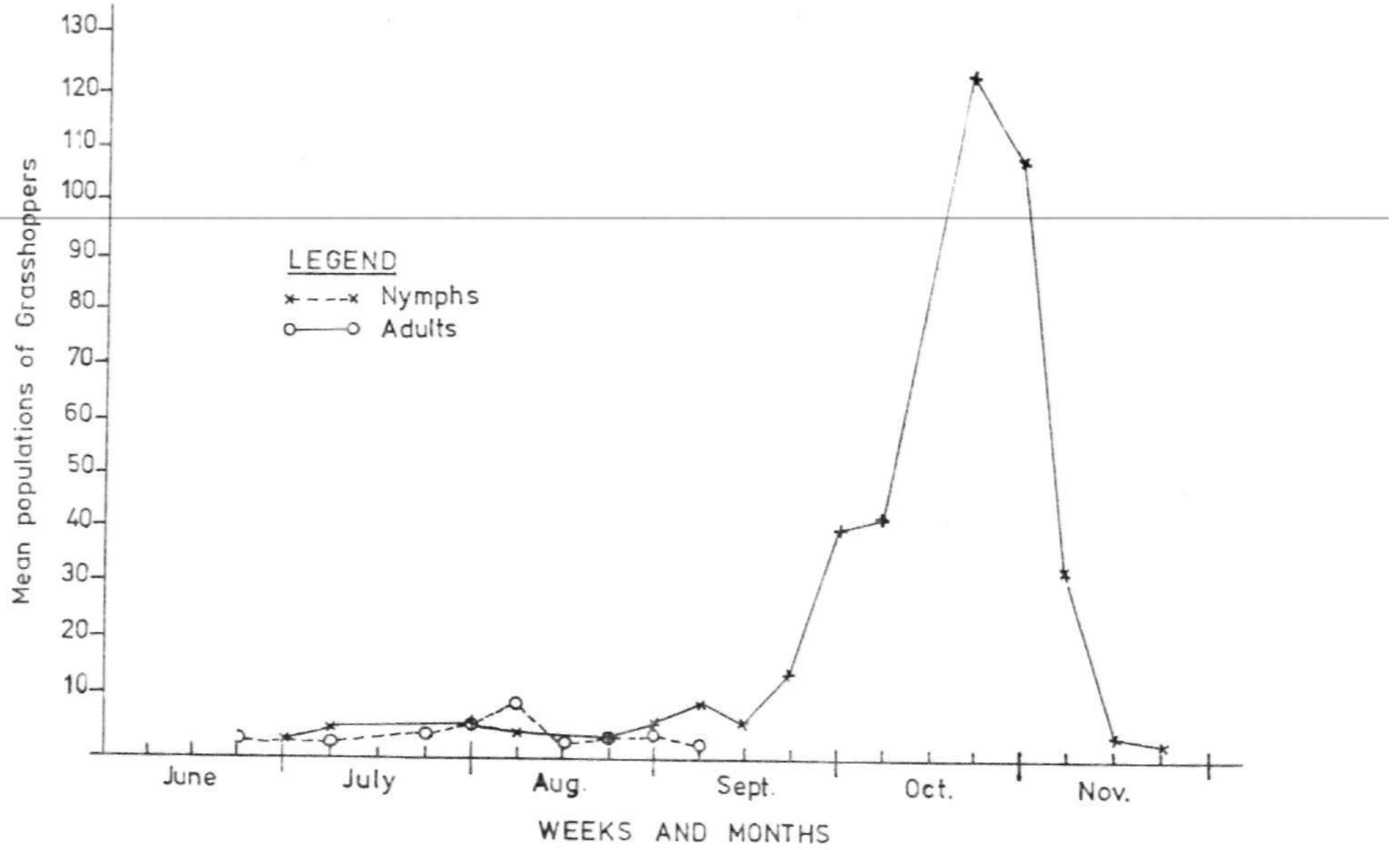


Figure 10. Population dynamics of O. Senegalensis in the Sahel zone 1984/1985.

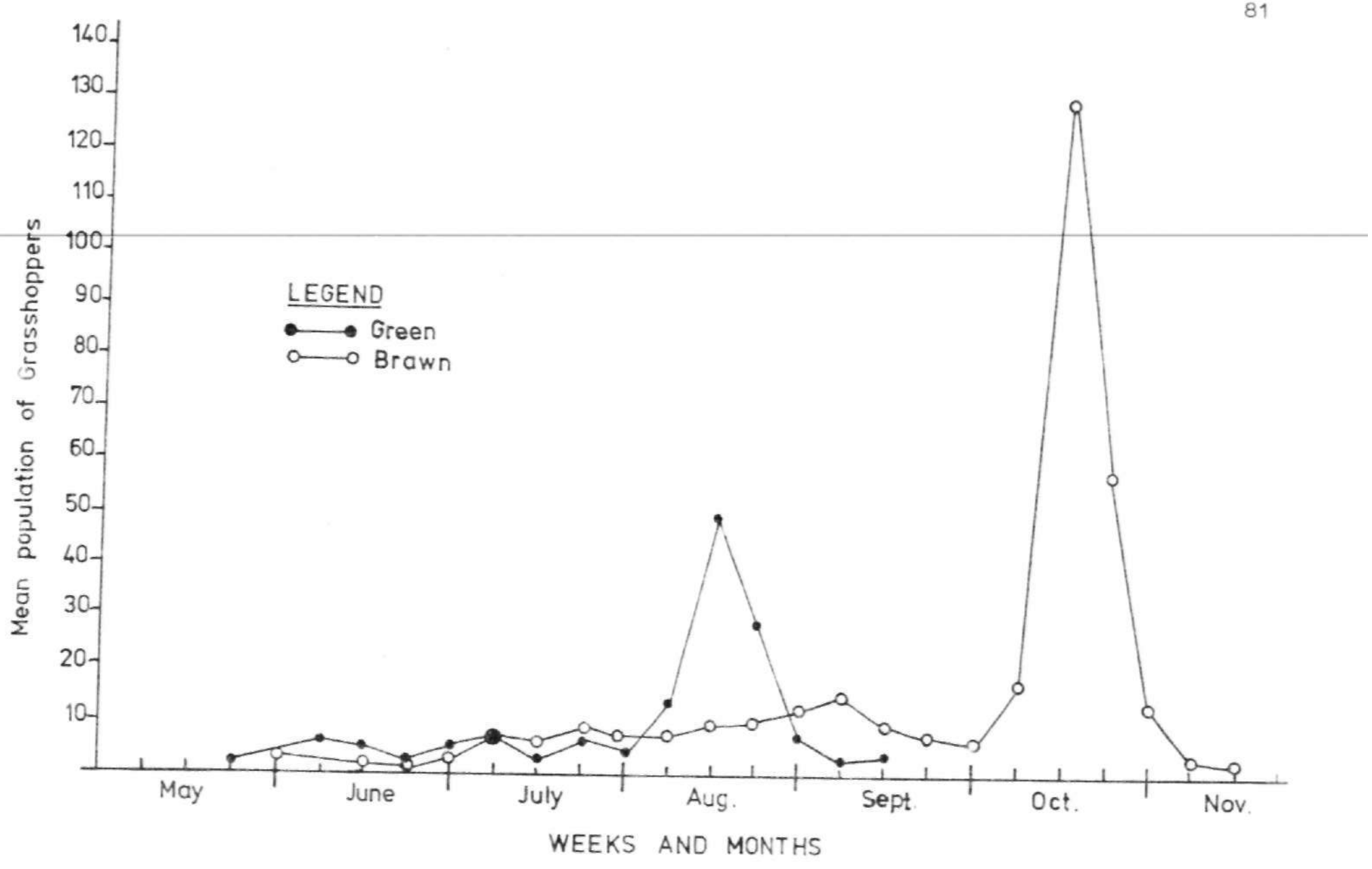


Figure 11. Populations of the Green and Brown O. Senegalensis in the Guinea Savanna zone in 1984/85 (Adult-Nymphs/SOM^2)

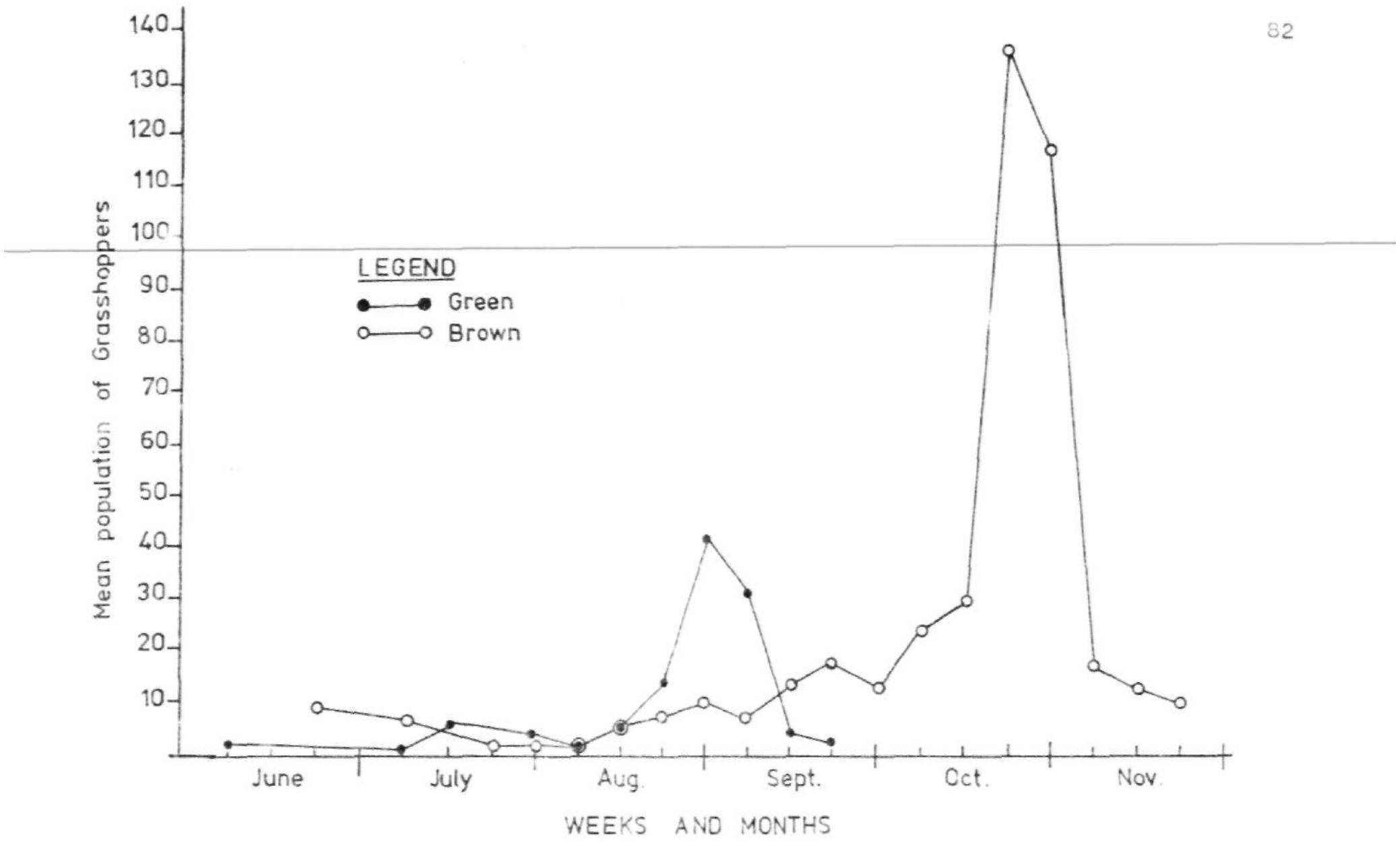


Figure 12. Population of the Green and Brown O. Senegalensis in the Sudan zone in 1984/85 (Adult - Nymphs / SOM^2)

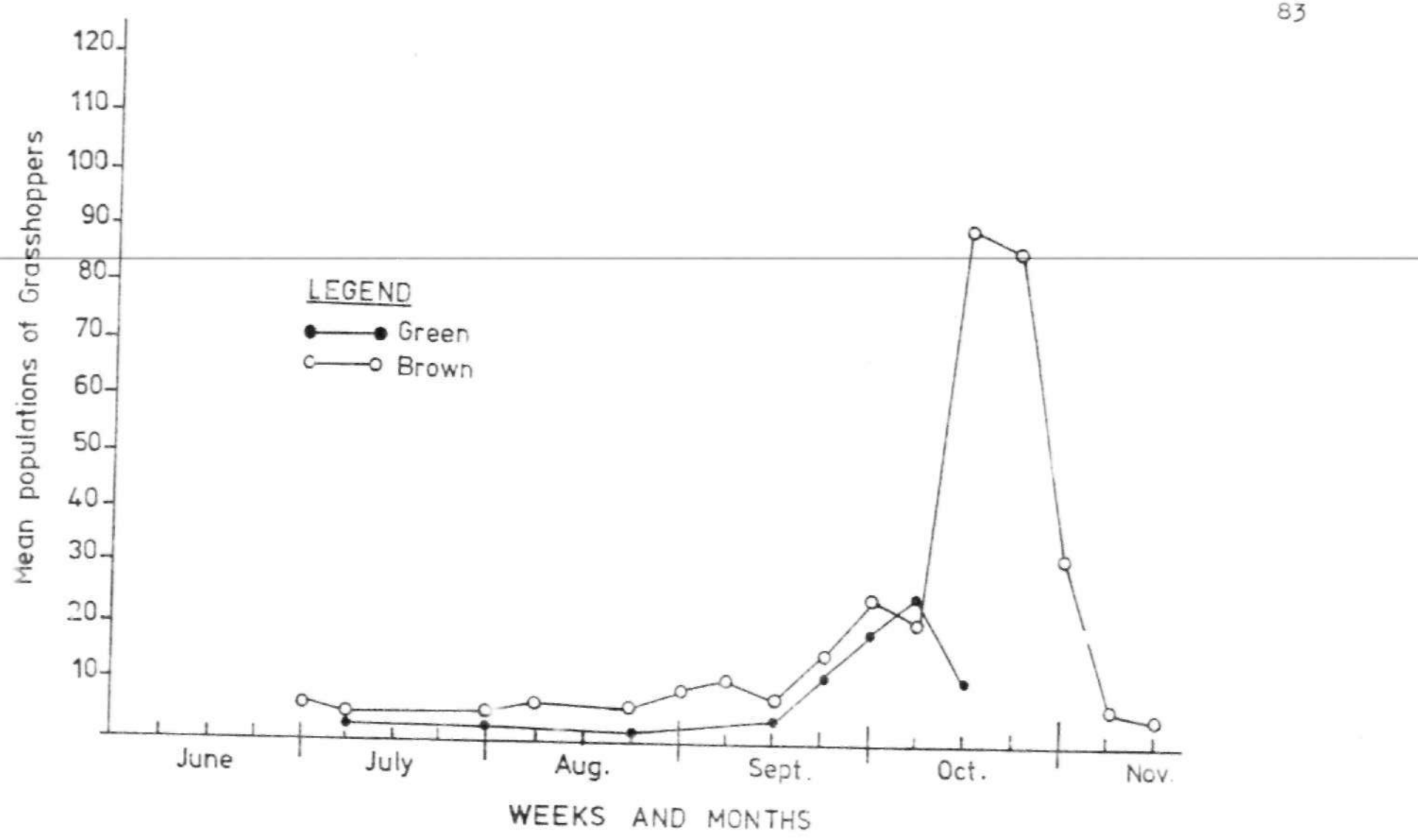


Figure 13. Population of the Green and Brown O. Senegalensis in the Sahel zone in 1984/85 (Adult-Nymphs/SOM^2)

Figure 14 represents the relative abundance of the green and brown morphs in the three ecozones. A mean total of 147 green and 390 brown forms were recorded in the Guinea savanna zone and 121 green and 464 brown forms in the Sudan zone, and 83 green and 335 brown forms in the Sahel zone. At all the zones, the brown morph exceeded the green by a ratio of 2.7 - 4 to 1, in all cases the differences being highly significant, x^2 = 56.63, 103.2, and 225.5 respectively. $P > 0.001$. The overall ratio was 3.4:1 (Table 14).

4.2.4 Sex Ratio:

The population fluctuation of O. senegalensis in Nigeria in 1983/84 was high. Grasshoppers caught by the light trap and sweep-net methods were grouped according to sex. A total of 399 males and 347 females were observed in the Sahel zone, 1472 males and 1178 females in the Sudan zone, and 469 males and 376 females in the Guinea zone. These gave a total of 2340 males and 1901 females in all the ecological zones and an overall sex ratio of 1.23:1 which is significantly different from 1:1 at the 0.1% level (x^2 = 45.42) (Table 15).

4.2.5 Observations on Movement of O. senegalensis:

During the study periods, spontaneous group flight was not recorded in the daytime. The evidence on the movement of adult populations by flight (migration) was based on the records of grasshoppers at light traps and on the observed changes of populations in the field.

Light trap catches were made everyday for 2-3 hours after dusk and day populations were caught by the sweep-net method carried out for 2-3 hours between 0900 and 1200 hours.

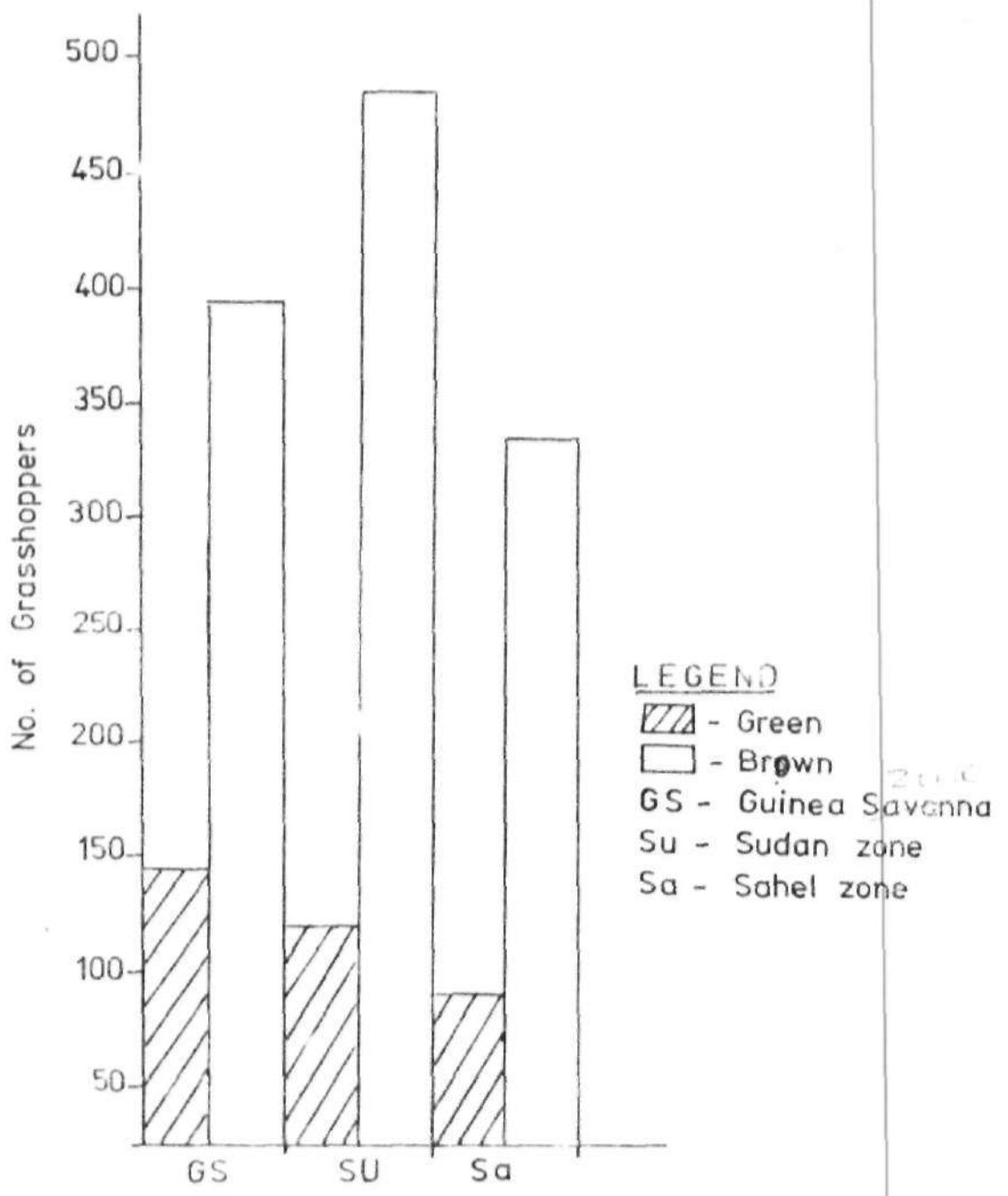


Figure 14. Relative abundance of the Green and Brown morphs of O. Senegalensis.

Table 14: Number of the Green and Brown forms of O. senegalensis recorded at the Guinea, Sudan and Sahel Zones.

Zones	Brown	Green	Ratio
Guinea	390	147	2.7:1
Sudan	464	121	3.8:1
Sahel	335	83	4: 1
TOTAL	1189	351	3.4:1

Table 15: Numbers of males and females of O. senegalensis recorded by light trap and sweep net catches in the ecological zones.

Zones	Males	Females	Sex Ratios	Significance test (x^2)
Sahel	399	347	1.15:1.00	3.62, $P < 0.05$
Sudan	1472	1178	1.25:1.00	33.59, $P < 0.001$
Guinea	469	376	1.25:1.00	10.26, $P < 0.001$
TOTAL	2340	1901	1.23:1.00	45.42, $P < 0.001$

Mean populations of the grasshopper recorded at the ecological zones in 1983/84 are presented in Table 3 and Figure 15. About 66.4% and 33.6% of the total grasshoppers recorded were caught by the light trap and sweep-net methods respectively.

In September, 1986 light trap catches were made in relation to the phases of the moon. All grasshoppers captured and their maturity were recorded. The numbers are plotted as histogram in Figure 16 and the maturity of the females is given in Table 16. During the same period, day populations were sampled by the sweepnet method and the maturity records of the females is presented in Table 17.

Figure 16 showed that the grassho
increasing steadily at the light trap
the 23rd when a maximum of 115 (64 mal
were caught and then decreasing rapi
none was recorded on the 30th. The ar
hoppers at the light trap from 12 Sept
coincided with the waning of the moon.
activity indicated by the arrival of th
its height (from dusk till 2100 hours),
virtually absent.

Evidence that the grasshoppers caught at the light trap came from places outside the vicinity of the light trap was given by the stages of maturity of the females presented in Tables 16 and 17. Those taken at the light were distinct and more homogeneous, comprising full-grown sexually

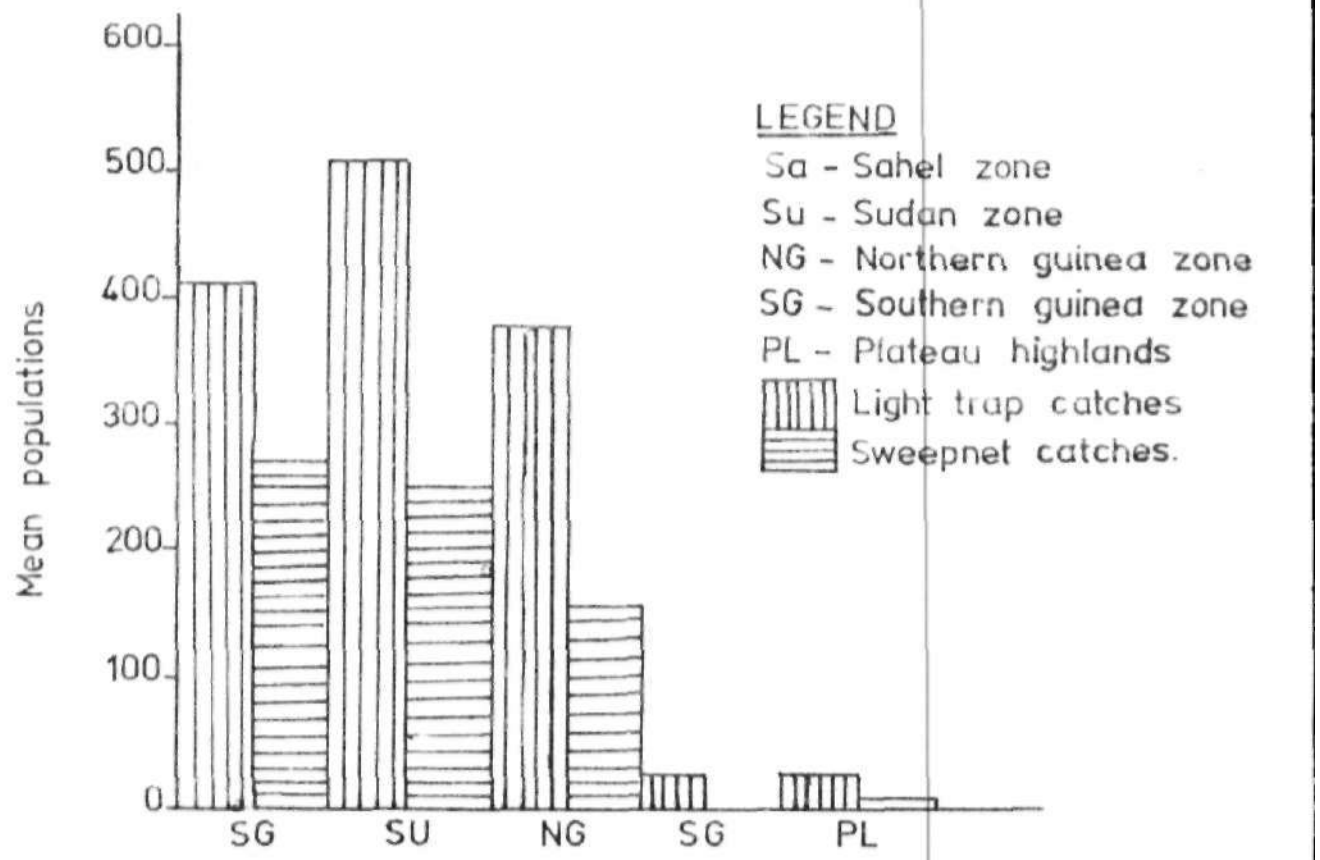


Figure 15. Comparison between night (Light trap catches) and day (Sweepnet catches) populations of O. Senegalensis at the ecological zones.

Table 16: Maturity records of females taken at light traps.

Development Dates	Immature		Mature			Total	
	F*	FG*	1*	2*	3*	Imm.	Mat.
12.9	2		1	(1)	(1)		
14.9	5		(2)	0	0		
15.9	3		2(1)	1(1)	0		
16.9	2		1	0	(1)		
17.9	2		0	(1)	0		
19.9	7		6(1)	5(2)	1(1)		
20.9	7		5	2(2)	2(1)		
21.9	8		6		0		
22.9	7		10(2)	3(1)	(1)		
23.9	14		15(2)	4(2)	2		
24.9	11		14(3)	(1)	1		
25.9	11	8	2(1)	(1)			
26.9	7		4	3(2)	3		
28.9	6		2		1		
29.9	5		1	2			
Total	97		86	36	16	97	185

F* = Soft bodied fledglings

FG* = Full grown hard bodied fledglings

1* = Adult with mature ovarioles

2* = Adults with mature eggs in the ovarioles

3* = Adults with mature eggs in the oviduct

() = Nos. with red dots at the base of ovarioles indicating that laying has taken place.

Table 17: Maturity records of females of day populations.

Development	Immature		Mature			Total	
Dates	F*	FG*	1*	2*	3*	Imm.	Mat.
12.9	2		2(1)	(7)	7(3)		
14.9			1	3(2)	6		
15.9	1		1	3(1)	5(4)		
16.9	4	3	1	2	1		
17.9	2			4(2)	3(1)		
19.9	1		2	1			
20.9	3	4		2	1		
21.9	3	9	(1)		1(2)		
22.9	4	1		(3)	1		
23.9	4	3		1(3)			
24.9	2	1			2(1)		
25.9	7	4	2(1)	2(4)			
26.9	9	3					
28.9	1			1	(2)		
29.9	1	4		1(4)			
TOTAL	44	32	13	40	40	76	93

F* = Soft bodied fledglings

FG* = Full grown hard bodied fledglings

1* = Adults with mature ovarioles

2* = Adults with mature eggs in the ovarioles

3* = Adults with mature eggs in the oviduct

() = Nos. with red dots at the base of ovarioles indicating that laying has taken place.

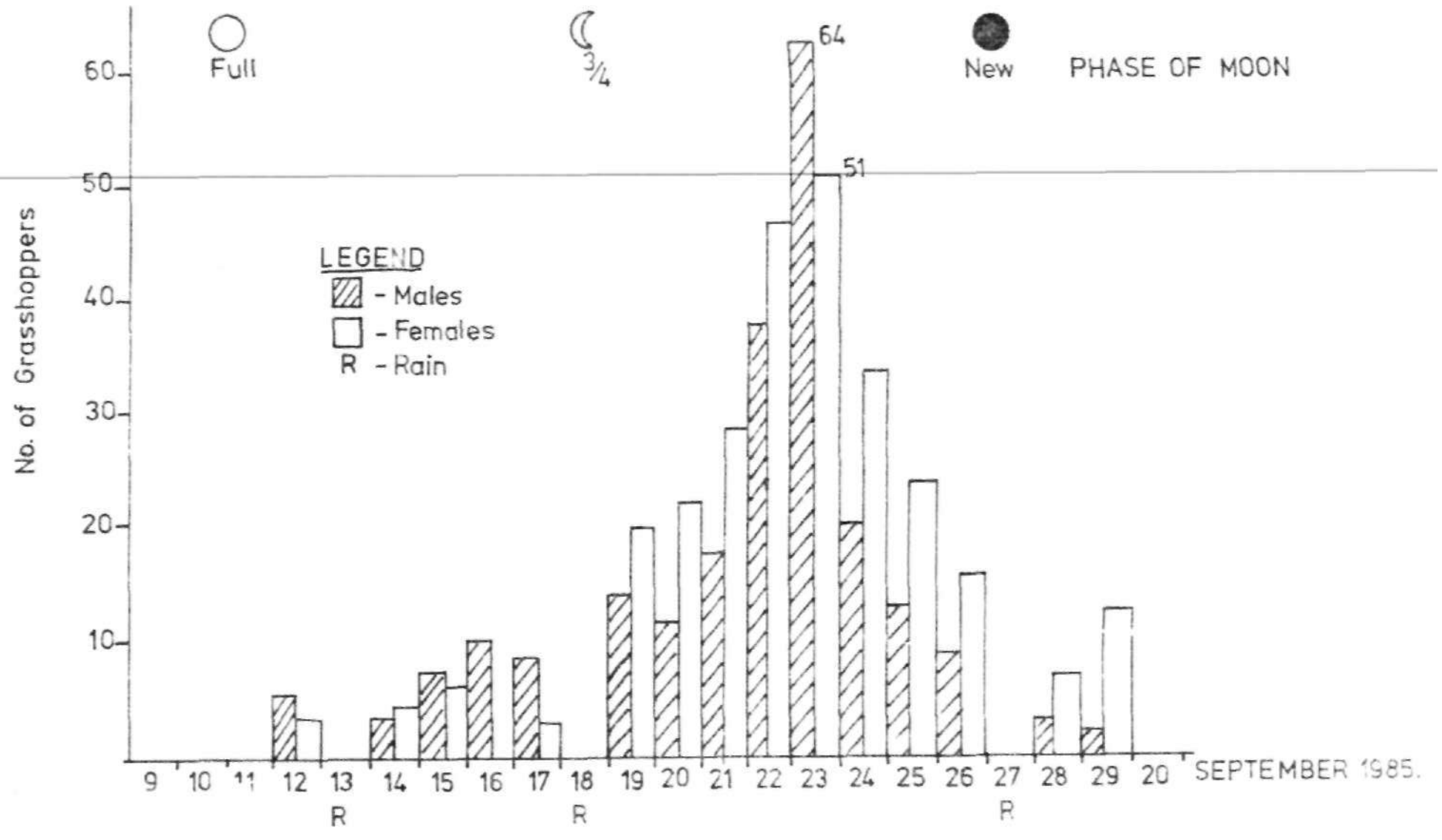


Figure 16. Light trap catches of O. Senegalensis in relation to moon phases.

immature adults and mature individuals in the early stages of maturation.

4.2.6 Observations on factors influencing concentration and gregarisation of O. senegalensis:

Two examples of different stages of concentration and the onset of gregarisation were observed during this study.

Several concentrations of adult grasshoppers were recorded during August and September at the various ecological zones. The sites where these observations were made included patches of bare sandy grounds in fallow lands, grazing fields and in cropped farms of groundnut, maize and millet. Concentrations of adults were also observed at road sides and foot paths.

During a close examination of one site, about 100m long and 27m wide in Katsina in August 1984, a varying estimate of 6000-8000 / grasshoppers per hectare was recorded. Further examination revealed that the grasshoppers, were largely composed of gravid females and mature males, and a few cases of copulation were noted. Greater numbers of the females were ovipositing.

The aggregated laying behaviour of the females was a potential factor observed likely to contribute towards bringing hoppers together from the time of hatching and to continue to build up their numbers for as long as hatching from the laying site continued.

4.3 Aspects of the general biology and life cycle of O. senegalensis

4.3.1 Number and duration of nymphal life and the effect of food plants on the rate of development:

Table 18 shows the number and duration of nymphal life of the Oedaleus grasshopper reared on different species of food plants. All the insects passed through five nymphal instars with the exception of few (18%) that were fed on sorghum which had six instar stages.

The rates of development of the females were similar to those of the males but the males took less time to develop than the females. The least average total duration of nymphal life of males was 43.85 ± 2.3 days and that of the females was 47.65 ± 3.1 days for insects reared on a combination of all the four food plants.

The mean duration of nymphal life for insects with five instars was 50.09 ± 2.2 days for the females and 45.63 ± 2.1 days for the males. Nymphs reared on Sorghum took more time to develop (63.57 ± 2.4 days for the females and 58.25 ± 1.7 days for the males) than those reared on millet, Cenchrus and Digitaria respectively. The difference arose as a result of the increase in the number of instars.

Table 18: Effect of Food Plants on the rate of development, number and duration of nymphal life (days) of *A. senegalensis*.

Food Plants	Sex	1	2	3	4	5	6	Mean days	Mean weigh after flegling(g
Millet, Cenchrus	Females	(n=14)	(n=12)	(n=12)	(n=10)	(n=10)		47.65±3.1	0.48
Digitaria and Sorghum	Mean	8.32±0.4	8.4?±0.5	8.42±0.3	9.97±0.6	12.53±1.0			
	Range	6 - 10	7 - 10	7 - 12	7 - 10	10 - 14			
	Males	(n=12)	(n=12)	(n=9)	(n=8)	(n=8)			
	Mean	7.62±0.5	7.9?±0.8	7.57±0.6	8.82±0.8	11.93±1.1		43.5±2.3	0.39
	Range	6-12	6-10	6-10	7-12	10-16			
Millet	Females	(n=10)	(n=10)	(n=8)	(n=8)	(n=8)	-	50.56±2.4	0.45
	Mean	8.8?±0.4	8.92±0.8	9.17±0.9	10.72±1.1	12.94±1.0	-		
	Range	7 - 12	7 - 12	8 - 12	8 - 12	10.20	-		
	Males	(n=8)	(n=4)	(n=4)	(n=6)	(n=6)	-		
	Mean	8.9?±0.2	8.44±0.4	7.0±0.9	9.92±0.5	11.0±0.8	-	45.27±2.1	0.38
	Range	7 - 10	6 - 12	8 - 12	8 - 12	10 - 12	-		
Cenchrus	Females	(n=14)	(n=10)	(n=10)	(n=10)	(n=10)	-	50.96±2.4	0.42
	Mean	8.37±0.2	8.73±0.5	8.8?±0.4	11.42±0.9	12.63±1.2	-		
	Range	8 - 11	7 - 12	8 - 12	10 - 14	10 - 16	-		
	Males	(n=10)	(n=8)	(n=8)	(n=8)	(n=8)	-		
	Mean	8.40±0.5	8.6?±0.9	7.38±0.7	10.74±0.6	11.22±0.8	-	46.35±2.1	0.38
	Range	7 - 10	7 - 10	7 - 13	7 - 13	7 - 13	-		
Sorghum	Females	(n=13)	(n=10)	(n=8)	(n=8)	(n=8)	(n=14)		
	Mean	9.11±0.5	9.35±1.1	9.17±1.2	10.41±1.0	12.32±1.2	12.8?±1.4	63.57±2.4	0.40
	Range	8 -14	7 - 17	8 - 20	8 - 14	10 - 17	11 - 13		
	Males	(n=12)	(n=12)	(n=8)	(n=8)	(n=8)	(n=2)		
	Mean	8.61±0.3	9.12±0.5	9.73±0.5	9.24±0.8	11.56±1.1	10 - 14	50.25±1.7	0.37
	Range	7 - 13	7 - 14	7 - 12	8 - 12	9 - 16			
Digitaria	Females	(n=10)	(n=10)	(n=8)	(n=8)	(n=8)	-		
	Mean	8.75±0.4	8.34±1.0	9.03±0.6	10.25±0.6	12.31±1.2	-	51.13±2.2	0.41
	Range	7 - 12	7 - 12	8 - 10	9 - 12	10 - 12	-		
	Males	(n=11)	(n=10)	(n=10)	(n=6)	(n=6)	-		
	Mean	8.71±0.3	8.62±0.5	8.73±0.4	9.74±1.0	11.25±0.8	-	47.05±1.8	0.38
	Range	6 - 12	6 - 12	7 - 15	8-15	10 - 13	-		

Further examination of Table 18 shows that there was little variation in the duration of each instar stadium of the insects fed on the different food plants. Also little variations exist between the lengths of the first three instars, but the last two instars, and especially the last,were considerably longer.

The weights of the fledglings were not affected by the food plants. The males weighed less than the females.

4.3.2 Fertility and Fecundity studies:

4.3.2.1 Numbers of Ovarioles per females and the number of mature eggs in the oviduct of O. senegalensis:

Table 19 presents the observations of field dissections of mature females of O. senegalensis taken from light trap catches (night samples) and sweep net catches (day samples). The results show that a mature adult female Oedaleus grasshopper contained 40.51 ± 2.4 ovarioles (range 38-42).

Counts of mature eggs in the oviduct of females from both the night and day populations gave a mean of 27.62 ± 9.1 with a range of 12-39 eggs.

4.3.2.2 Effects of food plants on egg production and Adult longevity:

Food plants appeared not to affect the sexual maturation of O. senegalensis. Judging from the period of first oviposition, fledglings fed on Sorghum took longer time to mature (19.80 ± 2.84 days). There were

Table 19: Number of Ovarioles per Female and Number of Mature eggs in the Oviduct of *C. senegalensis*.

Mean No. of Ovarioles	40.5±2.4	(n=201)
Range	(38 - 42)	
Mean No. of Mature eggs	27.62±9.1	
Range	(12 - 39)	(n =107)

slight variations between the pre-oviposition periods of insects fed on Millet, Cenchrus and Digitaria (Table 20). Fledglings fed on a combination of millet, Cenchrus and Digitaria had the least average pre-oviposition period of 16.84 ± 2.15 days.

Insects fed on Sorghum produced fewer number of egg pods (2.41 ± 0.41) than those fed on millet (3.52 ± 0.5), Digitaria (3.45 ± 0.2) and Cenchrus (3.52 ± 0.5). The variation in the number of eggs per pod produced by the insects fed on the different species of food plants was not significant. The maximum number of eggs per pod (28.87 ± 2.21 eggs) was recorded from insects reared on a combination of millet, Sorghum, Digitaria and Cenchrus, while the least number (26.71 ± 2,22 eggs) was recorded from Sorghum fed insects.

Adult longevity was not affected by food plants even though the insects reared on Sorghum had shorter adult life span (Table 20).

Generally the males were found to live longer than the females. The longest life span of 26.52 ± 3.66 days was recorded for females and 29.42 ± 2.71 days for males reared on Millet.

4.3.2.3 Number of eggs per pod:

Table 21 represents the mean number of eggs per pod from samples of the egg pods collected from the field and those that were laid in caged experiments in the laboratory. The maximum number of eggs recorded in the field was 35 and the minimum was 12. The mean number

Table 20: Effect of Food Plants on Egg Production and Adult Longevity of *O. senegalensis*

Food Plants	Millet	Digitaria sp.	Sorghum	Cenchrus biflorus	Millet Digitaria Sorghum Cenchrus
Time of First Oviposition	17.60±2.05 (n = 10)	17.35±2.3 (n = 8)	19.80±2.84 (n = 10)	17.33±2.0 (n = 9)	16.84±2.15 (n = 10)
Mean No. of Egg Pods	3.48±0.52	3.45±0.2	2.41±0.41	3.52±0.55	3.67±0.44
Mean No. of Eggs Per Pod	27.22±2.62 (n = 16)	26.90±2.42 (n = 12)	26.71±2.22 (n = 12)	27.42±2.21 (n = 10)	28.37±2.21 (n = 10)
Life Span of Females	26.52±3.66 (n = 10)	25.00±3.22 (n = 8)	22.61±3.42 (n = 8)	25.17±3.52 (n = 8)	26.04±2.27 (n = 10)
Life Span of Males	29.42±2.71 (n = 13)	28.53±2.81 (n = 8)	25.33±4.22 (n = 12)	28.91±3.53 (n = 11)	28.77±3.23 (n = 12)

Table 21: Number of eggs per egg-pod of C. senegalensis

	Eggs Pods laid in the Field	Egg Pods laid in the laboratory
Mean Number of Eggs	26.86±2.2 (n = 407)	27.42±2.2 (n = 50)
Range	(22 - 35)	(26 - 32)

of eggs per pod was 26.86 ± 2.2. In the laboratory the maximum and minimum number of eggs recorded were 32 and 16 respectively, the mean number of eggs for 50 pods being 27.42±2.2. These values are close to the mean number of 27.62 ± 91 eggs per female recorded from a sample of 107 females containing mature eggs in their oviducts(Table 19) and the mean number of eggs produced per pod by insects reared on different species of food plants (Table 20).

4.3.2.4 Effects of crowding on maturation, egg-production and longevity of females of O. senegalensis:

As in the case of the effect of food plants on the egg production and longevity (Table 20) the duration of the pre-oviposition period was calculated as the number of days passed from the day of last moulting to adult until the collection of the first egg-pod. In the crowded cages it was not possible to calculate the pre-oviposition period of individuals. The overall value of maturation rate was therefore obtained from the period from ecdysis until five egg pods (i.e. an average of one per female) had been laid.

Table 22 shows that females reared in crowds became mature more quickly than females reared in isolation. The average maturation period for crowded females was 16.87 ± 2.05 days and that of the isolated insects was 21.38 ± 2.31 days. Not only did the isolated

Table 22: Effects of Crowding on Maturation, Egg Production and Longevity of *C. senegalensis*

	Time of first laying (days)	No. of Egg Pods Per insects	No. of Eggs/Pod	Longevity
Isolated Females (n = 8)	21.33±2.31	4.38±0.5	27.87±2.4 (n=8) (23 - 30) (n=12)	34.83±2.37 (n=8)
Crowded females (n = 25)	16.07±2.05	3.46±0/4	28.24±2.2 (22 - 31)	28.54±2.24 (n = 15)

insects lay more egg-pods, but they also lived for longer periods. The average number of pods laid by 15 isolated females was 4.38 ± 0.5 compared with 3.46 ± 0.4 pods per female for 25 females in crowds of five males and five females.

Twelve egg-pods examined from the crowded insects contained 22 to 31 eggs with a mean of 28.24 ± 2.2 eggs per pod. Eight pods from isolated females contained a mean number of 27.87 ± 2.4 eggs, varying from 10 to 30 eggs per pod.

4.3.3 Incubation Period of the Eggs of O. senegalensis

Results of the field cage and laboratory incubation investigations presented in Table 23 show that the eggs of Oedaleus senegalensis took less time to hatch in the field than in the laboratory. At Samaru, Kano, and Maiduguri, the average incubation periods recorded were 18.17 ± 4.3, 16.98 ± 3.7 and 17.84 ± 2.8 days respectively. These vary from 20.11 ± 2.2 mean days recorded for 8 egg pods in the laboratory in Samaru.

4.3.4 Morphometrics

4.3.4.1 Morphometrics of the adults of Green and Brown morphs of O. senegalensis:

Table 24 shows the mean and standard deviations for measurements of femur length (F), and elytron length (E) for samples of green and brown adult O. senegalensis from the three ecological zones. It can be seen that there

Table 23: Incubation Period of the Eggs of *O. senegalensis* in Field Cages and Laboratory.

		Number of Egg Pods	Mean No. of days	Range
Field Cages	Samaru	23	19.17±4.3	12 - 24
	Kano	15	16.90±3.7	13 - 26
	Maiduguri	20	17.84±2.8	11 - 27
Laboratory	Samaru	8	20.11±2.2	16 - 20

were no significant differences between the measurements or E/F ratios of the green and brown males from the three ecozones. Thus, the males could be regarded as being morphometrically homogenous.

There were also, no significant differences between the measurements or the E/F ratios of the green females from the three zones and they also could equally be described as being morphometrically homogenous.

The morphometrics of the brown females, however, provided evidence of differences between populations in both space and time. Significant differences were found in the means of some measurements and of the E/F ratios in the samples taken at the same and different periods in the Sahel, Sudan, and Guinea zones (Table 24). Also, significant differences exist between the females of the green and brown morphs.

4.3.4.2 Effect of rearing density on adult morphometics and weight:

Adult morphometrics appeared not to be obviously affected by the density at which the nymphal stages were reared (Table 25). Females were however considerably bigger than males.

4.3.4.3 Morphometrics of day and night populations:

Tables 26 and 27 represent the mean Elytron and Femur lengths with standard deviations of day and night populations respectively of O. senegalensis collected at

Table 24: Morphometrics (mm) of samples of green and brown morphs of C. senegalensis taken from the various ecological zones: August - October, 1986

	GREEN						BROWN					
	Males			Females			Males			Females		
Site	Guinea	Sudan	Sahel	Guinea	Sudan	Sahel	Guinea	Sudan	Sahel	Guinea	Sudan	Sahel
Elytron (E)	22.65	22.82	22.71	29.86	29.73	29.69	22.87	22.81	22.84	30.61*	31.31*	30.57
Mean Standard dev.	1.42	1.27	1.29	2.07	2.26	2.05	1.22	1.24	1.34	2.07	2.62	2.05
Femur (F)	13.71	13.82	13.78	18.70	18.69	18.71	13.86	13.80	13.82	19.59*	19.74*	19.14*+
Mean Standard dev.	1.53	1.49	1.46	1.21	1.37	1.29	1.77	1.81	1.69	1.21	1.38	1.10
Ratio E/F	1.650	1.651	1.648	1.597	1.591	1.586	1.650	1.653	1.65	1.56*+	1.59*	1.60+
Mean Standard dev.	0.059	0.058	0.057	0.081	0.078	0.077	0.061	0.059	0.059	0.08	0.11	0.07
Number measured	85	105	96	83	94	66	98	118	106	68	120	100

* Appropriate pairs of means significantly different, $P \geq 0.05$

\+ Appropriate pairs of means significantly different, $P \geq 0.01$

Table 25: Effect of rearing density on adult morphometrics (mm) and weight of G. senegalensis.

	E	F	E/F	Weight(g)
Isolated Males	22.57±1.4	13.94±1.37	1.62:1	0.39±0.2
Number measured	8	8	8	8
Crowded Males	22.68±1.8	14.01±1.48	1.62:1	0.38±0.2
Number measured	56	56	56	56
Isolated Females	30.21±1.2	19.58±1.33	1.53:1	0.49±0.2
	6	6	6	6
Crowded Females	29.89±2.1	19.92±1.87	1.53:1	0.50±0.2
Number measured	62	62	62	62

E = Elytron Length

F = Femur Length

E/F = Ratio

Table 20: Mean Elytron and Femur lengths (mm) with standard deviations of day samples of *L. senegalensis*; August - October, 1986

			Males			Females	
Date	Site	n	$\overline{XE}$	$\overline{XF}$	n	$\overline{XE}$	$\overline{XF}$
Aug. 9	Samaru	8	21.65±1.47	12.48±1.12	4	27.77±1.93	17.79±1.36
Aug. 18	" Funtua	10	21.60±1.52	12.53±1.02	6	28.09±1.11	18.21±1.51
Sept. 2	Samaru	6	22.22±1.21	12.84±0.98	13	27.92±1.40	17.85±1.73
Sept.11	Malumfashi	37	21.84±1.23	13.19±1.06	21	28.18±1.51	17.97±1.48
Sept.11	Katsina	48	21.93±1.47	13.48±1.21	30	28.61±2.00	18.49±1.56
Sept.20	Katsina	10	22.11±1.02	13.22±1.13	11	28.59±2.29	17.91±1.38
Sept.20	Katsina	24	22.49±1.24	13.41±1.01	14	29.43±1.37	17.76±1.21
Oct. 7	Dutsennma	8	22.78±1.59	13.88±0.91	18	29.14±1.39	17.80±1.33
Oct. 10	Funtua	4	22.87±1.85	13.69±0.87	21	29.21±1.20	17.49±1.47
Oct. 18	Samaru	6	23.26±0.98	13.73±1.12	8	28.88±1.69	17.72±1.74
Oct. 24	Samaru	10	22.92±1.27	13.47±1.02	24	28.41±1.73	17.93±1.23
					16	28.92±1.60	18.26±1.28

Table 27: Mean Elytron and Femur lengths (mm) with standard deviations of night samples of *C. sanguilenella*; August - October, 1981.

		Males			Females		
Date	[illegible]	n	$\overline{XE}$	$\overline{XF}$	n	$\overline{XE}$	$\overline{XF}$
Aug. 14	Kano	8	23.86±1.21	13.47±1.29	12	30.21±1.47	17.00±1.29
Aug. 20	Kano	12	24.53±1.11	12.93±1.47	16	30.24±1.36	17.65±0.85
Aug. 30	Samaru	6	23.94±1.31	13.86±1.17	8	30.45±1.73	18.45±1.33
Sept.10	Kano	22	24.71±1.04	13.97±0.98	12	31.21±2.11	18.25±1.69
Sept.20	Katsina	11	24.83±1.35	14.06±1.41	24	30.91±1.25	17.95±0.88
Sept.25	Katsina	36	25.62±1.09	14.73±1.34	38	31.02±2.27	18.48±1.34
Oct. 3	Samaru	24	26.14±1.41	14.47±1.09	14	31.66±2.19	18.25±1.46
Oct. 10	Kano	16	25.72±1.08	15.07±1.38	28	30.44±1.94	18.39±1.69
Oct. 20	Samaru	8	25.81±1.72	14.81±1.44	22	30.47±1.80	18.59±1.56
Oct. 30	Samaru	12	25.88±1.68	14.44±1.20	16	30.34±1.72	18.55±1.13

various sites. These tables show that there was a corresponding increase in the elytron lengths of day, and night populations of both sexes of the grasshopper from August to September. Adult females caught in October showed a decrease but male measurements remained at the peak level. Furthermore, femur lengths varied with elytron lengths, the ratio between the two not altering markedly.

When sexes were compared separately, the day populations consistently appeared to have smaller mean values for both elytron and femur lengths than night populations. Table 28 shows that there was significant differences between day and night populations.

4.4 Enemies of O. senegalensis

4.4.1 Invertebrate parasites and Predators of the nymphs and adults of O. senegalensis:

The invertebrate parasites and predators observed attacking and preying on the nymphs and adults of O. senegalensis are shown in Table 29. They are considered under the following groups.

4.4.1.1 Insect Parasites:

Three dipterous flies belonging to two families were found as common parasites of the nymphs and adults of the Oedaleus grasshopper (Table 29). The larvae of these parasites were found at the various stages of their

Table 28: Morphometrics (mm) of Day and Night Samples of C. senegalensis.

	DAY		NIGHT	
	Males	Females	Males	Females
Elytron (E)	22.89±1.24	29.09±1.51	25.75±1.18	31.87±1.35
Range	(21.87 - 23.46)	(28.6 - 30.4)	(23.9 - 26.3)	(30.77 - 32.61)
Femur (F)	13.89±1.34	18.79±1.38	14.70±1.7	18.55±1.17
Range	(12.93 - 14.01)	(17.87 - 19.0)	(12.9 - 16.47)	(17.0 - 20.11)
Ratio E/F	1.65:1	1.56:1	1.75:1	1.72:1
Number of Insect measured	364	384	379	302

Table 29: Invertebrate enemies of the nymphs and adults of O. senegalensis.

ORDER/Family	Parasites/Predators
	Insect Parasites
DIPTERA	
NEMESTRINIDAE	Symmictus costatus
SARCOPHAGIDAE	Sarcophaga scheomani (Zumpt)
	Blaesoxipha filipjevi (Rohd)
	Parasitic mite
ACARINA	
TROMBICULIDAE	Eutrombidium sp.
	Artnropod Predators
ARACHNIDA	
SCORPIONIDAE	Scorpiones sp.
ARANEIDA	
ARANEAE	Argrope sp.
DIPTERA	
ASILIDAE	Promachus sp.
ORTHOPTERA	
MANTIDAE	Empusa fasciata (Brulla)
	Sphodromantis lineola (F)
HYMENOPTERA	
FORMICIDAE	Messor gallus Emery.
SPHECIDAE	Sphex aegyptius Lep.

development inside the body cavity of the nymphs and adults of the grasshopper. Most of the dead grasshoppers examined had holes on the neck through which full grown larvae escaped. Table 30 shows the percentage infestation of the grasshopper by the parasites. Of the 3701 Oedaleus grasshopper sampled over the three years (1984 - 1986), 6.09% were attacked by the parasites. Of these, Symmictus costatus accounted for 3.86%, Blaesoxipha 0.97% and Sarcophaga, 0.73%.

4.4.1.2 Parasitic mite:

Trombiculid red mites were found as common ectoparasites of the 4th - 5th instar nymphs and the adults of O. senegalensis. They were found attached to the wings, or to the skin at the base of the wings or wing pads. A good number of the nymphs (307 out of 1017 nymphs) and adults (211 out of 1000) sampled were infested.

4.4.1.3 Arthropod Predators:

Various arthropod predators recorded attacking and preying on the nymphs and adults of the Oedaleus pest are shown in Table 31. Most of these predators were recorded frequently in association with hopper bands of the 1st - 4th instars. Emerging hoppers during hatching were easy prey to ants since they were not strong enough to escape. In few occasions, the adults of the grasshopper were observed being attacked by scorpions and mantids.

Table 30: Percentage infestation of the nymphs and adults of C. senegalensis by insect Parasites, 1984 - 1986.

Year	No. of insects dissected	No. of Insects dissected	Symmictus sp.	Blaesoxipha sp. (parasite)	Sarcophaga sp.
1984	1064	87	47	18	12
1985	1424	64	50	14	-
1986	1219	65	46	4	15
Total	3701	216(6.09)	143(3.86)	36(0.97)	27(0.73)

Figures in brackets represent persentage

Table 31: Yearly records of arthropod predators collecting the nymphs and adults of C. senegalensis - July - November, 1984 - 1986.

Year	Scorpions	Acrrope sp.	Tromachus sp.	Empusa sp.	Sphodromantis sp.	Messor sp.	Sphex sp.	Total
1984	10	4	27	17	11	3	12	84(30.66)
1985	23	7	18	13	21	10	16	108(39.42)
1986	19	2	21	5	14	16	5	82(29.99)
Total	52(18.98)	13(4.74)	66(21.09)	35(12.77)	46(16.79)	29(10.58)	33(12.04)	274

Figures in brackets represent percentage

Table 31 gives the yearly records of the arthropod predators observed during the study period. Of the 274 incidences of predation by the arthropods, Promachus sp. was responsible for 21.09%, Scorpions 18.98% and the mantids 39.56% collectively. Sphex aegyptius and Messor gallus accounted for 12.04% and 10.58% respectively while the spider Argrope sp. accounted for 4.74%.

4.4.2 Vertebrate Predators of O. senegalensis:

The vertebrate enemies of nymphs and adults of O. senegalensis observed during the survey period were numerous. Only those that were observed regularly preying on the grasshopper, and appeared to have considerable influence on the population of the grasshopper pest are presented here (Table 32).

Large males and females of the rainbow lizard Agama agama and three snake species; Psammophis sibilans, Mehelya crossii and Rhamphiophis oxyhnchus were regular predators on Oedaleus senegalensis. The lizards were always recorded at the egg-laying sites of the grasshopper preying on ovipositing females, and at hatching sites preying on hoppers.

Bufo regularis featured prominently as an enemy of the grasshopper and was the only nocturnal predator recorded. They were observed feeding on adult grasshoppers which were attracted to street lights.

Table 32: Vertebrate Predators of the nymphs and adults of Cedaleus senegalensis.

ORDER/FAMILY	Predators
REPTILIA	
AGAMIDAE	
	Rainbow Lizard Agama agama
SERPENTES	
	African beauty snake - Psammaphis sibilans
	File snake Mehelya crossii
	Beaked snake Rhamphiophis oxyhynchus
ANURA	
BUFONIDAE	
	Bufo regularis
AVES	
PASSERIFORMES	
PLOCEIDAE	
	Black buffalo weaver Bubalornis albirostris
	Village weaver Ploceus cucculatus (L)
ALAUDIDAE	
	Crested lark Corydus cristatus (L)
LANIIDAE	
	Great grey shrike Lanius excubitor (L)

Table 32 (Contd.)

ORDER/FAMILY	Predators
STURNIDAE	
	Chestnut bellied starling Spreo pulcher (Muller)
CORVIDAE	
	Pied Crow Corvus albus (Muller)
MEROPIDAE	
	Carmine bee eater Merops nubicus (Gmel.)
	Abysinia (Senegal) roller Coracias abysinicus
	Red throated bee eater Merops bulockii
	White throated bee eater - Merops albicollis (Vieillet)
CICONIIFORMES	
ARDEIDAE	
	Cattle egrets Ardeola ibis (L)
	Great white heron Egretta alba (L)
CICONIIDAE	
	Abdims Stork Ciconia abdimii (Licht)
FALCONIFORMES	
ACCIPITARIDAE	
	Red tailed buzzard Buteo augularis (Sal)
	Black shouldered kite Elaneus caeruleus (Desf.)

Table 32 (Contd)

ORDER/FAMILY	Predators
	Swallo tailed kite Chelictinia riocourii (L).
	Chanting gawshawk - Melierax metabates (Heug)
	Black kite Milvus migrans (Bod).
	Grasshopper buzzard Bustatur rufipennis (Sund.)
	Abysinia tawny eagle Aquila rapax.

Numerous species of birds were recorded preying on both the nymphs and adults of the grasshopper (Table 32). It was particularly noticeable that the birds attacked and preyed on the grasshoppers in the more exposed habitats such as grazing fields, fallow lands and road sides.

Table 33 presents the annual records and percentage predation by the vertebrates. Substantial numbers of the birds were recorded over the three years of study. The Carmine bee eater Merops nubicus was the commonest bird predator. They movedin small flocks of 10-30 and were observed at hatching sites. M. nubicus has the highest percentage predation of 11.2% followed by Abdims Stork Ciconia abdimii with 10.8%. The grasshopper Buzzard Bustatur rufipennis and the Cattle egret Ardeola ibis accounted for 9.4% and 9.0% predation respectively.

4.4.3 Parasites and Predators of the eggs of Oedaleus senegalensis:

Insect parasites and predators were recorded as the most important natural enemies of the eggs of Oedaleus senegalensis. The observed parasites and predators presented in Table 34 are grouped as below.

4.4.3.1 Egg Parasite:

Only one egg parasite was recorded during this study. Adults of Scelio sudanenesis were caught as they deposited their eggs on partially buried egg pods of O. senegalensis

Table 33: Yearly records of the vertebrate predators attacking the nymphs and adults of O. senegalensis 1984 - 1986.

Year	Lizards	Snakes	Bufo regularis	Bubalornis albirostris	Plocepas cucullatus	Corydus cristatus	Lanius excubitor	Spreo pulcher	Merops nubicus	Corvus albus	Merops albicollis	Merops bulocki	Coracias abyssinicus	Ardeola ibis	Egretta alba	Ciconia abdimii	Buteo augularis	Elaneus caeruleus	Chelictinia riocourii	Melierax metabates	Milvus migrans	Bustatur rufipennis	Aquila rapax	Total
1984	74	7	23	44	59	13	97	11	148	37	84	38	51	122	14	131	54	70	27	41	23	141	28	1246(31.3)
1985	83	3	36	37	73	31	107	6	127	78	87	70	27	81	18	142	72	20	31	35	13	107	53	1267(31.7)
1986	85	11	43	52	88	31	77	15	171	39	102	83	40	157	28	159	62	41	51	21	27	128	47	1475(37.0)
Total	242	21	102	133	220	75	201	32	446	154	273	201	124	360	60	432	168	78	109	97	63	376	128	3984
%	6.11	0.5	2.6	3.3	5.5	1.9	5.1	0.8	11.2	3.9	6.9	5.1	3.1	9.0	1.5	10.8	4.2	2.0	2.7	2.4	1.6	9.4	322	

at Katsina in September 1985. At Damask, two adult S. sudanensis were also caught after they successfully deposited their eggs in Oedaleus egg-pod. Attempts to rear the parasitic eggs failed.

4.4.3.2 Egg Predators:

The majority of the Oedaleus egg-pod predators observed were dipteroid and coleopteroid larvae (Table 34). These larvae invariably consumed all the eggs in the pods leaving the pod cases intact. Pupation often took place inside the pods. This was the case with Xeramoeba. The predatory attack by Systoechus was characteristic in that after the eggs had been consumed, the larvae left the pods through large holes at the base. Pupation then took place inside the soil beyond the egg-pods. In the attacks by the meloid larvae, eggs were not often consumed, but the froth of the pods. Several Meloid pupae were collected within the vicinity of the damaged egg pods.

Adults of two Isopteroids found attacking the egg-pods of O. senegalensis were Microtermes and Odontotermes species. In their mode of attack, nothing was left of both the eggs and the pods. The incidences of attack was however low and occurred in harvested millet fields.

Damage to egg-pods arising from the attacks by the insect predators was relatively high in almost all the sampling sectors (Table 35). Of the total of 2281 egg pods examined, 37.66% were infested by the predators.

Table 34: Parasites and Predators of the Eggs of C. senegalensis

ORDER/FAMILY	Parasites/Predators
DIPTERA	
BOMBYLIIDAE	Systoechus leoninus Bowder
	S. melampogon Bezzi
	Xeramoeba ochracea Bec
CALLIPHORIDAE	Stomorhina rugosa Bigot
	S. lunata F.
COLEOPTERA	
HISTERIDAE	
	Contipus digitatus Mars.
PIMELIONIDAE	Pimelia senegalensis
MELOIDAE	Mylabris bifasciata Degeer
	Coryna hermanniae
ISOPTERA	
TERMITIDAE	
	Microtermis sp.
	Odontotermis sp.
HYMENOPTERA	
SCELIONIDAE	
	Scelio sudanensis

Table 35: Percentage infestation of C. senegalensis egg-pods at the various sites

Site	Total no. of Egg pods.	Number of Egg Pods Intact	Number of Egg Pods Infested	% Infestation
Zaria Funtua Gusau	276	187	89	32.25
Katsina Maradi	320	141	179	55.94
Maiduguri Damasak Dikwu Potiskum	723	412	311	43.02
Sokoto B/Kebbi Bakura	347	204	143	41.2
Kano Gumel	304	190	114	37.5
Gombe Bauchi	184	167	17	9.2
Yola Mubi	127	121	6	4.72
Total	2281	1422	859	37.66

Highest percentage predation was recorded at the Katsina sector (55.94%) followed by Maiduguri and Sokoto sectors with 43.02% and 41.2% respectively.

Table 36 presents the incidences of egg predation by the insects at different sectors. Of the 859 damaged egg-pods, 354 (41.21%) were destroyed by Pimelia senegalensis, 245 (28.52%) by Systoechus sp., 120 (13.97%) by Xeramoeba sp., 61 (7.10%) by Stomorhina sp. 33 (3.84%) by Mylabris sp., 23(2.68%) by Coryna sp., 18 (2.10%) by Contipus, sp. and 5 (0.58%) by the egg parasite Scelio sudanensis.

Table 35: Incidences of the insect predators and parasites of egg pods of O. senegalensis

Site	Stomorhina spp.	Systocchus spp.	Xeramocha spp.	Hylaeis sp.	Coryna sp.	Contipus sp.	Pimella sp.	Scelio sp.	Total number of ponds infested.
Zaria Funtua Gusau		17		21	15		36		89(10.36)
Katsina Maradi	18	43	37			9	69	3	179(20.84)
Maiduguri Damask Dikwa Potiskum	43	107	34			2	123	2	311(36.2)
Sokoto B/Kebbi Illela		39	22			7	74		143(16.65)
Kano Gumel		39	27				48		114(13.27)
Gombe Bauchi				8	6		3		17(1.98)
Yola Mubi				4	2				6(0.70)
Total	61(7.10)	245(28.52)	120(13.97)	33(3.84)	23(2.68)	18(2.10)	355(41.21)	5(0.58)	859

Numbers in brackets represent percentages

CHAPTER FIVE

DISCUSSION

This study has centred on the population dynamics of O. senegalensis, on the characterisation of adult populations using morphometric parameters; on the identification of the natural enemies, and on the biology of this grasshopper pest. These aspects therefore constitute the main body of the discussion.

O. senegalensis was recorded in all areas north of latitude 9°N (Fig. 5). These areas are within the Sahel, Sudan and the northern one-third of the Guinea savanna ecological zones of Nigeria. Although Golding (1948) described the distribution of O. senegalensis in Nigeria as being limited to areas north of 11°N, results from the present study have shown that the distribution of this grasshopper has considerably increased. Golding (1934) and Newman (1937) attributed this extended distribution of the grasshopper to factors which include extensive tree felling, bush burning, cultivation, grazing and desert encroachment which modified the natural vegetation into favourable habitat for the grasshopper.

Higher densities of the O. senegalensis were recorded in the Sudan and Sahel ecozones. The insect was observed to be less frequent in the Southern Guinea zone where only adults were recorded in low numbers in October and November, i.e. towards the end of each rainy season. In addition, the absence of nymphal stages in the Southern

Guinea zone indicated that there was no local breeding in the zone, and suggests that minority of individuals of insects observed in the zone were migrants.

The distribution and monthly fluctuations in the population of O. senegalensis was related to rainfall, temperature, and relative humidity (Fig. 7). These findings are in agreement with the results earlier investigations as reported for India by Ramchandra and Cherian (1942), for Wales by Clark (1949), and for Montan by Anderson and Wright (1952).

The distribution data of O. senegalensis in the different ecozones (Table 2) shows that the adult grasshoppers occurred in high densities and were widely distributed throughout the Sahel, Sudan and the northern Guinea zones. The distinct feature of these zones is the patchiness of the vegetation which is being essentially comprised of short grass especially in the northern stretches. O. senegalensis has been shown to prefer semi-arid areas as habitats (Batten, 1969; Amatobi, 1982). Potentially, the Sahel, Sudan and the northern Guinea zones therefore provide all the requisite features of a well balanced food-shelter, oviposition habitat for a grasshopper like O. senegalensis (Phipps, 1968; Jerath, 1968; Anderson, 1964; Clark, 1947; and Nefedov, 1936).

In contrast only few adult presence and no nymphal stages were recorded in the southern Guinea zone and the grasshoppers were completely absent from areas south of

this zone. These areas experienced early and prolonged periods of rainfall, resulting in relatively high humidity and dense vegetation growth all through the year. The major factors which were apparently responsible for the absence of the Oedaleus senegalensis in these zone were the weather and vegetation. The occurrence and distribution of O. senegalensis in Nigeria therefore appears to follow a well defined ecological zonation on a north-south transect. There is no doubt therefore that any major differences in the grasshopper population and distribution in Nigeria reflects the varied climatic and vegetation conditions of the ecological zones.

Observations on the timing of the occurrence of the life stages of O. senegalensis in the field have practical ecOlogical considerations. It is expected that from May in the Guinea zone, and June in the Sahel and Sudan zones, adequate rainfall would result in mass hatching of the grasshopper eggs to produce nymphs. Such early rainfall also encourages farmers to plant crops, such as guinea corn and millet, attacks by the nymphs of the grasshopper on the vulnerable seedlings, are to be expected. Furthermore, towards the end of the rainy season (September to October) outbreaks of the adult grasshoppers occur in the field: the insects feed on maturing and matured late crops, and occasionally completely defoliate the plants and eat up the seeds (Hergat, 1975; Cheke, Fishpool and Forrest, 1980). Thus different phases (Solitaria and

gregaria phases) of the grasshopper disrupt farming during the planting and harvesting seasons respectively.

Similar seasonal population fluctuations of O. senegalensis were recorded in the three ecological zones. The recorded densities varied from few individuals at the beginning of the rainy season to dense concentrations of hopper bands, and aggregations of adults at the rains (Tables 11, 12 and 13). Although comparisons based on the numbers of grasshoppers collected can rarely be justified (Davey and Johnston, 1966) the monthly differences in the grasshopper numbers observed during this study were large enough to reflect the favourable conditions prevailing in the various ecozones. Furthermore, Tables 11 and 12 suggest the existence of two seasonal populations of nymphs whose later emergence as adults gave rise to the two peak periods of abundance (Figs. 8, 9).

Evidence from the two peak populations recorded in the Guinea and Sudan zones indicates that O. senegalensis has two annual generations in these zones. This observation agrees with the two annual generations recorded elsewhere in West Africa (Davey et al., 1959; Saravia, 1962; Bhatia and Ahluwalia, 1966). However, in the Sahel zone where the rainfall is of shorter duration, the appearance of O. senegalensis in

in the field was late; only one peak population, indicating one annual generation was recorded. This finding reinforces the generalisation that the distribution and number of generations of O. senegalensis are related to rainfall (Fig. 7).

In the present study, the observation of the green morph predominating at the middle of the rainy season is in agreement with Faure (1932), Herz and Imms (1937), Albrecht (1965) and Rowell (1971), who showed that humidity was most single factor in predisposing experimental populations in favour of the green morph. However, towards the end of the rains the brown morph predominated and exceeded the green morph by a ratio of 3:1. This numerical superiority of the brown morph over this period has been attributed to the green morph changes to brown after exposure to light (Abushama and El-Khider, 1973).

The male grasshoppers consistently outnumbered the females throughout the study period (Table 15). This disproportion, however would not necessarily be seen to reflect a preponderance of males, but rather, as Davey and Johnston (1956) observed, resulted from the inherent ability of the females to migrate, so that after a movement out of a particular habitat, the remaining grasshoppers were often nearly all males. Furthermore, Merton (1959) suggested that one possible explanation for the small but real excess of males over female grasshoppers, was that ovipositing females were over-looked in the searches, or missed in sweeping

being at ground level. The male preponderance of O. senegalensis could also be attributed to the shorter life span of the female grasshoppers observed during this investigation.

The evidence from this study on the migratory movement of the adults of O. senegalensis was based on the records of the grasshoppers caught by the sweepnet and light traps, and the observed differences in the stages of sexual maturity of the females. The total number of grasshoppers caught in the three ecological zones by light traps (night populations) was consistently higher than the number caught by the sweepnet method (day population).

The stages of maturity of the females of the night population indicated that the grasshoppers came from outside the vicinity of the light trap. When the maturity of the night and day populations of the grasshopper was compared, the day population was heterogenous, comprising mostly of fullgrown immature and mature adults. When the morphometrics of the two populations were considered, the day population consistently had smaller mean values for both elytron and femur lengths than the night population. These findings indicated the difference in their spatial origin. It seems unlikely therefore that the grasshoppers caught at light traps were merely resident local individuals attracted from the immediate vicinity

rather they represented a migration passing through the area (Jago, 1979). Migration of O. senegalensis has been reported by other workers in several other countries. Popov (1975) indicated that O. senegalensis migrated from the south at the beginning of the wet season with the progression of the Intercontinental Convergence Zone (ITCZ) and returned with the latter's retreat. Lecoq (1978) described how a population of O. senegalensis changed during the course of a season and how numerous adults disappeared from his study areas in Upper Volta. He concluded that their departure was part of adaptive migration which was related to the ITCZ. The large population of O. senegalensis recorded in Nigeria in 1976 (Bindra, 1977) was suspected to be immigrants from the Maradi and Zinder regions of Niger (Oyidi, 1977; Cheke, Fishpool and Forrest, 1980).

Morphometric characterisation of the adult populations of O. senegalensis yielded very interesting results. Brown and green males from the three ecozones were morphometrically similar. Also adult green females from the ecozones were similar with respect to the elytron and femur measurements. The absence of any difference in these groups of insects was a reflection of the homogeneity of the populations. However, the marked significant differences in the elytron and femur length ratios between the day and night populations, and the relatively high elytron

and femur length value of the night population indicate that O. senegalensis exists in both solitaria and gregaria phases.

Several direct observations were made on concentrations of gravid females ovipositing at the same site. This group laying would result in high pod densities at the laying sites. Although Popov (1980) did not witness any group laying by O. senegalensis, they however observed aggregated distribution of egg-pods and attributed the high egg-pod densities to the consequence of a succession of individuals selecting similar suitable ovipositing sites. Whether or not this assertion holds, aggregated distribution of egg-pods is likely to contribute to bringing hoppers together for the time of hatching. For this phenomenon to result in aggregation or gregarisation as indicated by Popov (1980), depends on the number and density of hoppers in relation to the structure of the food-shelter habitat.

The life cycle of O. senegalensis is not basically different from that of other Acridids (Antoniou, 1973; Uvarov, 1966; Clarke, 1965). The rate of the development of the females was similar to that of the males; five nymphal instars with a duration of 45.62 ± 21 days and 50.09 ± 2.2 days for the males and females respectively. The little variation

between the lengths of the first four instars and the considerably higher variation in the last two instars was expected, as it was common to most Acrididae (Uvarov, 1966).

Food plants did not affect the rate of development and the duration of nymphal instars. All the four plant species tested in this experiment occurred in the three ecological zones in abundance and readily available in the field during the relevant period of O. senegalensis occurrence (May-September). However, insects reared on sorghum passed through six nymphal instars and took longer time to develop. This was in agreement with Woodhead and Bernays (1977, 1978) who showed that the palatability of sorghum increased with age of the plant and attributed this to the decreasing amounts of Cyanide and phenolic acids that the plants produce as they grow older.

Fertility and fecundity studies showed that an adult female Oedaleus senegalensis an average of 40.51 ± 2.4 ovarioles. It was expected therefore that an average female grasshopper would produce about 40 eggs at a time. However, counts of mature eggs in the oviducts of gravid females gave a mean of 27.62 ± 9.1 eggs. Furthermore the mean number of eggs per pod of samples from the field and those laid in the laboratory were 26.86 and 27.42 respectively, thus confirming that not all ovarioles produce eggs at the same time (Anene, 1986).

The variation in the number of egg pods and the number of eggs per pod produced by insects reared on different species of food plants was not significant, although those insects fed on sorghum produced significantly less number of egg pods (Table 20). Table 22 indicated that not only did isolated females laid more egg-pods, but also lived for longer periods (Table 23). Obviously, the considerably greater number of egg-pods produced was a reflection of the longer life span. Also, there was no significant difference between the number of eggs in the egg pods of isolated and crowded groups, but density affected the average egg-pod production by each female. Similar results were obtained for Ornithacris turbida (Antoniou, 1973) and Zonocerus variegatus (McCaffery, Cook, Page and Perfect, 1968). It has been shown that crowding and the presence of males stimulated oocyte development in Schistocerca gregaria and Locusta migratoria (Higham and Lusis, 1962; Higham and Haskell, 1964).

The natural enemies of O. senegalensis observed during this investigation were numerous and appeared to have important implication in relation to the control of this serious pest of cereal crops in Nigeria. However, only those that were encountered regularly and appeared to influence the population of the grasshopper pest would be discussed.

Three dipterous flies were common parasites of the nymphs and adults, accounting for 5.6% of the total population sampled (n = 3701). These parasites were found to be more prevalent where there was increase in numbers of the grasshopper, especially when the gravid females aggregated for oviposition. Adults of these parasitoids were reared from dead female grasshoppers. A low incidence of attacks was recorded among hoppers of the 4th - 5th instars. These parasites have been recorded attacking other acridid grasshoppers and appeared not to be specific in their choice of hosts and distribution. Khalifa (1966) recorded S. costatus on Schistocerca gregaria in southern Ethiopia. In the Sudan, Wood (1933) recorded B. filipjevi on Locusta migratoria and S. gregaria. In Russia and Central Asia, B. filipjevi was recorded on L. migratoria (Olsifiev, 1929; Rukavishnikov, 1930). Dempster (1957), and Greathead (1958) recorded these parasitoids on Dociostaurus maroccanus in Cyprus, and S. gregaria in eastern Africa respectively. In Nigeria, Taylor (1964) reported B. filipjevi as a parasite of Zonocerus variegatus, and, Bindra and Amatobi (1981) recorded Sarcophaga scheomani attacking Krausaria angulifera.

It is clear that the percentage attack by these insect parasites of nymphs and adults of the Oedaleus grasshopper was low, however, the additional parasitic

and predatory effects on the eggs (Popov, 1980; Anene and Vajime, 1988a) and predatory destruction of nymphs and adults (Anene and Vajime 1988b) are expected to reduce the population of the grasshopper.

No estimate of the percentage mortality of O. senegalensis by the attacks of the red mites was made, but it is highly probably that their attacks would adversely affect the vigour and reproductive potential of the grasshopper. This inference is a parallel to Dempsters (1957) suggestion that heavy infestation could jeopardise the final moult of the hoppers.

Similarly, although the frequency of attacks by the arthropod predators on O. senegalensis nymphs was low over the study period, the observations indicate the potential importance of arthropods particularly Promachus sp, Scorpions, and mantids in the biocontrol of O. senegalensis. Cheke, Fishpool and Forrest (1980) observed Promachus sp. and Messor gallus as predators on O. senegalensis in Niger, and Amatobi (1982) recorded preying mantis, mites, web building spiders and ants as arthropod enemies of the grasshopper in Nigeria.

Among the vertebrates, lizards, toads, snakes and birds were observed as regular predators of the nymphs and adults of the grasshopper. At several locations, lizards were observed at oviposition sites preying on laying females, and at hatching sites feeding on

emerging hoppers. Undoubtedly, predation by these lizards would exert considerable adverse influence on the number of eggs laid, and the proportion of hoppers developing into adults.

Several species of birds were undoubtedly the most numerous and regular predators on O. senegalensis. A similar range of bird predators of the grasshopper has been reported for India by Bhatia and Ahluwalia (1967) and for Niger by Cheke, Fishpool and Forrest (1980). Dempster (1957) observed several species of birds feeding on D. maroccanus in Cyprus but reported that the birds were not numerous enough to influence effective control of the grasshopper. In Nigeria too, birds have been reported (Davey and Johnson, 1956) to have the greatest effect in reducing the population of L. migratoria. Another report showed that birds were more effective in reducing the numbers of grasshopper nymphs than adults in the country (Amatobi, 1982). There is no doubt therefore that the effects of all these birds on grasshopper populations would be considerable, especially when they assemble in the neighbourhood of oviposition sites during egg laying and emergence of hoppers during hatching. The Sahel and Savanna zones of Nigeria possess peculiar ecological conditions that support vast concentrations of flocks of birds of

many species (Davey et al., Loc. cit.). Although no quantitative estimate of the actual reduction in numbers of this grasshopper pest was made over the study period, it was apparent that the numerous bird species observed feeding on the pest would affect the population drastically. Therefore, more detailed studies are required to ascertain the role of birds as biocontrol agents in the Sahel and savanna zones of Nigeria.

Prospection for the enemies of the eggs of the Oedaleus grasshopper showed that insects were the major and most abundant parasites and predators in the Sahel, Sudan and Guinea zones, destroying them not only by direct attack, but also by damaging the pods and thus permitting dessication, and entry of bacteria, moulds and nematods (Stower, Popov and Greathead, 1958). It was also observed that most of these insect enemies depended on the eggs of O. senegalensis and other acridids for their development (Dempster, 1957; Greathead, 1958, 1963). Of all the predatory species recorded, Pimelia senegalensis, Systoechus and Xeramoeba species were the most important in reducing the potential number of the Oedaleus senegalensis. The only true egg parasite observed during this study was Scelio sudanensis and was recorded from only two sites.

As O. senegalensis spends the greater part of its life in the egg stage in the soil (Batten, 1969) it is not surprising that these egg parasites and predators would be extremely important during this period.

There was a positive correlation between the incidence of these egg enemies and the number and density of the egg-pods of O. senegalensis. There were exceptionally heavy attacks and destruction in the sectors where the egg-pods were abundant, and there was a drop in the incidence of attack following a decrease in the number of the egg-pods. The predators appeared to be more prevalent in the drier and more northerly parts of the Sudan and Sahel zones of Nigeria.

Undoubtedly, destruction by these parasites and predators would exert a considerable influence on the number of the egg-pods, and ultimately on the population of O. senegalensis. It is desirable, therefore, to carry out more detailed studies on the bio-ecology of these egg parasites and predators and other natural enemies of this grasshopper to screen out the most promising species and assess their bio-control potentials.

CHAPTER SIX

SUMMARY AND CONCLUSION

The distribution, ecology and biology of Oedaleus senegalensis in Nigeria were investigated.

The results show that the known distribution of O. senegalensis in Nigeria has considerably increased, being extended and limited to areas north of Latitude 9°N. This extended distribution was as a result of the natural vegetation having experienced human interference over a considerable period through cultivation, settlement, bush burning, grazing and tree felling for firewood, hence providing favourable habitats for grasshoppers.

The grasshopper occurrence and distribution studies show that there were varying numbers and densities at the various ecozones. O. senegalensis occurred in high numbers in the Sahel, Sudan, and northern Guinea savanna zones. In the Plateau and southern Guinea savanna zones, the absence of the nymphal stages of the grasshopper indicated that there was no local breeding. The presence of few adult grasshoppers observed towards the end of the rains during October and November suggested migration.

Weather records show that there was a rainy season in which all the rains fall and a dry season during which there was little or no rain at all. The climates of the ecozones differed strongly in temperature regime and more in precipitation. More significant differences between the ecozones were observed in the monthly and seasonal distribution of precipitation.

Observations on the monthly fluctuations in the population of the O. senegalensis at the different ecozones showed that adult grasshoppers occurred in high densities and were widely distributed throughout the Sahel, Sudan and northern Guinea savanna zones. These areas have been observed as being mildly or not wooded, ephemeral grasslands. Furthermore, results have shown that the monthly grasshopper population was related to rainfall, temperature and relative humidity. O. senegalensis was more abundant when precipitation was low, relative humidity low, and temperature high. On the contrary, only few adult presence and no nymphal stages were recorded in Plateau and southern Guinea savanna zones, and the grasshopper was absent from areas south of this zone. These areas experienced early and prolonged periods of rainfall resulting in relatively low temperature, high humidity and dense vegetation growth which did not favour the occurrence and survival of the Oedaleus grasshopper. There is no doubt therefore that any major difference in the grasshopper population and distribution reflects the varied climatic and vegetation conditions of the ecological zones.

Results from field observations of the life stages of the grasshopper indicated that hatching of diapausing eggs occurred usually after the first rains in May in the Guinea savanna zone, and in June in the Sahel and Sudan zones. Subsequently, the ensuing nymphs preponderated till August

or September when they matured into adults. The adults persisted in the fields until November or December when they finally disappeared. Copulation and mating were observed from July to August and September to October while egg laying occurred from July to October. The highest and most frequent egg laying occurred during August and September, and these eggs remained in the soil throughout the dry period, until the arrival of the rains the following year.

Similar seasonal population fluctuations of the grasshopper were recorded in the three ecological zones studied. The fluctuations varied between few individuals at the beginning of the rainy season, and dense concentrations of hoppers, and aggregation of adults, which attained peak population during and towards the end of the rains respectively. Then a decline in population followed. Seasonal vegetational changes reflected on the seasonal populations of the Cedaleus grasshoppers which depended on it for their food and shelter.

The two seasonal populations of the nymphs whose later emergence as adults resulted in two peak periods of abundance of the adults indicated that this grasshopper has two annual generations in Nigeria.

The green and brown morphs of O. senegalensis maintained similar low populations at the beginning of the rains. By the middle of the season, however, the green

morph became preponderant and attained its peak population , followed by a decline. With the decline in the population of the green morph, the brown morph gradually predominated with very high population which reached the peak in October in all the ecological zones. The brown morph in the three ecozones exceeded the green by a ratio of 2.7 - 4 to 1, and in all cases, the differences were highly significant, x^2 = 56.63, 103.2, and 223.5 respectively, $P > 0.001$. The overall ratio was 3.4:1

The male grasshoppers outnumbered the females with a sex ratio of 1.23:1 which was significantly different from 1:1 at the 0.1% level (x^2 = 45.42). This disproportion, however did not necessarily reflect a preponderance of males but rather, arose as a result of migratory and reproductive habits of females which predisposed them from being caught.

Evidence of the movement of adults of O. senegalensis populations by flight was based on the records of grasshoppers caught by the sweepnet method (day population) and light traps (night populations), and the observed differences in the stages of sexual maturity of the females. Those taken at the light traps were distinct and more homogenous, comprising full grown immature adults and mature individuals in the early stages of maturation. Furthermore, morphometrics of the two populations showed that day population consistently had smaller mean values for both elytron and femur lengths than night population. It was unlikely that the night

samples of the grasshopper were merely resident local individuals attracted to light from the immediate vicinity.

Several direct observations were made of concentrations of gravid females ovipositing at the same time. This group laying would result in high pod densities and this was a potential factor likely to contribute towards bringing hoppers together in bands at the time of hatching.

The rate of development of the females of O. senegalensis was similar to that of the males. The insects passed through five nymphal instars with a duration of 45.63 ± 2.1 and 50.09 ± 2.2 days for the males and females respectively. The weight of the fledglings, rate of development and duration of the nymphal instars were not affected by the food plants.

Adult female O. senegalensis contained an average of 40.51 ± 2.4 ovarioles. It was therefore expected that a female grasshopper would produce an average of 40 eggs at a time. Contrarily, counts of mature eggs in the oviducts of gravid females gave a mean of 27.62 ± 9.1 eggs, Furthermore, the mean number of eggs per pod of Samples from the field and those laid in the laboratory were 26.86 ± 2.2 and 27.42 ± 2.2 eggs respectively. These observations indicated that not all ovarioles produced eggs at the same time.

Food plants did not affect the sexual maturation and adult longevity of O. senegalensis, even though the males lived longer than the females. Females reared under crowded

conditions matured more quickly than those reared in isolation. Females reared in isolation not only produced more egg pods than the crowded ones, but also lived for longer periods. Adult morphometrics were not affected by the density at which the nymphs were reared.

The incubation period of the eggs of the Oedaleus grasshopper in the field ranged between 16.98 ± 3.7 and 18.17 ± 4.3 days, and in the laboratory, it was 20.11 ± 2.2 days.

No significant difference was found between the elytron and femur measurements, or the E/F ratios of the green and brown males, and the green females from the three ecozones. These populations could be described as being morphometrically homogenous. The measurements of the brown females however provided evidence of differences between the populations from the ecozones. Also significant differences existed between the green and brown dimorphic females.

Corresponding increase was observed in the elytron lengths of day and night populations of both sexes of the grasshopper from August to September. Also the femur lengths varied with elytron lengths. When the sexes were compared separately, the day populations consistently had smaller mean values for both elytron and femur lengths than night populations, indicating the existence of significant morphometric differences between the two populations.

Three dipterous flies belonging to family Nemestrinidae and Sarcophagidae were observed as common parasites of the nymphs and adults of O. senegalensis. The larvae of these parasites were found at their various stages of development inside the body cavity of the grasshoppers. Trombiculid red mites were common ecto-parasites of the 4th - 5th instar nymphs and the adults of the grasshopper. They were found attached to the wings, or to the skin at the base of the wings, or wing pads.

Various arthropod predators of the nymphs and adults of the O. senegalensis included Promachus sp., Mantids, Scorpions, Sphex aegytius and Messor gallus.

The vertebrate enemies of nymphs and adults of O. senegalensis observed during the survey were numerous. Large males and females of the rainbow lizard Agama agama and three snake species were regular predators of the grasshopper. They were regularly observed at egg laying sites, preying on ovipositing females, and at hatching sites, preying on emerging hoppers.

Birds were probably the most important and conspicuous predators of the grasshopper, accounting for 90.79% of predation recorded over the study period. Since the birds were present throughout the life of the grasshopper, their depredations especially during the nymphal stages of the insect would affect the numerical fluctuation of this pest.

Insect parasites and predators were observed as serious enemies of the eggs of O. senegalensis in Nigeria. They occurred in relatively high numbers at all the ecological zones, and the percentage occurrence positively correlated with the number of egg pods. It is apparent that these insects would exert considerable influence on the number of the egg pods and hence on the population of O. senegalensis. It is desirable therefore to carry out more detailed studies on the bio-ecology of these egg parasites and predators, and other natural enemies of this grasshopper pest, to screen out the most promising species and assess their bio-control potentials.

LITERATURE CITED

ABUSHAMA, F.T. and ELKHIDER, E.T.M. (1973). Colour Change in the grasshopper Oedaleus senegalensis Krauss (Fam. Acridadae). Z. angew. ent. 72: 415-421.

ALBRECHT, F.O. (1956). La densite des populations et la croissance chez Schistocerca gregaria (Forsk) et Nomadacris septemfasciata. J. Agric, trop. Bot. appl. 2: 109-192.

ALBRECHT, F.O. (1965). Influence du groupement de l'etat hydrometrique et de la photoperiode sur la resistance au jeune de Locusta migratoria R & F (Orthoptera acridien). Bull. biol. Fr. Belg. 99: 287-339.

AMATOBI, C.I. (1982). The ecology of grasshoppers of Gumel Emirate. Unpub. Ph.D. Thesis of Ahmadu Bello University, Zaria. 457pp.

AMATOBI, C.I. (1985). Oviposition preference and the influence of cultivation on egg hatching in Oedaleus senegalensis Krauss. (Orthoptera: Acrididae). Samaru J. Agric. Res. 311-21: 81-85.

ANDERSON, N.L. and WRIGHT, J.C. (1952). Grasshopper Investigations on Montana range lands. Montana Agric. Sta. Tech. Bull. 486: 46pp.

ANENE, C. (1980). The Internal Anatomy and Physiology of the Reproductive Organs of the Female Brown and Green Polymorphs of Oedaleus senegalensis Krauss. Unpub. M.Sc. Thesis of Ahmadu Bello University, Zaria. 146pp.

ANENE, C. (1986). Investigation on the Structure of the ovary of Oedaleus senegalensis Krauss (Orthoptera : Acrididae). Nig. J. ento. Vol. 7 (In press).

ANENE, C. and VAJIME, C.G. (1988a). Insect enemies of the egg pods of Oedaleus senegalensis Krauss (Orthoptera : Acrididae). Nig. J. Pl. Prot. (In press).

ANENE, C. and VAJIME, C.G. (1988b). Parasites and Predators of Oedaleus senegalensis Krauss (Orthoptera : Acrididae) in Nigeria. Inter. J. Trop. Insect Science. (In press)

ANON. (1971). The use of soil surveys in assessing sites for forestry potentials in some areas of the northern states of Nigeria. UNDP/FAO/FO: SF/NIR 16. Tech. Report, No. 5.

ANON. (1977). Report to the Board of Governors on the Institutes Work in 1976 - 1977. Special Project and Services Institute for Agricultural Research, Ahmadu Bello University, Zaria. 75pp.

ANON. (1978). Resume des travax du project de recherche et de vulgarisation. COPR/OCLALAV sur les sauteriaux du Sahel dan la monyenne valle du Niger. Stations de recherche Acridienne sur le terrain series tech. No. AGP/DL/TS/25.

ANON. (1982). The Locust and Grasshopper. Agricultural Manual, C.O.P.R. aLond. 690pp.

ANTONIOU, A. (1973). The Life History of the grasshopper Ornithacris turbida Walk. (Orthoptera : Acrididae) in the laboratory. J. Appl. ecol. 6: 27-45.

ATKINSON, N.J. (1931). The increase of native insects to economic importance in the Prairie Province. Sci. Agric. 1: 200-203.

BATTEN, A. (1969). The Senegalese grasshopper Oedaleus senegalensis Krauss. J. Appl. ecol. 6: 27-45.

BEI-BIENKO, G. Y , and RICHTER, W. (1960). Acridoidea aus Iran (Orthoptera). Stuttg, Beitr. Naturk. 33: 1-19.

BHATIA, D.R. (1966). The Life History of the Desert Locust Schistocerca gregaria Forsk UNDP. Desert locust Project, No. UNSF/DL/TC/14, 25-36.

BHATIA, D.R. and AHLUWALIA, P.J.S. (1966). Oedaleus senegalensis Krauss (Orthoptera : Acrididae) plague in Rajasthan (India) Pl. prot. Bull. New Delhi, 18: 8-12.

BINDRA, O.S. (1977). Report to the Board of Governors on the Institutes work 1976-1977. Special Project and Services. Institute of Agricultural Research, Ahmadu Bello University, Zaria. 75pp.

BOYS, H.A. (1978). Food selection by Oedaleus senegalensis (Acrididae : Orthoptera) in grassland and millet fields. Ent. and Expt. appl. 24: 78-86.

CHEKE, R.A., FISHPOOL, L.D.C. and FORREST, G.A. (1980). Oedaleus senegalensis Krauss (Orthoptera : Acrididae) An account of the 1977 outbreak in West Africa and notes on eclosion under Laboratory Conditions. Acrida 9: 107-132.

CHEKE, R.A., FISHPOOL, L.D.C. and RITCHIE, J.M. (1980). An ecological survey of the egg-pods of Oedaleus senegalensis Krauss (Orthoptera : Acrididae). J. Nat. Hist. 14: 363-371.

CHOPARD, L. (1943). Orthopteroides de l'Afriques du Nord. Faune Emp. Fr. 1: 1-450.

CHOPARD, L. and VILLIERS, A. (1950). Contribution a l'etude de l'Air. Introduction et biogeographie, Mem. Inst. Fr. Afri. noire 10: 11-28.

CLARK, L.R. (1947a). Ecological observations on the small plague grasshopper Austroicetes cruciata Sauss. in Central Western New Southwales. Bull. coun. Sci. Industr. Res. Austr. No. 228: 26pp.

CLARK, L.R. (1947b). An ecological study of Australian plague locust Chortoicetes terminifera. Walk in Bogan Macquaire outbreak area. New Southwales. Bull. Coun. Sci. Industr. Res. Austr. No. 226: 71pp.

CLARK, L.R. (1949). The habits and community relations of the Acrididae of the Trangie District Central Western New South Wales. Bull Coun Sci. Industr. Res. Austr. Bull. 250.

CLARKE, D.P. (1965). On the Sexual Maturation, breeding and oviposition behaviour of the Australian plague locust Chortoicetes terminifera Walk. Aust. J. Zool. 13: 17-45.

CLAYTON, W.D. (1957). Preliminary survey of northern Nigeria. Min. Agric. Regional. Research Station Samaru (In Soil Survey Binder), 631.47.

DARLING, H.S. (1946). Locusts. Rep. Dep. Agric. Uganda, 181 Entebe, 1944-49 (2): 25-6.

DAVEY, J.T. and JOHNSON, H.B. (1956). The African migratory locust Locusta migratoria R & F in Nigeria. Anti-locust Bull. 22: 1-91.

DAVEY, J.T., DESCAMPS, M. and DEMANGE, R. (1959). Notes on the Acrididae of the French Sudan with special reference to Central Niger Delta Part 1. Bull. Inst. Fr. Afri. noire 21: 60-112.

DEMPSTER, J.P. (1957). The population dynamics of the Moroccan locust Dociostaurus maroccanus Thunberg in Cyprus Anti Locust Bull. 27: 1-59.

DESCAMPS, M. (1953). Observations relatives au criquest migrateur africain et a quelques autres especies d'Acrididae du Nord Cameroun. Agrou. trop. Nongent 8: 567-613.

DESCAMPS, M. (1965). Acridoides du Mali (deuxieme contribution). Regions de san et Sikasso (zone Soudannaise) (1et Partie). Bull. Inst. Fr. Afri. noire (Sci. nat.) 27: 922-962.

DESCAMPS, M. and DONSKOFF, M. (1965). Contribution a'la connaissance de la faune du moyen orient (Mission G. Remaudiere 1955 & 1962). Part 3 Orthopteres: Acridoides. Vie Millieu 16: 495-516.

DIRSH, U.M. (1953). Morphometrical studies on phases of the desert locust Schistocerca gregaria Forsk. Anti. Locust Bull. Lond. 16: 1-34).

FARAHBAKHSH, G. (1961). A check list of economically important insects and other enemies of plants and agricultural products in Iran. Publs. Dept. Pl. Prot. Iran 1: 1- 153.

FARROW, R.A. (1974). Comparative plague dynamics of tropical locusta. (Orthoptera: Acrididae) Bull. ent. Res. 64(3): 401-411.

FAURE, J.C. (1932). The phases of locusts in the South Africa. Bull. ent. Res. 23: 293-342.

FISHPOOL, L.D.C. (1982). The ecology of the West African grasshopper fauna of the Sahel and Sudan Savanna with Special reference to Oedaleus senegalensis Krauss 1877, Ph.D. Thesis, University of London, 423pp.

FROGGATT, W.W. (1910). Locust in Australia and Other Countries. FMrs. Bull. N.S.W. Dep. Agric. 29: 1-40.

GOLDING, F.D. (1934). On the ecology of Acrididae near Lake Chad. Bull. ent. Res. 25: 263-303.

GOLDING, F.D. (1946). The insect pests of Nigerian crops and stock. Spec. Bull. Dept. Agric. Nigeria 4: 1-48.

GOLDING, F.D. (1948). The Acrididae (Orthoptera) of Nigeria. Trans. Roy . Ent. Soc. Lond. 99: 517-587.

GREATHEAD, D.J. (1958). Observations on two species of Systoechus (Diptera: Bombyliidae) preying on the desert locust Schistocerca gregaria Forskal in eastern Africa. Entomophaga 3: 3-22.

GREATHEAD, D.J. (1963). A review of the insect enemies of Acridoidea (Orthoptera). Trans. R. ent. Soc. Lond. 114: 437-517.

HARGREAVES, H. (1948). List of recorded cotton insects of the world, London.

HERGERT, C.R. (1975). An analysis of grasshopper problems in Kano State, Nigeria. Samaru Agric. Newsletter 17(3): 91-94.

HERTZ, M. and IMMS, A.D. (1937). On the responses of the African migratory locust to different types of background. Proc. Roy. Soc. B. 122: 281-97.

HIGHNAM, K.C. and LUSIS, O. (1962). The Influence of mature males on the neurosecretory control of ovarian development in desert locust. Q. JL. microsc. Sci. 103: 73-83.

HIGHNAM, K.C. and HASKEL, P.T. (1964). The endocrine system of isolated and crowded Locusta and Schistocerca in relation to oocyte growth, and the effects of flying upon maturation. J. Insect. Physiol. 10: 849-64.

HUNTER-JONES, P. (1966). Rearing and breeding locusts in the laboratory. London Anti. Locust. Bull. 12pp.

ILESANMI, O. (1970). A study of Nigerian rainfall patterns from the viewpoint of precipitation. Ph.D. Thesis University of Wisconsin. 367 pp.

JAGO, N.D. (1971). Migratory locust Locusta migratoria (R & F) Survey in North-East Borno Province of Nigeria. Interim Report. September - October 1971. C.O.P.R. 9pp.

JAGO, N.D. (1977). Superfamily: Acridoidea Family: Acrididae. In KRANZ. J., SCHMUTTERER H. and KOCH W. (Eds.). Diseases, Pests and Weeds in tropical crops. pp 269-271, Berlin Paul Parey.

JAGO, N.D. (1970). Light trap sampling of the grasshopper Oedaleus senegalensis Krauss 1877 (Acrididae: Oedipodinae) and other species in W. Africa: A Critique. In the Proceedings of the 2nd Triennial Meeting, Bozeman Montana, U.S.A. 21-25 July, 1979. pp 165-198.

JERATH, M.L. (1968). Notes on short horned grasshoppers (Orthoptera: Acrididae) from eastern Nigeria. Proc. R. ent. Soc. Lond. 43: 27-38.

JOYCE, R.J. (1952). The ecology of grasshoppers in East Central Sudan. Anti. Locust. Bull. 11: 1-97.

KEAY, R.W.J. (1949). An example of Sudan zone vegetation in Nigeria. J. ecol. 37(2): 335-364.

KEAY, R.W.J. (1953). An outline of Nigerian vegetation, Nigeria. Govt. Printer. Lagos 55 pp.

KEAY, R.W.J. (1959). An Outline of Nigerian vegetation, Nigeria (3rd Ed.), Govt. Printer, Lagos. 75 pp.

KEVAN, D.K. McE and KNIPPER, H. (1955). Zur Systematik, Biologie, insbesondere Schwarmbildung und Morphometrie afrikanicher Homorcoryphus (Orth. Tittigon Concephalidae) Veroff uberseemus Bremen 2: 277-318.

KEVAN, D.K. McE and KNIPPER, H. (1961). Geradfluger aus Ostafrika (Orthopteroidea: Dermapteroidea and Blattopteroidea), Beitr. Ent. 11: 356-416.

KHALIFA, A. (1966). The morphology of the desert locust Schistocerca gregaria Forsk. Lectures on the Sixth Desert Locust training course in Iran 1966. No. UNSF/DL/TC/14.

KLINKENBERG, K. and HIGGINS, G.M. (1968). An Outline of northern Nigeria Soils. Niger. J. Sci. 2(2): 91-115.

KOBAKHIDZE, D.N. (1963). On the acridids of eastern Georgia (Orthoptera) (in Russia). Sb. Faun. Praci. ent. Odd. nar. Mus. Praze 9: 237-52.

KOWAL, J.M. and KNABE, D.F. (1969). An agroclimatological Atlas of northern states of Nigeria, A.B.U. Press 210pp.

KREBBS, C.J. (1978). Ecology: The experimental analysis of distribution and abundance. N.Y. Harper and Row, 678pp.

LAUNOIS, M. (1976). Etude comparee des preferences alimentaires des 26 acridiens du Sahel visa-vis des feuilles d'arachide, de niebe, de mil et de sorgho Rapport GERDAT/PRIFAS Paris C/003/1 D31 pp. 22.

LAUNOIS, M. (1978). Modelisation ecologique et simulation operationnelle en Acridologie. Application a' Oedaleus senegalensis Krauss Paris Ministere Le la Cooperation, 212pp.

LECOQ, M. (1978). Les deplacements per vol ā grande distance chez les Acridens des zones Sahelienne et Soudanienne en Afrique de ('ouest. C. r. hebd. Seanc. Acad. Sci. Paris (D) 286: 419-422.

MALLAMAIRE, A. (1948). Acridiens migrateurs et acridiens sedentaires en Afrique occidentale. Agron. trop. Nogent 3: 630-634.

McALEER, I.P.B. (1977). OSRO Prant Protection Project: On grasshopper Pests of the Sahel Lond. COPR (Unpub.) 27pp.

McCAFFERY, A.R., COOK, A.G. PAGE, W.W. and PERFECT, J.J. (1968). Utilisation of food by zonocerus variagatus (L) Orthoptera: Pyrgomorphidae). Bull. ent. Res. 68: 589-606.

MEIGS, P. (1953). World distribution of Arid and semi-arid homoclimates. Arid zone programme, 1: 203-209.

MERTON, L.F.H. (1959). Studies in the ecology of the Moroccan locust Dociostaurus macrocanus Thunb. in Cyprus. Anti-locust Bull. 34: 1-23.

MILLER, N.C.E. (1929). Acrididae collected in Tanganyika Territory. Trans. R. ent. Soc. Lond. 77: 61-97.

MISHCHENKO, L.L. (1949). Dermaptera, Blattodea, Mantodea, Phasmatodea and Salatoria (Orthoptera: S. Str.) of the Hissai valley (Tadzhikistan SSR in Russia). Trudy zool Inst Leningr. 8: 753-49.

MUNGOMERY, R.W. (1945). Report of the Division of Entomology and Pathology. Rep. Bur. Sug. Exp. Qd. Brisbane 45: 20-22.

NEFEDOV, N.I. (1936). The acridids of the First Kustanai Soviet grain farm and Moskalevo soviet farm and their distribution in various habitats. Rev. Appl. Ent. Vol. 21, p. 401.

NEWMAN, L.T. (1937). Grasshopper plague Austroicetes jungi. Branc. J. Dept. Agric. W. Aust. 2: 24-28.

NORRIS, M.J. (1952). Reproduction in the desert locust Schistocerca gregaria Forskal in relation to density and phase. Anti-locust Bull. 13: 1-51.

OYENUGA, V.A. (1967). Agriculture in Nigeria: An introduction. FAO Rome.

OYIDI, O. (1974). The migration of grasshopper (Orthoptera) in Northern Nigeria. Samaru Agric. Newsletter 17(3): 95-99.

OYIDI, O. (1975). The distribution of some species of grasshoppers in northern States of Nigeria. Samaru Agric. Newsletter 18(2): 83-92.

OYIDI, O. (1977). The ecological distribution, seasonal incidence and breeding patterns of Acridoidea (Orthoptera in Zaria area, Nigeria). Samaru Miscellaneous Paper, 70.

OYIDI, O. (1982). Grasshopper outbreaks and their Control in Nigeria. Samaru Conf. Paper, 37.

PAGE, W.W. (1977). Scientific Report on a visit to Niger on the Sahel grasshopper Project, COPR Report. 13pp

PHIPPS, J. (1968). The ecological distribution and life cycle of some tropical African grasshoppers (Acrididae), Bull. ent. Soc. Nig. 1: 71-79.

POPOV, G.B. (1968). Report on the Niger Mission, 1965. Progress Report, UNDP (SF) DL/TS/2. pp.102.

POPOV, G.B. (1970). Preliminary report on the grasshopper survey in the northern states of Nigeria during September/December 1970. (Unpub. report in COPR archives).

POPOV, G.B. (1975). Report on the helicopter survey of the Niger valley from Gao to Gaya during 13-23 October, 1975, London. COPR (Unpub.).

POPOV, G.B. (1976). The outbreak of grasshopper in West Africa, In USAID Report. Report of the Sahel crop Pest Management Conference, Berkely, University of California, pp. 35-43.

POPOV, G.B. (1980). Studies on oviposition, egg development and mortality in Oedaleus senegalensis Krauss (Orthoptera: Acrididae) in the Sahel COPR Miscellaneous Report, No. 53: 48pp.

RAMCHANDRA, R.Y. and CHERIAN, M.C. (1942). Control of the rice grasshoppers. Indian Fmg. 1(9-10): 433-436.

RILEY, J.R. and REYNOLDS, D.R. (1983). A long range migration of grasshoppers observed in the Sahelian zone of Mali by two radars. J. anim. Ecol. 52: 167-183.

RISBEC, J. and MALLAMAIRE, A. (1949). Les animaux predateurs et les insectes parasites des riz cultives en Afrique occidentale Agron. trop. nogent. 4: 70-76.

ROWELL, F.H.C. (1971). Environmental control of colouration in an acridid Gastrimagus africanus Sauss. Anti-locust. Bull. 47: 1-48.

ROY, R. (1960). Importance ecologique des Orthopteres dau l'Ouest African Bull. defl. FAN 22: 198-206.

RUNGS, C. (1949). Pullulation de differentes especies d'Orthopteres au Maroc au cours de l'ete R49 C. r. Seane Mens Soc. Sci. nat. phys. Maroc.

SARAVIA, A.C. (1962). Plague locusts - Oedaleus senegalensis Krauss and Schitocerca gregaria Forsk. in the Cape Verde Islands. Estudos agron. 3: 61-89.

SINGH, S. and BHATIA, D.R. (1965). Gregarisation of low density desert locust hopper populations as a result of association with other grasshoppers. Pl. Prot. Bull. 17(1-2), 7-9.

SOUTHWOOD, T.R.E. (1966). Ecological Methods with particular reference to study of Insect populations, 524pp. Lond. Methuen.

STOWER, W.J., POPOV, G.B., GREATHEAD, D.J. (1958). Oviposition behaviour and egg mortality of the desert locust Schistocerca gregaria Forsk on the coast of Eritrea. Anti locust Bull. 30: 1-33.

UVAROV, B.P. (1951). Locust research and control 1925-1950. Colon. Res. Publ. Lond. No. 10, 67pp.

UVAROV, B.P. (1953). Some effects of past climatic changes on the distribution of African Acrididae. Trans. IX Int. Cong. Ent. 2: 157-158.

UVAROV, B.P. (1957). Aridity factor in the ecology of locusts and grasshoppers of the old world. In Arid zone Res. VIII. Human and animal ecology reviews of res. Paris UNESCO. pp 164-198.

UVAROV, B.P. (1966). Grasshoppers and Locusts, Vol. 1. Cambridge University Press.

UVAROV, B.P. (1977). Grasshoppers and Locusts, Vol. 2. Lond. COPR, 613pp.

VENKATESH, M.V., AHLUWALIA, P.J.S. and HARAJAI, S.C. (1971). Influence of rainfall on the diapause of Oedaleus senegalensis Krauss (Orthoptera: Acrididae) Pl. Prot. Bull. New Delhi, 23: 20-27.

VINOKUROV, G.M. and RUBTZOV, I.A. (1930). Studies on the ecology of grasshoppers of Irkutsk region. Rev. appl. ent. 9: 97-101.

VOLKONSKY, M. (1939). Observations Sur le comportment du criquet pelerin (Schistocerca gregaria Forsk) dans le Sahara algero-nigerien. Arch. Inst. Pasteur. Alger. 20: 236-248.

WALTER, M.W. (1968). Length of rainy season in Nigeria. Samaru Res. Bull. No. 103.

WEIDNER, H. (1962). Die feld heuschrecken von Irak und ihre wirtschaftliche Bedeutung mit besonderer Berucksichtigung der Wanderheuschrecken-einfalle von den altesten zeiten bis zur Gegenwart Abh verh naturw ver Hamburg. 4: 61-145.

WOOD, A.W. (1933). Notes on some dipterous parasites of Schistocerca and lausta in the Sudan. Bull. ent. Res. 24: 521-530.

WOODHEAD, S. and BERNAYS, E. (1977). Changes in release rates of cyanides in relation to palatability of sorghum to insects. Nature, Lond. 270: 235-236.

WOODHEAD, S. and BERNAYS, E. (1978). The Chemical basis of resistance of Sorghum bicolor to attack by Locusta migratoria. Entomologia exp. appl. 24: 123-144.

ZACHER, F. (1925). Orthopteren, Geradflugler. Handb. Pflkrankh. (2 Aufl.), 4: 150-237.

ZACHER, F. (1949). Orthopteriodea, Geradflugler. Handb. Pflkrankh (5. Aufl.), 4: 228-352.

Appendix 1a: METERCLOGICAL DATA MEANS FOR DAMASAK 1983 - 1987

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Total
						Rainfall (mm)							
1983	00	00	00	00	.75	21.75	60	93.25	10.5	7.5	00	00	233.75
1984	00	00	00	00	11	32.5	59	82.5	31.25	7.75	00	00	224
1985	00	00	00	00	7.5	27.5	57	83	43.5	9.25	00	00	227.75
1986	00	00	00	00	10	31.75	85.75	79	42	5	00	00	253.5
1987	00	00	00	00	8.25	11.5	60.5	83.75	33.75	7.5	00	00	203.25
						Relative Humidity (%)							
1983	11	11	10	10	24	48	62	63	52	38	26	18	
1984	10	11	12	11	25	50	63	69	49	26	18	14	
1985	12	13	11	8	20	47	60	65	44	28	16	20	
1986	17	14	10	10	23	44	58	62	48	27	18	16	
1987	10	12	11	9	25	40	60	69	59	37	20	17	
						Maximum Temp (°C)							
1983	32	33	36	45	45	38	34	32	33	34	32	31	
1984	33	34	37	45	42	39	36	34	32	34	33	32	
1985	31	34	36	42	44	38	35	35	32	33	32	30	
1986	30	32	34	43	43	39	36	36	33	35	32	29	
1987	31	36	37	42	44	39	36	35	33	34	30	28	
						Minimum Temp (°C)							
1983	12	14	19	25	26	23	22	22	20	21	17	14	
1984	12	17	22	24	26	24	23	20	20	21	17	14	
1985	12	18	20	24	25	23	20	22	21	19	16	13	
1986	11	12	20	23	26	24	23	22	20	23	16	12	
1987	10	12	21	21	28	23	22	23	18	22	15	10	

Appendix 1b: METEOROLOGICAL DATA MEANS FOR KUKAWA 1983 - 1987.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Total
							Rainfall (mm)						
1983	00	00	00	00	3.25	47.25	82.75	85.75	20.5	5.75	00	00	245.25
1984	00	00	00	00	10.25	28	63.5	108	50.25	3.25	00	00	263.25
1985	00	00	00	00	3	22.75	40	85.25	32.5	11.5	00	00	197.25
1986	00	00	00	00	5.5	15.7	61	81.25	28.5	18.75	00	00	210.7
1987	00	00	00	00	6.25	18.25	63.25	91.5	28	10.5	00	00	217.5
							Relative Humidity (%)						
1983	10	11	11	10	25	44	60	68	52	37	18	20	
1984	11	12	10	8	22	47	62	65	57	28	22	18	
1985	11	14	12	10	26	50	62	67	49	26	18	18	
1986	12	13	13	10	25	40	60	69	59	37	20	17	
1987	10	12	11	9	22	34	58	62	48	28	14	20	
							Maximum Temperature (^{o}C)						
1983	32	35	36	39	43	40	36	35	32	33	32	30	
1984	31	36	37	40	44	38	35	36	34	36	33	30	
1985	32	33	36	42	45	37	34	32	33	34	32	31	
1986	30	33	36	38	42	44	39	37	34	36	32	30	
1987	33	34	37	40	43	38	35	33	33	34	34	32	
							Minimum Temperature (^{o}C)						
1983	13	18	22	24	25	23	22	22	21	19	15	13	
1984	12	14	20	22	28	23	22	23	18	22	18	14	
1985	11	13	24	23	25	24	23	20	22	21	16	13	
1986	12	17	22	25	26	24	23	20	20	22	17	14	
1987	12	14	19	24	26	23	22	22	20	21	17	14	

Appendix 2a: METEOROLOGICAL DATA MEANS FOR MAIDUGURI: 1983 - 1987

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Total
						Rainfall							
1983	00	00	00	00	18.25	30	55.25	182.5	64.25	5.25	00	00	355.5
1984	00	00	00	00	32.5	75.	160.75	195	52.5	00	00	00	525.25
1985	00	00	00	00	40	130	155	159	97.5	00	00	00	575.
1986	00	00	00	00	8.75	83.00	126.25	164.5	82.75	3.25	00	00	495.25
1987	00	00	00	00	39.25	61	125.0	116.25	66.75	6.75	00	00	415.0
						Relative Humidity (%)							
1983	16	13	16	19	46	71	71	79	73	23	23	20	
1984	20	16	18	24	48	62	71	67	41	39	17	20	
1985	18	14	27	17	44	65	79	80	70	33	24	21	
1986	19	13	14	18	42	57	76	74	74	48	28	18	
1987	16	12	21	12	35	58	71	76	68	39	18	15	
						Maximum Temperature (^{o}C)							
1983	28	32	32	38	39	35	32	30	32	34	33	31	
1984	27	31	27	38	36	34	32	32	33	34	33	27	
1985	31	29	34	36	38	34	28	31	31	33	33	28	
1986	28	34	37	40		35	31	31	32	34	32	27	
1987	30	33	36	38	39	35	32	30	32	35	33	28	
						Minimum Temperature (^{o}C)							
1983	13	18	18	23	25	23	22	21	21	18	15	13	
1984	11	14	19	23	23	21	19	20	20	19	14	11	
1985	13	14	23	24	26	22	19	21	21	18	16	14	
1986	12	17	21	24	24	23	21	21	21	20	17	13	
1987	13	16	21	23	25	24	23	21	22	21	16	12	

Appendix 2b: METEOROLOGICAL DATA MEANS FOR SOKOTO: 1983 - 1987

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
							Rainfall						
1983	00	00	0.00	00	25.25	38.75	00	118.75	6[illegible].5	00	00	00	339.3
1984	00	00	00	00	46.25	117.5	92.5	120	67.5	0.5	00	00	452.3
1985	00	00	0.4	00	16.75	35.25	125.25	140	45	00	00	00	362.3
1986	00	00	00	00	20.5	47.5	123.75	132.5	62	12	00	00	398.0
1987	00	00	00	00	33.75	27.5	89.50	105.25	52.75	00	00	00	308.8
							Relative Humidity						
1983	16	18	20	22	49	66	74	76.8	78	41.5	28	24.5	
1984	18.5	20.1	22	21	44.4	56.4	65.9	64.2	66.0	51	33	31	
1985	19	18	21.8	22	55.9	64	76.9	79.6	75.7	56	33	30	
1986	20	20	24	24	33.4	66	73	80	74.8	48	35	32	
1987	19	20	22	22	35	83	89	70	77	40	32	22	
							Maximum Temperature (°C)						
1983	24	35	35	41	41	34	31	30	31	36	36	32	
1984	30	34	39	42	36	32	36	33	36	34	37	30	
1985	33	31	34	37	33	43	34	32	30	36	39	34	
1986	32	37	40	41	40	39	33	32	32	33	35	30	
1987	34	35	38	38	43	37	34	33	34	37	39	34	
							Minimum Temperature (°C)						
1983	13	18	20	24	28	26	24.8	23.2	23	20	17	15	
1984	13	17	21	26	25	25	24.7	23.2	23	20	1[illegible]	14	
1985	16	16	21	23	26	25	24.0	24.0	23	24	19	14	
1986	14	15	24	26	26	26.2	23.5	23.1	22	21	19	13	
1987	14	17	21	24	28	25	25.1	24.1	24	22	17	14	

Appendix 2c: CLIMATOLOGICAL DATA MEANS FOR KANO 1983 - 1987

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1983	00	-	-	-	20.5	96.7	00.5	220.7	77.1	00	00	-	431.5
1984	00	-	-	11.0	34.9	93.0	109.4	55.2	113.0	00	00	-	507.3
1985	00	--	0.4	22.7	50.1	155.2	194.4	107.5	176.0	00	00	00	796.3
1986	00	-	-	2.0	10.7	99.5	156.4	203.9	129.4	4	00	00	605.9
1987	00	-	-	-	40.5	73.2	153.3	113.0	80.9	6.3	-	-	476.3
						Relative Humidity %							
1983	16	15	12	14	45	64	72	78	74	32	25	24	
1984	18	18	20	33	58	63	75	69	68	45	21	26	
1985	22	12	27	18	34	66	79	79	75	35	23	22	
1986	19	11	16	39	43	58	75	78	74	45	26	19	
1987	16	13	21	18	18	62	70	78	68	40	17	20	
						Maximum Temperature °C							
1983	28	32	29	38	39	35	32	32	35	34	33	29	
1984	27	31	27	38	36	34	31	32	31	34	33	27	
1985	31	29	24	36	37	33	28	31	31	33	33	28	
1986	29	34	37	40	38	35	31	31	31	34	33	27	
1987	30	33	36	38	40	35	32	30	32	35	33	29	
						Minimum Temperature °C							
1983	14	18	18	23	25	23	22	21	21	19	15	12	
1984	11	14	19	15	22	21	19	20	20	19	14	11	
1985	13	14	23	24	26	22	19	21	21	18	10	14	
1986	13	17	22	25	24	23	21	20	21	20	17	13	
1987	13	16	21	23	25	24	23	21	22	21	16	14	

Appendix 3: METEOROLOGICAL DATA MEANS FOR SAMARU; 1983 - 1987

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Total
						Rainfall (mm)							
1983	00	00	00	00	73	74	107	259	93	27	00	00	606
1984	00	00	5	30	99	54	174	158	189	30	00	00	709
1985	00	00	33	00	104	142	313	256	163	32	00	00	1050
1986	00	00	00	6	59	82	294	322	207	78	00	00	1158
1987	00	00	00	00	136	146	227	268	102	43	00	00	922
						Relative Humidity (%)							
1983	18	11	14	18	51	64	75	75	68	30	17	16	
1984	14	11	21	37	60	62	71	70	71	55	23	22	
1985	16	11	20	25	55	68	81	75	73	39	23	23	
1986	20	18	28	35	50	63	75	76	71	54	31	24	
1987	20	11	21	20	37	68	72	78	70	49	22	22	
						Maximum Temperature °C							
1983	24	32	33	38	35	32	29	28	30	32	32	31	
1984	28	31	36	35	32	32	29	30	30	31	31	28	
1985	31	30	35	35	34	30	28	29	29	31	32	28	
1986	30	35	36	38	34	30	29	29	29	31	32	27	
1987	31	33	35	36	37	31	30	29	30	31	32	30	
						Minimum Temperature °C							
1983	14	18	17	20	22	20	23	18	18	14	13	13	
1984	12	15	21	23	21	21	19	20	19	19	14	13	
1985	15	14	21	22	22	19	17	16	19	16	13	13	
1986	13	16	19	21	22	21	20	19	19	18	14	13	
1987	13	16	20	22	22	21	20	20	20	18	13	13	

Appendix 4a: Summary of Five Year (1983-87) Climatological Data Means For Southern Guinea Savanna (Minna and Mokwa)

Site	Jan.	Feb.	Mar.	Apri.	May	June	Jul6	Aug.	Sept.	Oct.	Nov.	Dec.	Total
						Rain Fall (mm)							
9^{o} 37^{1} Minna	2.2	6.4	12.7	59.2	122.2	165.2	231.6	251.7	281.5	121.6	6.1	2.9	1269.1
9^{0} 18 Mokwa	2.0	4.4	31.5	69.8	141.2	170.2	263.6	289.2	228.7	119.0	2.7	1.1	1323.4
						Relative Humidity							
Minna	35.2	31.7	40.4	55.2	73.6	78.2	77.	75.	76.	66.	49.	44.3	
Mokwa	30.7	36.4	52.8	70.9	81.6	84.9	81.6	82.4	86.	76.	55.7	34.9	
						Max. Tem. (^{o}C)							
Minna	34.3	36.4	36.9	34.8	32.5	31.2	29.0	28.4	29.0	31.4	34.2	34.8	
Mokwa	35.1	37.4	37.8	37.4	33.9	32.3	30.8	30.0	31.1	31.5	34.0	34.1	
						Min. Temp. (^{o}C)							
Minna	19.9	22.2	24.1	24.4	23.3	22.2	21.8	21.7	21.4	21.3	19.2	19.1	
Mokwa	15.0	19.0	23.2	24.8	23.1	22.6	22.2	22.0	21.9	21.6	17.3	14.3	

Appendix 5 : Plant species found in the Cedaleus grasshopper habitats in the three Ecozones under study.

1. Southern Guinea Zone: Fallow land, Grazing field habitats (Minna) Trees and Shrubs:

Ximenia americana

Lariaari polyandra

Grewia ilosa

Larkia clappertoniana

Khaya senegalensis

Sterculia setigera

Uraria picta

Litragyna inermis

Vitex doniana

Herbaceous Plants:

Borreria radiata

Sida rhombifolia

Hyptis suavolens

Desmodium hirtum

Sida ovata

Crotolaria senegalensis

Diocorea dumentorum

Boerhavia diffusa

Eriosema greseum

Ipomoae agertuerata

Vicoa letoclada

Lepidagathis collina

Gramineae Plants:

Andropogon schirensis

Rothboellia exaltata

Hyparrhenia rufa

Paspalum orbiculare

Dactyloctenium aegyptium

Setaria ancers

Mariscus alternifolius

Scleria africana

Sorghastrum bipinnatum

Eragrostis pilosa

Northern Guinea Zone Shrubs and Trees:

Daniellia oliveri

Desmodium velotinum

Maytenus senegalensis

Hannoa undulata

Trichilia emetica

Ficus ingens

Ureria picta.

Herbaceous Plants:

Indigofera capitata

Lepidagathis collina

Lippia chevalieri

Tephrosia bracteolata

Sida urens

Sida ovata

Scoporia dulin

Oldenlandia herbacea

Biophytum petersianum

The gramineae Plants:

Andropogon schivensis

Leudetia simplex

Brachiaria kotschyna

Eragrostis tremula

Digitaria horizontalis

The Sudan and Sahel zones: Trees and Shrubs

Dalbergia latifolia

Maerua oblongifolia

Zimenia americana

Sclerocarya birrea

Herbaceous Plants:

Pergularia tomentosa

Striga hermontheca

Triumpheta dubia

Marremia tridentata

Euphorbia polychnemoides

Corchorus tridens

Calotropis procera

Gramineae Plants:

Acalypha brachystachia

Brachiaria xantholeuca

Digitaria acuminatissima

APPENDIX 6



Breeding Cage