TRANSMISSION AND POPULATION STUDIES ON MAIZE STREAK VIRUS VECTORS: CICADULINA SPP. (HOMOPTERA 1 CICADELLIDAE)

BY

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DEPARTMENT OF CROP PROTECTION
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October, 1987.

DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented before in any previous application for a higher degree.

Sunday Oluwafemi OLOJEDE.

Date: December 9, 1987

The above declaration is confirmed.

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Date: 9th December, 1987

CERTIFICATION

This thesis entitled "TRANSMISSION AND POPULATION STUDIES ON MAIZE STREAK VIRUS VECTORS: CICADULINA SPP. (HOMOPTERA: CICADELLIDAE)" by Sunday Oluwafemi OLOJEDE meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

I dedicate my M.Sc. degree in Crop Protection to the glory of my Lord Jesus Christ,

Who sponsored this work.

The steadfast love of the Lord never fails,

His Mercy never comes to an end,

They are new every morning.

Great is Thy Faithfullness, O LORD to me !

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ABSTRACT

An intensive survey of Cicadulina species in Samaru between June, 1906 ana February, 1937 revealed the occurrence of four species: Cicadulina nbila. Naude; C. similis China; C. arachidis China and C. triangula Ruppel, in decreasing order of prevalence. C. mbila was caught in all the sites sampled and constituted 65.30% of Cicadulina populations in Samara. It is also shown that the female Cicadulina is always more abundant than the male.

Cicadulina populations at Samaru in 1986 built up with increases in rainfall. The numbers caught were very low at the onset of the rains in May ~ June, reached the maximum before the rains stopped in September, and declined sharply at the onset of harmattan in October.

The field survey revealed that Samaru had an average of 9.35% viruliferous leafhoppers in the field populations and that the Infective hoppers carried different strains of the virus depending on the host plants from which the hoppers got infected.

A survey of alternative hosts of the streak virus in Samaru and Zaria showed four grass species with symptoms of the streak virus diseases Panicum maximum Jacq. Brachiaria lata (Schumach) C.E. Hubbard ex Robynsj Pennisetuu podicellatum Trin. and Setaria palludefusea (Schumach.) Stapf and C.E. Hubbard.

Seventeen plants were screened for susceptibility to MSV and the following five were symptomatic hosts-. Acrocerus amplectus Stapf; Eleusine indica (L) Gaertn; Chlorix picnothrix Trin; Cyperus pustulatus Vahl and Oryzn glaberrima Steud. In addition, two other grass species were infected with MSV beside the screen cages used; Plgitaria adscendens Hern and Leptochloa fi1iformis (Lam.) P. Beauv. Susceptibility

under experimental conditions indicates likely susceptibility under field conditions.

This study also revealed that irrigated off-season maize crops carry the maize streak virus disease. It is thus concluded that irrigated maize crops, and grasses like E. indica that carry streak symptoms in the field, and that are susceptible to MSV from maize under experimental conditions, are sources of primary inoculum for the rain-fed maize crops as the virus could survive on them during the dry season.

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Chapter I

INTRODUCTION

Maize, Zea mays L., has been grown in West Africa for about four centuries now. Todate, it is the most widely grown cereal in the rainforest zone and the third major cereal, after sorghum and millet, in West Africa (Fajemisin and Shoyinka, 1976). It is widely grown in Nigeria and is an important cereal in the economy of the nation. The crop used to be grown mainly under traditional farming methods, with attendant poor yields, but lately a lot of governmental and scientific efforts have been geared towards mechanization and general modernization of its production. On such national programmes as "Operation Feed the Nation" (OFN) and "Green Revolution", massive campaigns for people to grow the crop (among others) were heeded. The newly established nationally coordinated programme on hybrid maize production is another effort being made to improve the production of maize.

The crop is eaten either as a vegetable, when the fresh cob is boiled or roasted, or the dried grains are prepared into a semi-solid pap. The growth and success of the poultry industry in Nigeria also depend largely on the availability of maize grains for ration formulations. The grain contains 70.79% starch, 9.69% protein and 4.42% oil (Olufade, 1974).

However the crop is bedevilled with many pests and diseases. Maize streak, which is caused by the maize streak virus (MSV), is the most important virus disease. It is transmitted by various species of Cicadulina (Heniptera: Cicadellidae) (Carter, 1953; Fajemisin and Shoyinka, 1976). The disease takes its name from the characteristic striped pattern on the leaves by the development of chlorotic streaks in longitudinal rows with very high yield reducing potentials.

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Maize streak virus (MSV) has been present in Nigeria for many years but Fajemisin, Cook, Okusanya and Shoyinka (1976) first reported epiphytotic incidence of the disease in the 1973 second maize crop in south western Nigeria. Later, scientists at the International Institute of Tropical Agriculture (IITA) also reported MSV at epiphytotic levels throughout north-central Nigeria in 1983 (IITA, 1983 a and b). Infection was found to be as high as 100% even in the northern Guinea savannah where the maize crop is a recent introduction. The disease is not peculiar to Nigeria because it has been widely reported in East Africa, South Africa and other places where maize is grown (Storey, 1925; Rose, 1972, a & b; Fajemisin et al., 1976).

Maize streak virus is known to be transmitted only by Cicadulina species (Storey, 1925 and 1928; Storey and McClean, 1930). These are grassland species of leafhoppers which are found most readily on irrigated grasses. Ruppel (1965) observed that Cicadulina seems to be restricted to moist grasslands in tropical and warm temperate regions of the world. These small and delicate insects, about 3-5mm in length, are known to migrate from the grasses to maize crops during the growing season. As they feed, MSV is thereby transmitted to the maize.

Research on MSV in Nigeria so far included surveys and identification of the Vectors, the biology of the vectors, the incidence of the disease, non-maize hosts of the vectors and virus, as well as control measures (Fajemisin and Shoyinka, 1976; Fajemisin et al., 1976; IITA, 1980, 1983 a & b, 1984 a & b; Ekukole, 1985; Ekukole, Ansa, Ajayi and Sundaram, unpublished; Okoth, 1985; Okoth, Dabrowski and Efron, 1984).

However, a detailed knowledge of non-maize hosts of the virus and the possibilities or otherwise of the existence of several

streak viruses and different strains need to be worked out. While workers at the IITA indicated that millet and sorghum cannot be infected with MSV (IITA, 1983b), Ekukole (1985) reported a streak virus of millet which was serologically related to MSV. Also we still do not have a full knowledge of the ecology of the vectors. This research was therefore designed to:

1. Survey and identify Cicadulina species in the Zaria area and relate the population densities with weather factors.
2. Survey non-maize hosts of MSV.
3. Carry out transmission studies on MSV from maize to widely occurring grasses in the Zaria area.
4. Survey MSV in native populations of the vectors.

Chapter 2

LITERATURE REVIEW

2.1 MAIZE STREAK VIRUS DISEASE

Fajemisin (unpublished) classified diseases of maize in Nigeria. He noted that Puccinia spp. (rusts) and Bipolaris spp. (blights) were considered the only maize diseases of economic importance until about ten years ago when maize streak virus disease was discovered at epiphytotic levels (Fajemisin, unpublished).

The maize streak virus disease, caused by the maize streak virus (MSV), is not new in Nigeria, though early observation on the disease had not been adequately documented and reported. Fajemisin et al. (1976) cited a lot of unpublished reports about the incidence of the disease in Nigeria.

2.1.1 Historical Records

Gorter (1953) credited the first publication and description of maize streak to Fuller in 1901. However the understanding of the disease as being caused by a virus (MSV) is the work of Storey. From his doctorate dissertation, he published useful information about the symptomatology and transmission of the disease (Storey, 1925, 1928, 1936 and 1937). Later, McClean (1947) noted the occurrence of different strains of the virus.

Over the years the disease has been reported in Ghana, Zimbabwe, Tanzania, Kenya, Uganda, Egypt, Mozambique, Republic of Benin, Nigeria and even India (Storey, 1936; Fajemisin and Shoyinka, 1976; Fajemisin et al., 1976; Rose, 1978; Ekukole, 1985). Rose (1978) feared that the disease might spread from Africa to South-east Asia, Australia and other parts of the world.

2.1.2 Symptomatology

Several workers have given detailed symptomatology of the maize streak virus disease (MSVD). The disease is characterized by broken, but almost continuous, narrow chlorotic streaks centred on secondary and tertiary veins, and distributed uniformly over the leaf surface. The parallel chlorotic streaks may partially or almost completely fuse, leaving irregular green lines or islands centred between veinlets. The green stripes vary from a few millimeters to several centimeters in length and from 0.5 mm to 1.0 mm in width. In addition to leaf symptoms, affected maize plants are shorter, have less vigour as well as smaller grains and ears than healthy ones. The disease also cause barrenness and premature death. (Storey, 1925, 1926, 1936 and 1937; Storey and McClean, 1930; McClean, 1947; Fajemisin et al., 1976; Daprowski, 1985 and Ekukole, 1985).

There is another virus disease of maize whith is very closely related to MSVD. It is called Maize Stripe Virus Disease (MSpVD). This other virus is transmitted solely by Peregrinus maidis Ashm (Hemiptera: Delphacidae) which does not transmit MSV. The Cicadulina vectors of MSV do not transmit MSpV either. Moreover, these two diseases also differ in the symptoms they induce in maize plants. The presence of sunken depressions due to the streaks of the mid-rib, leaf sheath, and also very small enations along the infected veins make the streak disease distinct from the stripe disease. Antiserum prepared against either of the two viruses will not react with the other virus antigen (Fajemisin and Shoyinka, 1976).

2.1.3 Epidemiology

The report in 1976 of MSVD epiphytotic on the second season crop of maize in 1973 by Fajemisin et al. (1976) prompted serious

research efforts on maize streak in Nigeria. The incidence of MSVD on commercial plots in the southern rainforest zone of Nigeria were over 90 percent (Fajemisin et al., 1976). Then the disease was thought to be restricted to the southern rainforest zone of Nigeria, and that it was probably not a very important factor in maize production north of the transitional rainforest zone. This view was however debunked by the workers of the virology unit of the IITA when in 1983 they reported epiphytotic levels of the disease throughout northcentral Nigeria. Infection was found to exceed 75 percent in most places and was often 100 percent in the northern Guinea savannah where MSVD was previously rarely seen (IITA, 1983a and b). The erroneous opinion that the disease was a late season (August - October) problem has now been corrected as investigations showed that the disease is also important on the early season (March - June) crop (Fajemisin et al., 1976; Fajemisin and Shoyinka, 1976).

The spread of a plant disease, and the subsequent development of an epiphytotic, generally depend on how effectively the pathogen is carried from plant to plant. The spread of MSV is influenced by factors governing the life history of the vectors. The most important of these are the climate, movement of the vectors (migration) and the host plants (Carter, 1953).

2.1.3a Climatic Factors

The effects of rainfall seem to be the most important factor affecting the epidemiology of maize streak. This is so because of the effect of rainfall on the condition and abundance of natural hosts and their suitability for supporting widespread breeding populations. It is known that the times when there were epiphytotic

outbreaks of maize streak have usually coincided with high rainfall (Rose, 1972a and b, 1978; Fajemisin et al., 1976). High rainfall supports green grasses on which the vectors feed and oviposit. Rose (1972a) reported a positive correlation between the total number of Cicadulina and the amount of rainfall. Researchers are therefore working on the possibility of predicting yearly outbreaks of the vectors (and hence the disease) based on available data and MSV incidence records (Rose, 1972a; Ekukole, 1985).

Changes in temperature during the year have also been found to affect egg and nymphal development periods, fecundity, and longevity of the females in Nigeria. The insects are less productive in the cool periods between July and September (IITA, 1983b). Storey (1928) found that high temperatures, up to a maximum of 31^{o}C favour infection.

Temperature affects the movement of the insects within a field. When the weather is cold, the hoppers are less mobile and conceal themselves within folded young leaves. But as the temperature rises, they become more active and, at comparatively high temperatures, they are very active, moving from plant to plant at short intervals. The chances of a maize crop becoming severely infected are therefore greater during a spell of hot weather than during a cold weather (Gorter, 1953; Rose, 1978).

2.1.3b Migration

Dabrowski (1983a) indicated that during most of the growing season the insects are scarce on grasses, maize, millet and other cereals. Population density is highest at the end of the growing season when adults migrate from older plants onto young seedlings or grasses grown under irrigation.

High populations are also found in irrigated cereals, grasses cultivated as pastures or naturally growing grasses on lakes, river or waterhole banks. Cicadulina females oviposit only on seedlings, any maize field that is planted late will therefore attract large numbers of females from older and drier grasses or cereals surrounding it (Dabrowski, 1983a). It has also been observed that Cicadulina are more common around the borders of crop fields than in the centre. The adults and nymphs move by frequent short jumps rather than by flight (Dabrowski, 1983a).

From the several reports of Rose (1972a and b; 1973a, b, and c; 1974a and b and 1978) on the ecology and population dynamics of Cicadulina in Zimbabwe, it is known that there is a large flight of Cicadulina species from drying grasses. The flight season begins in March, reaches a peak in April/May and then declines until September. During the flight season, many Cicadulina spp. fly long distances and cereal crops planted early in the dry season inevitably become infested with leafhoppers settling to feed.

According to Rose (1978), there are two types of flights within the leafhopper populations: the long distance flights and the short distance flights. During the first six months (April to September) of the dry season in Zimbabwe, irrigated cereal crops are invaded predominantly by female populations of long distance fliers. Both settled Cicadulina individuals and streak-infected ones are widely dispersed throughout susceptible crops far from breeding sources. Conversely, short distance fliers seem to be responsible for the transmission of the streak virus after the end of the main flight season (Rose, 1973c).

show that the vectors are able to feed and breed on a wide range of grasses, including the cultivated cereals and sugar cane. It has been demonstrated that the grass strips adjoining maize plots harbour infective hoppers which later carry the virus onto the maize plants (Gorter, 1953).

Ekukole (1985) reported the following grass species with typical symptoms of maize streak disease in the Zaria area of Nigeria: Dactyloctenium aegyptium (L.) P. Beauv; Digitaria ciliaris (Retz.) Kole; Brachiaria lata (Schumach.) C.E. Hubbard ex Robyns; Eleusine indica (L.) Gaertn and Eragrostis ciliaris (L.) R. Br. He also reported the occurrence of MSV symptoms on pearl millet, Pennisetum americanum (L.) K. Schum. although the team of workers in the virology unit of the IITA reported that millet and sorghum cannot be infected with MSV from maize (Thottappilly and Zagre, 1983).

Axonopus compressus P. Beauv., Setaria barbata (Lam.) Kunth and Brachiaria deflexa (Schumach.) C.E. Hubbard ex Robyns also carry MSV (Rossel and Nabukenya, 1983). Rossel and Nabukenya (1983) also reported that the MSV from E. indica, Thelepogon elegans Roth ex Toem and Schult and Brachiaria distichohylla (Trin.) Stapf was transmissible to maize , but caused only mild and mostly transient symptoms in some varieties and no symptoms at all in others. In addition, streak from Panicum maximum Jacq cannot be transmitted to maize, nor can MSV be transmitted from maize to P. maximum but Cicadulina triangula Ruppel readily transmits MSV from P. maximum to P.maximum (Rossel and Nabukenya, 1983).

2.1.4 Disease Severity

It is known that only a small proportion of leafhoppers migrating from grasses and alighting on maize during the flight

seasons transmit the virus. Some of the leafhoppers are inherently unable to transmit it (Rose, 1974a). The severity of streak disease, therefore, does not depend so much on the population of the immigrating Cicadulina alighting upon maize as on the age of the crop at the time of infection. It is generally agreed upon in the literature that the severity of the disease is highly correlated with the age of the plant at the time of infection (Fajemisin et al., 1976; Fajemisin and Shoyinka, 1976; van Rensburg and Kuhn, 1977; Rose, 1974a; Dabrowski 1983a and b). It can be said that the severity of MSV is dependent on a combination of the ability of the individual hoppers to transmit the virus, the population of the vectors, the age of the plant at the time of infection and cultural or cultivation practices.

Storey (1925) reported that one individual Cicadulina mbila Naude lived for five months and did not loose the power to transmit the virus during the period. Disturbance of infective hoppers during cultural practices such as roguing and weeding have been repeatedly reported to enhance the severity of the disease, especially since the viruliferous hopper is forced to look for a nearby maize plant upon the removal of a diseased one. Weeding also causes the hopper to fly around instead of settling down on a single plant (Rose 1973b and 1974a and b; Ekukole, 1985) ... . In view of these facts, and the great agility of the adult hopper, the potential of the individual hopper to disseminate the virus is considerably high, and comparatively few infective hoppers would be sufficient to carry infection throughout a plot of maize (Storey, 1925). Storey (1928) compared the effects of single hoppers with several hoppers together and reported that the severity of the disease was the same. He concluded that the effect of a group of hoppers was the effect of the most "powerful" individual in the group rather than the average

effects of the members of the group or the sum of the effects of the members. He suggested that for infection to occur, a minimal dose of the virus is required beyond which an excess produces no additional effect.

The plant builds up resistance against infection as it ages. While plants infected early may be so severly affected as not to be able to produce a good yield, those infected just before tasselling show no yield reduction (Fajemisin and Shoyinka, 1976). Incubation period increases with the age of the plant (Storey, 1928) while the percent infection decreases with the age of the plant (Dabrowski, 1983a). All serious outbreaks of streak have been attributed to the disease increasing exponentially at an early stage of the plant growth when they are most susceptible, and consequently yield losses are often very high (Rose, 1974a and b; van Rensburg and Kuhn, 1977). Epidemics of MSV are caused by the spread of the virus from infected to healthy plants within crops (Rose, 1974a).

2.2 THE INSECT VECTORS: CICADULINA SPP.

Recently, Hamilton (1982) placed Cicadulina in the subtribe Deltocephalini, subfamily Aphrodinae of the family Cicadellidae. The genus consists of grassland leafhoppers which range in length from 3 - 5 mm (Ruppel, 1965; Rose, 1972a, 1973a).

The adult insects are easily distinguished by their delicate appearance and a pair of round black spots on the anterior margin of the crown of the head (China, 1926, 1928; Ruppel, 1965; Nielson, 1968; Dabrowski, 1983a and b, 1984, 1985; Dabrowski and Okoth, 1984; Ekukole, 1985; Okoth, 1985). Adults are generally cream, yellow or greenish. The dorsum of the abdomen is marked with black in most species. The hind tibia are about as long as the abdomen; they are

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curved and have a double row of spines.

2.2.1 Species Composition

Although the genus is readily separated from related genera, the species are fairly similar in body structure, head shape, wing venation and most of the features of the male genitalia (Okoth, 1985). The genus has been reviewed by Ruppel (1965) and keys for the separation of some of the species were provided by Pennah (1959), Ruppel (1965) and Nielson (1968). Recently, more species have been described and new taxonomic revisions compiled (Ghauri, 1971; Kitching, Grylls and Waterfold, 1973; Vilbaste, 1976; Hamilton, 1982; Dabrowski, 1985, 1986, 1987; IITA, 1986).

The female Cicadulina has a long ovipositor which is absent in the male. The blackish ovipositor can easily be recognised with the unaided eye or with the use of a handlens (Dabrowski, 1984).

According to Rose's review (Rose, 1982), twelve species and subspecies of Cicadulina are known in Africa and these are C. arachidis China, C. triagula Ruppel; C. mbila Naude; C. chinai Ghauri; C. latens Fennah; C. parazea Ghauri; C. similis China; C. storeyi China; C. vesicula Ruppel; C. niger Ghauri; C. bipunctata bipunctata Melicher; and C. bipunctata bipunctella Metsumura.

Some of these species also occur outside Africa. For example, both C. mbila and C. triangula occur in Mauritius and the former also occurs in the Cape Verde Islands (Rose, 1978). C. arachidis, C. bipunctata bipunctata, C. bipunctata bipuntella and C. chinai are found in India and C. bipunctata bipunctata and C. mbila are also found in the Middle East and other parts of Asia (Rose, 1982).

Species that have been described but that are not reported in Africa include C. funeralis Distant (Seychelles); C. fijiensis

Linnaruori (Fiji); C. pastusae Ruppel and De Long (Columbia and Ecuador); C. tortilla Cadwell (Columbia and Peru) and C. bipunctata bimaculata Erans (Australia) (Rose, 1978).

The distribution of most species seems to be limited to fairly large regions within Africa (Rose, 1982). Groups of species are common either to the northern and eastern Africa or western and southern Africa. Species common to both north and south or east and west are rare (Rose, 1982).

Recently two new species, C. ghauriki Dabrowski and C. hartmansi Dabrowski have been reported to occur over a wide area in Nigeria and Cameroon (Dabrowski, 1986, 1987; IITA, 1986). This brings the number of species reported from Nigeria to eight and that from Africa to fourteen (Rose, 1978; Ekukole, 1985 and Okoth, 1985).

2.2.2 The Biology of Cicadulina spp.

De Long (1971) has adequately reviewed the bionomics of leafhoppers generally. Specific works on Cicadulina have been done only on a few species. Van der Merwe (1926), Rose (1973b), van Renburg (1982a and b) and Ekukole (1985) studied C. mbila. Ruppel (1965) studied the life history of C. pastusae while Ammar (1975) reported a detailed work on the biology of C. chinai. Dabrowski (1985) studied the biology and behaviour of C. triangula.

Rose (1973b) compared the biology of C. storeyi, C. mbila and C. parazea and found that the respective developmental periods for eggs and adults of the three species were similar. Rose (1973b) also found that the lifespan of males and females of C. mbila were similar although van Rensburg (1983a and b) found that females lived longer than males, a fact confirmed by Ammar (1975) for C. chinai and by De Long (1971) for leafhoppers generally.

The biology of C. mbila under the name Balclutha mbila on maize was described by van der Merwe (1926). He found that the eggs were inserted linearly along the midrib of the leaf. The incubation period varied between 9 - 12 days depending on the season and the temperature. There were five nymphal instars whose durations differed from each other but all varied between 3 - 6.2 days. The nymphal periods lasted from 18 to 31 days and the preoviposition period varied between 6 - 15 days. One female laid 339 eggs in 36 days and the greatest number of eggs laid in one day was 22.

According to Dabrowski (1985), temperature affects the biology of C. triangula. Under screen house conditions, the eggs hatched in 7 - 11 days at an average day temperature of 30° - 35°C and a night temperature of 24° - 25°C. At a lower temperature of 20°C, the eggs hatched in 13 - 15 days but the eggs did not develop at 15°C for up to 35 days. Nymphs developed in 15 - 25 days under the above screenhouse temperatures but took 15 - 23 days at 35°C and 15 - 35 days at 27°C while, at 20°C, they developed in 28 - 48 days. The first eggs were laid between the third and fourth day after adult emergence with oviposition continuing thereafter for 38 days. Insect longevity varied from 14 to 41 days. The average fecundity for the whole life of the female was 6.5 eggs per day.

From the studies of van Rensburg (1982a) on the effects of five different temperature regimes on C. mbila, the optimum temperature for development in this species was approximately 25°C. At this temperature, the incubation period was 8.1 days and the five nymphal instars had a total developmental period of approximately 16.8 days. At 25°C, 70% of the nymphs reached the adult stage. The temperature for the fastest development of C. mbila was 28°C. The mean development period from egg to adult at 28°C was 23.5 days and the sex ratio was 1:1.83 (male: female) (van Rensburg, 1982a).

Adult males of C. mbila had an average life span of 22.7 days while mated females lived for 28.0 days at 28°C. Virgin females lived for 68 days which is considerably longer than that of mated females (van Rensburg, 1982a).

Females commenced oviposition at 5.3 days after reaching the adult stage and attained maximum oviposition rate approximately 10 days later. A temperature above 30°C was detrimental to development (van Rensburg, 1982a). More eggs were laid on the leaf blades of host plants than on the leaf sheaths.

All the biological studies cited above involved single populations of Cicadulina species. Recently, Okoth (1985), Okoth et al. (1984); Okoth, Dabrowski, Thottappilly and van Emden, (1987) and Okoth, Dabrowski and van Emden (1987) compared the biology of various populations of C. mbila and C. triangula from three climatic zones in Nigeria; the rain forest (Ibadan); the southern part of the sudan savannah (Kadawa Irrigation Scheme) and the Jos Plateau. The C. triangula population that is used in mass rearing for resistance screening at the IITA, Ibadan, developed much more rapidly than the wild C. triangula population from Ibadan. Similarly, the C.mbila population from Kadawa Irrigation Scheme developed more rapidly than the population from the Jos Plateau. The IITA colony of C. triangula was significantly more fecund than C. mbila.

2.2.3 The Ecology of Cicadulina spp.

Most Cicadulina species seem to live in grassland (Rose, 1973a) Ruppel (1965) suggested that the genus was restricted to moist grasslands associated with lakes and rivers in tropical and warm temperate regions of the world. The leafhoppers were most abundant and most readily collected from such places. The only population studies that have been made are of C. parazea in Zimbabwe

(Rose, 1972a and b; 1973a and c.).

Okoth (1985), Dabrowski (1986) and Okoth, Dabrowski and van Emdan (1987) reported that Cicadulina populations were 3 - 4 times as prolific on pearl millet as on maize, sorghum or the grass Digitaria excilis (Hippest) Stapf . van Rensburg (1982b) also found that millet was more suitable for C. mbila oviposition than the other host plants (sorghum, maize, wheat and oat) which he used. The factors that control oviposition preferences in Cicadulina are not yet known.

In Nigeria, Cicadulina spp. were most often associated with particular grasses (Okoth, 1985). In the transitional rain forest zone (Ibadan), the insects were commonly sampled on Chloris pilosa Schumach , B. lata, B. mutica Stapf, E. indica and Digitaria horizontalis Willd. At the Kadawa Irrigation Scheme, the insects were commonly collected on Paspalum orbiculare Forest, C. pilosa and Fimbrystylis dichotonia Vahl. while they were associated with D. excilis, E. indica and Brachiaria sp. at Jos. At the onset of the dry season, when the grasses were beginning to dry up, most Cicadulina were sampled on Pennisetum polystachion (Linn.) Schult in the Ibadan area and on P. purpureum Schumach along water courses in the Jos area.

Environmental conditions and host plants seem to affect the occurrence and distribution of Cicadulina. In Zimbabwe, for example, high density breeding populations were found in grasses. Rose (1972a) reported a positive correlation between the numbers of Cicadulina adults captured in suction traps and the amount of rain in the preceeding few months. He also reported that the size of Cicadulina populations were dependent on host grasses and seasonal rains (Rose, 1972a).

2.2.4 Transmission of streak Virus by Cicadulina spp.

Maize streak virus (MSV) is transmitted by insects alone and Cicadulina spp. are the only vectors known (Storey, 1925, 1928, Storey and McClean, 1930; Fajemisin and Shoyinka, 1976; Fajemisin et al., 1976).

Several experiments confirmed the ability of Cicadulina spp. to acquire MSV by feeding on diseased maize and to transmit it to healthy maize plants with the production of normal symptoms (Storey, 1925, 1928, 1937; Storey and McClean, 1930; McClean, 1947; Fajemisin et al., 1976; Dabrowski, 1985 and Okoth, 1985). It has been shown that the insects transmit the virus from infected plants of each species to healthy plants of the same species i.e. the insect might transfer the virus from infected maize to healthy maize, or from infected sugar cane to healthy sugar cane etc.

The ability to produce the disease is not inherent in the insects but it is acquired as a result of feeding upon diseased plants (Storey, 1925). Experiments have shown that the young leaf-hoppers, as soon as they begin to feed on a fully diseased leaf, may acquire the power of infection (Storey, 1928). Hoppers which fed only upon healthy maize or cane plants were incapable of infecting a plant with streak disease (Storey, 1925). All nymphal instars of both sexes might be carrying infection, and the infective power is not lost during moulting nor passed to the progeny (Storey, 1928). Infectivity is still retained during periods of feeding on resistant plants (Storey, 1928).

According to Dabrowski (1985), only 24% of C. triangula transmitted MSV after an acquisition feeding period of 24 hours. An acquisition access period of 48 hours almost doubled the number of viruliferous transmitters while 72 hours of feeding did not significantly further

increase the percentage of viruliferous C. triangula. C. triangula females were more effective in transmitting the virus than males (Thottappilly, Zagre and Rossel, unpublished). The minimum acquisition feeding period for single adults was 30 seconds while the minimum inoculation access period was 1 hour and the minimum latent period was 12 to 24 hours (Thottapilly et al., unpublished).

From the transmission studies of streaks of maize and sugar cane, Storey and McClean (1930) indicated that there is not just one streak virus but several. They were of the opinion that there are different kinds of viruses or strains of a virus associated with particular hosts. Thus the maize streak is thought to be different from the cane virus. McClean (1947) showed that there are two forms, A and B, of maize streak virus. While both produced permanent infection in maize, the A form was severe while the B form was mild.

Many species of wild grasses have been observed in the field with symptoms of streak disease (Storey, 1925; Storey and McClean, 1930; McClean, 1947; Rossel and Nabukenya, 1983; Ekukole, 1985; Ekukole et al., unpublished).

In Nigeria, grasses such as A. compressus, S. barbata, B. deflexa, E. indica, T. elegans, B. distichophylla, P. maximum in southern Nigeria (Rossel and Nabukenya, 1983) and E. indica, B. lata, E. ciliaris, Dactyloctenium aegyptium, Digitaria ciliaris and pearl millet P. americanum in northern Nigeria (Ekukole et al., unpublished) were observed with streak symptoms on the field.

Transmission studies by Storey and McClean (1930), McClean, (1947), Rossel and Nabukenya (1983) from naturally infected grasses to maize produced variable results. In some plants the typical form of the MSV was recovered. In others the streak induced in the

maize was of a milder type, while in the rest it was not possible to transmit the virus from the grass species to MSV-succeptible maize cultivars.

In a detailed host range study by Damsteegt (1983), fifty-four grass species were symptomatic hosts of MSV. Cultivars of commonly grown cereal crops varied in susceptibility. Although most Zea mays L. accessions were susceptible, a few were resistant. Damsteegt (1983) showed that all cereal crops tested were susceptible to MSV infection. Barley, rye and wheat developed streak symptoms similar to those in maize but symptons in rice were narrow discontinuous streaks. Twenty-four Sorghum bicolor (L.) Moench accessions and four additional Sorghum species from the world collection were tested by force-feeding viruliferous leafhoppers on test seedlings in small cages and/or by natural preference feeding in a large cage. Six S. bicolor accessions developed symptoms of maize (Damsteegt, 1983). Eighteen accessions of S. bicolor were not susceptible to MSV infection. P. americanum, P. macrourum Trin, P. purpureum Schumach and several other grass species were immune to MSV infection (Damsteegt, 1983).

Chapter 3

GENERAL MATERIALS AND METHODS

3.1 Source of the Insects

3.1.1 Field Sampling

Sampling of Cicadulina spp. on the fields was done using a 1 m x 1 m sampling cage (Plate 1) that consisted of four 1.3 m iron poles and a dark green cotton cloth cover, one side of which was made of fine transparent netting. The four iron poles were stuck into the ground to cover approximately 1 m^2 of green grasses. The poles were then covered with the dark green cloth so that the transparent yellow netting side of the cage faced the sunlight. The leafhoppers and other insects, responding to light, moved from the grasses and dark sides of the cage onto the yellow netting. The Cicadulina adults (Plate 2) were then selectively collected using a mouth-operated aspirator (Plate 3). While erecting the cages, care was taken not to walk on the grasses from which the insects were to be collected so that the insects did not get disturbed and thereby fly away. This method has been found to be effective and preferred to the use of sweepnets (Dabrowski, 1983b).

3.1.2 Transportation of leafhoppers to the screenhouse

The insects caught were immediately caged singly on site onto seedlings of the streak-susceptible maize cultivar Tropical Zea B (TZB) planted singly in 13 cm (diameter) plastic pots. The insects were confined on maize seedlings using Polyvinyl chloride (PVC) cages measuring 5 cm in diameter and 25 cm long (Plate 4). The PVC cages had fine netting at the top and sides for good aeration. The insects were then transported to the screenhouse with official vehicles.



Plate 1. The author (left) and a field assistant (right) demonstrating the use of the 1 m x 1 m sampling cage used in sampling Cicadulina spp. in the field.



Plate 2. Dorsal view of an adult Cicadulina mbila Naude

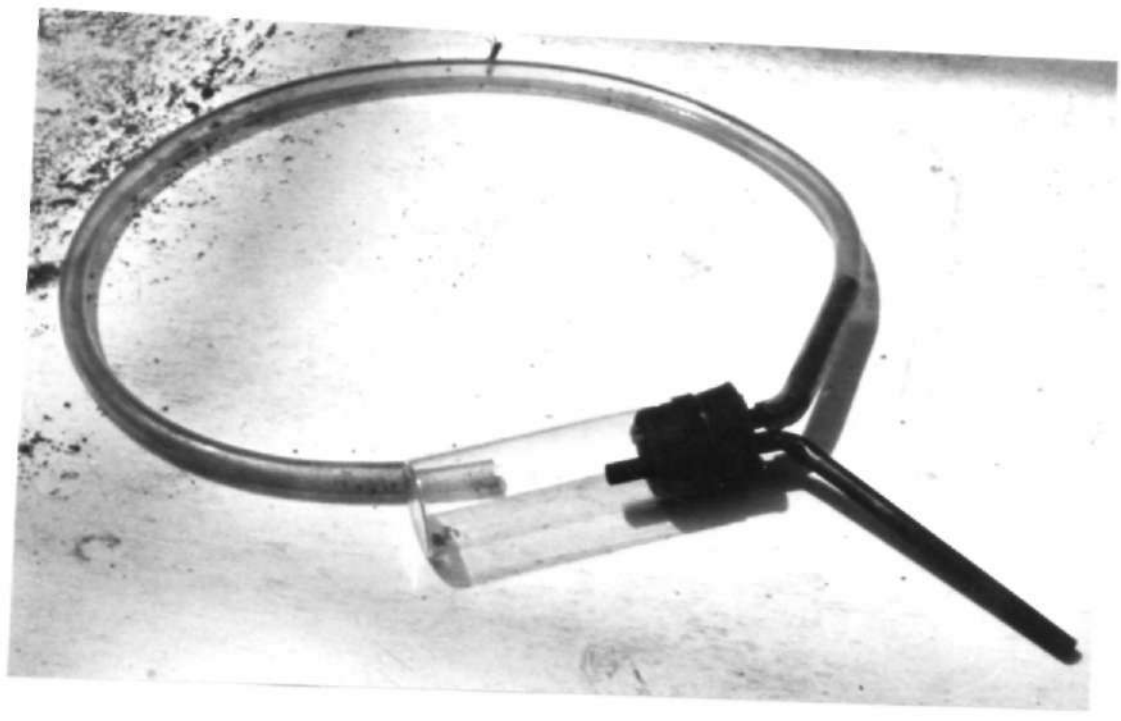


Plate 3. The mouth-operated aspirator used in collecting the Cicadulina spp. during field samplings.



Plate 4. The Poly Vinyl Chloride (PVC) cages used to confine the leafhoppers on the seedlings of experimental plants.

These insects were used for rearing Cicadulina colonies and to determine the level of field Cicadulina that carry the MSV.

3.1.3 Species Identification

During samplings aimed at determining species composition, the insects caught were transported from the sampling sites using glass tubes which were securely closed with wooden stoppers. The stoppers had their holes fitted with cotton wool to allow for aeration.

The insects were killed in the laboratory by placing them in a freezer for 15-20 minutes. The freezer was used because it was readily at hand and also effective as no part of the insects got damaged in the process of killing them. The insects were then separated into male and female sexes using a stereoscopic binocular microscope. The females were separated from the males on the basis of the blackish ovipositor of the females (Plate 5). The insects were then labelled and sent in small vials to Dr. Z. T. Dabrowski at the IITA, Ibadan for species identification and/or confirmation.

3.2 Transmission Experiments

All biological studies either in the screenhouse at the Institute for Agricultural Research (IAR), Ahmadu Bello University (ABU), Samaru or at the International Institute of Tropical Agriculture (IITA), Ibadan were carried out by confining insects on host seedlings using PVC cages described earlier (Plate 4). Virus acquisition feeding by the leafhoppers was tested at the IITA, Ibadan, using 5 m x 4m x 7 m wooden cages (Plate 6) with fine netting at the four sides and the top. All plants used for carrying out experiments at the IITA were grown under isolation in large insect-proof cages (Plate 7) outside the glasshouse to avoid contamination with "foreign insects". All maize and grass seedlings



Plate 5. Ventral view of two adult Cicadulina mbila Naude

Left: Female with long ovipositor

Right: Male without ovipositor

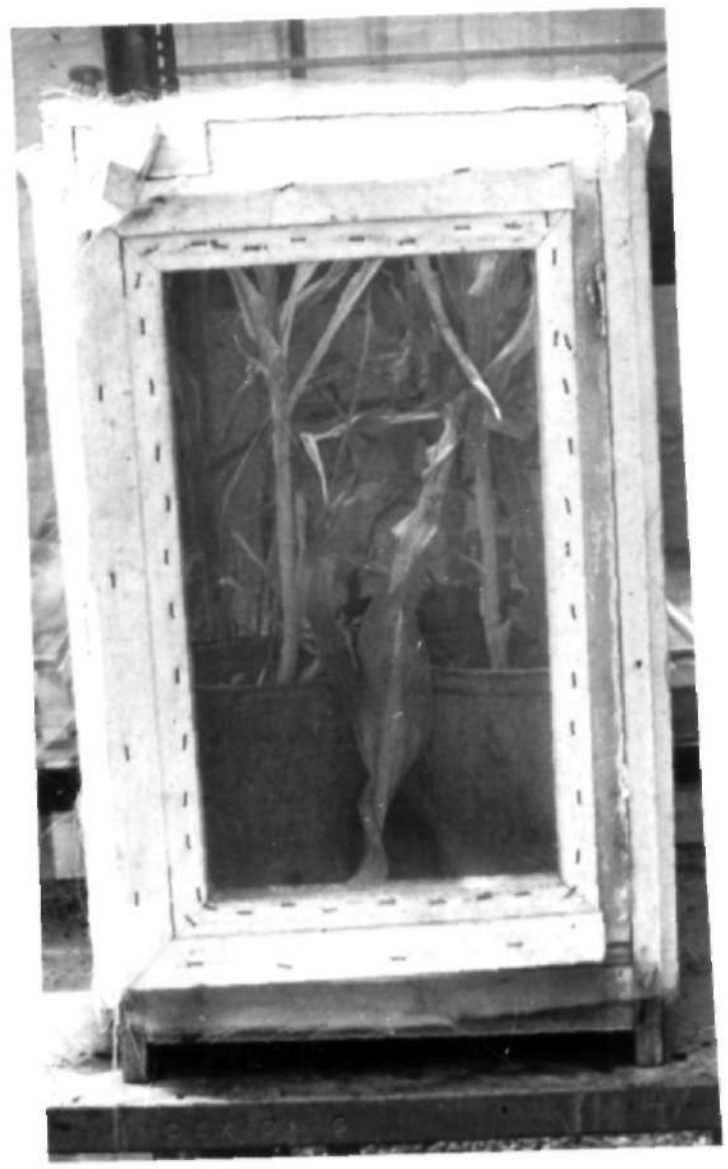


Plate 6. A wooden cage used for virus acquisition feeding of the leafhoppers inside the glasshouse.



Plate 7. Large insect-proof cages used to shield the experimental plants from "foreign insects" outside the glasshouse.

used in virus transmission work were left in the insect-proof cages for symptom development (Plate 7).

3.3 Source of Seeds for the Experimental Plants.

Maize seeds of the streak-susceptible cultivar, TZB, were supplied by the maize breeding unit of the IITA through Dr. Z. T. Dabrowski of the maize entomology unit. P. americanum var ex-Borno was supplied by Dr. Olupomi Ajayi of the Cereals Research Programme, IAR.

Other plants used, including Sorghum bicolor, were collected in the fields in Samaru and Zaria, and were identified at the herbarium section of the National Animal Production Research Institute (NAPRI), ABU, Zaria.

3.4 Source of Maize Streak Virus Isolate.

The maize streak virus isolate used for the transmission studies was obtained from the maize breeding fields and demonstration plots at the IITA, Ibadan. The isolate was maintained in young streak-susceptible TZ^B maize seedlings in a large cage or in the open (Okoth, 1985).

At Samaru, Cicadulina individuals were anaesthetized by putting them in a freezer for two minutes. They were then picked with a camel hair brush and put inside clip-on cages, 2 cm diameter (Ekukole, 1985). The insects were then taken to a farmer's field opposite the IAR campus and confined on streak-infected maize leaves. The insects were placed on the underside of the leaves to avoid sun-scorching. They were allowed an acquisition feeding period of three days before being transferred to TZB maize seedlings in the glasshouse using PVC cages. This virus was then maintained in the glasshouse during the dry season. The virus was transferred

successively to young maize seedlings as described above. The virus was thus obtained from many plants using several infected insects.

3.5 Rearing of Cicadulina spp. colonies.

Female insects caught from the field as described in Section 3.1.1. were immediately caged singly on site onto maize seedlings and transported to the screenhouse as described in Section 3.1.2. They were then left in the screenhouse for three to four weeks during which they laid eggs and the eggs hatched. The first instar nymphs were then transferred to fresh maize seedlings to ensure that they remain virus-free. Streak-susceptible TZB maize was used in rearing the insects to detect any one that carried MSV. Such viruliferous insects that transmitted the virus to the maize seedlings, with the developments of streak symptoms, were removed from the rearing experiments.

Males were collected from each clone and the species were identified as described in Section 3.1.3. After identification, clones of the same species were pooled together to form species colonies.

To ensure faster multiplications, the clones were serially transferred to fresh seedlings after three weeks, while the previous seedlings were thereafter covered with PVC cages to ensure that the eggs already laid on the seedlings hatched inside the PVC cages and the nymphs did not escape.

Chapter 4

FIELD STUDIES OF CICADULINA SPP.

4.1 Species Composition of Cicadulina Populations in Samaru and Kadawa.

4.1.1 Introduction

Rose (1978, 1982) has given a general description of the species distribution of Cicadulina in Africa. Environmental conditions and host plants are reported to play a big role in explaining the occurrence and distribution of Cicadulina species (Rose, 1972b; Okoth, 1985).

Since the literature indicates that the environment affects density and species composition of Cicadulina, it seemed possible that species composition would vary in different ecological zones of Nigeria. An intensive survey was therefore carried out to determine the different Cicadulina species in Samaru and at Kadawa Irrigation Scheme, Kano State. The influence of the rainfall and vegetation on the density of Cicadulina spp. in Samaru was also investigated.

4.1.2 Procedure

The following three locations were selected in Samaru where samplings of green grasses were undertaken:

a. IAR Dam, Bomo Village.
b. Maize fields at the IAR Farm.
c. IAR/Faculty of Agriculture complex of ABU campus, designated "IAR campus".

Three sites, about 50 m - 75 m apart, were sampled at each of the locations. Five random samplings were carried out at each site

every fortnight using the 1 m x 1 m trap cage described in Section 3.1.1. (Plate 2). The insects were transported as described in Section 3.1.2. and identified as decribed in Section 3.1.3.

Samplings were also done twice a week at Kadawa Irrigation Scheme, Kano State, in the months of January and February, 1987. Three different wheat fields were chosen and fiftaen random samplings were carried out in each of the fields per sampling date. The insects were also transported as described in Section 3.1.2. and identified as described in section 3.1.3.

The predominant plants on which the insects were caught in the sample sites were collected, labelled, and taken to the herbarium section of the NAPRI, ABU for identification. Rainfall and temperature data for Samaru during the sampling period were obtained from the IAR Meteorological Unit.

4.1.3 Results and discussion

The results of the surveys to determine the different Cicadulina species in Samaru and Kadawa are presented in Table 1. The table shows that there were four species of Cicadulina in Samaru and its environs. C. mbila Naude was the most prevalent species forming 65.38% of the species sampled in the three locations. C. similis China was second in abundance (31.43%) followed by C. arachidis China (3.89%) and C. triangula Ruppel (3.30%). C. arachidis was, however, the predominant species in the IAR maize fields while C. triangula was not caught at all in the IAR campus. These results confirm the earlier finding (Deeming, 1981) of the same four species of Cicadulina in a plot of cotton in Samaru.

The data on the numbers of each species at each location were compared using the X^2 analysis. The value of the X^2 for the species

Table 1. Incidence of male Cicadulina species at three locations in Samaru in 1986 and at the Kadawa Irrigation Scheme in January - February, 1987.

Species	IAR Maize Fields		IAR Dam		IAR Campus		Total for Samaru		Kadawa	
	No	%	No.	%	No.	%	No.	%	No.	%
Cicadulina mbila Naude	7	29.17	51	80.95	61	64.21	119	65.38	1	5.88
Cicadulina similis China	1	4.17	5	7.74	33	34.74	39	21.43	0	0
Cicadulina arachidis China	14	58.33	3	4.76	1	1.05	18	9.89	0	0
Cicadulina triangula Ruppel	2	8.33	4	6.35	0	0	6	3.30	16	94.12
TOTAL	24		63		95		182		17	
X^2	17.88**		105.32**		107.56**		170.57**		33.61**	

X^2 SPECIES X LOCATIONS IN SAMARU, 1986 = 96.85**

** = Significant at 1% level of probability.

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by locations (96.85) was highly singificant (P > 0.01). The X^2 values for each of the three locations in Samaru were also highly significant (P > 0.01), indicating that the composition of the four Cicadulina species in Samaru was dependent upon the locations sampled. The species composition differed between the Samaru locations in 1986.

Only two Cicadulina species, C. triangula and C. mbila, were recorded at Kadawa between January and February, 1987. C. triangula was the dominant species, forming 94.12%, while C. mbila constituted only 5.88% of the population. The X^2 value (33.61) for Kadawa was highly significant (P > 0.01).

Table 8 shows that female Cicadulina were always predominant over the males in Samaru and Kadawa. The female hoppers constituted 57.58% in Samaru in 1986 and 66.00% in Kadawa in January - February, 1987. The X^2 value for sexes by locations in Samaru (1.68) was not significant (P < 0.5), indicating that the different locations did not affect the sexes. However, the X^2 value for the sexes in the IAR Campus (10.96) and the total for Samaru (9.04) were highly significant (P < 0.01), The X^2 value for the Kadawa location (5.12) was also significant (P < 0.05), indicating that there were significant differences between the sexes at the IAR Campus, Samaru as an area, and Kadawa. There were no significant differences between the sexes at the IAR maize fields and the IAR Dam.

The mean catches of Cicadulina spp. in Samaru in relation to the total fortnightly rainfall (mm) and the monthly maximum and minimum temperatures (°C), between May, 1986 and February, 1987, are given in Figure 1. Cicadulina spp. were caught on the field after about one and a half months of rainfall. The Cicadulina populations increased thereafter and were highest between August and September.

Table 4: Sex ratio of Cicadulina spp. at three locations in Samaru in 1986, and in Kadawa in January - February, 1987.

Sex	IAR Maize Fields		IAR Dam		IAR Campus		Total for Samaru		Kadawa	
	No.	%	No.	%	No.	%	No.	%	No	%
Females	55	59.38	71	52.99	141	59.75	247	57.58	33	66.00
Males	34	40.68	63	47.01	95	40.25	182	42.42	17	34.00
Total	59		134		236		429		50	
X^2	3.06^{NS}		0.48^{NS}		8.96**		9.84**		5.12*	

X^2 Sexes x Locations in Samaru, 1986 = 1.60^{NS}

* = Significant at 5% level of probability

** = Significant at 1% level of probability

NS = Not significant at 5% level of probability

The populations declined sharply with the onset of harmattan in mid-October when the temperature dropped to 17.6°C. The temperature continued to drop until the end of 1986. The Relative Humidity (RH) fell from 85% at the beginning of October to 24% by mid-October (13/10/86) and continued to be low during the remaining part of 1986.

With the onset of the rains in May, the grasses spring up, and by the end of June there were enought green grasses on the field on which the leafhoppers could subsist. The insects subsisted on the green vegetation and good moistures provided by the rains. But with the stoppage of the rains, and the onset of harmattan in the first fortnight of October, 1986, the grasses dried up and became unsuitable for supporting the leafhoppers.

The data on the mean catches of Cicadulina spp. in Samaru in relation to the total fortnightly rainfall (mm), the cummulative rainfall (mm) and the monthly maximum and minimum temperatures were analysed using the linear correlation analysis. The r values are presented in Table 3. The r values between the mean Cicadulina spp. catches and the total fortnightly rainfall (r = + 0.245), the mean Cicadulina spp. catches and the cummulative rainfall (r = + 0.295), the mean Cicadulina spp. catches and the minimum temperatures (r = + 0.193) were positive but not significant (P >0.05). This possibly indicates that the leafhopper populations increased with increases in the rainfall and with higher minimum temperatures.

Table 4 shows the predominant plants on which the insects were caught. At the onset of the dry season when the grasses were beginning to dry up, most Cicadulina were caught on Pennisetum pedicellatum Trin. which was the predominant grass in Samaru at the time.

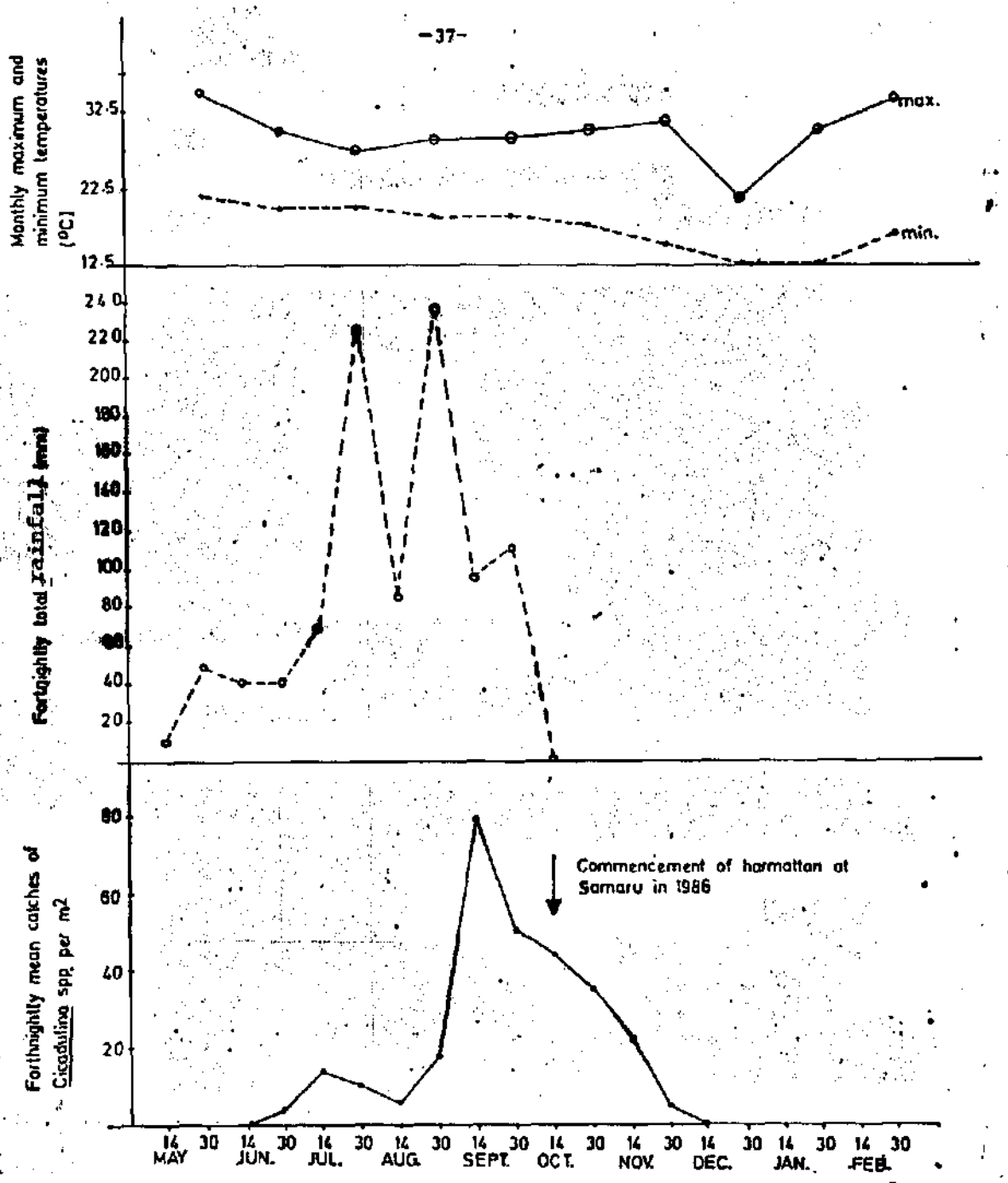


Fig. 1. Relationship between the fortnightly mean catches of Cicadulina spp./m² (—●—) the fortnightly total rainfall (mm) (●——●) the monthly maximum (—●—) and minimum (———) temperatures (°C) for Samaru between May, 1986 and February, 1987.

Table 3. Linear correlation coefficients among the monthly maximum temperatures, °C [variable 1], the monthly minimum temperatures, °C [variable 2], the mean catches of Cicadulina spp. per m^2 [variable 3], the cummulative rainfall, mm [variable 4] and the total fortnightly rainfall [variable 5] at Samaru in 1986.

Variable No	Monthly maximum temperature (°C)	Monthly minimum temperature (°C)	Mean catches of Cicadulina spp. (per m^2)	Cummulative rainfall (mm)	Total fortnightly rainfall (mm)
	V1	V2	V3	V4	V5
1	1				
2	0.389	1			
3	-0.016	0.193	1		
4	-0.241	-0.795	0.295	1	
5	-0.153	0.485	0.245	-0.237	1

Table 4: Predominant plants on which Cicadulina spp. were caught at Samaru in 1986

Family	Genera/Species	Location		
		IAR Dam	IAR Maize farms	IAR Campus
Amarantheceae	Amaranthus spinosus Linn	**		
Compositae	Acanthospernum hispidum DC		**	
	Ageratum conyzoides Linn.		**	
	Ethulia conyzoides Linn.	**		
	Sclerocarpus africanus Jack ex Murr	**		
	Synedrella nodiflora Gaertn	**		
	Vernonia panciflora (Willd) Less		**	
Cyperaceae	Cyperus distans Linn.	**		
	C. haspam Linn.	**		
	Fimbrystylis dichotoma (Linn.) Vahl.	**		
	F. pilosa Vahl.	**		
Gramineae	Andropogon gayanus Kunth	**	**	
	Brachiaria lata (Schumach.) C.E. Hubbard ex Robyns	**	**	
	B. xantholenca Hack ex Schinz		**	
	Chloris pilosa Schumach	**		
	Dactyloctenium aegyptium (Linn.) P. Beauv.	**	**	**
	Digitaria ciliaris (Retz.) Koel		**	
	D. horizontalis Willd.	**	**	
	Echinochloa obtusiflora Stapf.	**		
	Eleusine indica (Linn.) Gaertn	**	**	**
	Eragrostis gangetica (Roxb.) Steud.	**		
	E. pilosa (Linn.) P. Beauv.	**		**
	Hyparrhania rufa Stapf.	**		
	Pennisetum pedicellatum Trin.	**	**	**
	Setaria pallidefusca (Schumach) Stapf.	**	**	**
	Sporobolus pyramidalis P. Beauv.	**	**	**
Malvaceae	Sida acuta Burm. f.	**		
Onagraceae	Jussiaea suffuniticosa L.	**		
Papilionaceae	Aeschinomene sp.		**	
	Gotolaria netusa Linn.		**	
Rubiaceae	Borreria radiata DC		**	

** = Occurrence of a plant in the location sampled.

4.2 The Proportion of Viruliferous Insects in Natural Cicadulina Populations.

4.2.1 Introduction

It is known that maize steeak virus (MSV) is transmitted solely by Cicadulina spp. (Storey, 1925, 1928). The insects acquire the virus while feeding on infected plants and retain the virus for life. These vectors are also able to feed and breed on a wide range of grasses, including cultivated cereals. Grass fields could thus harbour infective hoppers which later carry the disease virus onto maize plants (Gorter, 1953).

A survey of Cicadulina populations was therefore carried out to determine the proportion of viruliferous insects among wild Cicadulina at the following locations around Samaru: IAR Campus, IAR Maize fields and IAR dam.

4.2.2 Procedure

The insects tested in this experiment were also collected in field surveys as described in Section 3.1.2. All Cicadulina caught were caged singly on 3 - 4 days old healthy seedlings of streak-susceptible maize cultivar TZB, using PVC cages described in Section 3.2.

The caged plants were left in the screen house at Samaru for three weeks for symptom development. The percentage of field infective Cicadulina individuals was derived indirectly by calculations from the number of seedlings streaked in relation to the total number of seedlings caged with insects. The symptoms developed on test maize seedlings were also noted.

The insects caged on maize seedlings were not removed before or after the three weeks. The primary interest was the development of streak symptoms. Most of the insects died before the final examination, some laid eggs and the eggs hatched within the three weeks, while a few caged insects survived throughout the period. Insects that survived during the period, or new clones that developed and that were not viruliferous, were included in raising virus-free colonies of Cicadulina species. An insect that actually survived the period and carried MSV was used in culturing the virus in the glasshouse by serial transfer from one maize seedling to another as described in Section 3.4.

4.2.3. Results

The results of the bioassay to determine the proportion of viruliferous Cicadulina in field populations are presented in Table 5. At Samaru, 9.35% of field Cicadulina were viruliferous. The streak symptoms that developed on maize were not the same. Whereas the virus transmitted by hoppers from the IAR maize farm No. 2 showed typical MSV symptoms on maize, the symptoms caused by the virus transmitted by hoppers from the Faculty of Agriculture area and IAR maize farm No. 1 showed transient symptoms which appeared only on the third to fourth leaves on maize seedlings. This is the first report that Cicadulina spp. collected from the field carried the different strains of MSV.

4.3. Discussion

This field survey shows that there are four species of Cicadulina leafhoppers in Samaru and its environs: C. mbila; C. similis; C. arachidis and C. triangula in decreasing order of prevalence. This confirms the works of Ekukole (1985) who recorded the above four

Table 5: Proportion of Viruliferous Cicadulina in field populations in Samaru in 1986 and the kinds of symptoms induced by the virus strains.

Location	No. of insects caged	No. of plants streaked	Percent infection	Remarks on Symptoms
1. IAR Campus, Faculty building area (no maize field in the immediate vicinity)	74	10	13.51	Mild streaks. Symptoms start from the base of the third leaves and show in some upper leaves but not fully systemic. A transient kind of infection.
2. IAR Campus, maize farm near Crop Protection Department area	20	0	0	
3. IAR Farm: Maize farm No. 1	13	2	15.38	Mild streaks, not typical of MSV, on the base of 3rd - 4th leaves.
4. IAR Farm: Maize farm No. 2	8	1	12.50	Typical maize streak symptoms.
5. IAR farm: Maize farm No. 3	24	0	0	
	139	13	9.35	

Average Infection for Samaru, 1986 = 9.35%.

species in Zaria, and also Okoth (1985) who reported that there are at least these four species of Cicadulina in Nigeria.

From this survey, and the reports of earlier workers (Ekukole, 1985; Okoth, 1985), C. mbila seems to be the most abundant species. C. mbila is prevalent in all the widely separated sites that were sampled in Samaru. Ekukole (1985) also recorded C. mbila in all the areas he sampled in Samaru and Zaria.

Only two species of Cicadulina were caught at Kadawa between January and February, 1987. These were C. triangula and C. mbila, with C. triangula being predominant. Although the samplings were intensive - fifteen random samplings each in three different wheat fields, twice a week - some other species may have been missed since samplings were done within only two months. One would have expected an abundance of Cicadulina in Kadawa in the dry months of January and February due to the availability of moisture and green vegetation. However it would appear that the vegetation was not very suitable for oviposition and rapid build up of Cicadulina populations. Wheat was the major crop cultivated and this crop is less preferred to millet for oviposition by Cicadulina females (van Rensburg, 1983b).

Analysis of the numbers of each species at each location, and of the species by locations using the X^2 were highly significant ($P < 0.01$) indicating that the composition of the four Cicadulina species in Samaru was dependent upon the locations sampled. The species composition differed significantly between the Samaru locations in 1986. There were also significant differences among the four Cicadulina species in Samaru as an area, with a highly significant X^2 value of 170.57 ($P < 0.01$).

Dabrowski (1986) noted that from three to six species of Cicadulina may occupy the same area but significant differences occur in species composition between locations in the same climatic zone. He observed greater differences between climatic zone. The proportion of C. arachidis and C. similis was never higher than 15 percent of the total Cicadulina population for 1983 and 1984 (Dabrowski and Okoth, 1984) but was higher for the 1985 growing season in Nigeria.

All the four Cicadulina species listed here as occurring in Samaru have been reported as vectors of the MSV (Rose, 1978; Okoth, et al., 1984; Dabrowski, 1986). C. arachidis showed the lowest percentage of males and females actively transmitting MSV to maize plants in comparison with C. triangula, C. mbila or C. ghaurii (Dabowski, 1986). Intraspecific differences in MSV transmission exist between populations of C. mbila and C. triangula originating from various ecological zones in Nigeria but the differences between the various species are much larger than the intraspecific differences in MSV transmission (Dabrowski, 1986).

This survey also shows that the female Cicadulina is always more abundant than the male in Samaru irrespective of the location where samplings were carried out. Analysis of the numbers of the sexes by locations using the X^2 showed that the different locations did not affect the sex ratio, as the X^2 value (1.66) was not statistically significant ($P > 0.5$). This is the first survey that showed that the sex ratio of Cicadulina spp. was not influenced by the locations sampled.

C. triangula females have been noted to be more effective in transmitting the MSV than males (Thottappilly, Zagre and Rossel, unpublished). Since the females are always more abundant than the males,

the efficiency of MSV transmission in the field within a species population is greatly enhanced.

The four species of Cicadulina were caught on the grass fields near the IAR Dam in Samaru. The dam bank can thus be viewed as a breeding site from where the insects can migrate to other fields. Since there are always pockets of green grasses near the dam, even during the dry and cold harmattan, consideration should be given to the influence of such breeding sites in the survival of the insects during adverse conditions, and in the epidemiology of maize streak virus. van Rensburg and Kuhn (1977) suggested that a succession of grasses or crops that are suitable as host plants is necessary for maintaining high vector population densities. This dam seems to provide such a succession of grasses and may be the source of some of the Cicadulina that transmit MSV to maize in the Samaru area.

From November, 1986 to the end of the sampling period in February, 1987, no successful sampling was done at the dam bank becuase it was flooded and most of the grasses were submerged. The farmers in the nearby village set fields on fire during the cultural dry-season bush burning leaving only grasses that were submerged in water.

Sampling for leafhoppers within maize fields was futile and successful samplings were done only on grass strips adjoining maize plots. Samplings on very young maize seedlings were also unsuccessful probably due to the absence of weeds which would otherwise have supported the insect populations. However the maize streak disease showed on the crops later, indicating that a few infective Cicadulina might have got into the fields to infect the crops. Ekukole (1985) noted that although he could not get any Cicadulina spp. in the Wusasa area of Zaria in 1984, the maize streak virus disease was observed, indicating that the leafhoppers must have fed on maize plants and moved

to other areas. Dabrowski (1983a) also indicated that during most of the growing season, the leafhoppers are scarce on grasses, maize, millet and other cereals, and that population density is highest at the end of the growing season. Ruppel (1965) stated that short flights of C. pastusae are the reason for the greater incidence of the disease around the border of field crops. The adults and nymphs move by frequent short jumps rather than by flight (Dabrowski, 1983a) and comparatively few infective hoppers would be sufficient to carry infection throughout a plot of maize (Storey, 1925).

Samplings within the IAR Campus showed that there were differences between sites in the number of Cicadulina caught even though the vegetation at these sites was similar. Very high numbers were caught at the Faculty of Agriculture Laboratory buildings while only a few were caught on the grasses in front of the screenhouse. These two lawns are separated by the Food Science and Technology Research Programme building. Also zero counts were consistently recorded at the field beside the Agricultural Extension and Research Liason Services (AERLS) while successful samplings were made in the nearby Central Stores and College of Agriculture areas. Since the populations at each site were probably started by a few individuals alighting from long-distance flights, it is possible that their movement away from these sites was restricted by the buildings which delimited the sites from each other. Also the availability of green, succulent vegetation may have reduced the need to disperse from the places where the insects first got settled. Thus while there would be many of the insects at some sites, there may be virtually none in other sites if no long-distance fliers had settled on them. Dabrowski (1986) indicated that Cicadulina adults tend to aggregate on young grasses rather than on an extensive area of maize, pearl millet or sorghum.

The surveys for viruliferous Cicadulina in field populations show that the grass strips adjoining maize fields harbour infective hoppers that carry the maize strain of the streak virus. This is in agreement with the report of Gorter (1953) who demonstrated that grass strips close to maize fields harbour infective hoppers and recommended a bare land of about 10 m wide around maize plots for the control of maize streak virus disease.

Infective hoppers in the field carry the different strains of the streak virus depending on the grass from which the hoppers got infected. Table 5 shows that whereas the virus transmitted by hoppers from the IAR maize field No. 2 elicited typical MSV symptoms on maize, the ones collected at the IAR Campus, Faculty of Agriculture Laboratory building showed different symptoms consistently. The symptoms were transient and showed first on the third leaves and some upper leaves of maize seddlings. The infection was not truly systemic as the symptoms disappeared completely in leaves that formed later. As it will be indicated later in Section 5.3., survey of the grasses in the area revealed two grass species with streak symptoms: P. pedicellatum and B. lata. This is the first survey that showed that viruliferous Cicadulina spp. in field populations carried the different strains of the virus depending on the host plants.

An average of 9.35% of the Cicadulina caught in Samaru were viruliferous. The range of 0 - 15.38% is comparable to the 0 - 11.50% reported by Okoth (1985) for Nigeria.

The linear correlation coefficients between the mean Cicadulina spp. catches and the total fortnightly rainfall ($r = 0.245$), the cummulative rainfall ($r = 0.295$) and the minimum temperatures ($r = 0.193$) were positive but not significant ($P > 0.05$). These probably indicate that the Cicadulina populations increase with higher rainfalls and higher minimum temperatures.

With the onset of the rains in May, the grasses spring up, and by the end of June there were enough green grasses in the field on which the leafhoppers could subsist. Generally the population size of Cicadulina is determined by the availability of young grasses for oviposition and feeding (Dabrowski, 1986) and these are influenced by weather conditions.

Cicadulina populations were generally highest in August and September in all the sampling sites in Samaru during 1986. The population declined sharply with the onset of the harmattan. The coldness, low Relative Humidity, and windiness during the harmattan period, coupled with the toughness and dryness of grasses seem to account for the low counts of leafhoppers during that period of the year. By August, the grasses on which these insects subsisted were fully matured and began to senesce a few weeks later. Dabrowski (1983a, 1986) indicated that the population density of Cicadulina is highest at the end of the growing season when adults migrate from older plants onto young seedlings or grasses grown under irrigation. Rose (1973a, 1978) showed that Cicadulina spp. begin their flight when the grasses are drying up. Maturing host plants become unattractive to Cicadulina spp. whose females then disperse without laying eggs before leaving (Rose, 1973a). The extreme windiness of the north-easterly harmattan wind would probably aid the long distance flight activity of Cicadulina from the drier north to the wetter southern part of the country. Even within the north, there would be short distance flights from the drier fields to the wet, lowland "fadamas" and irrigated fields where moisture and suitable grass hosts are available. The cold weather immobilises the insect within folded young leaves. The insects are less productive in the cooler periods between July and September (IITA, 1983b). Okoth (1985) also

noted the effects of this strong, dry harmattan wind which is often very hot during the day and very cold during the night. It seems that the insects are carried in the direction of the wind, and alight on suitable green vegetation on their paths. The effects of the dry harmattan wind and moisture - laden south-westerly wind need to be thoroughly studied as they may be carrying infective vectors of maize streak. Also irrigated plots and "fadamas" may be playing important roles in the epidemiology of the maize streak virus disease as they could provide survival sites for the insects during the off-season. Okoth (1985) reported that there were infective Cicadulina throughout the year in Nigeria (except December), in Ibadan (in the south-west) and Kadawa Irrigation Scheme (in Kano) where he ssmpled.

This field study agrees with the report of Dabrowski (1986) who indicated that Cicadulina leafhoppers were scarce on grasses, maize and pearl millet during most of the growing season in Nigeria. He collected the highest numbers of leafhoppers (31 - 136 adults per square meter) from the following grasses toward the end of the rainy season: Digitaria; Brachiaria, Eleusine, Pennisetum and Polystachion. The density fell progressively during the dry season and was low even on small irrigated areas covered by maize or preferred species of grasses. He asserted that the strong, dry, and cold harmattan winds from the Sahara affects the Cicadulina population in the Guinea savannah and some parts of the rain forest. Generally, the population size was determined by the availability of young grasses for oviposition and feeding but weather conditions modify those relationships (Dabrowski, 1986).

Chapter 5

FIELD SURVEY OF ALTERNATIVE HOSTS OF THE MAIZE STREAK VIRUS AND THE MODE OF SURVIVAL OF THE VIRUS DURING THE DRY SEASON

5.1 Introduction

Many species of wild grasses have been observed in the field with symptoms of streak disease (Storey, 1925; Storey and McClean, 1930; McClean, 1947; Rossel and Nabukenya, 1983; Ekukole, 1985; Ekukole et al., unpublished). Grasses with streak symptoms are thought to be important in the epidemiology of the maize streak virus disease, especially when streaks from such grasses are transmissible to maize. Rose (1978) presented an extensive review of grasses and crops that show symptoms of streak and claimed that it is possible that a source of the virus exists in grasses. Strains of streak virus naturally occurring in Eleusine and Sporobolus grasses proved to be highly pathogenic to exotic maize when this was introduced to Africa (Bock, 1974). Transmissions from naturally infected grasses to maize produced variable results (McClean, 1947; Rossel and Nabukenya, 1983). Though the streaks are usually serologically related to maize streak, they are not usually transmissible from grasses to maize.

Ekukole (1985) reported five grass species and pearl millet in Samaru and Zaria as showing symptoms of streak disease. A survey was therefore conducted to identify more grass species and cultivated cereals that are naturally infected in the field. The survey was done in the dry season of October, 1986 to February, 1987 to determine the possibility of the virus surviving the dry period in such grasses and irrigated cereals.

5.2 Procedure

The sites mentioned in Section 4.1.1. were surveyed for alternative hosts of the streak virus. Plants that showed MSVD - like symptoms were collected, labelled and taken to the herbarium section of the National Animal Production Research Institute (NAPRI), ABU, for identification. A similar search was made during the dry period for irrigated cereals or volunteer cereals that show the symptoms of MSVD.

5.3 Results

5.3.1 Survey of alternative hosts

Grasses that showed symptoms similar to those induced by the streak virus during the 1986/87 dry season in Samaru are presented in Table 6. Four grass species showed MSV-like symptoms in Samaru during the 1986/87 dry season: P. maximum, B. lata, P. pedicellatum and S. pallule-fusca.

5.3.2 Survival of MSV during the dry season

The search for MSV on irrigated cereals during the dry season revealed that irrigated maize with MSV symptoms were seen around the Galma River in Zaria in January, 1987. The author also travelled to Ibadan in the transitional rainforest zone and found that over 75% of irrigated maize along river courses had MSV disease in February, 1987. This is the first report in Nigeria of MSV occurring in irrigated maize crops.

5.4 Discussion

The survey carried out during the dry seasn between October, 1986 and February, 1987 to ascertain the possible means of survival of the MSV during the dry season and the possible sources of streak

Table 6. Grasses with streak symptons in Samaru and Zaria between October, 1986 and February, 1987.

Grass	Location
1. Panicum maximum Jacq	Galma River, Zaria.
2. Brachiaria lata (Schumach.) C.E. Hubbard ex Robyns	- IAR Campus, Faculty of Agriculture Building area.
3. Pennisetum pedicellatum Trin.	- IAR Campus, Faculty of Agriculture Building area. - IAR Dam; sugar cane farm.
4. Setaria pallidefusca (Schumach) Stapf and C.E. Hubbard	- IAR Dam; sugar cane farm.

inoculum for the new crops during the rainy season identified four grass species that were naturally infected with streak virus in Samaru and Zaria. These were P. maximum, B. lata, P. pedicellatum and S. pallude-fusca. Only B. lata has been reported before in northern Nigeria (Ekukole, 1985); while P. maximum has been reported in south western Nigeria (Rossel and Mabukenya, 1983; Thottappilly and Zagre, 1983). P. pedicellatum and S. pallude-fusca are reported here for the first time in Nigeria.

The prescence of streak on a grass does not necessarily pose a threat to the maize industry except if the virus strain is virulent on maize (Thottappilly, personal communication). From the transmission studies with infective hoppers collected at the Faculty of Agriculture building area, where B. lata and P. pedicellatum were

observed with streaks, the streak virus on those grasses was not very virulent on maize, as it incited only mild transient symptoms on the MSV-susceptible maize cultivar TZB.

It is however apparent from this study that the streak virus survives the dry season in grasses, and that these grasses could be sources of primary inoculum for the new maize crop. The virus could also survive the dry season in rhizomes of the grasses (Ajayi, personal communication) and be readily available when the rhizomes produce new shoots. This needs to be investigated further. More work also needs to be done on the different strains of streak virus occurring in grasses so as to get a more accurate knowledge of their effects in the epidemiology of the maize streak virus disease.

The report here of the presence of MSV in irrigated maize during the dry season also gives a clue to the question of survival of the virus during the dry season. Although irrigated cereal crops have earlier been implicated with the survival of the vectors during off seasons (Rose, 1970; Dabrowski, 1983a and b) this is the first report of the virus surviving in irrigated maize crops in Nigeria. Although streaks surviving in grasses may or may not be virulent on maize, thus the grasses may or may not be important sources of primary inoculum for the new maize crop, these infected irrigated maize crops are apparently major sources of the virus that infects the new crop. Leafhoppers on such irrigated fields are likely to be carrying virulent strains of the virus. The influence of the River Basins, "fadamas" and commercial irrigated farms on the survival and epidemiology of the disease and the vectors needs to be thoroughly studied.

Chapter 6

SCREENING OF PLANTS FOR SUSCEPTIBILITY TO MAIZE STREAK VIRUS DISEASE

6.1 Introduction

Adequate knowledge of the host range of a disease pathogen is indispensable for the proper management of the disease. While many grasses have been found naturally infected with streak virus, the streak virus exists as a group of related viral strains that has become host-adapted in several graminaceous species (Damsteegt, 1983).

In addition to surveys for grasses that carry streak virus in the field, vulnerability of native annual and perennial wild plants to MSV under the controlled environment of screenhouses is thought to be of epidemiological significance. An experiment was thus carried out to screen grasses that are commonly found at Samaru and Zaria areas for susceptibility to the maize streak virus.

6.2 Procedure

6.2.1 Collection and identification of plants

Mature plants were collected between October and November, 1986 in fields and farms at Samaru and Zaria. They were labelled and taken to the herbarium section of the NAHRI, ABU for identification. They were then taken to the IITA, Ibadan where the transmission studies were carried out.

6.2.2 The insects used

A virus-free C. triangula colony that is maintained in the glasshouse of the IITA for maize streak resistance screening was used throughout the experiment.

Sets of 500-600 C. triangula were collected using an electrically - operated aspirator (D-vac which operated like a vacuum cleaner) from the above virus-free IITA colony (Dabrowski, 1983b). These were then released onto four weeks old MSV - infected maize plants inside wooden cages (Plate 1). The infected maize plants were collected from the IITA demonstration plots. All the lower green leaves on the plants were removed, leaving the heavily infected leaves for the insects to feed upon. The insects were allowed an acquisition access period of at least three days.

6.2.3 Handling the leafhoppers

The leafhoppers were taken from the acquisition feeding wooden cages by covering the cage with dark green clothing as described in Section 3.1.1. and collecting them from the light panel with a mouth-operated aspirator. The insects were then transferred from the aspirator to PVC cages by putting the open end of the glass tube used in the aspirator onto the PVC cages and gently tapping and blowing with the mouth. Anaesthetizing the insects with carbon dioxide was not used because it weakens and could kill the insects (Dabrowski, persoal communication). Thus, all the insects were still alive and active by the time they were caged onto the plants.

6.2.4 Inoculation of the grasses with MSV

Thirty-five different plant species were collected as described in Section 6.2.1. and planted at the IITA in 13 cm (5 inches) plastic pots and then transplanted in twos into 13 cm (diameter) pots at the 2-3 leaf stage. Ordinary soil that was not sterilized was used, because the soil sterilising machine of the IITA was not in good order at the time of the experiment.

The plants were inoculated at the 2-3 leaf stage with MSV using infective C. triangula. Since the test plants germinated at different rates, inoculation was carried out on different dates. Three insects were caged per seedling using the PVC cages described earlier and there were two seedlings per pot (Plate 3).

The seedlings were then kept in insect-proof cages (Plate 5) for three days, giving three days inoculation access period. The seedlings were then removed from the insect - proof cages, taken to a nearby field where the PVC cages were removed and the insects released. The seedlings were then sprayed with 0.1% Dimethoate (Rogor) and NPK fertilizer was applied to the soil. The seedlings were returned to the insect-proof cages and observed for two to three weeks for symptom development.

6.3 Results

Of the 35 different plant species planted, 17 germinated within the experimental period of three months. The results are presented in Table 7. Pearl millet, P. americanum and cultivated sorghum, S. bicolor were not susceptible to MSV. A cultivated rice species Oryza glaberrima, collected from a farmer's field in Palladan, Zaria, was susceptible to MSV (Plate 6). Other plants that proved susceptible to MSV were E. indica, Chloris picnothrix Trin., Cyperus pustulatus Vahl. (Plate 7) and Acrocerus applectus Stapf (Plate 8). The streaks on E. indica were fine discontinuous ones similar to those described by Ekukole (1985), while the other plants had typical symptoms of MSV, with bleaching of leaves which indicated severe infections.

Two species of Panicum, P. maximum and P. laetum Kunth, were not susceptible to the streak virus from maize P. pellicellatum, Sporobolus helvolus (Trin.) Dur. and Schinz, Hyparrhenia rufa (Nees.) Stapf and S. pallidefusca which are the predominant grasses in Zaria could not be infected with MSV.

Table 7. Reactions of some plant species collected at Samaru and Zaria to MSV.

Plant Species	No. of plants inoculated	No. of plants with streak	%
Acroceras amplectus Stapf	32	19	59.38
Chloris pienothrix Trin	14	2	14.29
Cyperus pustulatus Vahl.	11	1	9.09
Dactyloctenium aegyptium (Linn.) P. Beauv.	4	0	0
Echinochloa colonum (Linn.) Link	15	0	0
E. pyramidalis (Lam.) Hitche	30	0	0
Eleusine indica (Linn.) Gaertn.	15	5	33.33
Hyparrhenia rufa (Ness.) Stapf	15	0	0
Oryza glaberrima Steud.	28	9	32.14
Panicum laetum Kunth	40	0	0
P. maximum Jacq.	40	0	0
Pennisetum americanum (Linn.) K. Schum.	50	0	0
P. pedicellatum Trin.	30	0	0
Setaria pallidefusca (Schumach.) Stapf	18	0	0
Sorghum bicolor (Linn.) Moench	50	0	0
Sporobolus helvolus (Trin.) Dur and Schinz	30	0	0
Thelepogon elegans Roth ex Roem and Schult	11	0	0
Zea mays L. cv. TZB	56	46	82.14



Diseased plants: No. 24 Left and Middle Healthy plant: No. 24C Right

Plate 8. Oryza glaberimma Steud



Diseased plant: No. 29 Left Healthy plant: No. 29C Right

Plate 9. Cyperus pustulatus Vahl.



Healthy plant: No. 12C Left Diseased plants: No. 12 Right

Plate 10. Acrocerus amplectus Stapf.

species
Two grass growing beside the insect-proof cages were seen with symptoms of streak virus disease. They were uprooted and taken to the Weed Science Section of the IITA where they were identified as Digitaria adscendens Hern (Plate 11) and Leptochloa filiformis (Lam.) P. Beauv. (Plate 12). There were three plants of L. filiformis that showed the streak symptoms. Apparently these grasses were infected from viruliferous C. triangula that might have escaped during the experiment. This is the first report that D. adscendens and L. filiformis are susceptible to MSV. The typical symptoms of MSV on maize are shown in Plates 13 and 14.

6.4 Discussion

Screening of grass species for susceptibility to MSV in maize was thought important as these grasses are reported to harbour infective hoppers and the streak virus (Carter, 1953; Rose, 1978). However, the prescence of streak symptoms on a grass in the field does not necessarily pose a threat to maize since not all strains of streak virus can be transmitted to maize (Thottappilly, personal communication). Grasses that show streak symptoms in the field may not be susceptible to the maize streak virus strain. This study shows that although the following grass species, and pearl millet have been reported as carrying streak symptoms, they are not susceptible to MSV from maize : D. aegyptum (Ekukole, 1985 ; Ekukole et al., unpublished) ; P. maximum (Rossel and Nabukenya, 1983; Thottappilly, personal communication); Setaria spp. (Fajemisin and Shoyinka, 1976; Rossel and Nabukenya, 1983); P. pedicellatum and B. lata (Olojede, present report, Section 5.3). Because these grasses could not be infected with MSV, the virus strain may not survive in them and they may not be important in the etiology and epidemiology of maize streak virus disease.



Plate 11. Digitaria adscendens Hern. Plants infected with maize streak virus



Plate 12. Leptochloa filiformis (Lam.) P. Beauv. Plants infected with maize streakvirus.



Plate 13. Fully streaked *Zea mays* L. CV. TZD showing the typical symptoms of MSVD.



Healthy plants: No. 40C (Left) Diseased plant: No. 40 (Right)

Plate 14. Typical maize streak virus disease symptoms in maize.

On the other hand, susceptibility of a grass species or cereal crop under experimental conditions indicates likely susceptibility under field conditions. A. amplectus, E. indica, C. picnothrix, C. pustulatus and O. glaberimma listed in Table 7, B. adscendens and L. filiformis which are reported here as susceptible to MSV under screenhouse conditions are therefore potential hosts of MSV in the field. For instance, the symptoms induced on E. indica under experimental conditions were similar to those reported earlier in the field by Ekukola (1985). The abundance of such plants in a locality and their prescence during the dry season could thereby have significant effects on the epidemiology of MSV. The fact that these grasses form rhizomes can aggravate the problem as the virus can survive in the rhizomes during the dry season when the shoots are dried or burnt (Ajayi, personal communication). As new shoots spring up with the onset of the rains, these sources of primary inoculum would be in the field for insects to be infected with. The grasses are usually in the field earlier than the crops, and could thus maintain both the virus and the vectors prior to the planting of maize

This study shows that MSV, as it occurs in maize, was not transmissible to pearl millet P. americanum, cultivated sorghum S. bicolor and a grass P. pedicellatum that is abundant and widely distributed in northern Nigeria. The revelation that these plants and others like S. helvolus , S . pallude-fusca, H. rufa, Echinochloa spp. and T. elegans (that are very prevalent in northern Nigeria) are non hosts of MSV strains in maize is comforting and indicates that the host range of MSV is possibly limited to few, sparsely distributed plants.

This study is in agreement with previous reports that P. maximum is a non-host of MSV (Rossel and Nabukenya, 1983) and that sorghum and millet cannot be infected with the virus (Thottappilly and Zagre, 1983; Damasteegt, 1983). Reports by Ekukole (1985) that pearl millet carries symptoms of MSVD may indicate that pearl millet is susceptible to some strains of the streak virus that are in the field. The importance of streaks on millet in the epidemiology of MSV depends on whether MSV is transmissible from maize to millet or whether the millet strain of the virus is transmissible to maize (Thottappilly, personal communication).

Grasses like E. indica that are frequently encountered in the field with streak symtpoms (Rossel and Nabukenya, 1983; Ekukole, 1985 and Ekukole et al., unpublished) and that are demonstrated to be susceptible to MSV from maize are of immense importance in the epidemiology of maize streak virus disease. Such grasses could serve as a means of survival to both the virus and the vectors, and their elimination from maize fields should be a major aspect in the integrated control of the maize streak virus disease.

Chapter 7

SUMMARY AND CONCLUSIONS

An intensive survey of Cicadulina species in Samaru between June, 1986 and February, 1987 revealed the occurrence of four species: Cicadulina mbila Naude; Cicadulina similis China; Cicadulina arachidis China and Cicadulina triangula Ruppel in decreasing order of prevalence. C.mbila was caught in all the sites sampled and constituted 65.38% of Cicadulina population in Samaru. A similar survey at the Kadawa Irrigation Scheme, Kano State, between January and February, 1987 identified C. triangula and C. mbila in the area. C. triangula was the dominant species. Analysis of the numbers of each species at each location; and of the species by locations, using the X^2, were highly significant ($P < 0.01$) indicating that the composition of the four Cicadulina spp. in Samaru was dependent upon the locations sampled. The species composition differed significantly between the Samaru locations in 1986.

The surveys also show that the female Cicadulina is always more abundant than the male, forming 57.50% at Samaru and 66.00% at Kadawa. Analysis of the numbers of the sexes by locations using the X^2 showed that the different locations did not affect the sex ratio, as the X^2 value (1.60) was not statistically significant ($P > 0.5$).

Cicadulina populations in Samaru built up with an increase in rainfall. The numbers caught were very low at the onset of the rains, generally rising, and reached the maximum before the rains stopped. The rains were highest between August and September, 1986. The numbers declined sharply as the harmattan

set in during the second week of October, 1986. The counts were mostly nil during the cold and dry months between October, 1986 and February, 1987. The linear correlation coefficients between the mean Cicadulina spp. catches and the total fortnightly rainfall (r = + 0.245), the mean Cicadulina spp. catches and the cummulative rainfall (r = + 0.295) and the mean Cicadulina spp. catches and the minimum temperatures (r = + 0.193) were positive but not significant (P > 0.05). These probably indicate that the leafhopper populations increase with higher rainfalls and higher minimum temperatures.

Bioassays to determine the proportion of infective hoppers in the field populations revealed that Samaru had an average of 9.35% viruliferous leafhoppers in the field with a range of 0 - 15.38%. It is also demonstrated that infective hoppers in the field carry the different strains of the streak virus depending on the host plants from which the hoppers got infected.

A survey of alternative hosts of the streak virus in Samaru and Zaria showed four grass species with symptoms of streak virus disease: Panicum maximum Jacq; Brachiaria lata (Schumach.) C.E. Hubbard ex Robyns; Pennisetum pedicellatum Trin, and Setaria palludefusca (Schumach.) Stapf C.E. Hubbard.

This study shows that the presence of streak on a grass in the field does not pose a threat to the maize crop except the virus strain is virulent on maize. A lot of the grasses carried virus strains that are not very pathogenic on maize as the virus elicits mild and transient symptoms on maize. On the other hand when a grass carries the virulent strain of the virus, the virus can survive the dry season in the grass, particularly in the rhizomes.

Seventeen plants were screened for susceptibility to MSV under screenhouse conditions, and the following five were susceptible: Acrocerus amplectus Stapf, Eleusine indica (L.) Gaertn; Chloris pycnothrix Trin; Cyperus pustulatus Vahl and Oryza glaberrima Steud. In addition, two grass species, Digitaria adscendens Horn and Leptochloa filiformis (Lam.) P. Beauv.) were infected with MSV beside the screen cages used.

This study also show that plants that show streak symptoms in the field may not be susceptible to MSV from maize. MSV could not be transmitted to pearl millet and the following grass species which have been reported as having streak symptoms in the field: Dactyloctenium aegyptium, (Linn.) P. Beauv. D. maximum, Setaria spp; and P. pedicellatum. Such grasses may not be important in the etiology and epidemiology of the maize streak virus disease as they could not be infected with MSV,

However, susceptibility of a plant under experimental conditions indicates likely susceptibility under field conditions. Such plants whether cultivated cereals or grasses, are therefore potential hosts of MSV in the field. Their abundance in a locality and prescence during the dry season could have significant effects on the epidemiology of MSV as the virus can survive in them or their rhizomes.

This study shows that certain grasses, like E.indica, that are frequently encountered with streak sysmptoms in the field are also susceptible to MSV from maize. Such grasses are thus of great importance in the epidemiology of the maize streak virus disease as both the virus and the vectors can survive in them during the dry season. The virus could also survive in the rhizomes of such plants, and from them the virus can be transmitted to maize. Their prescence in maize fields or irrigated plots could pose serious threats to maize crops.

During the dry season between November, 1986 and February, 1987, irrigated maize crops in Samaru and Ibadan were seen with maize streak symptoms. It is thus concluded that irrigated and volunteer maize crops could be a means of survival for MSV from one wet season to another.

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Appendix 1. Mean catches of Cicadulina spp. (per m^2) in relation to the total fortnightly rainfall (mm), the cummulative rainfall (mm), and the monthly maximum and minimum temperatures for Samaru between May, 1986 and February, 1987.

VAR	Max. Temp [°C]	Min. Temp [°C]	Mean catches of Cicadulina (per m^2)	Cummulative rainfall (mm)	Rainfall (mm)
ROW (CASE)	(V1)	(V2)	(V3)	(V4)	(V5)
1	34.4	21.7	0	11.2	11.2
2	34.4	21.7	0	59.1	47.9
3	30	20.5	0	100.7	41.6
4	30	20.5	3.6	141.2	40.5
5	27.9	19.7	13.7	210.2	69
6	27.9	19.7	10.6	434.8	224.6
7	28.6	18.8	5.8	520	85.2
8	28.6	18.8	16.62	756.9	236.9
9	28.9	19.1	78.4	852	95.1
10	28.9	19.1	50.6	962.6	110.6
11	31.1	17.1	43	962.6	0
12	31.1	17.1	35.1	962.6	0
13	31.5	14.2	21.8	962.6	0
14	31.5	14.2	4.45	962.6	0
15	21	12.5	0	962.6	0
16	21	12.5	0	962.6	0
17	30.5	12.5	0	962.6	0
18	30.5	12.5	0	962.6	0
19	33.1	16.3	0	962.6	0
20	33.1	16.3	0	962.6	0

1: cico

VAR NO.	LABEL	MEAN	STD DEV
1	(V1)	29.7	3.559
2	(V2)	17.75	3.180
3	(V3)	14.183	21.621
4	(V4)	603.34	275.409
5	(V5)	48.129	72.301

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