STUDIES ON THE MAIZE STREAK VIRUS AND ITS VECTORS

BY

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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.

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The above declaration is confirmed.

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CERTIFICATION

This thesis entitled 'STUDIES ON THE MAIZE STREAK VIRUS AND ITS VECTORS' by George EKUKOLE 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

To my parents, Mr. E.M. Ekukole and Mrs. C.N. EKUKOLE and to Robert, Stella, Rita, Daniel, Fidelis, Henrietta and Georgiana for their patience and sacrifice.

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ABSTRACT

A survey of Cicadulina species around the Zaria area between March, 1984 and October, 1985 revealed the occurrence of four species: Cicadulina mbila Naude, C. triangula Ruppel, C. arachidis China and C. similis China. C. mbila was caught more often than the other species. A greater number of species and individuals was caught during the rainy season than during the dry season.

Studies on the development of C. mbila at Samaru in 1985 revealed that at a temperature of 29 to 31°C the life cycle from egg to adult took 27 days and 26 days at a temperature of 32 to 34.5°C. Temperature appears to play a very important role in the development of this species.

A survey of alternative hosts of the maize streak virus (MSV) in the Zaria area showed five grass species with typical symptoms of the maize streak virus disease (MSVD): Dactyloctenium aegyptium (L.) Beav., Digitaria ciliaris (Retz.) Koel., Brachiaria lata (Schumach.) C.E. Hubbard ex. Robyns., Eleusine indica Gaertn. and Eragrostis ciliaris (Linn.) R. Br. MSVD symptoms were also observed in pearl millet, Pennisetum americanum (L.) Leeke. Serological studies proved conclusively that MSV in maize is serologically related to the virus which elicits streak symptoms in millet and the grasses mentioned. Precipitation lines were more intense with partially purified sap of Dactyloctenium aegyptium and Digitaria ciliaris than with B. lata, E. indica and millet. In the field, D. aegyptium and D. ciliaris tend to be more severely affected by MSVD than the other hosts mentioned.

A survey of MSVD in the Zaria area from March, 1984 to September, 1985 revealed that the incidence of the disease was lower in 1985 than in 1984 and that early planted maize suffered less disease than those planted late, particularly in the research farm of the Institute for Agricultural Research at Samaru. Rainfall and the presence of weeds, particularly of the family Gramineae, were identified as possible important factors responsible for differences in the incidence of the MSVD in Zaria. Digitaria ciliaris and Eleusine indica may be very important in the etiology of the disease from season to season and year to year in the Zaria area.

The effect of the method and frequency of weed control on MSVD incidence, severity and yield was investigated at Samaru in 1984 and 1985. Four treatments were involved : pre-emergence herbicide application, pre-emergence herbicide plus one hoe-weeding at 4 weeks after planting (WAP), pre-emergence herbicide plus two hoe-weedings at 4 and 6 WAP and three hoe-weedings only at 4, 6 and 8WAP (control). Both incidence and severity of the disease were lower in plots treated with pre-emergence herbicide only and pre-emergence herbicide plus one hoe-weeding than in those with pre-emergence herbicide plus two hoe-weedings and three hoe-weedings only. Disease was consistently high in the latter two treatments in both 1984 and 1985. Grain yields in all the treatments were similar and this was possibly due to late infection by the virus.

In 1984 and 1985, carbofuran, demeton, thiometon, endosulfan, dimethoate and carbaryl were evaluated for their effect on incidence and severity of the MSVD at Samaru. Carbofuran - treated plots consistently had the lowest disease and the highest yield in both years.

In another trial (1984), 30 maize varieties were exposed to natural infection of the MSVD at Samaru. TZSR-Y-1 and SZV-6 consistently suffered low disease incidence and severity at 4WAP and 8WAP and TZSR-Y-1 also had the highest grain yield. None of the varieties was immune to the disease.

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Chapter 1

INTRODUCTION

Maize (Zea mays, L.) is believed to have originated from Mexico and Central America (Galinat, 1979). It was introduced into West Africa about three and a half centuries ago (Kassam et al; 1975; Fajemisin and Shoyinka, 1976) and since then it has been cultivated in Nigeria (Van Eijnatten, 1965). Now it occupies a very important position among cereals in Nigeria (Anon; 1973). It is widely grown in the southern parts of the country (Kassam et al; 1975). However, the total hectarage devoted to the production of this crop is on the increase in the northern states (Anon; 1973). Despite its position, the average hectarage cultivated to this crop per farmer is very small, about 0.5 - 1ha (Anon; 1973). Moreover, it is still largely grown under traditional methods of farming in most areas. This cereal crop is grown mainly for human consumption. It is either roasted or boiled and eaten on the cob or ripe grains are prepared in several other ways (Anon; 1973; Fajemisin and Shoyinka, 1976).

The importance of maize in West Africa was realised in 1950 when there was an epidemic of the rust disease (Van Eijnatten, 1965). This disease caused an initial total failure and in later years severe reductions in maize yield. Alongside other diseases, the maize streak virus (MSV), which causes the maize streak virus disease (MSVD), and is vectored by several species of the leafhopper, Cicadulina, is one of the most important factors limiting maize production in West Africa and other parts of Africa where this crop is grown (Storey, 1925; Van der Merwe, 1926; Storey and McLean, 1930; Anon; 1972; Fajemisin and Shoyinka, 1976; Van Rensburg and Kuhn, 1977; Soto et al; 1982; Keyser, 1983; Dabrowski, 1983). Research in Nigeria has so far been limited

to surveys to identify the vectors of MSV; studies on the biology of the vectors; the incidence of the disease; non-maize hosts of the vectors and virus as well as studies on control measures, particularly the use of streak-resistant varieties of maize (Esenam, 1965; Anon; 1973a,b; Fajemisin and Shoyinka, 1976; Fajemisin et al; 1976; Medaiyedu, 1976; Anon; 1980; Kim et al., 1981; Anon; 1982). However, a lot still remains to be done in order to understand the ecology of Cicadulina spp. and appropriate control measures necessary to keep the vector and virus below the economic threshold level.

The objectives of this project were as follows: survey of Cicadulina spp. in the Zaria area; an attempt to study the development of Cicadulina mbila under glasshouse conditions at Samaru, Zaria; an attempt to identify non-maize hosts (alternative hosts) of MSV; a survey of the incidence of MSVD in the Zaria area; an attempt to control the disease by controlling the vector using chemical and cultural methods; and an attempt to evaluate the reaction of some varieties of maize to MSVD.

Chapter 2

REVIEW OF LITERATURE

2.1 Cicadulina

2.1.1 Systematics

Class	Insecta
Sub-class	Pterygota
Division	Exopterygota
Order	Hemiptera
Sub-order	*Homoptera*
Super-family	Cicadelloidea
Family	Cicadellidae
Sub-family	Deltocaphalinae
Tribe	Macrostelini

2.1.2 Species described and distribution

In the tribe Macrostelini, 16 vector species are known and the vector genus Cicadulina China has six vector species and subspecies among 15 described in the world (Nielson, 1979). A good proportion of these species has been recorded in Africa (six from Nigeria) (Ruppel, 1965; Ghauri, 1971). Cicadulina species already described include the following: C. bipunctella bipunctella; C. funeralis C. mbila, C. bipunctella zeae (China, 1928, 1936); C. bipunctella bimaculata; C. tortilla; C. pastusae (Ruppel and DeLong, 1956); C. latens (Fennah, 1960); C. idyia) fijiensis; C. vescula; C. parazeae, C. chinai (Ghauri, 1961, 1965). Table 1 shows the known distribution of Cicadulina species in the world (Rose, 1978). Rose (1983) noted that groups of species are common either to the northern and

eastern parts of Africa, to the eastern and southern parts, or to the western and southern parts, but rarely are species common both in the north and south or east and west.

2.1.3 Biology

(a) Morphology

Cicadulina species are easily recognised in the field by their delicate appearance and by a pair of round black spots on the anterior margin of the crown of the head (Ruppel, 1965; Nielson, 1968; Rose, 1978; Dabrowski, 1983). The insects range in length from 2 to 4mm, and they are most readily seen when they sit head up in the shelter of the funnel of leaves of maize plants (Ruppel, 1965; Dabrowski, 1983). Adults are generally cream, yellow or greenish. The dorsum of the abdomen is black in most species and some have black markings on the elytra, pronotum or venter. The hind tibiae are about as long as the abdomen; they are curved and have a double row of spines (Dabrowski, 1983). The female Cicadulina is distinguished from the male by its long ovipositor (Dabrowski, 1984).

(b) Host plants

Interpretation of host records of Cicadulina has always been a cautious exercise because some species have been recorded on non-gramineous host plants, for example, C. similis and C. arachidis from groundnuts (China, 1928); C. bipunctata bipunctella from Mesembryantheum (Ruppel, 1965); C. chinai from cotton, clover, vegetables and fruit trees and C. mbila, C. storeyi and C. bipunctata bimaculata and C. pastusae from alfalfa (lucerne) (Ruppel, 1965; Rose, 1973b).

Table 1. The distribution of Cicadulina species in the World

Identity	Distribution
* C. arachidis China	Gambia, India, Nigeria
C. bipunctella bimaculata (Evans)	Australia (NSW E. Queensland)
C. bipunctata bipunctata (Melichar)	Kenya, Egypt, Yemen, India, Saudi Arabia.
C. bipunctella bipunctella (Matsumura)	Algeria, Egypt, Tripolitania, Israel, Iraq, Turkey, India
C. bipunctata (Melichar) spp.	Pacific Islands, Philippines, Taiwan, W.Malaysia, N. Australia,
C. chinai (Ghauri)	Kenya, Egypt, India.
C. fijiensis (Linnavuori)	Fiji
C. fieneralis (Distant)	Seychelles
* C. latens (Fennah)	Kenya, Nigeria
* C. mbila (Naude)	Kenya, Nigeria, South Africa, Rhodesia, Tanzania, Zaire, Mauritius, Cape Verde, Islands, Yemen, India, Tadzhic S.S.R.
C. niger Ghauri	Kenya, South Africa, Tanzania
C. parazeae Ghauri	Rhodesia
C. pastusae Ruppel & Delong	Columbia, Ecuador
* C. similis China	Gambia, Rhodesia, Tanzania, Nigeria
* C. storeyi China	Rhodesia, Tanzania, Nigeria
C. tortilla Cadwell	Columbia, Peru
* C. triangula Ruppel	Nigeria, Rhodesia, Egypt, Sudan
C. vescula Ruppel	Rhodesia, Zaire

(* Recorded in Nigeria) Modified from Rose (1978).

These plants are regarded as holding plants on which hoppers feed temporary (Rose, 1978).

Cicadulina are generally regarded as grassland species (Ruppel, 1965; Nielson, 1968). However, most host records are for specimens from maize plants. C. mbila, C. parazeae, C. bipunctata bipunctella, C. bipunctata bimaculata, C. chinai, C. pastusae and C. bipunctata bipunctata have been collected from field maize. Some species have been recorded and bred on many grass hosts including the following: Eleusine indica, Urochloa panicoides, Setaria homonyma, Digitaria velutina, Panicum maximum, Pennisetum sp. and Brachiaria sp. (Van der Merwe, 1926; Ruppel, 1965; Anon; 1976; Rose, 1978; Dabrowski, 1983). Grasslands are extensive and are important sources of Cicadulina dispersing during the dry season in parts of Africa (Rose, 1978).

(c) Dispersal

Like in the Auchenorrhyncha (Medaiyedu, 1975), the causal factors for dispersal by flight of Cicadulina species may include hunger, overcrowding, drying of host plants and the formation of grain heads. According to Rose (1972a) however, movement of these hoppers from one area to another is influenced by changes in environmental conditions, especially rainfall. The growth of grass hosts on which large populations of Cicadulina are known to breed in the absence of maize plants is affected by rainfall (Rose, 1973b and 1974). A knowledge of the distribution of rainfall, therefore, can be used to predict what the size of Cicadulina populations would be in

a particular year as well as the degree of severity of the maize streak virus disease (Rose, 1974, 1978).

(d) Life cycle

The biology of most species of Cicadulina is unknown. However, the life cycle of C. mbila (Naude) was studied and presented, in some detail by Van der Merwe (1926) and Rose (1973a). The life cycle of this species is typical of that of many species of cicadellids. The eggs are inserted into leaves or mid-veins of the host, incubation lasts from 8 to 21 days; there are five nymphal instars which last from 18 to 31 days; the first eggs are laid a week or two after emergence of adults. The females may lay as many as 22 eggs per day and 339 in their life time; the adult may live for several months. Recently, Dabrowski (1984) also studied the development of C. mbila and C. triangula Ruppel in Nigeria. He noted that under natural conditions (average day time temperature 30° to 35° and night-time temperature 24° to 26°C), eggs of C. triangula developed in 7 to 11 days; at a constant temperature of 35°C, in only 6 to 8 days; at 27°C in 9 - 11 days; at 20°C in 13 to 15 days; and at 15°C, the eggs could not develop after 45 days. Most of the eggs were inserted in the midveins of leaves, only 3 to 6 percent in other parts of the leaf. Nymphs developed in 15 to 25 days under screenhouse conditions and 15 to 23 days at a constant temperature of 35°C. The emergence of adults was also more prolonged at temperatures lower than 35°C. The eggs were laid on the third and fourth days after emergence.

(e) Feeding habits

The mouthparts of Cicadulina are the typical piercing and sucking type of most cicadellids. According to Storey (1938), C. mbila feeds on both the phloem and mesophyll of its host plant. This species, according to Storey, changes its location when feeding, a habit that undoutedly increases its efficiency as a vector of the maize streak virus.

2.2 The maize streak virus disease

2.2.1 Distribution

Work on the maize streak virus disease was first published by Fuller (1901) in Natal. The occurrence of this disease was not reported elsewhere until after Storey described the transmission of the disease by C. mbila (Naude) in 1924. Then it was reported from Ghana in 1929, Rhodesia in 1935, and Tanzania, Kenya, Uganda and possibly Egypt in 1936 (Storey, 1936). The disease has also been reported from Mocambique, Nigeria (West, 1938; Esenam, 1965; Fajemisin and Shoyinka, 1976; Fajemisin et al., 1976), Dahomey (Benin Republic) (Le Conte, 1974) and Mauritius. The first occurrence of the disease in India was reported by Seth et al., (1971), and in view of the widespread distribution of Cicadulina spp., there is a real possibility of spread of this disease from Africa to South-East Asia, Australia and other parts of the world (Rose, 1978).

2.2.2 Transmission of the maize streak virus

The epidemiology of MSV cannot be discussed without mentioning Storey's investigations on its transmission by the leafhopper, C. mbila (Naude). He started his investiga-

yield was found to decrease from 13.2 metric tons to 1 metric ton or less when plants were infected by streak at 25cm or less. In Samaru, the maize streak is still the most severe disease of late maize and infestations of 80 to 90 per cent have been recorded in many fields; in 1983 generally up to 91.1 percent loss in grain yield was noticed in virus infected plants (Anon., 1983).

2.3 Control of Maize streak virus and its vectors

Generally virus diseases are very difficult to control. Once a plant is infected with a virus recovery becomes very difficult (Kuhn and Jellum, 1970; Matthews, 1970; Gibbs and Harrison, 1976; Horne, 1978). Control measures are, therefore, directed at preventing the virus from getting into the plants. This ultimately means that the vector must be controlled. For this to be effective, the sources and pattern of dispersal of the vector must be known (Rose, 1972a, 1973a & b, 1974, 1978). The control measures currently used in Africa, and in Nigeria in particular include: cultural control, chemical control of vectors and the use of resistant varieties of maize (Hill, 1975; Fajemisin and Shoyinka, 1976; Rose, 1978). According to Purcell (1979), integrated control combining some or all of these control measures may eventually prove to be the most effective approach.

2.3.1 Cultural control

(a) Time of planting

It has been observed in all places where the maize streak virus disease is a problem that time of planting has an effect on disease incidence and perhaps severity (Gorter, 1953; Fajemisin

and Shoyinka, 1976; Van Rensburg and Kuhn, 1977; Rose, 1978). Planting early in the season allows the plants to escape the most vulnerable stage of MSVD. A knowledge, therefore, of climatic parameters such as rainfall and temperature is very useful in this respect. According to Esenam (1965) and Rose (1978), the amount of rainfall during a particular season influences the population of vectors and hence, the incidence of the maize streak virus disease.

(b) Sanitation

It has been proved experimentally that many species of grass sustain large populations of Cicadulina spp. when preferred hosts like maize, wheat or millet are absent (Gorter, 1953; Rose, 1978). Land should, therefore, be kept clean of grasses before planting to maize. Gorter (1953) found that a barrier of bare land of about 10m wide between previously planted infected maize and experimental plots of maize reduced MSVD infection to 9.7 percent by comparison with 33.0, 41.6 and 51.7 percent in plots separated by sunflower, cowpeas and maize from sources of vectors.

2.3.2 Chemical control of vectors

Once a maize plant has shown visible symptoms of the maize streak disease, chemical control becomes very difficult (Fajemisin and Shoyinka, 1976). Indirect chemical control of MSV has been attempted by controlling the insect vectors, Cicadulina spp. Fajemisin and Shoyinka (1976) recommended spraying of vectors on grass around maize with aldicarb whereas crop hosts like millet and maize could be sprayed with a contact insecticide like carbaryl. Van Rensburg and Kuhn (1977)

ABU ZARIA LIBRARY

advocated the use of granular formulation of a systemic insecticide, carbofuran 10G, at the rate of 200g granules per 100m row length. Rose (1978) noted that results of investigations on control of Cicadulina with insecticides are mostly in unpublished reports. However, he reported that the leafhoppers are killed by contact insecticides like DDT and carbaryl; systemic insecticides such as dimethoate, demetonmethyl, and granular systemic insecticides like disulfoton applied to the soil. Carbofuran and aldicarb used as soil treatment have been shown to give better protection than disulfoton and phorate (Rose, 1974). Recently, Sundaram and Ajayi (1984) found that carbofuran used as soil treatment protected maize plants against MSVD better than solvirex and dimethoate at Samaru in northern Nigeria.

2.3.3 The use of disease resistant maize varieties

The use of resistant varieties of crops is gaining a lot of ground in Africa and the rest of the world. Being practicable, it affords a relatively cheap and effective means of combating pest problems. According to Fajemisin and Shoyinka (1976), the use of cultural and chemical control in lowering initial infection by MSVD cannot be relied upon for effective control under the conditions in West Africa which are extremely favourable to both the vector and the disease.

In order to develop disease resistant varieties, a source of resistance has to be located and incorporated into high yielding varieties (Fajemisin and Shoyinka, 1976). Gorter (1953) reported that Fielding was the first to recognise that a South Africa maize variety - Peruvian Yellow (P) -

possessed a high degree of resistance to maize streak virus infection. Rose (1938) also found that the Hickory (H) variety was as resistant as Peruvian Yellow. In Nigeria emphasis is now on a search for streak-resistant cultivars. The International Institute of Tropical Agriculture (IITA) Ibadan (Nigeria) has already done a lot of work on breeding of MSV resistant varieties of maize (Anon., 1980; Kim et al., 1981; Anon., 1982; Soto et al., 1982). Sundaram and Ajayi (1984) evaluated 14 indigenous maize varieties for their reaction to MSVD at Samaru, Nigeria. They found that 12 test entries were infected with MSVD in the final count. However, seedling stage resistance was observed in the entry, SZV-6. The least affected among the entries in the final count were: SZV-6 (25.9%), SZV-5 (41.1%), TZB-S (45.1%) and SZV-2 (47.1%); all others suffered over 50 percent infection.

Chapter 3 FIELD SURVEY OF CICADULINA SPP

3.1 Introduction

Field surveys have not been carried out on a regular basis around Zaria with a view to identifying Cicadulina spp. (Ajayi, pers. comm.). These surveys were aimed at finding out the species of Cicadulina in the Zaria area.

3.2 Materials and methods

3.2.1 Sampling sites

The following four locations (Fig.1) were used as sampling sites for Cicadulina spp. : Galma River (Jos Road); the research farm of the Institute for Agricultural Research (I.A.R.) (Sokoto Road); the Ahmadu Bello University farm (Sokoto Road) and Wusasa (Kaduna Road). The following grasses were common in all sites studied : Panicum spp., Setaria spp., Digitaria ciliaris (Retz) Koel., Eleusine indica Gaertn., Brachiaria spp. and Dactyloctenium aegyptium (L.) Beav. The area around the Galma River was planted to several crops including tomato, maize, garden eggs and rice in this succession between November, 1983 and November, 1984 and to maize and okra between April and August, 1985. The University and the I.A.R. farms were either left to fallow or were planted to maize, sorghum, millet, groundnuts, soybean, sun-flower, cowpea or cotton between March and September, 1984 and also between May and October, 1985. Between March and September, 1984 and May and October, 1985, the Wusasa site (three farms) was planted to yam, onions, pepper, maize/sorghum (inter-crop) or cowpea.



FIG. 1 ZARIA AND ITS ENVIRONS WITH SURVEY SITES

3.2.2 Sweeping

The distribution and occurrence of Cicadulina were studied at the four sites already mentioned. Sampling commenced in March, 1984 and continued until November, 1984 and in April, 1985 to October, 1985. Random two-weekly sweep-net samples of Cicadulina were taken at each site using a net made of muslin cotton material and with a cone length of 69cm, a mouth piece diameter of 42cm and a hollow aluminium handle measuring 43.5cm. Each survey consisted of twenty 180° random sweeps made in areas with a lot of grass, particularly those mentioned in section 3.1.2. This method was found by Dabek (1983) to be efficient for sampling leaf-hoppers. During sweeping, casting of shadows was minimized as much as possible because this disturbs the leaf-hoppers (Rose, 1973b).

3.2.3 Preservation

After each sweep, the Cicadulina caught were quickly transferred into glass tubes (8.5cm x 2.0cm) which were then plugged with cotton wool. These tubes were then taken to the laboratory and put into a freezer to keep the specimens fresh for identification. Some specimens were also preserved dry as recommended by Dabrowski (1983).

3.2.4 Identification

Preliminary identification of Cicadulina was carried out in the laboratory using a binocular microscope and this enabled specimens to be sorted out at the genus level. For identification to the species level, the specimens were frozen in 70 percent alcohol and taken to the Insect Laboratory of the International Institute of Tropical Agriculture, Ibadan.

Only male individuals were used for identification and this involved looking at the genital organs and comparing with a pictorial key of male genitalia of Cicadulina spp. prepared by Ruppel (1965).

3.3 Results

In 1984 two species were identified among the specimens taken to Ibadan and these were Cicadulina triangula Ruppel (Plate I) and C. mbila (Naude) (Plate II). Two additional species - C. arachidis China (Plate III) and C. similis China - were identified in 1985 (Table 2). The results therefore, showed that a total of four species of Cicadulina were caught in 1984 and 1985 around the Zaria area.

In 1984, only C. mbila was caught in the Galma River area. C. mbila was more abundant than C. triangula in the I.A.R. farm area (Table 2). At the University farm, C. triangula and C. mbila were caught in equal numbers and no hoppers were caught at Wusasa.

In 1985, both C. triangula and C. mbila were caught in the Galma River area but in small numbers only (Table 2). The highest number of leafhoppers in this area was recorded in June. C. mbila, C. triangula, C. arachidis and C. similis were caught in the I.A.R. farm in 1985. In this area, C. mbila and C. triangula were most frequently caught in June, July and August, but in September and October, C. arachidis was caught more often and made up the greater proportion of the total insect catch for these months. Three Cicadulina species were caught at the University farm. In July both C. mbila and C. triangula were caught, with the former making up a greater proportion of the catch. Between August and October C. mbila, C. triangula and C. arachidis were caught with the latter constituting a greater proportion of



Plate I. Cicadulina triangula (adult)



Plate II. Cicadulina mbila (adult)



Plate III. Cicadulina arachidis (adult)

Table 2. Number of Cicadulina caught at four sites around Zaria (Nigeria) from March, 1984 to October, 1984 and April, 1985 to October 1985

Month of survey	Number of Cicadulina caught in two-weekly samples per month								Total	
	Galma River		I.A.R. Farm		University Farm		Musasa			
	1984	1985	1984	1985	1984	1985	1984	1985	1984	1985
March	0	X	0	X	0	X	0	X	0	X
April	0	1^{Cm}	0	0	0	0	0	0	0	1
May	0	0	0	0	1^{Ct}	0	0	0	1	0
June	3^{Cm}	2^{Cm}; 7^{Ct}	0	1^{Cm}; 3^{Ct}	2^{Cm}; 2^{Ct}	0	0	0	7	13
July	0	1^{Cm}; 1^{Ct}	0	8^{Cm}; 7^{Ct}	1^{Cm}; 8^{Ct}	0	0	1^{Cm}	1	43
August	0	X	9^{Cm};2^{Ct}	19^{Cm};8^{Ct};2^{Ca};1^{Cs}	0	4^{Cm};6^{Ct};5^{Ca}	0	0	11	46
September	0	X	14^{Cm};3^{Ct}	9^{Cm};5^{Ct};30^{Ca}	0	12^{Cm};20^{Ct};19^{Ca}	0	1^{Cm};5^{Ca}	17	101
October	1^{Cm}	0	4^{Cm};2^{Ct}	6^{Cm};5^{Ct};14^{Ca};1^{Cs}	0	4^{Cm};3^{Ct};1^{Ca}	0	0	7	34
Total	4	12	34	119	6	100	0	7	44	238

X No sampling ; Cm, Cicadulina mbila ; Ct, Cicadulina triangula ; Ca, Cicadulina arachidis;

Cs, Cicadulina similis

the catch particularly in September 1985 (Table 2). Two species were caught at the Wusasa area - C. mbila and C. arachidis (Table 2).

3.4 Discussion

The survey revealed that there are at least four species of Cicadulina in Zaria. In surveys carried out in the dry and rainy seasons on grasses in Zaria, Jos and Ibadan, Okoth (1984) recorded a total of four species: C. mbila, C. triangula, C. similis and C. arachidis. He found C. similis and C. arachidis only in the Jos and Zaria areas. C. mbila and C. triangula are the most important vectors of the maize streak virus in Nigeria (Dabrowski, 1984). Recently, C. similis and C. arachidis were added to the list of six other Cicadulina previously identified in East Africa as vectors of the maize streak virus (Anon., 1984).

The high numbers of Cicadulina recorded in the I.A.R. farm between August and October, 1984 and 1985, was possibly due to the presence of maize (this was planted late June) and some grasses, particularly Digitaria ciliaris and Eleusine indica whose growth was enhanced by high rainfall (Appendix 1). Although no Cicadulina was caught in the Wusasa area in 1984, the maize streak virus disease was observed, indicating that the leafhoppers must have fed on maize plants and possibly moved to other areas. Moreover, the maize was planted early (May 1984) and was always well weeded; this possibly affected the initial build up of Cicadulina population and allowed most of the plants to out-grow the most susceptible stage (seedling) of the maize streak virus disease. In 1985, although C. mbila and C. arachidis were caught at the Wusasa site, they were infrequent and few.

Farmers' fields were well weeded in this area and although some grasses were observed, they were sparsely distributed. These factors possibly accounted for the low numbers and few species of Cicadulina recorded in the Wusasa area. Very few Cicadulina (C. mbila and C. triangula) were caught at the River Galma in both 1984 and 1985. Since it is a wet, lowland area ("fadama"), one would have expected a greater number of Cicadulina particularly in the drier months of the year due to the availability of suitable grass hosts. Although some Panicum spp. and Setaria spp. were observed, it would appear that they were not very suitable for oviposition and this possibly accounted for the low numbers of Cicadulina recorded. In August and September, 1985 no surveys were carried out at the Galma because flood water made the area inaccessible. The latter possibly explains the absence of insects there in October, 1985. Fewer insects were caught at the University Farm area in 1984 than in 1985. In 1984 large areas were cultivated but in 1985 a good proportion of the fields was left to fallow. The high amount of rainfall (Appendix 1) encouraged the growth of Dactyloctenium aegyptium, E indica and D. ciliaris and possibly enhanced the build up of Cicadulina and accounted for the greater number of leafhoppers caught, particularly in September, 1985.

More Cicadulina spp. were caught in the wetter months (June, to September), than in the drier months (March, April and October) of both 1984 and 1985. Weeds, particularly of the family Gramineae support Cicadulina populations (Mukole, 1985) and their growth is affected by rainfall. Esenam (1965) and Rose (1974 and 1978), have discussed the correlation between the total amount of rainfall,

Cicadulina population and the occurrence of the maize streak virus disease. Rose (1973b) observed that high rainfall encourages the growth of grass weed hosts and thereby the number of Cicadulina spp. It is worthwhile to add that most of the grass weeds observed just after the first rains (March, 1984 and 1985) were produced as young shoots (some of which showed MSVD symptoms) from rhizomes and stolons which survived the previous dry season - this was particularly so for Digitaria ciliaris and Brachiaria lata. Such infected young leaves undoubtedly serve as sources of primary inoculum for young, healthy adult Cicadulina (Ekukole, 1985).

Chapter 4 THE DEVELOPMENT OF CICADULINA MBILA (NAUDE) UNDER GLASSHOUSE CONDITIONS AT SAMARU

4.1 Introduction

Although the life cycle of Cicadulina mbila and C. triangula has been studied at Ibadan, in southern Nigeria (Dabrowski, 1984), such a study has not been carried out in northern Nigeria.

The objective of this experiment, therefore, was to study the development of C. mbila under glasshouse conditions at Samaru, Zaria.

4.2 Materials and methods

Female C. mbila were caught from Brachiaria lata (Schumach.) C.E. Hubbard ex. Robyns using a sweep net. Such females were quickly transferred individually into rearing cages (Plate IV). The cages were made of transparent Xylonite tubes measuring 50 cm x 7 cm with one end covered with a Dacron netting material. Two round windows, one near the covered end and the other close to the open end, also covered with Dacron, served for ventilation (Medaiyedu, 1975). The cages were then inverted over potted seven-day old millet plants (CV. ex. Bornu) in the glasshouse and pushed firmly into the soil, to allow for oviposition. The cages and leafhoppers were removed after one day. Oviposition sites were observed as purplish spots mostly on the mid-rib of millet leaves. The pots were placed in a tray of water (Plate V) in order to create high humidity (Rose, 1973a). Clip-on cages (Plate VI) were then placed at random over five oviposition sites and plants were observed for nymphs and adults at 10.00h every-day.



Plate IV. Rearing cage



Plate V. Potted millet plants in a tray of water



Plate VI. Clip-on cage fastened onto millet leaves.

After the eggs had hatched five nymphs were confined individually to leaves of vigorously growing millet plants with clip-on cages in order to determine the duration of the different nymphal instars. The instars were distinguished by observing the number and size of the skin cast of the nymphs. Alongside these observations, temperature was also recorded at 10.00h daily.

4.3 Results and discussion

The results in Table 3 show that with a temperature range of 29 to 31°C, eggs took an average of eight days to hatch while with a temperature range of 32 to 34.5°C, the eggs took an average of seven days to hatch. Nymphal development in both temperature ranges took 19 days (Table 3). The first, second, third, fourth and fifth nymphal instars had mean developmental periods of five, three, four, two and five days respectively, with a temperature range of 29 to 31°C and four, three, three, three and six days respectively, with a temperature range of 32 to 34.5°C (Table 3). Development of leafhoppers from egg to adult took an average of 27 days at a temperature of 29 to 31°C and 26 days at a temperature of 32 to 34.5°C.

Van der Merwe (1926) was the first to report a detailed description of the life cycle of Cicadulina (Balclutha) mbila. According to him, eggs took 9 to 21 days to hatch, while nymphal development lasted for 18 to 31 days. Although Van der Merwe did not carry out his studies at controlled temperatures, he observed that incubation of eggs and nymphal development may be longer in colder than in hotter months. Rose (1973a) found that the eggs of C. mbila hatched in 14 days at 23°C, 9 days at 25°C and 7 days at 30°C; development from egg to adult

Table 3. The developmental periods of Cicadulina mbila under glasshouse conditions at Samaru, 1985.

Month	Temperature range (°C)	Mean duration of developmental stages[a]						
		Eggs	Nymphal instars I	II	III	IV	V	Egg to adult
July	29-31	8.0	5.0	3.0	4.0	2.0	5.0	27.0
August	32-34.5	7.0	4.0	3.0	3.0	3.0	6.0	26.0
S.E.	-	0.58	0.32	0.24	0.45	0.32	0.51	0.32

[a]mean of five caged individuals

lasted for 39 to 40 days at 23°C, 28 to 29 days at 25°C and 19 to 21 days at 30°C. The temperatures recorded in the present study were close to the highest temperature of 30°C at which Rose (1973a) carried out his investigations and the results of this study do not differ very much from Rose's.

Temperature appears to play a very crucial role in the development of Cicadulina mbila. At low temperatures the life cycle is prolonged while it is comparatively shorter at high temperatures. Rose (1973a) suggested that the fecundity of C. mbila reaches a maximum at about 28 to 30°C and this appears to be the optimum temperature range for development in this species. During the 1985 growing season in Zaria temperature ranged from 27.8°C to 30°C from June to September (Appendix 2). This temperature range falls within that suggested by Rose (1973a) as being very favourable for oviposition. As many as five generations of Cicadulina mbila can be produced during the growing season (June to September) in Zaria. This period coincides with the time during which the maximum number of Cicadulina are usually caught. Many more plants infected with the maize streak virus disease are also recorded at this time.

Chapter 5 FIELD SURVEY OF ALTERNATIVE HOSTS OF THE MAIZE STREAK VIRUS

5.1 Introduction

The maize streak virus (MSV) is known to be transmissible to some wild grasses which exhibit the typical symptoms of the maize streak virus disease (MSVD) (Plate VII) (Storey, 1925; Storey and McLean, 1930; McLean, 1947; Gorter, 1953; Anon., 1972; Rose, 1972[a], 1972[b], 1973[b] and 1978; Soto et al., 1982; Dabrowski, 1983; Rossel and Nabukenya, 1983; Ekukole, 1985). Among these grasses, Eleusine indica, Urochloa panicoides, Setaria homonyma, Digitaria velutina and Panicum maximum are very important in the etiology of the maize streak virus disease (Van der Merve, 1926; Ruppel, 1965; Rose 1973b and 1978). Smith (1972) listed 25 grasses frequently observed with symptoms of the maize streak virus disease and noted that Digitaria horizontalis and Eleusine indica were commonly affected.

The aim of this survey which lasted from March, 1984 to November, 1984 and April, 1985 to September, 1985, was to identify grasses and other non-maize hosts with maize streak virus disease symptoms in the Zaria area.

5.2 Materials and methods

5.2.1 Collection of alternative hosts

The sites mentioned in section 3.2.1 were also surveyed for alternative hosts of the maize streak virus. Grasses (particularly mature ones) and other non-maize hosts with MSVD symptoms were collected, labelled and put into small polythene bags and taken to the herbarium of the Soil Survey Unit of the I.A.R., Samaru for identification. The sites were visited twice a month.

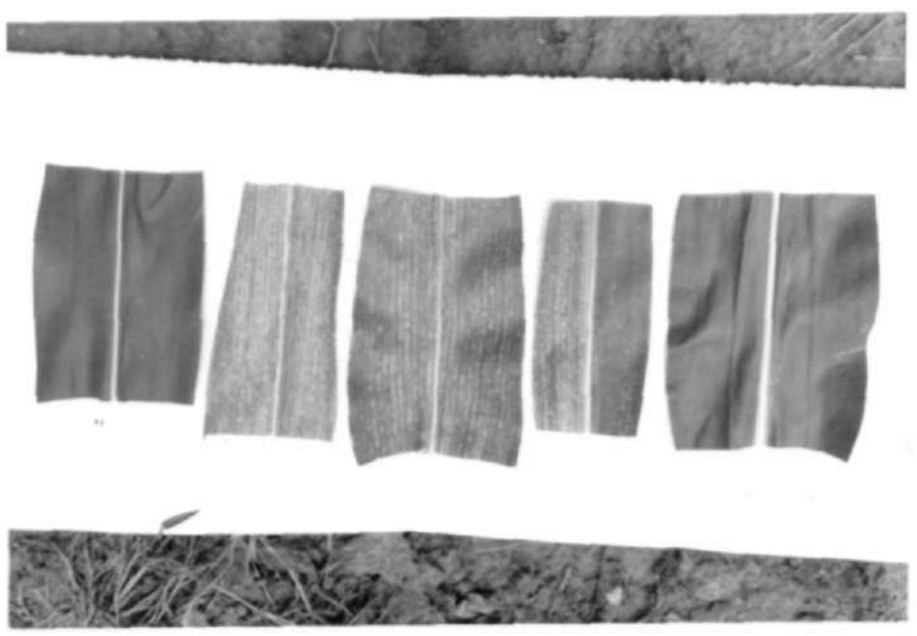

Plate VII. Typical maize streak virus disease symptoms in maize. D- diseased leaves and H - healthy leaf.

5.2.2 Serological studies

5.22a Partial purification:

Leaves of the following grasses (20g): Dactyloctenium aegyptium (1), Digitaria ciliaris (2), Brachiaria lata (3), Eleusine indica (4) and those of maize (5) and millet (6) with MSVD symptoms were homogenized separately in 80 ml of 0.01M potassium phosphate buffer (pH7) containing 0.1 percent thioglycollic acid. The homogenates were treated with n-butyl alcohol (7ml/100ml extract) and stirred at room temperature for 45 minutes after which they were centrifuged at low speed (10,000r.p.m) for 10 minutes. Each supernatant was then treated with polyethylene glycol (PEG) and sodium chloride (NaCl) depending on the volume of the extract and stirred at room temperature for 1 hr after which they were centrifuged at 15,000r.p.m. for 30 minutes. Pellets of the different samples were resuspended in 1ml of potassium phosphate buffer (pH7.5) and centrifuged at 10,000r.p.m for 10 minutes. The resultant supernatants were poured into small glass tubes to which a drop of sodium azide (NaN_3) was added to prevent spoilage.

5.22b Agar double diffusion tests:

The tests were conducted in 100 x 15 mm plastic petri dishes containing 10ml of 0.38g Agar Noble, 0.43g sodium chloride and 0.05g sodium azide dissolved in 50ml of distilled water. Wells were made in the agar with a gel punch equipped with 7mm - diameter bores spaced 1cm apart.

The partially purified preparations of grasses, maize and millet (10µl of each) were placed in the outer wells in the following anti-clock-wise order: well 1 (Dactyloctenium aegyptium), well 2

(Digitaria ciliaris), well 3 (Brachiaria lata), well 4 (Eleusine indica), well 5 (maize) and well 6 (millet). An MSV antiserum (10µl) prepared against the Ibadan isolate and obtained from the Virology Unit of the International Institute of Tropical Agriculture, Ibadan, Nigeria, was placed in the central well. In another set of six wells partially purified maize sap (10µl) only was used with the MSV antiserum in the central well. The set up was allowed to stand for 48hr in a humid chamber (glass beaker plus wet filter paper) after which observations were made.

5.3 Results

5.3.1 Survey of alternative hosts of MSV

Table 4 shows the different alternative hosts (mostly grass weeds) with maize streak disease symptoms collected from four sites around the Zaria area. The following five grass species were collected and identified: Eleusine indica (Plate VIII) Digitaria ciliaris (Plate IX), Brachiaria lata (Plate X), Dactyloctenium aegyptium (Plate XI) and Eragrostis ciliaris. In the I.A.R. farm site, pearl millet (Pennisetum americanum L.) Leeke (Plate XII) was observed with MSVD symptoms. Digitaria ciliaris was found at the four sites surveyed while E. indica was found in three sites (Table 4). These two grasses were the most frequently seen with MSVD symptoms. Eragrostis ciliaris and B. lata were found at only one site each (Table 4). The I.A.R. farm had many more infected grass species (five) than any of the other sites surveyed.

Table 4. Grass species with maize streak virus disease symptoms collected from four sites in Zaria, Nigeria

Site of survey	Grass species (and others)
Galma River	Eleusine indica Gaertn.
	Digitaria ciliaris (Retz.) Koel.
I.A.R. Farm	Eleusine indica
	Digitaria ciliaris
	Dactyloctenium aegyptium (L.) Beav.
	Brachiaria lata (Schumach.) C.E. Hubbard ex. Robyns.
	Eragrostis ciliaris (Linn.) R. Br.
	Pennisetum americanum (L.) Leeke
University Farm	Digitaria ciliaris
	Eleusine indica
Wusasa	Digitaria ciliaris



Plate VIII. Eleusine indica - healthy (left) and diseased (right) leaves. Note the streaks on diseased leaf.



Plate IX. Digitaria ciliaris - healthy (right) and diseased (left) plants.



Plate X. Brachiaria lata - healthy (right) and diseased (left) leaves.



Plate XI. Dactyloctenium aegyptium - healthy (left) and diseased (right) plants. Note the chlorotic leaves of the diseased plant.



Plate XII. Pennisetum americanum (pearl millet) - diseased (left) and healthy (right) leaves.

5.3.2 Agar diffusion tests

Partially purified sap of the four grasses, maize and millet reacted positively with MSV antiserum as shown in Plate XIII. However, the intensity of the precipitation lines obtained were different. Maize had the most intense lines followed by Digitaria ciliaris, D. aegyptium, B. lata, E. indica and millet.

5.4 Discussion

Many workers, including Storey (1925), Van der Merwe (1926), Gorter (1953), Smith (1972), Rose (1972a, 1973b and 1978) and Ekukole (1985) have pointed out the importance of grass hosts in the etiology of the maize streak virus disease: they support populations of Cicadulina spp. at a time when the preferred maize host is absent in the field.

Four grass species: D. ciliaris, E. indica, Setaria barbhata and Eragrostis gangetica were observed in the Samaru area of northern Nigeria with typical maize streak symptoms (Anon., 1972). MSVD symptoms have also been observed on Brachiaria deflexa, Setaria spp., Rottboellia sp. and Paspalum polystachyum Br. on fields at Moor Plantation, Ibadan (Fajemisin and Shoyinka, 1976). The survey reported here provisionally identified the following three new grasshosts of the maize streak virus in Nigeria : D. aegyptium, Brachiaria lata and Eragrostis ciliaris. The survey also showed that maize streak disease symptoms were more frequently seen on D. ciliaris and E. indica than on any of the other grasses. Smith (1972) also noted that D. horizontalis and E. indica were commonly infected in the field.

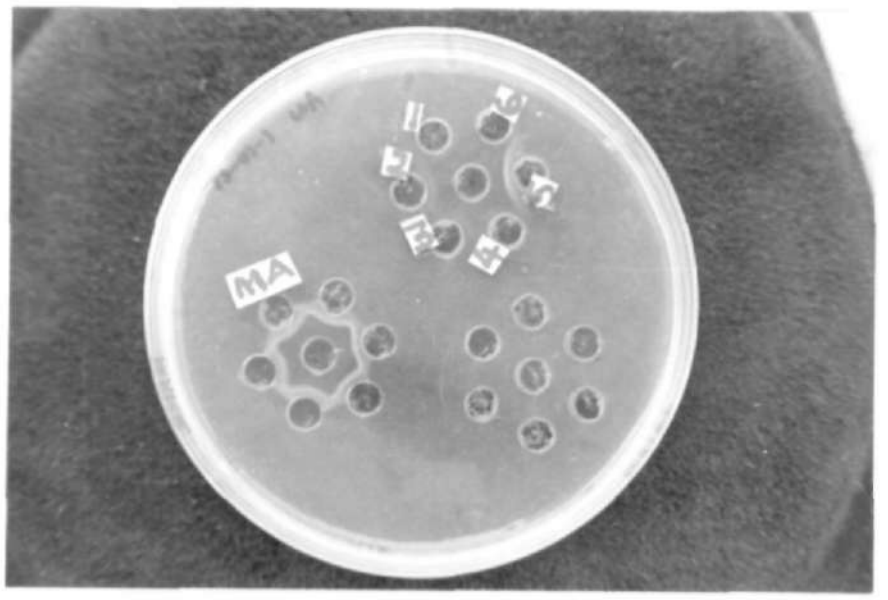

Plate XIII. Serological reaction of isolates of the maize streak virus (MSV) in four grasses (1, 2, 3, 4), maize (5) and millet (6) on an agar gel - diffusion plate containing antiserum (central well) prepared against the Ibadan isolate of MSV. MA indicates reaction with partially purified maize sap.

D. ciliaris and E. indica may possibly be very important in the etiology of the maize streak virus disease in the Zaria area. In their survey of grasses in Ibadan, Rossel and Nabukenya (1983) observed maize streak disease symptoms on Axonopus compressus, Setaria barbhata, Brachiaria deflexa, Eleusine indica and Panicum maximum. According to these two workers, maize streak disease symptoms are most common on P. maximum in southern Nigeria and, therefore, this species may play a very important role in the development of the maize streak virus disease from season to season in that area. They also succeeded in transferring the streak from infected P. maximum plants to healthy ones but transmission to maize was unsuccessful.

The occurrence of MSVD symptoms on millet in Zaria supports the finding in India (Seth et al., 1971) that pearl millet is a host for the disease.

Results of the serological studies reported here show that the virus found in D. ciliaris, D. aegyptium, B. lata, E. indica, maize and millet is related to the MSV isolate from Ibadan and that all the isolates (grasses, maize and millet) are also related to one another. A more extensive survey may reveal more grass and other alternative hosts of MSV in the Zaria area. It should also be possible to assay for MSV in hosts with or without symptoms in the near future if the modern ELISA technique is used (Ansa, pers. com). Variations in the intensity of precipitation lines obtained in the serological tests appear to suggest that the different grass hosts, maize

and millet contain various amounts of the maize streak virus. Dactyloctenium aegyptium and Digitaria ciliaris formed more intense lines possibly because the disease is usually more severe in them. The faint precipitation lines obtained with Brachiaria lata and Eleusine indica possibly indicate a low concentration of the virus in these grasses - MSVD symptoms in them are usually very sparse in the field. Although severe MSVD symptoms were observed on late planted millet, the reaction with MSV antiserum produced very faint precipitation lines.

Chapter 6 FIELD SURVEY OF THE INCIDENCE OF THE MAIZE STREAK VIRUS DISEASE (MSVD) IN THE ZARIA AREA

6.1 Introduction

In 1972 the maize streak virus disease almost attained epiphytotic levels in many parts of northern Nigeria (Anon., 1972). The same situation occured in 1983 - fields surveyed by the Virology Unit of the IITA had an average of 75 percent infection (Keyser, 1983). Unfortunately, records of the disease around the Zaria area, where maize is increasingly being grown, are not readily available.

The objective of this survey was, therefore, to find out the incidence of the maize streak virus disease at four different locations in the Zaria area in order to establish a basis for comparison from year to year.

6.2 Materials and methods

The sites chosen for this survey were those surveyed for Cicadulina spp. and alternative hosts of the maize streak virus - Galma River, University Farm, the research farm of the Institute for Agricultural Research (I.A.R.) and Wusasa (along Kaduna road).

Farmers' fields at three of the four sites were chosen on the basis of the age of the maize plants. It was not possible to survey the I.A.R. farm at the same time as the other sites because maize was planted in the former in June just after the rains were established. Records were, therefore, taken at the I.A.R. farm four to eight weeks after the other sites.

The incidence of the maize streak disease, which was recorded at four and eight weeks after planting (WAP), involved counting infected plants and calculating the percentage infection using the following formula:

$$\frac{\text{Number of plants infected}}{\text{Total number examined}} \times 100$$

Plants infected at 4WAP were distinguished from those infected at 8WAP by tagging them with labels made out of hard white card-board paper.

6.3 Results

Table 5 shows that the incidence of the maize streak virus disease (MSVD) ranged from 1.2 percent (Galma River) to 29.7 percent (I.A.R farm) in 1984 and from 0.0 percent (Galma River) to 23.4 percent (I.A.R. Farm) in 1985 at the sites surveyed. The results also show that the incidence of MSVD was lower at the Galma River, the University farm and Wusasa sites than at the research farm of the Institute for Agricultural Research (I.A.R.), Samaru in both 1984 and 1985 (Table 5). Although maize was planted at the Wusasa site at about the same time as at the University farm (Table 5), the incidence of the disease at the latter was higher at 4WAP and 8WAP in both years. Late planted maize at the I.A.R. farm (Table 5) suffered from more disease than other plantings in 1985.

6.4. Discussion

The 1984 and 1985 results indicate that the incidence of MSVD in the Zaria area was lower than that reported for other sites in northern Nigeria in 1983 by Keyser (1983). According to her, MSVD

Table 5. Maize streak virus disease incidence at four sites in Zaria surveyed from April to August, 1984 and April to October 1985

Site	Date planted		Number of plants examined				Number Affected				% streak incidence			
			4WAP		8WAP		4WAP		8WAP		4WAP		8WAP	
	1984	1985	1984	1985	1984	1985	1984	1985	1984	1985	1984	1985	1984	1985
Galma River	15-4-84*	6-4-85*	500	1000	450	1000	6	0	9	2	1.2	0.0	2.0	0.2
University Farm	15-5-84*	25-5-84*	1000	1500	970	1480	61	0	145	5	6.1	0.1	14.9	0.3
Wusasa	22-5-84*	28-5-85*	1000	2000	960	1880	52	0	54	4	5.2	0.0	5.6	0.2
I.A.R. Farm	20-6-84	28-6-85	7726	4508	7183	4449	466	33	2135	148	6.0	0.7	29.7	3.3
I.A.R. Farm	-	5-8-85	-	3800	-	3775	-	100	-	885	-	2.6	-	23.4

* Approximate dates

WAP Weeks after planting

affected an average of 75 percent of the maize plants in areas surveyed by the IITA Virology Unit. This difference can possibly be attributed to the rainfall pattern in Zaria between 1981 and 1985 (Appendix 1). In 1981 and 1982 rainfall was evenly distributed throughout the period from April to October. This would have encouraged the maize streak epiphytotic which occurred in 1983 in most parts of northern Nigeria where maize was grown (Keyser, 1983) through the survival of grass hosts harbouring the maize streak virus and possibly some infective Cicadulina (Fajemisin et al., 1976). According to Owonubi (1985) rainfall for 1983 was the lowest recorded at Samaru since 1928. In 1984 there was a marked improvement in the rainfall. However, the MSVD was still much lower than that recorded in 1983. It is possible that the 1983 drought depleted the Cicadulina population around Zaria in 1984 and because maize was planted early (April) they out-grew the most susceptible stage of the MSVD by the time the viruferous insects were abundant. On the other hand higher maize streak incidence was recorded in the I.A.R. farm where maize was planted late both in 1984 and 1985. The presence of maize in this area coincided with the period of heavy rainfall and high numbers of Cicadulina. This possibly accounted for the high maize streak incidence recorded in this area. Whereas rainfall was evenly distributed from March to October in 1984, (Appendix 1) there was a severe drought in April 1985 which possibly affected the build up of Cicadulina population. Maize planted during this period escaped infection by the maize streak virus disease and this possibly accounted

for the lower streak incidence recorded in 1985 particularly around the Galma River, the University farm and Wusasa. Although maize planted in June 1985 at the IAR farm suffered very low infection, those planted in August, 1985 had comparatively higher MSVD incidence. Rose (1972a & b, 1973b, 1974 and 1978) has pointed out the relationship between rainfall, Cicadulina population and the etiology of the maize streak virus disease. According to him, high populations of Cicadulina and a high incidence of the MSVD occur in grasses in high rainfall areas and under irrigation while low populations of the leafhoppers and low MSVD are common in areas with long dry seasons. This is possibly so because grasses in high rainfall areas remain fresh and attractive to Cicadulina for longer periods than those in dry areas (Gorter, 1953). Observations on the occurrence of the MSVD by Gorter (1953) (at Ohrigstaa - South Africa) over a number of years also showed that in years when the rainfall was evenly distributed the maize crops were severely infected, but after very dry winters followed by late summer rains the disease was always of minor importance.

Chapter 7 CULTURAL CONTROL OF THE MAIZE STREAK VIRUS DISEASE

7.1 Introduction

Weeds, particularly of the family Gramineae, infected with the maize streak virus disease, have been identified as important sources of maize streak virus inoculum for healthy Cicadulina which eventually feed on and infect healthy maize plants (Storey, 1925; Storey and McLean 1930; McLean, 1947; Gorter, 1953; Anon., 1972; Rose, 1972b, 1973b and 1978; Soto et al., 1982; Rossel and Nabukenya, 1983; Ekukole, 1985). Sanitation, that is, the removal of weeds before planting to maize, has been shown to reduce the incidence and spread of the disease (Gorter, 1953). Some other workers, on the other hand, have shown that the disease increases when plants are manually shaken or rogued during weeding operations (Rose, 1973b and 1974; Soto et al., 1982).

The objective of this experiment, therefore, was to find out the effect of the frequency and method of weed control on the incidence and severity of the MSVD and on the yield of maize.

7.2 Materials and methods

The experimental area was ploughed, harrowed and ridged at a spacing of 75 cm between ridges. A basal dose of compound fertilizer (NPK 15.15.15) was applied at the rate of 120 kg/ha before ridging and a top dressing of calcium ammonium nitrate (26% N) was applied at a rate of 130 kg/ha four weeks after planting. Seeds of a maize streak virus - susceptible maize variety (TZB-S) were sown at a spacing of 30 cm along the ridges

on 20 June in 1984 and 28 June in 1985, and thinned to one plant per stand three weeks later. Each plot consisted of four rows, each 5m long and was surrounded by a 1.5m unplanted discard.

Four treatments were applied as follows : pre-emergence herbicide application only (A); pre-emergence herbicide application plus one-hoe-weeding at 4 weeks after planting (WAP) (B); pre-emergence herbicide application plus two hoe-weedings at 4WAP and 6WAP (C); three hoe-weedings at 4, 6 and 8WAP with no herbicide application (D). The latter treatment is what the farmer would normally do and therefore, constituted the control. Each treatment was replicated four times in a completely randomized block design. The pre-emergence herbicide consisted of a mixture of atrazine (Gesaprim) 500FW (249ml) and metolachlor (Dual) 720 E.C. (174ml) in 20l of water applied immediately after planting with a CP-3 Knapsack sprayer. The sprayer was operated at a pressure of 30 psi with a green nozzle which nominally delivered 1.25kg a.i/ha of each herbicide.

The incidence and severity of MSVD were recorded at two growth stages - 4WAP and 8WAP. The severity of the disease was measured using a scale of 1 - 5 as shown below. All the infected leaves were rated.

Rating	Description of symptom	Infection (% of leaf area)
1	No streaking	0
2	Slight streaking	1 - 25
3	Moderate streaking	26 - 50
4	Severe streaking	51 - 75
5	Very severe streaking	76 - 100

Disease incidence was measured by counting plants showing symptoms of MSVD and computing the percentage infection. Plants infected at 4WAP were distinguished from those infected at 8WAP by tagging them with labelled pieces of hard white card-board paper.

At crop maturity the cobs in each plot were harvested (moisture content : 21.1 percent), dehusked and taken to the laboratory where they were allowed to dry for a week (moisture content : 17.0 percent). They were then counted and their weight recorded. The cobs were then shelled and the weight of the shelled grains recorded.

7.3 Results

Tables 6a, 6b and appendices 4a-f show the effects of the method and frequency of weed control on the incidence and severity of the maize streak virus disease in 1984 and 1985.

In 1984 the incidence of the MSVD at 4WAP was similar in all treatments although plots with herbicide application plus two hoe-weedings (C) and those with three hoe-weedings only (D) had the highest mean streak incidence. At 8WAP, significantly more ($P < 0.05$) plants were infected by the virus in treatment C than in treatment B (herbicide plus one hoe-weeding) but other treatment differences were not significant. In 1985, the incidence of the maize streak disease at 4WAP was significantly higher ($P < 0.05$) in treatment D (control) than in all other treatments and, at 8WAP, significantly more ($P < 0.05$) plants were infected in treatments C and D than in treatments A (herbicide only) and B (Table 6a). The incidence of the disease was significantly higher ($P < 0.05$) at 8WAP than at 4WAP in both years.

Table 6a. Effects of the method and frequency of weed control on the incidence of maize streak virus disease (MSVD) at two dates at Samaru, Nigeria, 1984 and 1985.

Treatments	1984 Incidence (%) of MSVD at		1985	
	4WAP	8WAP	4WAP	8WAP
Pre-emergence herbicide	0.00[a]	28.87[a]	0.39[a]	4.12[a]
Pre-emergence herbicide + 1 hoe-weeding	2.71[a]	26.06[a]	0.42[a]	3.92[a]
Pre-emergence herbicide + 2 hoe-weedings	3.98[a]	40.06[b]	1.16[a]	7.46[b]
3 hoe-weedings only (control)	3.07[a]	31.34[a]	3.38[b]	10.09[b]
Mean	2.44	31.58	1.34	6.39

L.S.D (0.05) treatments (1984) = 8.65

L.S.D.(0.05) dates (1984) = 8.17

L.S.D (0.05) treatments (1985) = 1.49

L.S.D (0.05) dates (1985) = 1.34

WAP weeks after planting

Means followed by the same letter in a column are not significantly different at P = 0.05.

Table 6b. Effects of the method and frequency of weed control on the severity of MSVD at two dates at Samaru, Nigeria, 1984 and 1985

Treatments	1984 Severity of MSVD (1 - 5) at		1985	
	4WAP	8WAP	4WAP	8WAP
Pre-emergence herbicide	1.00[a]	4.03[a]	1.25[a]	2.00[a]
Pre-emergence herbicide + 1 hoe-weeding.	2.43[b]	3.79[a]	1.25[a]	2.00[a]
Pre-emergence herbicide + 2 hoe-weedings	2.56[b]	3.88[a]	2.00[b]	2.74[b]
3 hoe-weedings (control)	3.33[b]	4.06[a]	2.29[b]	3.00[b]
Mean	2.33	3.94	1.69	2.44

L.S.D. (0.05) treatments (1984) = 1.16

L.S.D. (0.05) dates (1984) = 1.11

L.S.D. (0.05) treatments (1985) = 0.51

L.S.D. (0.05) dates (1985) = 0.45

WAP weeks after planting

Means followed by the same letter in a column are not significantly different at P = 0.05.

In 1984, the disease was significantly more severe ($P < 0.05$) in treatments B, C and D than in A at 4WAP, but the differences between B,C and D were not significant (Table 6b). At 8WAP there was no significant difference between the four treatments, although treatment D had a slightly higher mean severity than all the others. The severity of the disease at both growth stages in 1985 was significantly lower ($P < 0.05$) in treatments A and B than in treatments C and D but the differences between A and B and C and D respectively, were not significant (Table 6b). As with the incidence score, maize streak severity was significantly higher ($P < 0.05$) at 8WAP than at 4WAP in both years.

In both years, there was no significant difference in grain yield between the four treatments (Table 6c and Appendices 4g - i).

7.4 Discussion

The data on the incidence and severity of MSVD show that the method and frequency of weed control affect the spread of the disease in the field. In treatments A (pre-emergence herbicide only) and B (pre-emergence herbicide plus one hoe-weeding), manual disturbance of the plants and leafhoppers was minimal or greatly reduced. This would account for the lower incidence and severity of the disease in these treatments especially at 4WAP. Generally, the results indicate that treatments C and D (in which there were two and three hoe-weedings respectively), had higher disease incidence and severity at 4WAP and 8WAP in both 1984 and 1985. The similarity in disease severity between treatments at 8WAP in 1984 is noteworthy

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Table 6c. The effects of the method and frequency of weed control on the grain yield of maize at Samaru, Nigeria (1984 and 1985)

Treatments	Mean grain yield (Kg/4 rows) 1984	1985
Pre-emergence herbicide	3.77[a]	8.58[a]
Pre-emergence herbicide + 1 hoe-weeding.	4.30[a]	8.80[a]
Pre-emergence herbicide + 2 hoe-weedings	5.47[a]	8.93[a]
3 hoe-weedings only (control)	5.22[a]	9.28[a]
L.S.D (0.05)	N.S	N.S

N.S. Not significant at P = 0.05

and may have been caused by the movement of leafhoppers from hoe-weeded to herbicide - treated plots.

During the hoe-weeding process, the ridges are remoulded, the plants get shaken and the leafhopper vectors are disturbed. Infected individuals, therefore, move from plant to plant during which time they transmit the virus. Rose (1973b, 1974 and 1978) pointed out that although roguing may rid a field of some infected plants, it may, on the other hand, actually increase the maize streak disease as the plants are manually shaken during the roguing process. As part of a screening trial at the International Institute of Tropical Agriculture, Ibadan, Soto et al., (1982) found that manual disturbance of maize plants twice daily for 10 days enhanced insect and virus spread.

The incidence and severity of the maize streak disease at 8 WAP were significantly higher than at 4WAP. At the onset of the rains the vector number is usually low but as the season progresses, the number increases and so does the disease (Rose, 1974). Many workers including Rose (1973b and 1974) and Fajemisin and Shoyinka (1976). have shown that maize streak incidence and severity are usually higher in late than in early maize. MSVD incidence and severity were generally lower in 1985 than in 1984. This possibly explains why some treatments were significantly different from each other in one year and similar in another.

In 1984 and 1985, the grain yield of maize was similar in all the treatments. This was possibly due to the fact that most plants were infected at 8WAP.

The effect of the disease is most severe at the seedling stage (4WAP) of maize. If the plant can out-grow this stage before infection sets in, reduction in yield is usually minimal (Fajemisin and Shoyinka, 1976; Van Rensburg and Kuhn, 1977; Rose, 1978). Generally grain yield of maize was higher in 1985 than in 1984. This difference can be attributed to better weed control, less and late disease incidence and severity and more rainfall. Moreover, groundnuts planted in the experimental site in 1984 possibly improved the nitrogen content of the soil thereby increasing yield of maize. Lombin and Abdullahi (1981) pointed out that the yield of some cereals (particularly sorghum) can be increased by planting them after groundnuts.

Chapter 8 CHEMICAL CONTROL OF THE MAIZE STREAK VIRUS DISEASE

8.1 Introduction

Once a plant is infected with a virus, recovery becomes very difficult (Kuhn and Jellum, 1970; Matthews, 1970). Theoretically, the spread of insect - transmitted viruses can be reduced or even prevented by effective vector control (Pitre, 1968; Damsteegt, 1981). Fajemisin and Shoyinka (1976) pointed out that chemical control of the maize streak virus (MSV) has been attempted by controlling the vectors, Cicadulina spp. Contrary to expectation, however, application of insecticides to crops in certain cases failed to decrease the severity and incidence of some virus diseases (Broadbent, 1957). Several insecticides including aldicarb, carbaryl, carbofuran, DDT, dimethoate, demeton-methyl, disulfoton, phorate, endosulfan, demeton, and mephosfolan have been used by various workers particularly Rose (1974), Van Rensburg and Kuhn (1977), Drinkwater et al., (1979), Sundaram and Ajayi (1984), against MSV and its vectors.

The objective of the present study was to test six insecticides (four granular and two spray formulations) for their effect on the incidence and severity of the maize streak virus disease and on the yield of maize.

8.2 Materials and methods

The test site which was located in the research farm of the Institute for Agricultural Research, (I.A.R.) Samaru, Zaria, was prepared as stated in section 7.2. Samaru falls in the northern guinea savanna zone. According to Valette and Ibanga (1984), the soil type of the I.A.R. farm is the typical Haplustult (USDA) and

a profile of it shows that the first 11cm is sandy-loam while the next 100cm is alternation of clay-loam to clay, and sand-clay. A typical rainfall pattern at Samaru (1981-1985) is given in Appendix 1.

A local maize streak virus - susceptible variety of maize (TZB-S) was planted at a spacing of 30cm on 75cm ridges in plots measuring 5m by 4 ridges and surrounded by a 1m guard row. There were seven treatments which were replicated four times in 1984 and three times in 1985, in a randomized block design: carbofuran 3G (at the rate of 1.0kg a.i/ha)(A); demeton 5G (at 1.0kg a.i/ha) (B); thiometon 5G (at 250g a.i/ha) (C); endosulfan 5G (40g a.i/ha) (D); dimethoate 40 E.C. (at 0.5kg a.i/ha)(E); carbaryl 85 percent W.P. (1.5 kg a.i/ha) (F) and control (0.3l water per plot) (G). The chemicals were chosen on the basis of their systemic nature while the rates used were those recommended by the manufacturers and other workers who have used the chemicals. Treatments A through D were applied by spreading the chemicals evenly into 30cm deep furrows made on the ridges and covering with some soil into which the maize seeds were then planted. Treatments E and F involved spraying the appropriate chemical (in 225l of water/ha) with a CP-3 Knapsack sprayer at two and four weeks after planting (WAP).

The incidence and severity of the maize streak virus disease were recorded at 4WAP and 8WAP. Disease incidence was measured by counting the number of plants infected with the maize streak disease and computing the percentage infection while severity was scored on a scale of 1-5 (see section 3.5.2). Infected plants at 4WAP were distinguished from those at 8WAP by tagging them with labelled hard white card-board paper.

Yield was assessed by harvesting all the dry cobs (moisture content : 23.2 percent) from each plot. The cobs were allowed to dry further in the laboratory for a week (moisture content : 18 percent) after which they were counted and their weight recorded. The cobs were then shelled and the weight of shelled grains recorded.

8.3 Results

Tables 7a, 7b and appendices 5a - f show the effect of six insecticides on the incidence and severity, of the maize streak virus (MSVD) in 1984 and 1985.

In 1984, there was no significant difference between the treatments in the incidence of the disease (7a). However, plots treated with carbofuran had no disease at 4WAP. At 8WAP disease incidence was significantly lower ($P < 0.05$) in carbofuran - treated plots than in those treated with the other insecticides. Disease incidence was significantly lower ($P < 0.05$) in demeton and carbaryl-treated plots than in that treated with thiometon (Table 7a). In 1985, the incidence of the disease at 4WAP was similar in all the treatments under comparison (Table 7a). As was the case in 1984, carbofuran-treated plots had no disease at 4WAP. At 8WAP, disease incidence was significantly lower ($P < 0.05$) in plots treated with carbofuran than those treated with demeton, thiometon, carbaryl and water but was similar to the incidence in endosulfan and dimethoate - treated plots (Table 7a). The incidence of the disease was significantly higher ($P < 0.01$) in 1984 than in 1985 (Appendix 5c).

Disease severity at 4WAP in 1984 was significantly lower ($P < 0.05$) in carbofuran - treated plots than in all the others except the control

Table 7a. Effect of six insecticides on the incidence of the maize streak virus disease (MSVD) at Samaru, Nigeria (1984 and 1985).

Treatments	Rate (a.i/ha)	1984 % incidence of MSVD at		1985	
		4WAP	8WAP	4WAP	8WAP
Carbofuran 3G	1.0kg	0.00[a]	0.83[a]	0.00[a]	0.00[a]
Demeton 5G	1.0kg	5.09[a]	17.48[b]	0.92[a]	3.22[b]
Thiometon 5G	250g	6.38[a]	32.79[c]	0.48[a]	3.95[bc]
Endosulfan 5G	40g	3.85[a]	23.91[bc]	0.43[a]	2.82[ab]
Dimethoate 40G	(0.5kg)	1.01[a]	23.29[bc]	0.49[a]	2.69[ab]
Carbaryl 85 WP	1.5kg	1.52[a]	18.96[b]	0.93[a]	6.09[c]
Control	-	2.27[a]	21.59[bc]	0.51[a]	6.76[c]
Mean		2.87	19.84	0.54	3.65

L.S.D. (0.05) treatments for 1984 = 7.72

L.S.D. (0.05) dates for 1984 = 4.11

L.S.D. (0.05) treatments for 1985 = 2.83

L.S.D. (0.05) dates for 1985 = 1.51

Means followed by the same letter in a column are not significantly different at P = 0.05.

(Table 7b) while at 8WAP, the disease was significantly less severe ($P < 0.05$) in plots treated with carbofuran than in all the others. The disease was significantly more severe ($P < 0.05$) at 8WAP than at 4WAP (Table 7b). The severity of the disease at 4WAP in 1985 was similar in all treatments although no disease was recorded in plots treated with carbofuran (Table 7b). At 8WAP, the severity of the disease was significantly lower ($P < 0.05$) in plots treated with carbofuran than in those treated with thiometon, endosulfan, carbaryl and water but similar to those treated with demeton and dimethoate (Table 7b). The severity of the disease was significantly higher ($P < 0.01$) in 1984 than in 1985 (Appendix 5f).

Table 7c and appendices 5g - i show the effect of six insecticides on the grain yield of maize. The treatments were not significantly different from each other in both 1984 and 1985. However, plots treated with carbofuran yielded more than the others in both years (Table 7c).

8.4 Discussion

Carbofuran - treated plots had less disease and higher grain yield than plots treated with thiometon, carbaryl, dimethoate, endosulfan and demeton. These results confirm those obtained by Sundaram and Ajayi (1984) who reported that carbofuran performed better than demeton and dimethoate in controlling the MSVD.

Several workers, including Fitre (1968), Rose (1974), Van Renburg and Kuhn (1977), Soto and Buddenhagen (1978) and Drinkwater et al. (1979), have used carbofuran to control MSVD and other virus diseases with encouraging results.

Table 7b. Effect of six insecticides on the severity of the maize streak virus disease at Samaru, Nigeria (1984 and 1985).

Treatments	Rate (a.i/ha)	1984 Severity of MSVD at		1985	
		4WAP	8WAP	4WAP	8WAP
Carbofuran 3G	1.0kg	1.00[a]	2.25[a]	1.00[a]	1.00[a]
Demeton 5G	1.0kg	2.65[bc]	4.44[b]	1.50[a]	2.20[ab]
Thiometon 5G	250g	3.17[c]	4.48[b]	2.00[a]	2.80[b]
Endosulfan 5G	40g	3.29c	4.29[b]	1.50[a]	2.44[b]
Dimethoate 40E.C.	0.5kg	2.75[bc]	4.16[b]	1.67[a]	2.00[ab]
Carbaryl 85 WP	1.5kg	2.13[bc]	4.28[b]	1.50[a]	2.33[b]
Control	-	1.44[ab]	3.92[b]	2.00[a]	2.70[b]
Mean		2.35	3.97	1.59	2.21

L.S.D (0.05) treatments for 1984 = 1.14

L.S.D. (0.05) dates for 1984 = 0.61

L.S.D. (0.05) treatments for 1985 = 1.26

L.S.D. (0.05) dates for 1985 = 0.48

Means followed by the same letter in a column are not significantly different at P = 0.05.

Table 7c. Effect of six insecticides on maize yield at Samaru, Nigeria, 1984 and 1985.

Treatments	Rate (a.i/ha)	Mean grain yield (kg/4 rows) 1984	1985
Carbofuran 3G	1.0kg	6.49[a]	9.13[a]
Demeton 5G	1.0kg	5.22[a]	8.63[a]
Thiometon 5G	250g	5.58[a]	8.87[a]
Endosulfan 5G	40g	4.39[a]	7.57[a]
Dimethoate 40 E.C.	0.5kg	4.42[a]	6.87[a]
Carbaryl 85 W.P.	1.5kg	5.55[a]	7.37[a]
Control	-	3.74[a]	7.03[a]
L.S.D (0.05)	-	N.S.	N.S.

The use of carbofuran to protect maize against leafhoppers other than Cicadulina spp. has been examined by Bhirud and Pitre (1972a, b and c) and other workers, particularly Mitra et al. (1970) and Pitre (1968). They showed that carbofuran is not phytotoxic to maize, and that its efficacy is affected by the position of the infected leaves on the plant as well as by soil moisture and soil type. All the insecticides used in this trial have some systemic effect although this property is stronger in some (particularly carbofuran) than in others (especially carbaryl) (Hill, 1975; Hill and Walter, 1982). In this trial 4 out of the 6 insecticides were applied to the soil at planting. The absorption, translocation and persistence of most systemic insecticides are affected by soil type and soil moisture (Getzin and Chapman, 1959). When the insecticides, particularly the granular systemic formulations (carbofuran, demeton, thiometon and endosulfan), were applied in June 1984, the soil at the experimental site was barely moist (rainfall for June was 55.4mm - Appendix 1). Many areas had patches of hard crusted soil. This would have affected the availability, absorption and translocation of these insecticides and possibly accounted for the poor performance of some of the insecticides in reducing both the incidence and severity of MSVD at 4WAP. At 8WAP there was a significant difference in severity and incidence of the disease between carbofuran - treated and the other plots. This was possibly due to the higher rainfall in July and August, 1984 (Appendix 1) which improved the moisture content of the soil and enhanced the absorption and translocation of the insecticides. Bhirud and Pitre (1972a) found that carbofuran and disulfoton performed best at the highest soil moisture level and

were less effective at the lowest soil moisture level. Some treatments, particularly, thiometon, endosulfan and dimethoate, still performed poorer than the control at 8WAP in 1984. It is possible that some treated plots attracted more leafhoppers because of the vigorous growth of the plants and therefore, performed poorly (Elemo, pers. com.). Van der Plank (1963) has also discussed extensively the spread of viruses and fungal spores from unsprayed to sprayed plots located in the same experimental area.

Generally the insecticide - treated plots performed better than the control plots at 4WAP and 8WAP in 1985. No disease was recorded in the carbofuran - treated plots at both 4WAP and 8WAP. Rainfall in 1985 was almost twice as much as in 1984 (Appendix 1) and moisture was therefore not a limiting factor to the effectiveness of the insecticides.

Plots treated with carbofuran had the highest grain yield and the least disease in both 1984 and 1985. Generally the treated plots performed better than the control plots in both years. The lack of a significant difference between the treatments in terms of yield can be attributed to the late infection of plants by MSVD. Usually yield is reduced considerably when plants are severely infected at about 4WAP (seedling stage) (Anon., 1972; Fajemisin and Shoyinka, 1976; Van Rensburg and Kuhn, 1977; Rose, 1978; Soto and Buddenhagen, 1978) but once the most susceptible stage is passed, reduction in yield is usually minimal.

Chapter 9 THE REACTION OF THIRTY VARIETIES OF MAIZE TO THE MAIZE STREAK VIRUS DISEASE AT SAMARU

9.1 Introduction

The use of resistant varieties of crops in pest management programmes in order to enhance high crop yields has gained a lot of ground in Nigeria and other parts of Africa (Kim et al., 1981; Anon., 1982; Soto et al., 1982). According to Fajemisin and Shoyinka (1976), the use of cultural and chemical control in lowering initial infection by the maize streak virus is not reliable for effective control under conditions which are extremely favourable to the virus such as those found in West Africa. The most promising way of control is to breed resistant varieties. This is particularly true for an area like West Africa where over 80 percent of maize production is in the hands of peasants who are too poor and ill-equipped to cope with the financial and technical burdens of chemical control. The International Institute of Tropical Agriculture has produced some varieties (particularly TZSR-W-1[illegible] which are resistant to the maize streak virus disease (MSVD) (Anon., 1980; Anon., 1982).

This trial was aimed at determining the reaction of 30 maize varieties (some of which are reportedly resistant to MSVD) in terms of disease incidence and severity. Crop yield was also measured.

9.2 Materials and methods

Thirty maize varieties made available by the maize Agronomist, Institute for Agricultural Research, Samaru, were used in this trial.

Seeds of all the varieties were sown at an inter-row spacing of 75cm and interplant spacing of 30cm on 20 June, 1984. Each plot consisted of four ridges which were 5m long. The plants were thinned to one per stand 3 weeks after planting (WAP).

The incidence and severity of the maize streak disease were recorded at 4WAP and 8WAP. Disease incidence was measured by counting plants showing symptoms of the maize streak virus disease and calculating the percentage infection. Disease severity index was calculated using the following formula (McKinney, 1923):

$$\text{Disease severity index} = \frac{\text{Sum of individual ratings}}{\text{Number of plants assessed}} \times \frac{100}{5^*}$$

(* maximum disease category)

Plants showing infection at 4WAP were distinguished from those at 8WAP by tagging them with labels made out of hard white card-board paper.

At crop maturity plants in all four rows per plot were harvested and the cobs dehusked and taken to the laboratory where they were allowed to dry at a temperature of 28°C and a relative humidity of 50 percent. After one week of drying (moisture content: 17.2 percent), the cobs were counted and their weight recorded. The cobs were then shelled and the weight of shell grains recorded.

9.3 Results

Table 8 and appendices 6a and 6b show the reaction of 30 varieties of maize to MSVD in terms of incidence and severity. The incidence of MSVD at 4WAP ranged from 0.00 to 15.85 percent; it was significantly higher ($P < 0.05$) in SZV-2 and ATS-1 than in Bomo Local but similar in all the other varieties under comparison (Table 8). At 8WAP the incidence of MSVD was very variable, ranging from 6.22 percent in Bomo Local to 63.80 percent in Safit 104 (Table 8). MSVD incidence in Safit 102, IRAT 785, Pozarica, El XEl Mex. and SZV-3 was similar but significantly higher ($P < 0.05$) than in all other varieties under comparison. The varieties TZSR-Y-1, SZV-6, Bomo Local and TZB-5 had consistently low MSVD incidence at both 4WAP and 8WAP. The incidence of the disease was significantly higher ($P < 0.05$) at 8WAP than at 4WAP.

At 4WAP, the severity of the disease in SZV-4 and IRAT 785 was significantly higher ($P < 0.05$) than in Trop x Temp 27, TZB-S, Bomo Local, SZV-6, TZSR-Y-1, Pop Senegal, EV 7982, EV8176, EV Gusan and NB-1 but similar to that in other varieties (Table 8). The lowest MSVD severity at 4WAP was recorded in TZSR-Y-1 (2.81), SZV-6 (2.78), TZB-S (2.57) and Bomo Local (1.00) (Table 8). At 8WAP, disease severity in SZV-2, SZV-3, El x El Mex. and TZPB Conne was significantly higher ($P < 0.05$) than in Bomo Local and SZV-6 but similar to that in all the other varieties under comparison (Table 8).

Table 8. Incidence and severity of MSVD on thirty maize varieties at Samaru, Nigeria 1984.

Variety	Incidence (%) at		Severity (1-5) at	
	4WAP	8WAP	4WAP	8WAP
Bomo Local	0.00^{a}	6.22^{a}	1.00^{a}	3.00^{ab}
TZB-S	5.75^{ab}	17.08^{abc}	2.57^{b}	3.67^{abc}
SZV-6	6.28^{ab}	8.73^{a}	2.78^{b}	2.87^{a}
Trop X Temp 27	4.27^{ab}	27.78^{cde}	2.80^{b}	3.93^{abc}
TZSR-Y-1	9.38^{ab}	20.04^{abcd}	2.81^{b}	3.26^{abc}
Pop Senegal	8.18^{ab}	36.96^{efg}	2.87^{b}	4.03^{bc}
EV 7982	4.56^{ab}	18.14^{abc}	2.89^{b}	3.59^{abc}
NB-1	3.85^{ab}	20.33^{abed}	2.89^{b}	3.73^{abc}
EV Gusau	7.56^{ab}	43.69^{fgh}	2.93^{b}	4.00^{bc}
EV 8176	6.19^{ab}	36.18^{efg}	2.93^{b}	3.98^{abc}
SZV-3	12.45^{ab}	54.32^{hij}	3.00^{bc}	4.13^{c}
SZV-1	11.16^{ab}	39.43^{efgh}	3.01^{bc}	4.28^{c}
Pips Abaki	14.07^{ab}	39.29^{efgh}	3.09^{bc}	3.69^{abc}
ATK 827-R	6.68^{ab}	36.45^{efg}	3.11^{bc}	4.02^{bc}
SZV-2	15.85^{b}	28.96^{cdef}	3.17^{bc}	4.17^{c}
ATS-1	14.86^{bc}	34.81^{defg}	3.19^{bc}	4.04^{bc}
Western Yellow	9.16^{ab}	45.33^{ghi}	3.33^{bc}	4.01^{bc}
Trop X Temp 3	6.45^{ab}	20.13^{abcd}	3.42^{bc}	3.86^{abc}
SZV-5	3.65^{ab}	27.23^{cde}	3.44^{bc}	3.84^{abc}
Bako Comp.	7.02^{ab}	31.89^{cdefg}	3.52^{bc}	3.97^{abc}
Safit 102	14.03^{ab}	63.80^{j}	3.54^{bc}	4.03^{bc}
EV 8188	3.33^{ab}	18.97^{abc}	3.55^{bc}	4.03^{bc}
Pozarica	12.84^{ab}	62.31^{j}	3.55^{bc}	4.04^{bc}
Trop X Temp 42	8.72^{ab}	25.65^{bcde}	3.62^{bc}	3.92^{abc}
Safit 104	7.26^{ab}	28.07^{cdef}	3.67^{bc}	3.65^{abc}
TZB-G	3.02^{ab}	10.77^{ab}	3.67^{bc}	4.07^{bc}
El X El Mex	11.39^{ab}	58.47^{ij}	3.80^{bc}	4.10^{c}
TZPB Conne	7.34^{ab}	25.77^{bcde}	3.90^{bc}	4.12^{c}
IRAT 785	8.51^{ab}	63.27^{j}	4.05^{c}	3.92^{abc}
SZV-4	7.93^{ab}	45.84^{ghi}	4.12^{c}	4.06^{bc}
Mean	8.06	32.76	3.23	3.86

Using Duncan's Multiple Range test, means in each column followed by the same letters are not significantly different (P = 0.05)

The lowest mean MSVD severity at 8WAP was recorded in SZV-6 (2.87), Bomo Local (3.00) and TZSR-Y-1 (3.26). The latter three varieties showed consistently low MSVD severity at both 4WAP and 8WAP. Out of the 30 varieties exposed to MSVD infection, 29 had a mean severity of greater than 2 (Table 8). The severity of the disease was significantly higher at 8WAP than at 4WAP (Table 8).

The grain yield of the 30 maize varieties exposed to natural infection of the virus is given in appendices 6c and 6d. TZSR-Y-1 had the highest grain yield.

94 Discussion

Most of the maize varieties tested reacted in about the same way to MSVD in terms of incidence and severity. However, a few varieties, particularly TZSR-Y-1, SZV-6 and Bomo Local had consistently low disease at both 4WAP and 8WAP. Disease was consistently more common and severe in the varieties SZV-4, Safit 102, IRAT 785 and Pozarica.

The results obtained in this trial are similar to those obtained by Sundaram and Ajayi (1984) who reported seedling resistance to MSVD in the variety SZV-6 at Samaru. Among the 30 varieties tested against MSVD, none of them was immune but their reaction to the disease varied to some extent. Sundaram and Ajayi tested 14 maize varieties (Western Yellow, SZV-2, SZV-5, SZV-6, TZB-5 and NB-1 were used in this trial) and found that 12 entries were infected with MSVD in the final count. According to them, the least affected were : SZV-6, SZV-5, TZB-5 and SZV-2; all the others suffered over 50 percent infection.

Bomo Local and TZB-S were used as susceptible checks in this trial but suffered less disease than most of the varieties under comparison. Since plots were completely randomized, it is possible that their proximity to more tolerant varieties offered these varieties (Bomo Local and TZB-S) some protection from MSVD. This would account for the low disease recorded in them. It is worthwhile to mention that susceptible maize varieties have been shown in some cases to stand up to MSVD epidemics. For example, in an MSVD epidemic in Sao Tome in 1979, susceptible populations stood up to the epidemic and gave excellent yields. This was possibly a case of escape.

Although TZSR-Y-1 had the highest grain yield, the varieties, per se cannot be compared because yields of healthy and disease plants per variety were not recorded separately.

It is suspected that the seeds of these three varieties were wrongly labelled.

Chapter 10

SUMMARY AND CONCLUSIONS

A survey of Cicadulina species around the Zaria area between March, 1984 and October, 1985 revealed the occurrence of four species: Cicadulina mbila Naude, C. triangula Ruppel, C. arachidis China and C. similis China. C. mbila was caught more often than the other species. A greater number of species and individuals was caught during the rainy season than during the dry season.

Studies on the development of C. mbila at Samaru in 1985 revealed that at a temperature of 29 to 31°C the life cycle from egg to adult took 27 days, and 26 days at a temperature of 32 to 34.5°C. Temperature appears to play a very important role in the development of this species.

A survey of alternative hosts of the maize streak virus (MSV) in the Zaria area showed five grass species with typical symptoms of the maize streak virus disease (MSVD): Dactyloctenium aegyptium, Digitaria ciliaris, Brachiaria lata, Eleusine indica, and Eragrostis ciliaris. MSVD symptoms were also observed in pearl millet, Pennisetum americanium (L.) Leeke. Serological studies proved conclusively that MSV in maize is serologically related to the virus which elicits streak symptoms in millet and the grasses mentioned. Precipitation lines were more intense with partially purified sap of Dactyloctenium aegyptium and Digitaria ciliaris than with B. lata, E. indica and millet. In the field, D. aegyptium and D. ciliaris tend to be more severely affected by MSVD than the other hosts mentioned.

Survey of MSVD in the Zaria area from March 1984 to September 1985 revealed that the incidence of the disease was lower in 1985 than in 1984 and that early planted maize suffered less disease than those planted late, particularly in the research farm of the Institute for Agricultural Research at Samaru. Rainfall and the presence of weeds, particularly of the family Gramineae, were identified as possible important factors responsible for differences in the incidence of the MSVD in Zaria. Digitaria ciliaris and Eleusine indica may be very important in the etiology of the disease from season to season and year to year in the Zaria area.

The effect of the method and frequency of weed control on MSVD incidence, severity and on yield was investigated at Samaru in 1984 and 1985. Four treatments were involved : pre-emergence herbicide application, pre-emergence herbicide plus one hoe-weeding at 4WAP; pre-emergence herbicide plus two hoe-weedings at 4 and 6WAP and three hoe-weedings only at 4, 6 and 8WAP (control). Both incidence and severity of the disease were lower in plots treated with pre-emergence herbicide only and pre-emergence herbicide plus one hoe-weeding than in those with pre-emergence herbicide plus two hoe-weedings and three hoe-weedings only. Disease was consistently high in the latter two treatments in both 1984 and 1985. Grain yields in all treatments were similar and this was possibly due to late infection by the virus.

In 1984 and 1985, carbofuran, demeton, thiometon, endosulfan, dimethoate and carbaryl were evaluated for their effect on the incidence and severity of the MSVD at Samaru. Carbofuran - treated plots consistently had the lowest disease and the highest yield in both years.

In another trial (1984) 30 maize varieties were exposed to natural infection of the MSVD. TZSR-Y-1 and SZV-6 consistently suffered low disease incidence and severity at 4WAP and 8WAP and TZSR-Y-1 also had the highest grain yield. None of the varieties was immune to the disease.

The key to pest management lies in the ability to use all known control measures singly or in appropriate combinations so as not to cause any social, economic or environmental upheavals. For any pest management programme to be successful, the pest has to be identified, its pest status established and its life cycle and habits have to be fully comprehended. Only after making such analyses can suitable control measures be determined.

In the present study, attempts were made to identify the pest, that is, Cicadulina spp. and some investigations were made on the biology of C. mbila, a well known vector of the MSV. Attempts were also made at controlling the disease and vector by cultural and chemical methods. Some maize varieties were also evaluated for their reaction to the MSVD. If all these facts are put together in a flexible system and weather conditions are right (particularly rainfall) the yield of maize can be doubled in the Zaria area as well as other parts of northern Nigeria where this crop is increasingly gaining ground.

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APPENDICES

Appendix 1. The amount of rainfall (mm) at Samaru between 1981 and 1985

Month	Year				
	1981	1982	1983	1984	1985
January	0.0	0.0	0.0	0.0	0.0
February	0.0	0.0	0.0	0.0	0.0
March	0.0	0.0	0.0	5.2	32.9
April	100.7	59.7	0.0	30.1	0.0
May	90.7	72.1	73.3	98.9	140.7
June	159.0	113.9	74.3	55.4	142.2
July	254.8	168.7	107.5	173.8	313.3
August	280.6	190.7	259.7	158.1	256.3
September	133.3	117.6	93.4	189.0	163.3
October	0.0	45.6	0.0	177.5	3.3
November	0.0	0.0	0.0	0.0	-
December	0.0	0.0	0.0	0.0	-
Total	1019.1	768.5	608.2	886.0	1052.0

Source: Agro-meteorological Unit, I.A.R., Samaru, Nigeria

Appendix 2. Mean temperature (^{o}C) at Samaru, Nigeria between January and September, 1985

Month	Temperature (^{o}C)
January	31.6
February	29.5
March	35.1
April	34.5
May	33.5
June	30.0
July	27.8
August	28.8
September	29.3

Source: Agro-meteological Unit, I.A.R., Samaru, Nigeria

Appendix 3 Pesticides used in field trials

Common name	Trade name	Chemical nature
Atrazine (H)	Gesaprim Atratol	2 - chloro-N-isopropl-acelanilide
Metolachlor (H)	Dual	&-chloro-6-ethyl-N-(2-methoxy-1-methyl-ethyl)-O-acetololuidide
Carbofuran (I)	Furadan	2,3 -dihydro-2,2-dimethylbenzofuran-7-yl-methyl carbamate.
Demeton (I)	Solvirex	OO- diethyl O-2-ethylithio ethyl phosphoro-thionate
Thiometon (I)	Ekatin	S-2-ethyl thioethyl-OO- dimethyl phosphoro-dithioate
Endosulfan (I)	Thiodan	6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a -hexa-hydro-6,9- methano-2,4,3 benzo(e) dioxathiepin 3-oxide
Dimethoate (I)	Rogor	OO- dimethyl S- methyl-carbomoyl methyl phosphoro-dithionate
Carbaryl	Carbaryl 85	1-naphthyl methyl carbamate

H : Herbicide

I : Insecticide

Appendix 4a. Analysis of variance for the effect of the method and frequency of weed control on the incidence of the maize streak virus disease (MSVD) at two dates[a] at Samaru, Nigeria, 1984.

Sources of variation	DF	SS	MS	F
Rep	3	168.542	56.181	1.903
Trt.	3	308.928	102.976	3.489*
Date	1	6794.9	6794.9	230.208**
Trt x Date	3	165.055	55.018	1.864 NS
Residual	21	619.842	29.516	
Total	31	8057.26		

* Significant at 0.05

** Significant at 0.01

NS Not significant

a 4WAP and 8WAP

Appendix 4b. Analysis of variance for the effect of the method and frequency of weed control on the incidence of MSVD at two dates at Samaru, Nigeria, 1985

Sources of Variation	DF	SS	MS	F
Rep	3	6.507	2.169	1.467
Trt.	3	111.172	37.057	25.071**
Date	1	205.082	205.082	138.745**
Trt. x Date	3	17.008	5.669	3.835*
Residual	21	31.041	1.478	
Total	31	370.809		

Appendix Uc Combined analysis of variance for the effect of the method and frequency of weed control on the incidence of MSVD at two dates at Samaru, Nigeria 1981+ and 1985.

Sources variation	DF	SS	MS	P
Rep	3	119.791	39.93	2.577
Yrs	1	2763.3U	2763.3a	17B.315"'
Rep x Yrs	3	55.258	18.M9	1.139
Trt	3	300.973	100.32U	6.U7U**
Yrs x Trt	3	119.127	39.709	2.562 NS '
Date	1	1+680.27	U680.27	302.01?
Yrs. x Date	1	2319.39	2319.39	1U9.667,H
Trt x Date	3	12U.115	U1.372	2.67 NS
Yrs x Trt x Date	3	57.925	19.308	1,21+6 NS
Residual	1+2	15.U97		
Total	63	11191.1		

Appendix 1+d. alysis of variance for the effect of the method and frequency of weed control on the severity of MSVD at two dates at Samaru, Nigeria, 198U.

Sources of variation	DF		MS	F
Rep.	3	1.113	0.371 .	0.775
Trt	3	5.627	1.876	3.563*
Date	1	20.656	20.656	
Trt x Date	3	5.855	1.952	3.7 '
Residual	21	11.055	0.526	
Total	31	M+.307		

Appendix 4e. Analysis of variance for the effect of the method and frequency of weed control on the severity of MSVD at two dates at Samaru, Nigeria, 1985.

Sources of variation	DF	SS	MS	F
Rep	3	0.377	0.126	0.73
Trt	3	6.551	2.184	12.69**
Date	1	4.351	4.351	25.288**
Trt x Date	3	0.002	0.001	0.005 NS
Residual	21	3.613	0.172	
Total	31	14.894		

Appendix 4f. Combined analysis of variance for the effect of method and frequency of weed control on the severity of MSVD at two dates at Samaru, Nigeria, 1984 and 1985.

Sources of variation	DF	SS	MS	F
Rep	3	0.685	0.228	0.653
Yrs	1	18.137	18.137	51.933**
Rep x Yrs.	3	0.806	0.269	0.769
Trt	3	11.172	3.724	10.663**
Yrs x Trt	3	1.006	0.335	0.96 N.S.
Date	1	21.984	21.984	62.949**
Yrs x Date	1	3.023	3.023	8.657**
Trt x Date	3	3.008	1.003	2.871*
Yrs. x Trt x Date	3	2.85	0.95	2.72 NS
Residual	42	14.668	0.349	
Total	63	77.338		

Appendix 4g. Analysis of variance for the effect of the method and frequency of weed control on maize yield at Samaru, Nigeria, 1984.

Sources of variation	DF	SS	MS	F
Blocks	3	1.43085	0.47695	0.87747
Trt	3	5.52646	1.84215	3.38910 N.S
Residual	9	4.89197	0.54355	
Total	15	13.8493		

Appendix 4h. Analysis of variance for the effect of the method and frequency of weed control on maize yield at Samaru, Nigeria, 1985.

Sources of variation	DF	SS	MS	F
Blocks	3	5.582	1.860	2.927
Trt	3	1.026	0.342	0.538 N.S.
Residual	9	5.720	0.635	
Total	15	12.3295		

Appendix 4i. Combined analysis of variance for the effect of the method and frequency of weed control on maize yield at Samaru, Nigeria 1984 and 1985

Sources of variation	DF	SS	MS	F
Rep	3	3.581	1.194	1.0428
Yrs	1	141.456	141.456	123.54**
$Error_a$	3	3.436	1.145	
Trt	3	6.483	2.161	3.662*
Yrs x Trt	3	2.051	0.684	1.158 N.S
$Error_b$	18	10.622	6.59	-
Total	31	167.629	-	-

Appendix 5a. Analysis of variance for the effect of six insecticides on the incidence of MSVD at two dates at Samaru, Nigeria, 1984.

Sources of variation	DF	SS	MS	F
Rep	3	89.466	29.822	0.749
Trt	6	1567.58	261.263	6.563**
Date	1	4028.33	4028.33	101.194**
Trt x Date	6	828.315	138.052	3.468**
Residual	39	1552.52	39.808	
Total	55	8066.21		

Appendix 5b. Analysis of variance for the effect of six insecticides on the incidence of MSVD at two dates at Samaru, Nigeria, 1985.

Sources of variation	DF	SS	MS	F
Rep	2	0.35	0.175	0.043
Trt	6	55.47	9.245	2.297 N.S.
Date	1	101.339	101.339	25.18**
Trt x Date	6	38.925	6.488	1.612 N.S.
Residual	26	104.641	4.025	
Total	41	300.726		

Appendix 5e. Analysis of variance for the effect of six insecticides on the severity of MSVD at two dates at Samaru, Nigeria, 1985.

Sources of variation	DF	SS	MS	F
Rep	2	1.842	0.921	1.166
Trt	6	7.649	1.275	1.614 N.S.
Date	1	3.981	3.981	5.041*
Trt x Date	6	0.993	0.165	0.21 N.S.
Residual	26	20.53	0.79	
Total	41	34.993		

Appendix 5f. Combined analysis of variance for the effect of six insecticides on the severity of MSVD at two dates at Samaru, Nigeria, 1984 and 1985.

Sources of variation	DF	SS	MS	F
Rep	2	0.95	0.47	0.59
Yrs	1	30.964	30.964	38.479**
Rep x Yrs	2	2.678	1.339	1.664
Trt	6	22.171	3.695	4.592*
Yrs x Trt	6	5.541	0.924	1.148 N.S
Date	1	29.81	29.81	37.044**
Yrs x Date	1	6.96	6.96	8.65**
Trt x Date	6	1.58	0.263	0.327 NS
Yrs x Trt x Date	6	2.208	0.368	0.457
Residual	52	41.845	0.805	
Total	83	143.852		

Appendix 5g. Analysis of variance for the effect of six insecticides on maize yield at Samaru, Nigeria, 1984.

Sources of variation	DF	SS	MS	F
Blocks	3	1.09697	0.365655	1.969
Trt	6	2.07543	0.345905	1.863 N.S.
Residual	18	3.34157	0.185643	
Total	27	6.51397		

Appendix 5h. Analysis of variance for the effect of six insecticides on maize yield at Samaru, Nigeria, 1985.

Sources of variation	DF	SS	MS	F
Blocks	2	6.344	3.172	1.114
Trt	6	15.611	2.601	0.914 N.S
Residual	12	34.142	2.845	
Total	20	56.0983		

Appendix 5i. Combined analysis of variance for the effect of six insecticides on maize yield at Samaru, Nigeria, 1984 and 1985.

Sources of variation	DF	SS	MS	F
Rep	2	0.892	0.446	0.06
Yrs	1	95.885	95.885	13.38**
$Error_a$	2	14.332	7.166	
Trt	6	38.225	6.371	2.704*
Yrs x Trt	6	4.327	0.721	0.306
$Error_b$	24	56.536	2.356	
Total	41	210.101		

Appendix 6a. Analysis of variance for the incidence of MSVD at two dates in 30 maize varieties at Samaru, Nigeria, 1984.

Sources of variation	DF	SS	MS	F
Rep	2	26.037	13.018	0.13
Var.	29	15546.2	536.077	5.366*
Date	1	26496.3	26496.3	265.241**
Var. x Date	29	10377.4	357.843	3.582
Residual	118	11787.7	99.95	
Total	179	64233.7		

Appendix 6b. Analysis of variance for the severity of MSVD at two dates in 30 maize varieties at Samaru, Nigeria, 1984.

Sources of variation	DF	SS	MS	F
Rep	2	2.29	1.145	1.985
Var	29	29.484	1.017	1.762*
Date	1	17.848	17.848	30.934**
Var. x Date	29	11.987	0.413	0.716 N.S.
Residual	118	68.082	0.577	
Total	179	129.691		

Appendix 6c. Grain yield of 30 varieties of maize exposed to natural infection of the MSVD at Samaru, Nigeria, 1984.

Variety	Mean grain yield (Kg/4 rows)	Rank
Pop Senegal	3.49^{a+}	29
SZV-4	3.56^{a}	28
SZV-1	4.20^{ab}	27
EV Gusan	4.33^{ab}	26
IRAT 785	4.58^{ab}	25
Bako Comp.	4.79^{ab}	24
Bomo Local	4.88^{ab}	23
SZV-5	4.97^{ab}	22
Trop x Temp 42	5.03^{ab}	21
EV 8188	5.24^{ab}	20
Pozarica	5.24^{ab}	20
ATS-1	5.30^{ab}	19

Appendix 6d. Analysis of variance for the grain yield in 30 maize varieties at Samaru, Nigeria, 1984

Sources of variation	DF	SS	MS	F
Blocks	2	3.342	1.671	9.769
Var	29	9.07697	3.12999	1.829*
Residual	58	9.92072	1.71047	
Total	89	22.33969		