BACTERIAL BLIGHT OF CASSAVA (Manihot esculenta Crantz) IN THE DRIER SAVANNAS Of NIGERIA

BY

SAMUEL TABOT DUALA

B.Sc. (Botany) University of Yaounde

A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, AHMADU BELLO UNIVERSITY, ZARIA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CROP PROTECTION.

DEPARTMENT OF CROP PROTECTION,

FACULTY OF AGRICULTURE,

AHMADU BELLO UNIVERSITY,

ZARIA, NIGERIA.

AUGUST, 1995

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.

Samuel Tabot Duala — Date: 19/09/95

The above declaration is confirmed.

Professor I.D. Erinle
(Major Supervisor) — Date: 20/9/95

CERTIFICATION

This thesis entitled "BACTERIAL BLIGHT OF CASSAVA (Manihot esculenta Crantz) IN THE DRIER SAVANNAS OF NIGERIA" by Samuel Tabot Duala 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.

Prof. I.D. Erinle
Internal Examiner

Date: 20/9/95

Dr. A.D. Akpa
Internal Examiner

Date: 21.09.95

Dr. I. Onu
Head,
Department of Crop Protection

Date: 21/09/95

Prof. Dalhatu Muhammad
Dean,
Postgraduate School.

Date: 4/10/96

DEDICATION

To my parents, Pa and Ma Duala

ACKNOWLEDGEMENT

My profound gratitude and appreciation go to my major supervisor, Professor I.D. Erinle for suggesting the topic and his meaningful suggestions, corrections, and critical review of the manuscripts.

I also wish to thank him for his fatherly understanding and encouragement during my trying moments in the course of this work.

My sincere thanks also go to my co-supervisor, Dr. A.D. Akpa for his relevant suggestions and advice.

I wish to express my sincere thanks to Ahmadu Bello University and the Department of Crop Protection for providing the necessary facilities which led to the successful completion of this work.

My thanks also go to Dr. I.J. Ekanayake, Mr. E.M. Chukwuma and especially Chris Okonkwo all of TRIP unit of IITA for their material assistance and for giving me access to their research fields.

Sincere thanks go to Mrs. J.A. Uwakwe, Messrs. A. Kwarra, J. Due, Abdullahi Maaji, J. Ochube, Sam Atesang for their technical assistance, Mr. J.D. Dazan for his photographic assistance and Prof. M.K. Ahmed for statistical assistance.

I wish to express my profound gratitude and deep appreciation to my parents, Pa and Ma Duala; my sisters, Edna and Bea; my brother, Dan; My brothers in-law, Messrs. Fombang and Dasi; and my uncle, S.N. Duala for their love, selfless sacrifices, patience, understanding, prayers and encouragement that saw me through all my trying moments in the course of this work and have brought me to

its successful completion.

My sincere thanks go to Jacques Beyo and Celestin Klassou for their love and care in the course of this work. I also wish to thank Mr. Isah Abdulkarim and M.Y. Nadabo, Department of Mathematics, A.B.U., Zaria for their effort and patience in typing the manuscripts.

Finally, glory, praise and thanks to the Almighty God for His mercies, guidance and blessings throughout the course of this programme and for bringing the study to a successful end.

ABSTRACT

Cassava bacterial blight is the most important of several bacterial diseases of cassava and is of wide occurrence in Nigeria.

Surveys were undertaken at Zaria and other sites in the Northern Guinea and Southern Guinea Savanna zones to evaluate the incidence and severity of the disease. The incidence and severity of the disease were higher in the Southern Guinea Savanna zone than in the Northern Guinea Savanna zone. Some variations were observed within every environ visited and these were attributed to the nature of crop mixture, cassava cultivar type, spacing and plant age.

The incidence and severity of the disease were significantly reduced following late planting with a local cassava variety while the decrease was non-significant with the improved variety TMS 4(2)1425. in the intercrops, a significant reduction of the incidence and severity of the disease were achieved with the improved variety. On the other hand, incidence and severity of the disease were significantly higher in the sole improved cassava. There were no significant differences between the time of introduction of the components of the mixture on the incidence and severity of the disease in both varieties.

Screening for resistance to the disease in field and in pot trials using six cassava varieties revealed that disease incidence and severity were lowest in TMS 30572 and TMS 1(2)1425 while a local variety, TMS 91934 and 60506 were highly susceptible.
The improved cassava varieties TME II, TMS 305" TMS 4(2)1425, TMS

81983 and the local varieties, Isu and Broni were identified as being fairly resistant to bacterial blight compared to other varieties tested in two different trials.

Leaf trash collected in the field from beneath diseased plants at approximately 9 months yielded the pathogen. In both local and improved cassava varieties, bacterial populations in the trash were found to be minimum in April and maximum in October.

TABLE OF CONTENTS

Chapter		Page
	Declaration	ii
	Certification	iii
	Dedication	iv
	Acknowledgement	v
	Abstract	vii
	Table of contents	ix
	List of tables	xiii
	List of figures	xv
	List of plates	xvi
	Abbreviations	xvii
	List of appendices	xviii
1.	INTRODUCTION	1
1.1	Nomenclature and classification of the cassava plant	1
1.2	Origin and distribution of cassava	1
1.3	Economic importance of cassava	2
1.4	Pests and diseases of the cassava plant	3
1.5	Objectives of the investigation	6
2.	LITERATURE REVIEW	7
2.1	Nomenclature	7
2.1.1	Pathogenic variability	7
2.1.2	Distribution and host range	8
2.1.3	Economic importance of CBB	8

2.2 Symptoms of CBB 8
2.3 Epidemiology 9
2.3.1 Transmission 9
2.3.2 Favourable weather conditions for disease development 12
2.4 Survival of the pathogen 13
2.5 CBB in cassava intercrops 14
2.6 Control of CBB 15
2.6.1 Pruning 15
2.6.2 Sanitation 15
2.6.3 Cultural practice 15
2.6.4 Resistant cultivars 16
2.6.5 Biological control 16
2.6.6 Physical control 17

3. A SURVEY OF THE INCIDENCE AND SEVERITY OF CASSAVA BACTERIAL BLIGHT IN SOME SAVANNA AREAS OF NIGERIA IN 1993 18
3.1 Introduction 18
3.2 Materials and method 18
3.3 Result and discussion 20

4. EFFECT OF SOME CULTURAL PRACTICES ON THE INCIDENCE AND SEVERITY OF CBB 28
4.1 Introduction 28
4.2 Materials and method 28
4.2.1 Local variety 29

4.2.2 Improved variety 29
4.3 Results and discussion 32
4.3.1 Local variety 32
4.3.1.1 Planting date 32
4.3.1.2 Intercropping 37
4.3.2 Improved variety 38
4.3.2.1 -Planting date 38
4.3.2.2 -Intercropping 38

5. EVALUATION OF CASSAVA VARIETIES FOR RESISTANCE TO BACTERIAL BLIGHT..... 40
5.1 Introduction 40
5.2 Materials and method 40
5.2.1 1992 wet season trials 40
5.2.1.1 On the I.A.R. Research Farm, Samaru, Zaria 40
5.2.1.2 On the University Farm, Shika, Zaria 41
5.2.1.2.1 Twenty-nine varieties established from rooted cuttings 41
5.2.1.2.2 Fifty-three varieties established from "true" seeds 41
5.2.2 1993 Trials 41
5.2.2.1 Pot Experiments 41
5.2.2.2 Field Experiments 42
5.2.2.2.1 Eight cassava varieties established from in-vitro culture 42

5.2.2.2.2 Thirty cassava genotypes established from "true" seeds 43
5.3 Results and discussion 44
5.3.1 1992 Wet Season Trials 44
5.3.1.1 The I.A.R. Research Farm Trial 44
5.3.1.2 The University Farm Trial 48
5.3.1.2.1 Twenty-nine cassava varieties established from rooted cuttings 48
5.3.1.2.2 Fifty-three cassava varieties sown from "true" seeds 52
5.3.2 1993 Trials 55
5.3.2.1 Pot Experiments 55
5.3.2.2 Field Experiments 59
5.3.2.2.1 Eight cassava varieties established from *in-vitro* culture 59
5.3.2.2.2 Thirty cassava genotypes sown from "true" seeds . 62

6. SURVIVAL AND POPULATION DYNAMICS OF *Xanthomonas campestris* pv. *manihotis* IN LEAF TRASH 67
6.1 Introduction 67
6.2 Materials and method 67
6.2.1 Pathogenicity tests of isolates 68
6.3 Results and discussion 69
7. SUMMARY AND CONCLUSION 76
8. REFERENCES 78
9. APPENDICES 93

LIST OF TABLES

Table		Page
3.1	Incidence and severity of cassava bacterial blight at four cassava-growing areas in 1993	21
3.2	Summary of mean incidence and severity of cassava bacterial blight in the four areas surveyed in 1993.	24
4.1	Effects of planting date and intercropping on the incidence and severity of bacterial blight on a local cultivar during the 1993 wet season	34
4.2	Effects of planting date and intercropping on the incidence and severity of bacterial blight on an improved cassava cultivar (TMS 4(2)1425) during the 1993 wet season	35
4.3	Weather records in Samaru during the field experimental periods: 1993	36
5.1	Incidence and severity of bacterial blight on 6 cassava varieties at the I.A.R Research Farm, Samaru during the 1992 wet season.	46
5.2	Weather records in Samaru during the field experimental periods: 1992	47
5.3	Incidence and severity of bacterial blight on 29 cassava varieties established from seedlings at the University Farm, Shika during the 1992 wet season ...	49

5.4 Correlation analysis of pairs of parameters obtained in screening 29 cassava varieties for bacterial blight at the University Farm, Shika during the 1992 wet season 51

5.5 Incidence and severity of bacterial blight on 53 cassava varieties sown from "true" seeds at the University Farm, Shika, during the 1992 wet season 53

5.6 Incidence and severity of bacterial blight on 6 cassava varieties in the 1993 pot experiment 57

5.7 Weather records in Samaru during the period for the pot experiment in 1993. 58

5.8 Incidence and severity of bacterial blight on 8 cassava varieties from in-vitro establishment at the University Farm, Shika during the 1993 wet season 60

5.9 Correlation analysis of pairs of parameters obtained in screening 8 cassava varieties for bacterial blight at the University Farm, Shika during the 1993 wet season 61

5.10 Incidence and severity of bacterial blight on 30 cassava genotypes sown from "true" seeds at the University Farm, Shika during the 1993 wet season 63

5.11 Correlation analysis of pairs of parameters obtained in screening 30 cassava genotypes for bacterial blight at the University Farm, Shika during the 1993 wet season.. 65

6.1 Weather records in Samaru during the experimental periods 73

LIST OF FIGURES

Figure		Page
6.1	Population of X. campestris pv. manihotis surviving in leaf trash every two weeks	71
6.2	Monthly population of X. campestris pv. manihotis surviving in leaf trash	72

LIST OF PLATES

Plate		Page
1.	Leaf of a local cassava variety showing extensive blight and water-soaked angular spots (lower surface)	11
2.	Extensive blight in leave of TMS 91934 (upper surface)	11
3.	Local cassava variety intercropped with maize	30
4.	Healthy local cassava plant in maize intercrop	31
5.	Diseased local cassava plant in maize intercrop	31
6.	Tip die-back of main shoot in 60506	56
7.	Colonies of Xanthomonas manihotis (indicated by arrows) on plate of SPA after 72 hours incubation	70

ABBREVIATIONS

ANOVA	-	Analysis of Variance
DF	-	Degree of Freedom
DMRT	-	Duncan's Multiple Range Test
F	-	F value
MS	-	Mean Square
NS	-	Not Significant
SS	-	Sum of Squares
**	-	Highly Significant (P = 0.01)
*	-	Significant (P = 0.05)

LIST OF APPENDICES

Appendix		Page
9.1	Analysis of variance (ANOVA) of parameters used in the evaluation of cassava bacterial blight in the 1993 disease area survey.....	93
9.1.1	Locations visited.....	93
9.1.1.1	Mean disease incidence.....	93
9.1.1.2	Mean disease severity score	93
9.1.2	Areas visited.....	94
9.1.2.1	Mean disease incidence	94
9.1.2.2	Mean disease severity score.....	94
9.2	Analysis of variance (ANOVA) of parameters used in determining the effects of planting date and intercropping of local cassava variety on the incidence and severity of cassava bacterial blight (CBB) in the 1993 field experiments.....	95
9.2.1	Mean* disease incidence	95
9.2.2	Mean* disease severity score	95
9.3	ANOVA of parameters used in determining the effects of planting date and intercropping of improved cassava variety (TMS 4(2)1425) on the incidence and severity of CBB in the 1993 field experiments.	96
9.3.1	Mean* disease incidence	96
9.3.2	Mean* disease severity score	96

9.4 ANOVA of parameters used in the evaluation of 6 cassava varieties for resistance to bacterial blight in the 1992 field trial..... 97

9.4.1 Mean disease incidence..... 97

9.4.2 Mean disease severity score 97

9.5 ANOVA of parameters used in the evaluation of 29 cassava varieties for resistance to bacterial blight at the University Farm, Shika; 1992 wet season..... 98

9.5.1 Mean disease incidence 98

9.5.2 Mean disease severity score 98

9.5.3 Mean number of main shoot die-back per stand. .. 99

9.6 ANOVA of parameters used in the evaluation of 53 cassava varieties for resistance to bacterial blight at the University Farm, Shika; 1992 wet season..... 99

9.6.1. Mean disease incidence 99

9.6.2 Mean disease severity score 100

9.7 ANOVA of parameters used in the evaluation of 6 cassava varieties for resistance to bacterial blight in the 1993 pot experiment. 100

9.7.1 Mean disease incidence 100

9.7.2 Mean disease severity score 101

9.8 ANOVA of parameters used in the evaluation of 8 cassava varieties from in-vitro establishment for resistance to bacterial blight at the University Farm, Shika; 1993 wet season. 101

9.8.1 Mean disease incidence 101

9.8.2 Mean disease severity score 102

9.8.3 Mean number of main shoot die-back per stand... 102

9.9 ANOVA of parameters used in the evaluation of 30 cassava genotypes for resistance to bacterial blight at the University Farm, Shika; 1993 wet season..... 103

9.9.1 Mean disease incidence 103

9.2.2 Mean disease severity score..... 103

9.9.3 Mean number of main shoot die-back per stand... 104

1. INTRODUCTION

1.1 Nomenclature and classification of the cassava plant

Cassava (Manihot esculenta Crantz), is a woody perennial shrub belonging to the family Euphorbiaceae, the tribe Manihotae, and the sub-family Crotonoideae (Viegas, 1976). In the older literature, it is referred to as Manihot Utilissima. Other common names of the crop include "mandioca", "yuca", "manioc" and "tapioca" (Bellotti and van Schoonhoven, 1985).

The different levels of cyanogenic glucosides it contains in the root has often made varieties to be classified into "sweet" and "bitter" types, but there is no clear-cut demarcation between the two.

1.2 Origin and distribution of cassava

Cassava originated in South and Central America where its widest morphological diversity exists ;(Leon, 1977; Lozano, 1977). Renvoise (1973) reported that sweet cassava may have been domesticated first in Mesoamerica and bitter cassava in northern south America.

The crop was first introduced to the congo basin as early as 1558 by the Portuguese and spread rapidly through what is now Angola, Zaire, Congo and Gabon, and later into West Africa (Jones, 1959). Its introduction to Asia from South America is more recent (Jennings, 1959). It is now grown throughout the tropics between latitudes 30^0N and 30^0S, although the bulk of it is grown between 20^0N and 20^0S (Jones, 1959).

Cassava has been cultivated in Nigeria for over 400 years (Mauny, 1953) and is one of the oldest Nigerian food crops.

1.3 Economic importance of cassava

There are well over 200 Manihot spp., of which M. esculenta is the most important from the nutritional and economic point of view (IITA, 1985). M. esculenta exists only as a cultivated crop, but there are large numbers of wild Manihot spp. The only other species of economic importance is Manihot glaziovii, Ceara rubber, which is used on a very limited scale for production of latex (CIAT, 1985).

Cassava is a major source of food for 300 to 500 million people (Bellotti et al., 1985) especially in developing countries where calorie deficiency and malnutrition are widespread. It ranks fourth as an important source of food energy after rice, sugarcane, and maize in the tropics (FAO, 1980). Cassava storage roots form the basic carbohydrate element of the diet and leaves are eaten as a preferred vegetable in many parts of Africa, providing protein, minerals and vitamins (Hahn, 1984). The bitter varieties are processed and used to make "gari", "atieke"; "chikwangue", "fufu" as the dishes are known in Africa (Silvestre, 1989). The tubers are also used as livestock feed, while other important products of the crop are starch and processed starches such as tapioca (Bellotti and Van Schoonhoven, 1985).

World production is about 157 million tonnes from 15.6 million hectares of land (Mbanaso et al., 1993). FAO (1980) reports indicate that approximately 65% of total production is used for

human consumption, about 19% goes for animal feed, about 5% is for industrial uses and the remainder is wasted.

Nigeria is a leading world producer, accounting for 16% of total world production (FAO, 1990) with the country producing about 26 million tons (FAO, 1991). Cassava is extensively cultivated in Nigeria (Okpala, 1974) providing the daily carbohydrate needs of over half the population and sustains the people during adverse situations when other food crops fail (Okeke and Ene, 1985). Its importance has increased within the country with diversification of its use in industry and as feed for poultry and livestock (Okeke and Ene, 1985).

1.4 Pests and diseases of the cassava plant

Cassava's low average yield of 6.4 t/ha in Africa compared to the world's average of 8.8t/ha is primarily a result of heavy disease and pest infestation in addition to poor soil and crop management practices (Hahn and Theberge, 1985; IITA, 1990).

Whyte (1985) listed some of the important insect pests attacking cassava as the green spider mite (Mononychellus tanajoa), shootfly (Silba pendula), lace bug (Vatiga manihotae), mealybugs (Phenacoccus manihoti and P. herreni), and the white scale (Aonidomytilus albus), with the greatest diversity of the pests in the Americas. The green spider mite and mealybug are the most devastating pests to cassava production in Africa after their accidental introduction to Uganda and Zaire respectively (Bellotti, 1977; Hahn et al., 1979).

A number of cassava diseases have been reported to be of economic importance throughout the world (Lozano and Booth, 1974; Terry, 1982). About 20 fungal diseases have been reported affecting the leaves, stems and roots of cassava. The Cercospora leaf-spots (Cercospora spp.), concentric leafspots (Phyllosticta spp.), superelongation disease (Elsinoe brasiliensis, and anthracnose (Colletotrichum spp.) affect the leaves; Glomerella and Botryodiplodia spp. affect stems; and Phytophthora, Pythium, Sclerotium and Rhizoctonia spp. affect the roots (Hahn et al., 1979; Lozano, 1977).

Lozano and Booth (1974) reported a number of virus and mycoplasma-like diseases of cassava (Manihot esculenta Crantz) including cassava mosaic disease (African mosaic disease) transmitted by the whitefly, Bemisia spp.; cassava common mosaic; cassava broom streak disease; cassava vein mosaic disease; witches brown disease; and latent virus.

The root knot nematode, Meloidogyne spp. may be a serious disease of cassava when grown simultaneously in the field with okra or eggplant (Luc and Deguiran, 1968).

Several bacterial species have been reported on cassava (Terry and McIntyre, 1976) but only Xanthomonas campestris pv. manihotis, causal organism of cassava bacterial blight (Terry, 1973a); Xanthomonas campestris pv. cassavae, causal organism of cassava bacterial leafspot (Wiehe and Dowson, 1953); Erwinia carotovora var. carotovora (Erwinia cassavae), causal organism of cassava bacterial stem rot (Maraite and Meyer, 1975; Mattos, 1977); and

Agrobacterium sp., responsible for bacterial stem gall (Heys, 1975) have been established as being truely pathogenic to cassava.

Cassava diseases of major importance in Africa are cassava mosaic disease, cassava bacterial blight, (CBB) and cassava anthracnose disease (Hahn and Theberge, 1985).

Major cassava diseases in Nigeria are six pre-harvest fungal diseases caused by Cercospora henningsii., C. caribea, Phyllosticta sp., Oidium manihotis, Glomerella manihotis, Uromyces sp.; four pre-harvest bacterial diseases caused by Xanthomonas campestris pv. manihotis, Bacterium cassavae, Xanthomonas campestris pv. cassavae. Bacterium tabaci; three pre-harvest viral diseases: cassava mosaic disease, cassava brown streak, cassava latent virus; and cassava rot diseases associated with four major fungal pathogens: Sclerotium rolfsii, Fomes lignosus, Phytophthora sp.and Roselina necatrix, as well as the bacteria, Bacillus sp. and Corynebacterium sp. (Arene, 1990).

Cassava bacterial blight is the most important of several bacterial diseases of cassava (Costa, 1940; IITA, 1972; Lozano, 1972; Pereira and Zagatto, 1967). The disease was first observed in Nigeria in 1972 in many locations in the central and southern regions (Williams et al., 1973). Erinle (1981) reported its occurrence in all areas of Nigeria. The highest incidence was observed in the then East-Central and Mid-Western states where 100% crop losses were recorded (Terry, 1975). Losses due to CBB range from 20 to 100% depending upon the cultivar, bacterial strain and environmental conditions (IITA, 1985). Thus CBB is a contributory

factor to Nigeria's average yield of 9.5t/ha compared to a potential yield of 37.5t/ha (FAO, 1973).

1.5 Objectives of the investigation

Cassava production has intensified in the drier savannas of Nigeria during the last twenty years where traditional "sweet" types are being grown alongside "bitter" types (Erinle, personal communication). Often, cassava is the only surviving crop on upland sites during the dry season and consequent upon their perceived importance, farmers often erect fences around their cassava crops to prevent livestock encroachment.

From casual observations, CBB is a very serious limiting factor to production of cassava in the semi-arid zones of Nigeria but there are no reports to confirm this. it is in the light of this that a detailed work on this disease was deemed necessary. The objectives of the study include the following:

(i) A survey to assess the level of disease incidence and severity.

(ii) To determine the effect of planting date and inter-cropping of cassava with maize on the incidence and severity of the disease.

(iii) To screen cassava varieties (local and improved) for resistance to the blight disease, and

(iv) To determine the longevity and population dynamics of the pathogen in infected leaf trash.

2. LITERATURE REVIEW

2.1 Nomenclature

The causal organism of CBB is Xanthomonas campestris pv. manihotis Dowson. The pathogen was first named Bacillus manihotis (Arthaud-Berthet (Bondar, 1912) and later Phytomonas manihotis (Arthaud-Berthet and Bondar) Viegas (Viegas, 1940). Later, Starr (1946) changed the name to Xanthomonas manihotis (Arthaud-Berthet) Starr (Bergey, 1957). Studies of the bacterium isolated in Colombia, Brazil and Venezuela revealed that the three strains of Phytomonas manihotis were sufficiently different from Xanthomonas manihotis to be considered a separate strain (CIAT, 1971, CIAT, 1972; Lozano, 1972; Lozano and Sequeira, 1974a). Lozano and Sequeira (1974a) described the characteristics of the causal organism and indicated that the cassava blight bacterium should be considered as a strain of Xanthomonas manihotis.

2.1.1 Pathogenic variability

Studies carried out during four years from plantations in Africa, Asia and America to determine the virulence of 52 strains of X. c. pv. manihotis suggest the presence of strains of the pathogen differing in virulence (CIAT, 1976).

Verdier et al. (1993) investigated the establishment of virulent and avirulent strains of Xanthomonas campestris pv . manihotis on leaves of in-vitro cassava plants and found that, within six days the aggressive strain increased rapidly and lesions developed on the leaves while the non-aggressive strain did not lead to visible alterations in leaf tissues.

2.1.2 Distribution and host range

The disease was first recorded in Brazil in 1912 (Bondar, 1912) but has since been reported in Colombia and Venezuela (Lazano, 1972; Lozano and Sequeira, 1974a and b), Nigeria (IITA, 1972) Zaire (Hahn and Williams, 1973), Cameroon (Terry, 1975), and also been observed in several other countries of tropical America and Africa (Lozano, 1975).

It has only been reported in species and varieties of the genus Manihot (Amaral, 1942; Bondar, 1915; Burkholder, 1942).

2.1.3 Economic Importance of CBB

CBB is the most important of several bacterial diseases of cassava (Costa, 1940; IITA, 1972; Lozano, 1972; Pereira and Zagatto, 1967). The disease has caused severe losses in several Latin American countries and Africa where epiphytotics have been recorded in the most important cassava growing areas (CIAT, 1985). The disease has been recognised as one of the most important factors limiting production in affected areas, where in wet seasons it can result in complete loss of yield (Costa, 1940; Lozano, 1972; Lozano and Sequeira, 1974a; Pereira and Zagatto, 1967). Cock (1974) reported a reduction in yield from 47t/ha to 25t/ha in susceptible clones.

2.2 Symptoms of CBB

The bacterium penetrates the host via stomatal openings or through wounds (Lozano, 1972; Lozano and Sequeira, 1974a and b). Following penetration, the organism finds its way into the vascular system, where bacterial cells are able to move systemically

throughout the plant (Lozano, 1972; Lozano and Sequeira, 1974a).

In general, symptoms develop within 11-13 days after infection (Lozano, 1972; Lozano and Sequeira 1974a and b). Symptoms of the disease are characterized by angular leaf spotting and blight, wilting, defoliation, die-back, gum exudation, and stem and root vascular necrosis (Lozano, 1975). Leafspots appear initially as water-soaked angular areas and later become brown or dark-brown (Plates 1 and 2) and sometimes depending upon the susceptibility of the cultivar, a yellow halo surrounding the spots is clearly noticeable (Lozano, 1975). Dry rotting of stems and roots caused by the disease has also been reported (Lozano, 1975).

Hahn (1978) indicated that as plants become older, the tip die-back symptom of CBB increases and older, lower leaves exhibit more serious symptoms than younger ones. Young plants are more susceptible than older ones. Severe attack results in rapid defoliation of the plant, leaving bare stems commonly referred to as "candle sticks" (IITA, 1990).

2.3 Epidemiology

2.3.1 Transmission

Amaral (1945) suggested the possibility of the pathogen spreading from one area to another by the use of infected cuttings. Lozano (1972) and Lozano and Sequeira (1974b) confirmed this and also indicated that splashing rain is the most important means of dissemintion in localised areas. This accounts for the increased incidence of the disease in the rainy season (Drummond and Hipolito, 1940-41). Contaminated irrigation water has been

considered to be of minor importance (Lozano, 1975). The pathogen can also be spread through true seeds taken from infected crops (CIAT, 1981).



Plate 1: Leaf of local cassava variety showing extensive blight and water-soaked angular spots (lower surface)



Plate 2: Extensive blight in leaves of TMS 91934 (upper surface).

The spread of the pathogen by soil movement during cultural operations or by the use of contaminated tools during pruning has been suggested by some workers (Carneiro, 1940; Drummond and Hipolito, 1940-41; Pereira and Zagatto, 1967). Other suggestions on the use of contaminated tools in the bacterial dissemination have also been made (Lozano, 1972; Lozano and Sequeira, 1974a and b).

Insects have also been suggested as possible agents of dissemination (Amaral, 1945). This has been demonstrated at CIAT (Lozano, 1975) but the spread attributed to insects only occur over short distances (CIAT, 1972; Lozano, 1972; Lozano and Sequeira, 1974b). It has also been observed that mouth parts and appendages of the variegated grasshopper (Zonocerus variegatus) become contaminated with moist bacterial exudate (Terry, 1974b); it thus seems likely that they may aid in spreading the disease.

Possible dissemination of the pathogen by the movement of man, animals and insects through the crop has also been suggested (Lozano, 1975).

2.3.2 Favourable weather conditions for disease development

Lozano (1972) found that, at least 12 hours at 100% relative humidity are required for the bacterial establishment following artificial inoculation experiments. During dry periods, disease development slows down, little gum containing bacteria is exuded and hence spread of the disease is halted, but the bacteria remain viable in the plant and become active during subsequent rainy periods (Lozano, 1975).

The optimum temperature for growth and development of Xanthomonas campestris pv. manihotis has been shown to be 30°C (UCL/IITA, 1980). CBB severity, however, is higher is cooler areas where the day and night temperatures average 20-25°C and where night and day temperatures are 15-20°C and 20-30°C, respectively (Takatsu et al., 1979). Hahn and Theberge (1985) also reported that CBB severity is higher in cooler areas where day and night temperatures average 20-30°C.

2.4 Survival of the Pathogen

Xanthomonas campestris pv. manihotis does not survive in the soil but in the bacterial exudate and infected plant parts. This was demonstrated by Ikotun (1975, 1977, 1982) in the laboratory and greenhouse studies and confirmed by Terry (1974a, 1976). Other reports (Lozano, 1975; Arene, 1976) indicate a short survival of the pathogen in the soil.

The pathogen can survive for up to 6 months in plant debris but its survival time is reduced by flooding or desiccation (CIAT, 1976). The pathogen is unable to survive for more than a few weeks in debris in the soil kept at field capacity, but can survive several months if the soil remains dry (Persley, 1978). Amusa et al. (1992), using three sources of the inoculum: infected plant debris, plastic mulch material and the soil showed that the bacterial population was high in the rainy season and low in the dry months in a field fallowed for one year under mucuna. Ikotun (1977) showed that, Xanthomonas campestris pv. manihotis survived for up to 24 months in field-collected bacterial ooze, for 30

months in infected stems and for 6 months in infected leaves. The bacterial cells within pellets remained infective after 22 months' dry storage at room temperature (IITA, 1976). Studies by Persley (1978) in three geographical regions of Nigeria (forest, forest/savanna, savanna) revealed that, debris collected beneath dead plants at 5 months yielded the pathogen.

It has also been suggested that a low population of the pathogen can survive the dry season as epiphyte (IITA, 1976) following detection of an epiphytic population of X. c. pv. manihotis on the surface of apparently healthy leaves during the dry season (January) and also during the growing (rainy) season (June).

2.5 CBB in cassava intercrops

At least a third of cassava is planted in mixed culture worldwide (Cock, 1985). The use of cassava as a component of mixed cropping systems is a common practice in Brazil (Porto et al., 1979) and in various countries in Asia (Chew, 1979. Effendi, 1979; Sinthuprama, 1979), Africa (Ezeilo, 1979), and Latin America (Moreno and Hart, 1979; Thung and Cock, 1979).

Estimates of the incidence of CBB made in Nigeria during field surveys range from 14% in cassava plots interplanted with both maize and melon to 100% with cassava as a sole crop (Terry, 1973b). Experiments carried out at Umudike, Nigeria have shown that intercropping cassava with maize and melon reduced the disease while the highest incidence (22.8%) occurred in sole cassava plantings (Arene, 1977).

Cassava yields are usually 6-8t/ha in mixed cropping and 10-12t/ha in sole cropping against experimental yields of 15-20t/ha and 25-30t/ha in the former and the latter cropping systems respectively (Mbanaso et al., 1993). Higher returns and a greater number of calories have been reported from the following complex mixtures: cassava/maize/melon; cassava/maize/okra/melon; cassava/maize/okra/cowpea (IITA, 1990).

2.6 Control of CBB

2.6.1 Pruning

Delay in spread of the disease by pruning most of the above ground portion of infected plants has been reported (CIAT, 1972; Lozano, 1972; Lozano and Sequeira, 1974b). However, the success of this method depends on the susceptibility of the cultivar and the interval between initial infection and pruning (Lozano, 1975).

2.6.2 Sanitation

The complete control of CBB and exclusion of the pathogen by the use of clean "seed" has been suggested (Carneiro, 1940; Drummond and Hipolito, 1940-41; and Gonclaves, 1948). A successful means of producing bacteria-free "seed" has been established (Lozano, 1975). Amusa et al. (1992) suggested that, after harvesting infected plant debris, the infested plastic mulch material should be collected together and burnt, and the soil should be turned over and left fallow.

2.6.3 Cultural Practice

The use of crop rotation has been suggested as a possible means of control (Carneiro, 1940). Drummond-Gonclaves (1948)

recommended a 4-5 year crop rotation, but Lozano and Booth (1974) suggested a six-month fallow period while Leu and Chen (1972) recommended that plants be replanted on the same site on the same day after harvest. However, young cassava plants grown on bare ridged soils have been reported to develop CBB in plots that had been left to mucuna fallow for one year (Amusa et al., 1992).

2.6.4 Resistant cultivars

Control of bacterial blight by the use of resistant cultivars was first suggested by Gonclaves (1948) and numerous resistant cultivars have been reported (Carneiro, 1940; Drummond and Gonclaves, 1953; Pereira and Zagatto, 1967).

Some cassava varieties which are low in cyanide levels and resistant to various viral, bacterial and fungal diseases and widely adopted in Nigeria are: TMS 30572, TMS 30555, TMS 4(2)1425, TMS 50395, TMS 63397 and TMS 91934 (Otto, 1989).

2.6.5 Biological control

Both the number of angular leaf spots per leaf and the number of blighted leaves per plant have been significantly reduced by foliar applications of a strain of Pseudomonas putida on three cassava clones of varying susceptibility (Lozano and Laberry, 1993). The yield of the most susceptible clone (MCol 22) increased 2.7 times following such a control.

2.6.6. Physical control

Control by the use of physical treatments such as exposure to hot air, hot water, microwaves, and ultraviolet light for the inactivation of bacteria in infected planting material have so far given negative results (Lozano, 1975).

3. A SRUVEY OF THE INCIDENCE AND SEVERITY OF CASSAVA BACTERIAL BLIGHT IN SOME SAVANNA AREAS OF NIGERIA IN 1993

3.1 Introduction

Cassava bacterial blight (CBB) induced by Xanthomonas campestris pv. manihotis is the most devastating bacterial disease of cassava (Hahn et al., 1989). The disease was first observed in Nigeria in 1972 in many locations in the central and southern regions (Williams et al., 1973) and later reported to occur in all areas of the country (Erinle, 1981). CBB is more widespread and damaging in the savanna and forest/savanna transitional zones than in the forest zone (Persley, 1977). It was therefore necessary to determine if there were any variations in the incidence and severity of the disease in some cassava-growing regions of the Nigerian Guinea savannas and to identify some of the factors that were responsible for such variations.

3.2 Materials and method

The survey was conducted in some cassava-growing areas in the Northern Guinea Savanna (NGS) and Southern Guinea Savanna (SGS) zones of Nigeria. Since most farmers usually plant cassava in the middle of the rainy season (mid-June to end of June), this survey was conducted at the end of the rains between the 28th of September and 30th of October 1993 (on local and improved farmers' fields) depending on the location visited.

A random sampling procedure was adopted with a view to presenting an adequate overall disease picture of the farms and to enable data to be analysed statistically. Small farms (less than

300m^2) were entirely evaluated for cassava bacterial blight (CBB) incidence and severity. Larger farms (equal to or greater than 300m^2) were divided by visual approximation into four quadrants and twenty plant stands from two neighbouring ridges were assessed for the disease from each quadrant. On the whole, 40 farms were visited and assessed for the incidence and severity of CBB. Other parameters recorded on each farm included the crop mixture, cassava cultivar (local or improved), cassava spacing, and the age of the plant.

A disease severity scale of 1-5 was used (IITA, 1990) as follows:

1. no symptoms
2. only angular leafspot
3. extensive leaf blight, wilt, defoliation, gum exudation on stem and petioles
4. extensive leaf blight, wilt, defoliation and stem die-back
5. complete defoliation and stem die-back, plus stunting and die-back of lateral shoots.

The mean disease score for each farm survey was calculated from the raw data.

$$\text{Mean disease score} = \frac{\text{Sum of all disease scores}}{\text{Total number of stands observed}}$$

Disease incidence is expressed as percentage of diseased plants relative to the total number of stands.

$$\text{Percentage diseased plant stands} = \frac{\text{Total no. of plants infected}}{\text{Total no. of stands observed}} \times 100$$

Data was analysed statistically on a completely randomized design and significant differences evaluated by the t test (Snedecor and Cochran, 1967) because of the differences in the number of plots assessed on various sites.

3.3 Results and discussion

The results of the 1993 survey are presented in Table 3.1. The differences between the means of locations (sites) in relation to both disease incidence and severity were highly significant ($P = 0.01$).

The Abuja environs in the SGS recorded higher means of both disease incidence and severity than the three areas in the NGS (Table 3.2). The differences between the means of areas in relation to disease incidence and severity were significant and highly significant respectively. Disease incidence and severity were generally high in all four areas visited. This is in partial agreement with the report of Persley (1977). However, some variation was observed at any one environ visited.

CBB incidence and severity were generally higher in sole than in intercropped cassava farms. The highest disease incidence (100%) in sole cassava cropping system was recorded in Abuja environs, Zaria-Saminaka, and Zaria-Funtua areas but this did not differ significantly from the highest mean disease incidence (98.28%) recorded on the University Farm in the Zaria environs in the same sole cassava cropping system. Sole cassava farms of Sako (Zaria-Saminaka road) and Tudu Ngyia (Zaria-Funtua road) registered the lowest means of CBB incidence (0%) and CBB rity score (1.0)

Table 3.1: Incidence and severity of cassava bacterial blight at four cassava-growing areas in 1993.

Serial No.	Site	Area	Farm size (m^2)	Cropping pattern	Cassava cultivar	Cassava spacing (m)	Age of cultivar (months)	Mean disease incidence (%)	Mean disease severity score
1.	University farm	Zaria environ	270	cassava/maize	local	1.0x1.0	3	77.51ab	2.391bc
2.	"	"	150	"	improved	"	"	42.46abc	1.68def
3.	"	"	600	scle cassava	local & improved	0.5x1.0	"	92.93a	2.90a
4.	"	"	105	"	improved	"	"	98.28a	2.92a
5.	Samaru	"	100	cassava/yam	local	"	12	25.00bc	1.50def
6.	"	"	130	cassava/maize/ okra/potato	"	1.0x1.0	4-5	44.44abc	1.89bcde
7.	"	"	400	cassava/pepper/ okra/cowpea	"	"	3-4	20.00bc	1.29def
8.	"	"	600	cassava/pepper/ g.corn	"	.75x1.0	4-5	18.75bc	1.38def
9	-	Abuja environ	450	cassava/maize/ yam	improved	.75x1.0	12	80.00ab	2.80ab
10.	-	"	15	sole cassava	local	0.5x0.5	3	100.00a	3.20a
11.	-	"	300	"	local & improved	.75x.75	4	75.00ab	2.63abc

12.	-	"	"	cassava/banana	local	0.5x1.0	4	100.00a	3.20a
13.	-	"	45	sole cassava	local	0.5x0.5	12	100.00a	3.20a
14.	-	"	600	cassava/maize	local & improved	1.0x1.0	4-5	100.00a	3.00a
15.	Yakasi	Zaria-Saminaka road	900	cassava/cowpea	local	0.5x1.0	2-3	14.29bc	1.29def
16.	Wanka	"	2500	sole cassava	"	0.5x.75	4-5	100.00a	3.00a
17.	Wanka	"	2500	sole cassava	local	0.5x.75	2-3	63.33ab	2.30abcd
18.	Maigana	"	5600	"	"	1.0x1.0	5-6	65.00ab	2.30abcd
19.	Sako	Zaria-Saminaka road	300	sole cassava	local	0.5x1.0	12	66.50ab	2.33abcd
20.	"	"	900	"	"	"	2	0c	1.00f
21.	"	"	1200	"	"	"	3-4	55.00abc	2.10bcde
22.	"	"	3000	"	"	"	5-6	95.00a	3.00a
23.	Don Sowe	"	3200	"	"	"	4-5	85.71a	2.71ab
	Saminaka	"	2000	cassava/maize	"	"	"	75.00ab	2.50abc
	"	"	1400	"	"	"	"	75.00ab	2.50abc
	"	"	70	sole cassava	"	"	3-4	75.00ab	2.55abc
27.	"	"	150	sole cassava	"	"	"	85.00a	2.65abc
28.	"	"	120	cassava/maize/ egg plt.	"	"	"	65.00ab	2.30abcd

29.	"	"	300	sole cassava	"	"	2-3	6.67c	1.13ef
30.	"	"	90	cassava/g.corn	"	.75x1.5	4-5	65.00ab	2.30abcd
31.	Tashar Zomo	Zaria-Funtua road	400	sole cassava	"	0.5x.75	3-4	80.00ab	2.68abc
32.	Tashar Zomo	Zaria-Funtua Road	1600	sole cassava	local	0.5x.75	3-4	88.00a	2.76ab
33.	"	"	280	cassava/cowpea	"	0.5x1.0	"	20.00bc	1.40def
34.	"	"	150	sole cassava	"	"	6-7	100.00a	3.00a
35.	Gangara	"	1400	"	"	"	5-6	36.37bc	1.73cdef
36.	"	"	2500	"	"	"	3-4	76.67ab	2.53abc
37.	Tudu Ngyia	"	2400	"	"	"	2-3	0c	1.00f
38.	"	"	4500	"	"	"	4-5	33.75bc	1.68def
39.	"	"	4500	"	"	"	3-4	36.53bc	1.73cdef
40.	"	"	2400	"	"	"	5-7	68.89ab	2.38abc

Column values followed by the same letter(s) are not significantly different (P=0.01).

Table 3.2: Summary of mean incidence and severity of cassava bacterial blight in the four areas surveyed in 1993.

Area surveyed	Mean disease incidence (%)	Mean disease severity score (1-5)
Zaria environs	68.00ab	2.34b
Abuja environs	90.00a	3.04a
Zaria-Saminaka road	59.31b	2.22b
Zaria-Funtua road	49.00b	2.01b

Column values followed by the same letter(s) are not significantly different (P=0.05)

which however, did not differ significantly from means obtained on the same type of farm in Saminaka (6.67 for disease incidence and 1.13 for disease severity score) and Tudu Ngyia (33.75% for CBB incidence and 1.68 for CBB severity score). The cassava/banana mixture in the Abuja environs recorded the highest means of both CBB incidence (100%) and severity score (3.20), closely followed by the cassava/maize mixture (100% CBB incidence and 3.0 for CBB severity score) in the same area. There was no significant difference between these means and lower means (80% CBB incidence and 2.8 for CBB severity score) recorded on the cassava/maize/yam mixture in the Abuja environs, as well as those registered on the local cassava cultivar/maize mixture (77.51% CBB incidence and 2.39 for CBB severity score) on the University farm in Zaria.

The high incidence and severity of CBB in some mixed cropping combinations may be due to other factors such as the cassava cultivar, bacterial strain or favourable environmental conditions (IITA, 1985). The other component(s) of the mixture and the time of introduction of the component(s) could also influence the incidence and severity of the disease. For example, the high incidence and severity of CBB in the cassava/banana mixture was probably as a result of the low banana plant population density and/or the late introduction of cassava relative to the establishment of the banana plants. On the contrary, the cowpea plant provides a higher population density which may have reduced field spread of CBB, hence low values of disease incidence.

With reference to the type of cultivar, the highest means of CBB incidence (100%) and severity score (3.20) were recorded on a farm with local cultivar. There was however, no significant difference between the means of this cultivar and the improved cultivar which recorded the highest means of CBB incidence (98.28%) and severity score (2.92) on the University farm in Zaria. The lowest means of disease incidence (42.46%) and severity score (1.68) in relation to improved cassava cultivar were recorded on another site on the University farm, but the mean disease incidence did not significantly differ from the mean of other farms with improved cassava cultivar. The difference between the means in relation to mean disease severity score was however, highly significant (P = 0.01).

Farms with a mixture of both local and improved cassava cultivars recorded relatively higher means of disease incidence and severity score compared to farms with only improved cassava cultivar, suggesting that, the local cultivar probably constituted a source of inoculum to the improved cultivar. The highest means of disease incidence (100%) and severity score (3.0) in relation to mixtures of local and improved cassava cultivars were recorded in the Abuja environ followed by those of the University farm, and lastly by those of another farm in the Abuja environ. The differences between the means with respect to disease incidence and severity score on all three farms were not significant.

The means of both disease incidence and severity score were generally higher on farms with cassava stands having a spacing of

0.50m x 0.50m and 0.50m x 1.0m than those with a spacing of 0.75m x 1.0m and 1.0m x 1.0m but the differences between these means were not significant. There was however, some variation among farms having the same spacing of cassava stands suggesting that other parameters like crop mixture (Terry, 1973a), cassava cultivar, bacterial strain and environmental conditions (IITA, 1985) were probably responsible for such variations.

There were significant differences between means of 2-3 months old cassava plants and those more than three months in relation to disease incidence and severity score with the former recording higher values. This agrees with a report of IITA (1990) that, the manifestation of the severity of CBB depends on plant age and time of evaluation.

The results of this investigation indicate that CBB is more widespread and severe in some parts of the Nigerian savanna than others. Often, farmers have the tendency of transferring cuttings from one location to another with the view to meet the planting requirements of an area. This operation enhances the spread, development and even severity of bacterial blight in areas previously not affected or where it was minimal. It is therefore necessary to encourage the rapid propagation of resistant germplasm and their distribution.

4. EFFECT OF SOME CULTURAL PRACTICES ON THE INCIDENCE AND SEVERITY OF CBB

4.1 Introduction

CBB incidence has been shown to be greatly influenced by rainfall patterns and has been demonstrated to be highest during heavy rains (Arene, 1972; Terry, 1976). Manipulation of planting has therefore been recommended as a means of control. Ezumah and Terry (1974a) recommended that planting should be just prior to the dry season or soon after the first rain of the year. Satisfactory control has also been achieved by planting early, before the heavy rains, with maize and melon as intercrops (Arene, 1990).

Results of several cassava-based intercropping studies have shown that land productivity is higher under intercropping of maize-cassava, bean-cassava and cowpea-cassava than monocropping of maize or cowpea (IITA, 1974; CIAT, 1975; Okigbo, 1977). Terry (1973b) and Arene (1977) reported lower incidences of CBB in cassava/maize/melon mixtures than in sole cassava plantings.

Based on the rainfall pattern in the Northern Guinea Savanna zone (900-1400mm/annum, falling mostly between May and October), it was therefore necessary to establish the effects of planting date and intercropping of cassava with maize as well as the time of introduction of the components of the mixture on the incidence and severity of the disease.

4.2 Materials and method

One local and one improved cassava varieties were used. Each variety was tested in two separate trials on the same site.

4.2.1 Local Variety

Cuttings of approximately 20cm length were planted on the crest of 5m long ridges at a spacing of 1m x 1m. Plot size was $5m^2$. Maize, variety TZB, was sown on one side of the ridge at a rate of two seeds per hole and a spacing of 50cm, on various dates (Table 4.1). Approximately 52.5kg/ha of NPK (15-15-15) fertilizer was applied by side dressing on both cassava and maize plants three weeks after planting (WAP). The experiment was laid out in a Randomized Complete Block Design (RCBD) comprising three dates of planting treatments viz: 3rd July 1993; 17th July 1993 and 31st July 1993 in nine replicates. With respect to cropping pattern, there were five treatments designated as A,B,C,D and E respectively (Plates 3,4 and 5).

A sole cassava ridge was maintained at the beginning of each replication as control and to enhance natural field infection. Assessment of the incidence and severity of bacterial blight on plants was done as outline earlier (Section 3.2). The data was analysed statistically and differences between means determined with Duncan's Multiple Range Test (Duncan, 1955).

4.2.2 Improved Variety

The improved cassava variety, TMS 4(2)1425 and maize variety TZB were used. The procedure was as outlined for local variety above, but there were only two planting dates corresponding to the last two dates of the local variety (17th July 1993 and 31st July 1993) and four cropping patterns or treatments (T1, T2, T3, T4) in six replicates (Table 4.2).



Plate 3: Local cassava variety intercropped with maize.



Plate 4: Healthy local cassava plant in maize intercrop.



Plat 5: Diseased local cassava plant in maize intercrop.

4.3 Results and Discussion

4.3.1 Local Variety

The results of the 1993 field trial are presented in Table 4.1.

4.3.1.1 Planting date

CBB incidence and severity score were generally higher in plants evaluated 14WAP than the same plants evaluated 8WAP but the differences between these means were not significant. The means of CBB incidence and severity score for July 3rd (A) plants were greater than those for July 17th (C) plants, however, there were no significant differences between them. These were followed by July 31st (D) plants whose means were significantly ($P = 0.01$) lower than those of A and C plants. The lower means of CBB incidence and severity for C and D plants compared to those of A plants were correlated to the decrease in the amount of rainfall and relative humidity (Table 4.3) following late planting.

This experiment has demonstrated that the number of plants infected and the severity of the disease were significantly decreased with late planting. With reference to cassava crops planted on July 3rd (A), planting on July 17th (C) and July 31st (D) in the same year reduced the number of plants infected by 9.4% and 54.7% respectively and decreased the severity of CBB by 9.8% and 38.7% respectively.

Disease incidence and severity for July 3rd plants were greater than those of July 17th plants probably because both maize and cassava were planted at the same time (contrary to 17th and 31st July plants in which maize was planted two weeks before

cassava) with the result that, the maize plant (in A) was not sufficiently established leading to a low population density which did not sufficiently reduce the dissemination of the CBB pathogen which is known to occur through rain splash (Lozano and Sequeira, 1974b).

Table 4.1 Effects of planting date and intercropping on the incidence and severity of bacterial blight on a local cultivar during the 1993 wet season.

Cropping Pattern	Mean disease incidence (%)					Mean disease severity score (1-5)				
	8WAP	10WAP	12WAP	14WAP	Mean*	8WAP	10WAP	12WAP	14WAP	Mean*
A	88.89^{ab}	91.66^{a}	91.66^{a}	91.66^{a}	90.97^{a}	2.73^{ab}	2.92^{ab}	2.92^{a}	2.92^{ab}	2.87^{a}
B	88.89^{ab}	91.78^{a}	91.78^{a}	91.78^{a}	91.19^{a}	2.61^{ab}	2.84^{ab}	2.92^{a}	2.92^{a}	2.82^{a}
C	74.44^{b}	85.00^{a}	85.00^{a}	85.00^{a}	82.36^{a}	2.26^{b}	2.62^{b}	2.74^{a}	2.74^{b}	2.59^{a}
D	35.33^{c}	43.11^{b}	43.11^{b}	43.11^{b}	41.17^{b}	1.51^{c}	1.80^{c}	1.86^{b}	1.86^{c}	1.76^{b}
E	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	2.85^{a}	3.04^{a}	3.12^{a}	3.20^{a}	3.05^{a}

* Column values followed by the same superscript(s) are not significantly different at P = 0.01, using Duncan's Multiple Range Test (DMRT).

Legend:

A - Cassava and maize planted on July 3rd

B - Cassava planted on July 3rd and maize on July 17th

C - Maize planted on July 3rd and cassava on July 17th

D - Maize planted on July 17th and cassava on July 31st

E - Sole cassava planted on July 17th

Table 4.2

Effects of planting date and intercropping on the incidence and severity of bacterial blight on an improved cassava cultivar (TMS 4(2)1425) during the 1993 wet season.

Cropping Pattern	Mean disease incidence (%)					Mean disease severity score (1-5)				
	8WAP	10WAP	12WAP	14WAP	Mean*	8WAP	10WAP	12WAP	14WAP	Mean*
T1	28.50^{b}	45.83^{b}	49.16^{b}	52.50^{b}	44.00^{b}	1.45^{b}	1.85^{b}	1.98^{b}	2.01^{b}	1.82^{b}
T2	44.16^{ab}	50.83^{b}	50.83^{b}	50.83^{b}	49.16^{b}	1.62^{b}	1.91^{b}	2.01^{b}	2.08^{b}	1.91^{b}
T3	24.16^{b}	27.50^{b}	37.33^{b}	37.33^{b}	31.58^{b}	16.33^{b}	1.55^{b}	1.55^{b}	1.73^{b}	1.54^{b}
T4	73.00^{a}	87.00^{a}	87.00^{a}	87.00^{a}	83.50^{a}	2.30^{a}	2.61^{a}	2.73^{a}	2.73^{a}	2.59^{a}

* Column values followed by the same superscript(s) are not significantly different at P = 0.01, using Duncan's Multiple Range Test (DMRT).

Legend:

T1 - Cassava and maize planted on July 17th

T2 - Cassava planted on July 17th and maize on July 31st

T3 - Maize planted on July 17th and cassava on July 31st

T4 - Sole cassava planted on July 17th

Table 4.3: Weather records in Samaru* during the field experimental periods: 1993.

Months	Rain fall (mm)	Mean temp. (°C)		% R.H.		Sunshine hours	Wind-speed (km/h)
		Max.	Min.	10a.m	4p.m		
July	269.0	29.5	20.2	78.4	56.7	6.6	166.80
August	300.8	28.4	19.5	81.8	62.1	5.0	132.03
September	181.8	30.2	19.3	76.7	58.2	7.0	71.55
October	32.4	34.1	18.7	63.1	54.0	8.4	70.27

* Data were taken at the weather station in the IAR farm close to Shika.

4.3.1.2 Intercropping

The sole cassava treatment (E) (Table 4.1) recorded the highest disease incidence (100%) eight weeks after planting (WAP). All other treatments recorded higher CBB incidence 10WAP compared with those recorded at 8WAP but the differences were not significant (P = 0.01). The disease did not spread beyond the incidence recorded at 10WAP. The means of CBB severity score obtained 12WAP were higher than those recorded 10WAP for all treatments except for treatment A. Disease severity did not increase following 12WAP in all the mixtures except in the sole cassava.

With respect to means of CBB incidence and severity score (Table 4.1), treatment E had the highest mean, followed by treatments A, B and C in that order but there were no significant differences between these means. Treatment D recorded the lowest mean for both CBB incidence and severity. With respect to sole cassava plantings (E), planting maize two weeks before cassava (C) reduced the incidence and severity of the disease by 17.6% and 15.1% respectively. Within the cassava-maize intercrops, with respect to simultaneous planting of cassava and maize (A), planting maize two weeks after cassava (B) increased the disease incidence by 0.2% and reduced the severity by 1.7%. On the other hand, planting cassava two weeks after maize (C) reduced both CBB incidence and severity by 9.5% and 9.8% respectively with respect to simultaneous planting of cassava and maize.

4.3.2 Improved Variety

The results of the 1993 field trial are shown in table 4.2.

4.3.2.1 Planting date

The means of both CBB incidence and severity were lower for July 31st plants (T3) than July 17th plants (T2). However, the differences between these means were not significant (P = 0.01). Late planting therefore, decreased CBB incidence and severity and these were probably due to the decrease in the amount of rainfall and relative humidity (Table 4.3).

4.3.2.2 Intercropping

In general, the means of CBB incidence and severity for the treatments at 14WAP were higher than those recorded at 8WAP (Table 4.2) but the differences between these means were not significant. Treatment T4 registered the highest means of CBB incidence and severity. This was followed by treatment T2, T1 and T3 in that order, whose means did not significantly differ from those of treatment T4. With respect to sole cassava planting (T4), planting maize two weeks after cassava (T2) reduced both CBB incidence and severity by 41.1% and 26.3% respectively. With reference to simultaneous planting of cassava and maize (T1), planting maize two weeks after cassava (T2) increased CBB incidence and severity by 11.7% and 5.0% respectively. In contrast, CBB incidence and severity were reduced by 28.2% and 15.4% respectively when cassava was planted two weeks after maize (T3).

In both trials, CBB incidence and severity were reduced in the intercrops with the decrease being non significant in the local variety but significant in the improved variety. On the other hand, incidence and severity of the disease were higher in the sole cassava with the increase being non significant in the local variety but highly significant (P = 0.01) in the improved variety.

5. EVALUATION OF CASSAVA VARIETIES FOR RESISTANCE TO BACTERIAL BLIGHT

5.1. Introduction

Cassava bacterial blight (CBB) has been reported to cause losses ranging from 20 to 100% depending upon the cultivar, bacterial strain and environmental conditions (IITA, 1985). Otoo (1989) listed some cassava varieties low in cyanide level and resistant to various viral, bacterial and fungal diseases and widely adopted in Nigeria. The level of susceptibility or resistance of some of the materials in the savanna regions of Nigeria has not been determined previously. It was against this background that some randomly selected cultivars were evaluated for their resistance to bacterial blight.

5.2. Materials and method

5.2.1. 1992 Wet Season Trials

5.2.1.1. On the I.A.R. Research Farm, Samaru, Zaria

A field trial was conducted during the months of July-October in which six varieties of cassava (TMS 91934, TMS 30001, TMS 30572, TMS 4(2)1425, 60506 and local) were screened for resistance to bacterial blight under natural field infection. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The plot size was 3m x 5m, consisting of three ridges spaced 1m apart.

Each plot was surrounded by a guard row of 2m wide. Cassava cuttings of approximately 25cm length were planted on 14 July 1992 at a spacing of 1m on the ridges.

Assessment of the incidence and severity of bacterial blight was done as outlined in section 3.2, from eight weeks after planting (WAP) to 14WAP.

5.2.1.2. On the University farm, Shika, Zaria

Two cassava farms of IITA's experiments were assessed as follows:

5.2.1.2.1 Twenty-nine varieties established from rooted cuttings

These were planted on 10 July 1992 at a spacing of 1m x 1m on 20m long ridges.

5.2.1.2.2 Fifty-three varieties established from "true" seeds

These were sown in June and transplanted on 13 July 1992 at a spacing of 0.5m x 1.0m on 20m long ridges.

Both experiments were laid out in a Completely Randomized Design (CRD) and were assessed at the end of September 1992 for CBB severity as outlined in section 3.2.

5.2.2 1993 Trials

5.2.2.1 Pot Experiments

The pot trial was conducted during the months of March-June in Samaru, Zaria for comparison of results with the six varieties tested on the field during the previous year. Clay pots were filled with heat sterilized soil and cassava cuttings, 20-25cm long, of each of the six varieties was planted on 26 March 1993 in pots. The pots were arranged in a completely randomized design in the open air and were watered daily throughout the duration of the experiment.

Plants were inoculated 6WAP in the evening with a suspension of the CBB pathogen prepared from plates of sucrose peptone agar (SPA). The suspension contained ca. $2.2x10^7$ cfu/ml. Adjustment of the inoculum concentration to an optical density of 0.08 at 640nm wavelength was carried out by the use of a spectrophotometer (Spectronic 20, Bausch and Lomb, G. Britain). Inoculation was by dipping a sterilized tooth-pick into the inoculum and producing a scratch of approximately 6mm long on the leaf blade of the three lowest leaves of each plant. A separate toot-pick was used for each leaf inoculated. Also, each plant was inoculated by stem puncture using a different tooth-pick which was dipped into the inoculum and maintained in the second axil (from the stem apex) for approximately 12 hours. Control plants were treated in the same way but using sterile distilled water.

Plants were observed daily and assessed for bacterial blight using the method outlined in section 3.2.

5.2.2.2 **Field Experiments**

Two IITA's experimental cassava farms located at the University farm were used for this study as follows:

5.2.2.2.1 **Eight cassava varieties established from *in-vitro* culture**

These varieties were transplanted on 7 July 1993 at a spacing of 1m x 1m.

5.2.2.2.2 Thirty cassava genotypes established from "true" seeds

These varieties were transplanted on 30 June 1993 at a spacing of 0.5m x 1m after a one month nursery period. Both trials were laid out in a CRD and also assessed three months after transplanting for CBB incidence and severity under natural field infection.

5.3 Results and Discussion

5.3.1 1992 Wet Season Trials

5.3.1.1 The I.A.R. Research Farm Trial

The results of the 1992 field trial on six cassava varieties are shown in Table 5.1. The differences between the varieties in relation to CBB incidence and severity were significant (P=0.05).

With respect to CBB incidence, the local variety; varieties 91934, 60506 and 30001 registered the highest means followed by varieties 4(2)1425 and 30572. The means of variety 91934 and the local variety were significantly higher than that of variety 4(2)1425. However, the mean of variety 4(2)1425 did not significantly differ from that of variety 30001. Variety 30572 had the lowest mean disease incidence but there was no significant difference between it and that of variety 30001.

In relation to CBB severity,varieties 91934, local and 60506 had the highest means followed by those of varieties 30001 and 4(2)1425. The mean of variety 91934 was significantly higher than those of varieties 30001 and 4(2)1425. The mean of variety 60506, however, did not significantly differ from that of variety 4(2)1425. Variety 30572 again had the lowest mean but there was no significant difference between it and that of variety 4(2)1425.

Hahn and Theberge (1985) indicated that, screening for CBB should be done during the wet season when conditions for symptom development are maximum. Weather records during the experimental period (Table 5.2) reveal that conditions were favourable enough for any difference between varieties to be observed.

Although there were no significant differences between varieties TMS 91934 and local with respect to disease incidence and severity, however, the local variety recorded more main shoot die-backs than TMS 91934.

Table 5.1 Incidence and severity of bacterial blight on 6 cassava varieties at the I.A.R research farm, Samaru during the 1992 wet season.

Variety	Mean disease incidence (%)					Mean disease severity score (1-5)				
	8WAP	10WAP	12WAP	14WAP	Mean*	8WAP	10WAP	12WAP	14WAP	Mean*
TMS 91934	81.48^{a}	85.65^{ab}	88.98^{a}	88.98^{a}	86.27^{a}	2.55^{a}	2.58^{a}	2.78^{a}	2.82^{ab}	2.68^{abc}
TMS 30001	49.00^{abc}	55.66^{bcd}	59.25^{bc}	61.55^{b}	56.37^{abc}	1.90^{abc}	1.93^{abc}	2.02^{b}	2.05^{b}	1.98^{bcd}
TMS 30572	22.79^{c}	26.49^{d}	29.41^{d}	32.38^{c}	27.77^{c}	1.44^{c}	1.47^{c}	1.56^{b}	1.63^{c}	1.53^{d}
TMS 4(2)1425	37.76^{bc}	41.12^{cd}	53.41^{c}	53.41^{b}	46.43^{bc}	1.73^{bc}	1.75^{bc}	1.86^{b}	1.98^{bc}	1.83^{cd}
60506	65.69^{ab}	70.65^{abc}	80.77^{ab}	80.77^{a}	74.47^{ab}	2.27^{ab}	2.32^{ab}	2.55^{a}	2.72^{a}	2.47^{abc}
Local	82.09^{a}	87.16^{a}	88.89^{a}	92.49^{a}	87.66^{a}	2.54^{a}	2.56^{a}	2.67^{a}	2.83^{a}	2.65^{ab}

* Column values followed by the same superscript(s) are not significantly different at P = 0.05, using DMRT.

Table 5:2: Weather records in Samaru during the field experimental periods; 1992.

Month	Rain-fall (mm)	Mean Temperature (^{0}C)		% R.H		Sunshine hours	Wind-speed (km/h)
		Max.	Min.	10a.m	4p.m.		
July	243.6	28.4	19.8	82.6	68.1	6.2	146.78
August	287.3	29.5	20.0	83.0	22.8	4.9	150.46
September	229.7	29.5	20.2	78.6	65.1	4.6	94.58
October	39.2	31.5	17.7	61.1	35.2	8.9	68.98

5.3.1.2 The University Farm Trial

5.3.1.2.1 Twenty-nine cassava varieties established from rooted cuttings

The results are presented in Table 5.3. Varietal differences were highly significant (P = 0.01) with respect to CBB incidence, severity score and the number of main shoot die-back per stand.

With respect to CBB incidence, the mean of variety TME II was the lowest. There was no significant difference between it and those of varieties 81/01135, Chop-an-die, 91/00931, 89/10003, ISU, 30572, 91/01189, Danwaru and Akala which recorded higher means. The mean of variety 30572, however, was not significantly different from that of variety Rogo-1 and all other varieties that had the highest mean of CBB incidence.

In relation to CBB severity score, the mean of TME II was again the lowest and was not significantly different from those of varieties 81/01135, 91/00931, Chop-an-die, 89/10003 and ISU that recorded much higher means. The mean of variety ISU, however, did not differ significantly from that of variety Danwaru and all other varieties that had the highest means of CBB severity score.

The means of varieties Local-3, Local-2, Bakin Rogo, 91/0351, 91/00126, Danwaru, Dankporo, 82/00260, Bakin IRI-2, Local-1, 91/01189 and Chop-an-die were the highest with respect to the number of main shoot die-back per stand evaluated. This were followed by those of varieties 60506, 1-4 and ex-Obasanjo which were significantly different from that of variety Chop-an-die.

Table 5.3: Incidence and severity of bacterial blight on 29 cassava varieties established from seedlings at the University farm, Shika during the 1992 wet season.

S/ No.	Variety	Source	Mean disease incidence (%)	Disease severity	
				Mean Score (1-5)	Number of main shoot die-back/ stand (%)
1.	30572	1990GP ZARIA	72.35abc	2.45c	0c
2.	ex-Obasanjo	"	96.30ab	2.98abc	04.67bc
3.	91/00058	"	100.00a	3.00abc	0c
4.	91/00126	"	100.00a	3.45ab	54.54abc
5.	91/00931	"	54.54bc	2.09cd	0c
6.	91/01189	"	72.73abc	2.55bc	18.18abc
7.	91/00363	"	100.00a	3.00abc	0c
8.	91/0351	"	100.00a	3.36abc	63.64ab
9.	Danwaru	"	75.00abc	2.90abc	56.25ab
10.	TME II	"	0c	1.00d	0c
11.	60506	1990GP ZARIA	100.00a	3.06abc	09.09bc
12.	82/00260	"	100.00a	3.45ab	27.27abc
13.	91934	"	94.18ab	2.88bc	0c
14.	4(2)1425	"	89.99ab	2.81bc	01.80c
15.	Local-1	ZARIA	100.00a	3.19abc	19.05abc
16.	Bakin Rogo	"	100.00a	3.74a	83.33a
17.	Bakin Iri-2	"	100.00a	3.25abc	25.00abc
18.	1-4	1990GP ZARIA	100.00a	3.09abc	09.09bc
19.	Local-2	"	87.50ab	3.44ab	97.32a
20.	Local-3	Ebeya village	100.00a	3.78a	100.00a
21.	Chop-an-die	-	50.00bc	2.13cd	12.50abc
22.	30555P	-	100.00a	3.00abc	0c
23.	81/01135	-	42.86bc	1.86cd	0c
24.	Isu	-	66.67bc	2.33cd	0c
25.	Rogo-1	-	80.00ab	2.60bc	0c
26.	Akala	-	75.00abc	2.50bc	0c
27.	89/10003	-	57.14bc	2.14cd	0c
28.	Atu-Iwo	-	90.91ab	2.82bc	0c
29.	Dankporo	-	100.00a	3.44ab	44.44ab

Column values followed by the same letter(s) are not significantly different at P = 0.01.

The mean of variety 4(2)1425 was the lowest but there was no significant difference between it and that of variety ex-Obasanjo. All other varieties did not show a die-back of the main shoot.

Correlation analysis (Table 5.4) revealed that the relationship between CBB incidence and severity score, and CBB severity score and number of main shoot die-back per stand evaluated were positive (0.928 and 0.651 respectively) and highly significant with 86% and 42% coefficient of determination respectively. The relationship between CBB incidence and the number of main shoot die-back per stand was positive (0.331) but not significant. On these bases, varieties TME II, 81/01135, 91/00931, 89/10003, Isu and 30572 were most resistant to the disease.

Table 5.4: Correlation analysis of pairs of parameters obtained in screening 29 cassava varieties for bacterial blight at the University farm, Shika during the 1992 wet season.

Pairs of Parameters	Correlation Coefficient (r)	Coefficient of Determination (r^2)
Disease incidence and severity score	0.928**	0.86
Disease incidence and number of main shoot die-back/stand evaluated	0.331NS	0.11
Disease severity score and number of main shoot die-back/ stand evaluated	0.651**	0.42

** = Highly significant (P = 0.01)

5.3..1.2.2 Fifty-three cassava varieties sown from "true" seeds

The results are shown in Table 5.5. The differences between varieties was highly significant (P=0.01) with respect to means of CBB incidence and severity.

In relation to CBB incidence, the mean of variety 82/00576 was the lowest. This was followed by those of varieties Broni and 4(2)1425 respectively. The mean of CBB incidence was high in 43 out of the 53 varieties evaluated, amongst which was variety 4(2)0267 whose mean, however, was not significantly different from those of varieties 60506, Zaria bulk and 1095-D with lower means.

With regards to CBB severity score, the mean of variety Broni was the lowest. This was followed by those of varieties 82/00576 and 81983 which did not significantly differ from the means of varieties 82/0447, Local-3, Atu Iwo, 4(2)1425 and 4(2)0267 with much higher means. Thirty-two out of the 53 varieties had very high CBB severity scores amongst which were varieties Olekanga and Kwukwuri Ehinia whose means were not significantly different from those of varieties 30001, Zaria bulk, B11 and NR 8212, but differed significantly from that of variety 4(2)0267.

As evident from this trial, no cassava variety was immune to the disease based on disease severity scores. However, some improved varieties such as 4(2)1425, 81983 and some local varieties such as Broni, Atu Iwo and Local-3 were relatively resistant compared to the other varieties. To better assess the economic importance of the disease, it will be necessary to determine the potential yield of these varieties under disease-free conditions.

5.5: Incidence and severity of bacterial blight on 53 cassava varieties sown from "true" seeds at the University farm, Shika, during the 1992 wet season.

Serial No.	Variety	Source	Mean disease incidence (%)	Mean disease severity score (1-5)
1.	PYT Y/R	ZARIA, 1992 GSN.	100.00a	3.00a
2.	High Yield and Resistant	"	100.00a	3.00a
3.	Terraka	Uganda	80.00g	3.02a
4.	B11	Uganda	85.60f	2.85d
5.	CE Exotics	ZARIA 1991GSN	100.00a	3.00a
6.	Mokwa bulk	"	100.00a	2.80e
7.	CGM evaluation	"	100.00a	3.00a
8.	NR 8212	-	100.00a	2.83de
9.	90853	-	100.00a	3.00a
10.	CE Poundable	-	100.00a	3.00a
11.	PYT bulk	-	100.00a	3.00a
12.	Ankara	Ghana	100.00a	3.00a
13.	Ankara Tatum	"	100.00a	2.70ef
14.	Broni	Mokwa 1991 Local Germplasm	58.33i	1.58k
15.	82/00576	ZARIA 1991GSN	38.46j	1.77j
16.	Busumensia	Ghana	100.00a	3.00a
17.	Suleja-4	Niger	100.00a	3.00a
18.	81983(LCM Poundable)	Zaria 1991GSN	75.89h	1.86j
19.	Dan Pam	Mokwa, 1991 Local germplasm	100.00a	3.00a
20.	AYT Serra Leon bulk	Serra leon	100.00a	3.00a
21.	Clonal bulk	Serra leon	100.00a	2.70f
22.	84/00040	Zaria, 1991GSN	100.00a	3.00a
23.	82/00249	"	100.00a	3.00a
24.	82/00033	"	100.00a	3.00a
25.	Rogo-Giwa	Mokwa, 1991LGP	100.00a	3.00a
26.	Rogo-2 (Zuguruma)	"	100.00a	2.69f
27.	Panya-Akpu	"	100.00a	3.00a
28.	Omi-Alata	"	100.00a	3.00a
29.	40764	"	100.00a	2.40gh
30.	Rekiya Osojokodo	"	100.00a	3.00a
31.	820422	"	100.00a	3.00a
32.	81/01135	"	100.00a	3.00a
33.	30474	"	100.00a	3.00a
34.	30555	"	100.00a	3.00a

Serial No.	Variety	Source	Mean disease incidence	Mean disease severity score (1-5)
35.	Local-1 (Okonkwo-1)	Ubiaja	100.00a	3.06a
36.	30040	Mokwa, 1991LGP	100.00a	3.00a
37.	Local-2	Ubiaja	100.00a	2.67f
38.	Rogor-1 (Zugurumu)	Mokwa, 1991LGP	100.00a	3.00a
39.	Atu Iwo	"	100.00a	2.00ij
40.	Local-3	"	100.00a	2.00ij
41.	4(2)1425	"	75.56h	2.11i
42.	83672	Zaria, 1991GSN	100.00a	3.00a
43.	82/00003	"	100.00a	3.00a
44.	1095-D	"	100.00a	3.00a
45.	30001	"	95.45de	2.91bcd
46.	82/0447	"	100.00a	2.00ij
47.	Olokanga	Mokwa, 1991LGP	100.00a	3.00a
48.	Kwukwuri Ehinia	"	100.00a	3.00a
49.	30572	Zaria, 1991 GSN/PIS	100.00a	2.63f
50.	91934	"	94.12e	2.59f
51.	4(2)0267	"	100.00a	2.13hi
52.	60506	"	96.43bcd	2.43g
53.	Zaria bulk	Zaria, 1990PYT	96.15cde	2.88cd

Column values followed by the same letter(s) are not significantly different at P = 0.01.

5.3.2 1993 Trials

5.3.2.1 Pot Experiments

The results obtained are shown in Table 5.6. Varietal differences in CBB incidence were not significant. Varietal differences in CBB severity score were, however, highly significant ($P = 0.01$). The means of the local variety; varieties 60506, 91934 and 30001 were the highest. These were followed by the means of varieties 4(2)1425 and 30572, which did not significantly differ from those of varieties 30001 and 91934.

Although environmental conditions of rainfall and humidity (Table 5.7) were not so favourable for symptom development, the results of the 1993 pot experiment had thus confirmed the results of the 1992 field trial that CBB incidence and severity were lowest in variety 30752 followed by variety 4(2)1425. The local variety, varieties 91934 and 60506 (Plate 6) were the most susceptible. Variety 30001 in both trials was moderately resistant compared to varieties 4(2)1425 and 60506.



Plate 6: Tip die-back of main shoot in 60506

Table 5.6: Incidence and severity of bacterial blight on 6 cassava varieties in the 1993 pot experiment.*

Variety	Mean disease incidence (%) 10WAP and 12WAP	Mean disease severity score (1-5) 10WAP and 12WAP
TMS 91934	100.00	2.83ab
TMS 30001	100.00	2.67ab
TMS 30572	63.50	2.13b
TMS 4(2)1425	71.43	2.29b
60506	100.00	2.67ab
Local	100.00	3.50a

Column values followed by the same letter(s) are not significantly different at P = 0.01

Table 5.7. Weather records in Samaru during the period for the pot experiment in 1993.

Month	Rainfall (mm)	Mean temperature (^{0}C)		% R.H		Sunshine hours	Wind-speed (km/h)
		Max.	Min.	10a.m	4p.m		
March	Nil	34.4	18.2	31.5	29.7	-	442.17
April	8.3	36.5	23.5	42.7	33.8	-	161.6
May	113.6	37.8	22.0	62.9	46.8	8.2	204.74
June	155.8	31.7	20.9	72.7	51.8	7.6	183.0

5.3.2.2 **Field Experiments**

5.3.2.2.1 **Eight cassava varieties established from *in-vitro* culture.**

The results of the trial are shown in Table 5.8. Varietal differences in CBB incidence, CBB severity score and the number of main shoot die-back per stand were highly significant (P=0.01).

With respect to CBB incidence and severity score, the means of variety TMS 30555 were significantly lower than the other seven varieties (TMS 60444, TME II, TMS 91934, TMS 30001, TMS 63397, TMS 30572 and TMS 4(2)1425). In relation to the number of main shoot die-back per stand, the mean of variety TME II was significantly higher than that of variety TMS 60444. The other varieties which did not have any die-back of the main shoot were not significantly different from variety TMS 60444.

Correlation analysis (Table 5.9) revealed that the relationship between CBB incidence and severity score was positive (0.899) and highly significant (P=0.01) with 81% coefficient of determination. The relationships between CBB incidence and number of main shoot die-back per stand, CBB severity score and number of main shoot die-back per stand were positive (0.189 and 0.537 respectvely) but non-significant.

Table 5.8: Incidence and severity of bacterial blight on 8 cassava varieties from in-vitro establishment at the University farm, Shika, during the 1993 wet season.

Variety	Mean disease incidence (%)	Disease severity: Mean score (1-5)	Disease severity: Number of main shoot die-back/ stand (%)
TMS 60444	100.00a	2.92a	2.78b
TMS 4(2)1425	96.23a	2.89a	0b
TMS 91934	100.00a	2.89a	0b
TMS 30555	72.73b	2.36b	0b
TME II	100.00a	3.20a	20.00a
TMS 30001	100.00a	2.82a	0b
TMS 63397	100.00a	2.97a	0b
TMS 30572	100.00a	2.97a	0b

Column values followed by the same letter(s) are not significantly different at P = 0.01.

Table 5.9: Correlation analysis of pairs of parameters obtained in screening 8 cassava varieties for bacterial blight at the University farm, Shika during the 1993 wet season.

Pairs of Parameters	Correlation Coefficient (r)	Coefficient of Determination (r^2)
Disease incidence and severity score	0.899**	0.81
Disease incidence and number of main shoot die-back/stand evaluated	0.189NS	0.04
Disease severity score and number of main shoot die-back/ stand evaluated.	0.537NS	0.29

** = Highly significant (P = 0.01)

CBB severity in plants can result in die-back of the main shoot as was the case with TMS 60444 and TME II. However, some cassava varieties such as TMS 4(2)1425, TMS 91934, TMS 30001, TMS 63397 and TMS 30572 though with similar disease severity score like TMS 60444 and TME II, did not show any main shoot die-back. These varieties, however, showed other symptoms of severe attack such as wilting and defoliation.

5.3.2.2.2 Thirty cassava genotypes sown from "true" seeds

The results of the trial are presented in Table 5.10. Differences between genotypes with respect to CBB incidence, severity score and the number of main shoot die-back per stand were highly significant (P=0.01).

In relation to CBB incidence, the mean of genotype 89/00053 S_1 was the lowest amongst the 26 genotypes that had the highest means. The mean of genotype 30572 x 30001 Zaria was the lowest. However, there was no significant difference between it and that of genotype 89/00053 S_1.

With respect to CBB severity score, the means of genotypes 30572 x 30001 Zaria, C/E Bulk Zaria and (91/01124 x BP)HS were the lowest. The differences between these genotypes and that of genotype 30572 x 4(2)1425 Zaria, which was among the genotypes that had the highest means, were not significant. However, the means of genotypes [820249HS]HS = HS^2, 30572 x 60121 Zaria, and (Local 1285 HS) HS=HS^2, which were also among those genotypes with the highest means, were significantly different from that of genotype (91/01124 x BP)HS.

Table 5.10: Incidence and severity of bacterial blight on 30 cassava genotypes sown from "true" seeds at the University farm, Shika during the 1993 wet season.

S/No.	Genotype	Mean disease incidence (%)	Disease severity: Mean Score (1-5)	Disease severity: Number of main shoot die-back/stand(%)
1.	C/E. CIAT Bulk 1992 Ibadan	96.67ab	3.00abcd	13.33bcd
2.	C/E. NY/R	100.00a	3.00abcd	0d
3.	C/E. Exotics HS[1]	100.00a	2.87cd	2.19d
4.	PYT Bulk HS Zaria	97.50ab	2.90cd	0d
5.	Mokwa bulk HS[2]	98.11a	2.98bcd	3.77d
6.	PYT Y/R	97.14ab	2.91cd	2.86d
7.	C/E CGM	100.00a	2.98bcd	0d
8.	C/E Poundable and low cyanide HS[2]	100.00a	3.08abcd	7.69cd
9.	C/E 1992 SM1248-15	100.00a	3.00abcd	8.33cd
10.	AYT Bulk Zaria	100.00a	2.90cd	20.00abcd
11.	C/E Bulk Zaria	88.24bcd	2.76d	5.88cd
12.	[820249HS]HS=HS[2]	100.00a	3.42a	34.62a
13.	[820447HS]HS=HS[2]	100.00a	3.24ab	29.41ab
14.	(4074HS}HS=HS[2] Zaria	100.00a	3.20ab	25.00abc
15.	(91/01124xBP)HS	93.10abc	2.76d	0d
16.	(91/01121xBP)HS	88.24bcd	2.82cd	5.88cd
17.	Isu	96.00ab	3.20ab	40.00a
18.	30001 x BP Zaria	92.31abc	2.77cd	7.69cd
19.	30572 x 30001 Zaria	71.43d	2.57d	14.29abcd
20.	30001 HS	90.91abc	3.00abcd	18.18abcd
21.	30572 x 60121 Zaria	100.00a	3.35a	35.29a
22.	30572 x 4(2)1425 Zaria	75.00cd	3.00abcd	50.00a
23.	(LOCAL-1045 OP)OP=Zaria	90.00abcd	2.90cd	10.00cd
24.	(LOCAL-1285 HS)HS=HS[2]	100.00a	3.33a	33.33ab
25.	89/00053 S_1	88.89abcd	2.78cd	0d
26.	84/00042 Zaria	100.00a	2.90cd	0d
27.	30572 S_2	100.00a	3.20ab	20.00abcd
28.	91/01138 S_2	100.00a	3.06abcd	12.50bcd
29.	91/00300 HS	91.30abc	2.83cd	8.70cd
30.	91/02261 HS	91.67abc	3.17abc	41.67a

Column values followed by the same letter(s) are not significantly different at P = 0.01.

With respect to the number of main shoot die-back per stand, the means of genotypes C/E Exotics HS[1], PYT Y/R, and Mokwa bulk HS[2] were the lowest among those genotypes that had a die-back of the main shoot. There were, however, no significant differences between their means and those of the genotypes that had no die-back. The mean of genotype C/E Exotics HS[1] was not significantly different from that of genotype AYT Bulk Zaria which was among the genotypes with the highest number of die-backs. That of genotype C/E Exotics HS[1], however, was significantly different from the mean of genotype [820249HS]HS=HS[2] which was also among those that had the highest number of die-backs.

Correlation analysis (Table 5.11) revealed that, the relationship between CBB incidence and the number of main shoot die-back per stand was negative and non-significant. Genotypes could not therefore be easily separated on this basis because most genotypes that recorded a high disease incidence did not necessarily record high values of main shoot die-back and vice versa. This was clearly demonstrated by genotypes 84/00042 Zaria and 30001 x BP Zaria. The relationships between CBB incidence and severity score, CBB severity score and the number of main shoot die-back per stand were positive (0.554 and 0.669 respectively) and highly significant with 31% and 45% coefficient of determination respectively. Genotypes were easily separated on the last two bases. On the basis of this screening, genotypes C/E Exotics HS[1], PYT Bulk HS Zaria, PYT Y/R, C/E Bulk Zaria, (91/01124 x BP)HS and (91/01121 x BP)HS were the most resistant to the disease. On the

Table 5.11: Correlation analysis of pairs of parameters obtained in screening 30 cassava genotypes for bacterial blight at the University farm, Shika during the 1993 wet season.

Pairs of Parameters	Correlation Coefficient (r)	Coefficient of Determination (r^2)
Disease incidence and severity score	0.554**	0.31
Disease incidence and number of main shoot die-back/stand evaluated	-0.148NS	0.02
Disease severity score and number of main shoot die-back/ stand evaluated.	0.669**	0.45

** = Highly significant (P = 0.01)

contrary, genotypes (820249HS)HS = HS^2, (820447HS)HS = HS^2, [4074HS]HS=HS^2 Zaria, (Local 1285HS)HS = HS^2, 30572 S_2 and 91/02261 HS were the most susceptible.

6. SURVIVAL AND POPULATION DYNAMICS OF *Xanthomonas campestris* pv. *manihotis* IN LEAF TRASH.

6.1 Introduction

Xanthomonas campestris pv. *manihotis* causes the severe cassava bacterial blight (CBB) disease characterised by angular leaf spots and blights, and a systemic infection of the stem leading to wilt. The epiphytic phase of *X. c.* pv. *manihotis* has important implications in the epidemiology of the disease, constituting one source of inoculum (Daniel and Boher, 1985). The objective of this work was to determine the longevity and population dynamics of the pathogen in infected cassava leaf trash during the dry season.

6.2 Materials and method

Trash showing angular spots was collected from beneath diseased cassava plants every two weeks during the dry season for laboratory assay. Five grammes of the sample was comminuted in 100ml sterile distilled water and allowed to stand for two hours at room temperature. Serial dilutions of the suspension ranging from 10^{-1} to 10^{-6} were then prepared. Approximately 0.1ml of the suspension was pipetted on to the surface of sucrose peptone agar (SPA) in Petri dishes and gently swirled round to ensure a uniform spread of the suspension. Three Petri dishes were used for each dilution. Plates were then incubated at 30^{0}C for 48-72 hours after which the bacterial colonies were counted and identified. A suspension of the pure culture of the CBB pathogen in sterile tap water was prepared and preserved for use in subsequent comparisons with isolates from other samples.

Trash from two cassava varieties, local and improved (TMS 4(2)1425) were sampled separately. The colony count per gramme of trash was calculated using the method indicated by Collins and Lyne (1976) viz:

Colony count/g tissue = Average no. of colonies per plate x reciprocal of the dilution.

6.2.1 Pathogenicity Test of Isolates

The isolates obtained from plates of SPA were purified by repeated sub-culturing of colonies onto SPA plates. The pathogenicity of isolates obtained was determined using two methods at the beginning of the investigation (April 1993) and just prior to the establishment of the rains (June 1993). The first was the hypersensitive reaction (HR) of plants using potted tobacco (Nicotiana tabacum var. White Burley) plants (Klement, 1975). A bacterial suspension of *ca*. 2.2 x 10^7 cfu/ml was prepared as indicated in section 5.2.2.1. The suspension was then injected into the intracellular spaces of the tobacco leaf using a 30 G needle.

The second method of pathogenicity test involved the use of six week old potted cassava plants. The bacterial suspensions were prepared from 48 hour old culture grown on SPA and injected into the intracellular spaces of the cassava leaf using a 30 G needle and maintained in a humid condition for 8 hours. Control plants were inoculated with distilled water and treated in the same way.

6.3 Results and Discussion

Two types of colonies, a fast growing mucoid colony and a more discrete cream colony were observed 48 hours and 72 hours respectively after incubation (Plate 7). Only the more discrete cream isolate proved pathogenic to cassava plants. This isolate was obtained almost as a pure culture following re-isolation from artificially inoculated cassava plants on which angular leaf spots were observed 4 days after inoculation. However, neither of the two isolates was able to evoke the HR on tobacco plants which agrees with earlier observation by Lozano and Sequeira (1974a).

The population of X. campestris pv. manihotis is given in Figures 6.1 and 6.2. The pathogen was found to survive for approximately 9 months in leaf trash collected beneath diseased cassava plants. In general, as relative humidity increased (Table 6.1) between the months of April-June, so did the bacterial populations. The bacterial population then gradually declined as humidity decreased with the enduring dry season (October-March).

Bacterial populations were generally higher in the local cultivar than the improved cultivar except during November and December. In the local cultivar, these populations were significantly higher than those of the improved cultivar in May-June and January-March compared with other sampling periods. The populations of the pathogen in April were minimum (4.67×10^6 and 4.33×10^6 colonies/g of trash for the local and improved cultivars respectively) while the highest was recorded in October (384.83×10^6 and 321.5×10^6 colonies/g of trash for the local and improved



Plate 7: Colonies of Xanthomonas manihotis (indicated by arrows) on plate of SPA after 72 hours incubation.

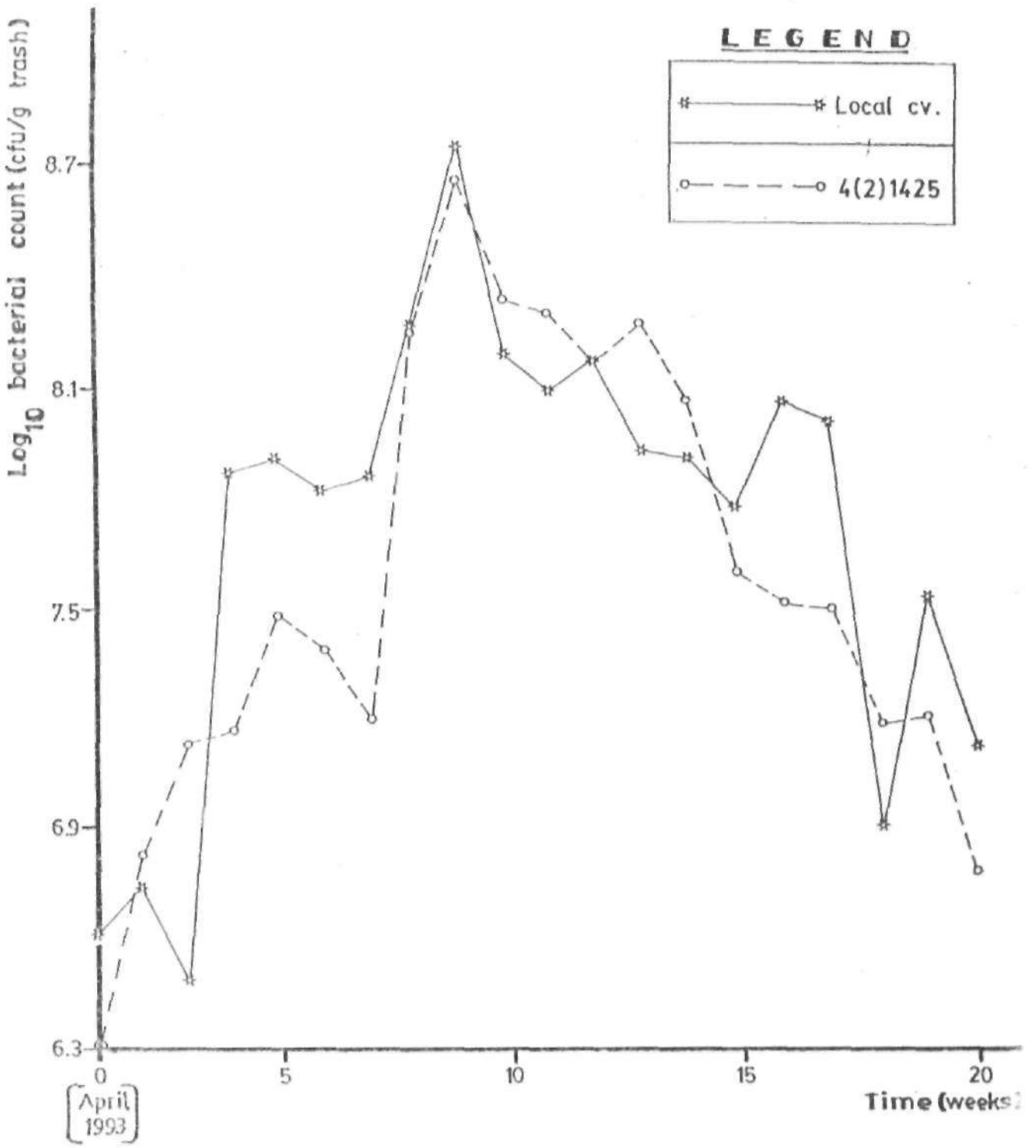


Figure 6.1: POPULATION OF X. compestris pv. manihotis SURVIVING IN LEAF TRASH.

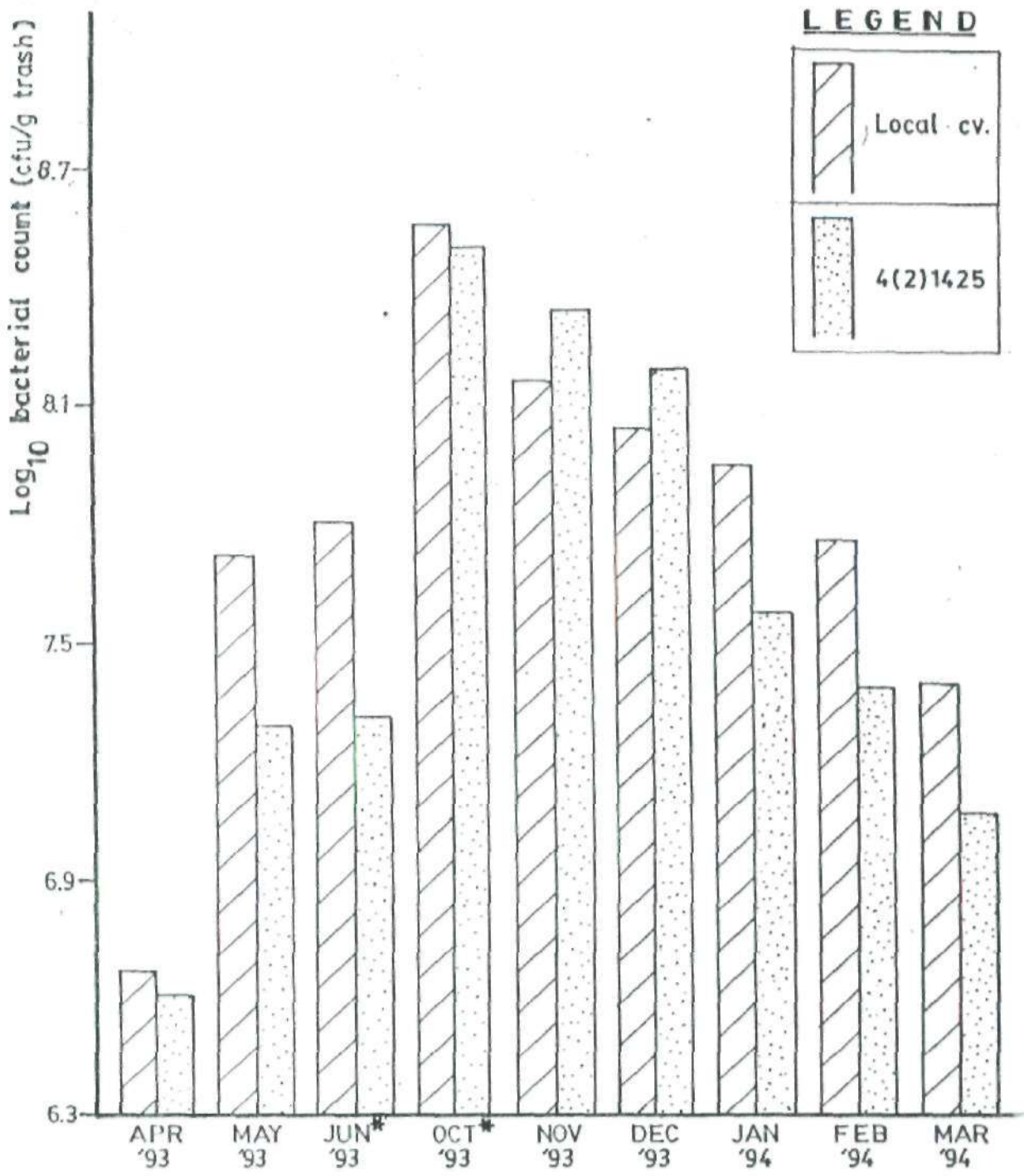


Figure 6.2: **MONTHLY POPULATION OF X. campestris pv. manihotis SURVIVING IN LEAF TRASH.**

* Between these months, trash was not collected as a result of decomposition following heavy rains.

Table 6.1: Weather records in Samaru during the experimental periods.

Month	Rainfall (mm)	Mean temperature (^{0}C)		% R.H		Sunshine hours	Wind-speed (km/h)
		Max.	Min.	10a.m	4p.m		
March'93	-	34.4	18.2	31.5	29.9	-	442.17
April'93	8.3	36.5	23.5	42.7	33.8	-	161.6
May '93	113.6	37.8	22.0	62.9	46.8	8.2	204.74
June'93	155.8	31.7	20.9	72.7	51.8	7.6	183.0
Sept'93	181.8	30.2	19.3	76.7	58.2	7.0	71.55
Oct.'93	32.4	34.1	18.7	63.1	54.0	8.4	70.27
Nov.'93	Nil	33.6	14.1	-	-	8.6	74.51
Dec.'93	Nil	29.1	14.1	31.0	25.0	6.2	136.88
Jan.'94	Nil	29.6	13.8	23.1	18.7	6.8	100.41
Feb.'94	Nil	31.6	16.0	13.8	12.6	5.9	92.149
March'94	Nil	37.3	19.9	19.7	25.7	6.4	83.78

cultivars respectively. These observations were comparable to those of Persley (1978) who indicated that a higher population of Xanthomonas campestris pv. manihotis is known to survive in plant debris at the beginning of the dry season (December) than after the first rains (April) in the savanna region.

CBB incidence and severity are high during the rainy season (Hahn and Theberge, 1985). Therefore, before October, senescent infected cassava leaves that fell during the cropping season (June-July) and subjected to mild environmental conditions (temperature of 20-30^{0}C and relative humidity of 52-82%) were probably responsible for the high bacterial populations in October. In contrast, before April, the harsh environmental conditions (temperature of 14-37^{0}C and relative humidity of 13-32%) of the dry season were probably responsible for the low bacterial populations in April.

Most plant pathogenic bacteria do not form spores and this places them at a disadvantage during the intercrop season (Leben, 1974). Moreover, Xanthomonads are known to lack competitive saprophytic ability, hence Buddenhagen (1965) classified them as pathogens whose soil phase is one of a rapid decline in population, without contributing much to the propagation of disease from one season to another.

The survival time of X. c. pv. manihotis in leaf trash is further supported by earlier reports (Ikotun, 1977) that, the pathogen survives long periods of desiccation in the field mainly in bacterial ooze and in infected host tissues or remains. To prevent them from serving as a source of inoculum, infected plant debris should be gathered and burnt.

7. SUMMARY AND CONCLUSIONS

A disease survey was conducted at the end of the 1993 wet season to determine the status of bacterial blight in some cassava-growing areas in the Nigerian savanna. Various locations were visited and assessed for the incidence and severity of the disease. The Southern Guinea Savanna zone recorded higher means of both disease incidence and severity than the Northern Guinea Savaana zone. Some variation was observed at every environ visited and this was attributed to the crop mixture, cassava cultivar, spacing and plant age.

Field trials were carried out during the 1993 wet season on the University farm, Zaria to investigate the effects of planting date and intercropping of cassava with maize on the incidence and severity of the bacterial blight disease on two cassava cultivars. Control of cassava bacterial blight (CBB) was achieved through late planting of cassava. The decrease in CBB incidence and severity was significant and non-significant in the local and improved cultivars respectively in two separate trials. In both varieties, CBB incidence and severity were significantly reduced in the intercrops than in the sole cassava plots. However, there were no significant differences in the time of introduction of the components of the mixture with respect to means of CBB incidence and severity.

Screening for CBB resistance in the 1992 field and 1993 pot trials in Samaru, Zaria using six cassava varieties of varying susceptibilities revealed that, CBB incidence and severity were

lowest in TMS 30572 followed by TMS 4(2)1425. The local variety, TMS 91934 and 60506 were the most affected. TMS 30001 was moderately resistant compared to TMS 4(2)1425 and 60506. In two separate trials using 29 and 53 cassava varieties, the improved varieties TME II, TMS 30572, TMS 4(2)1425, TMS 81983 and the local varieties, Isu and Broni were found to be resistant to CBB. Assessment of eight improved cassava varieties from in-vitro culture under natural field infection during the 1993 wet season on the University farm revealed a higher incidence and severity of CBB compared with plants established from rooted cuttings in the previous year. However, CBB incidence and severity were significantly reduced in TMS 30555 than the other seven varieties (TMS 60444, TMS 4(2)1425, TMS 91934, TME II, TMS 30001, TMS 63397 and TMS 30572).

Research aimed at determining the potential yield of these cassava varieties need to be carried out in this agro-ecological zone in order to correlate the results of this finding to yield.

Lastly, investigations were also carried out to determine the longevity and population dynamics of Xanthomonas campestris pv. manihotis during the dry season. The pathogen was found to survive for approximately 9 months in leaf trash collected from beneath diseased plants. The bacterial populations were found to be minimum at the beginning of the rainy season (April) and maximum at the beginning of the dry season (October) in trash of local and improved cassava cultivars.

REFERENCES

AMARAL, J.F. do. (1942). Estudo do organismo causador da bacteriose da mandioca Arquivos da Instituto Biologica. Sao Paulo 13: 119-126.

AMARAL, J.F. do. (1945). Doencas vasculares das plantes causadas por bacterias. O. Biologica, Sao Paulo 11: 250-253.

AMUSA, T; IKOTUN, T; HAHN, S.K. (1992). Survival of Xanthomonas campestris pv. manihotis in soil under mucuna fallow. In: Akoroda, M.O. and Arene, O.B. (eds.). Promotion of Root Crop-Based Industries. Proceedings of the fourth Triennial symposium of the International Society of Tropical Root Crops-Africa Branch held in Kinshasha, Zaire. 5th-8th Dec., 1989. pp. 193-196.

ARENE, O.B. (1972). Cassava mosaic virus: progress and problems (Abstr.) Nigerian Society of Plant Protection (Occasional paper) 1:14.

ARENE, O.B. (1976). Influence of shade and intercropping on incidence of cassava bacterial blight caused by Xanthomonas manihotis. In: Proceedings of cassava bacterial blight workshop, International Development Research Centre/IITA, Ibadan, Nigeria. Ottawa: IDRC-096c. pp. 28-29.

ARENE, O.B. (1977). Susceptibility of Nigerian local cassava cultivars to CBB and CMD (abstr.). Agric. Soc. of Nigeria. Vol. 1, No. 1. Ahmadu Bello University Press, Zaria, Nigeria.

ARENE, O.B. (1990). Advances in integrated control systems of economic diseases of cassava in Nigeria. In: Hahn, S.K. and Caveness, F.E. (eds.). Integrated Pest Management for Tropical Root and Tuber crops. Proceedings of the Workshop on the global status and prospects for integrated pest management of root and tuber crops in the tropics, 25-30 October 1987, IITA, Ibadan, Nigeria. pp. 169-175.

BELLOTTI, A.C. (1977). An overview of cassava entomology. In: Brekelbaum, T., Bellotti, A.C., and Lozano, J.C. (eds.). Proceedings of cassava production workshop, CIAT, Cali. Colombia 7-12 Nov. 1977. pp. 29-39.

BELLOTTI, A.C., HERSLEY, C.H.; and VARGAS, O. (1985). Recent advances in resistance to insect and mite pests of cassava. In: Hersley, C.H. (ed.). Cassava breeding, A multidisciplinary review. Proceedings of a workshop held in the Philippines, 4-7 March 1985. pp. 117-146.

BELLOTTI, A.C. and VAN SCHOONHOVEN, A. (1985). Cassava Pests and their control. Cassava: Research, Production and Utilization. Cassava Program-material used in the cassava training courses offered by CIAT, pp. 343-392.

BERGEY, D.H. (ed.) (1957). Manual of Determinative Bacteriology. 7th ed. pp.1094. The Williams and Wilkins Co., Baltimore.

BONDAR, G. (1912). Uma nova molestia bacteriana das hastes de mandioca. Chacras e Quintaes, Sao Paulo 5: 15-18.

BONDAR, G. (1915). Molestia bacteriana da mandioca. Boletin de Agricultura, Sao Paulo 16: 513-24.

BUDDENHAGEN, I.W. (1965). The Relation of Plant-Pathogenic Bacteria to the soil. In K.F. Baker and W.C. Synder (eds.). Ecology of soil-borne plant pathogens: Prelude to the biological control, Berkeley, Los Angeles, University of California Press.

BURKHOLDER, W.H. (1942). Three bacterial plant pathogens: Phytomonas caryophylli sp. n., Phytomonas allicola sp. n., and Phytomonas manihotis (Arthaud-Berthet et Bondar) Viegas. Phytopathology 32: 146-148.

CARNEIRO, J.G. (1940). Doenca bacteriana da mandioca. Notas e Informacoes. Portaria do Ministerio Agricultura. Sao Paulo 573: 447.

CHEW, W.Y. (1979). Cassava intercropping patterns and practices in Malaysia. In: E. Weber, B. Nestel and M. Campbell (eds.). Intercropping with cassava: Proceedings of interdisciplinary workshop held in Trivandrum, India, Nov. 27-Dec. 1, 1978. pp. 57-65.

CIAT (1971). CIAT Annual Report 1971. pp. 120. CIAT = Centro Internacional de Agricultura Tropical, Cali, Colombia.

CIAT (1972). CIAT Annual Report, 1972 pp. 192. CIAT, Cali. Colombia.

CIAT (1975). Annual Report, CIAT, B, Cali. pp. 8-10.

CIAT (1976). Cassava Production Systems Program. In: Nickel, J.K.; Eduardo Alvarez-Luna; Rachie, K.O. (eds.). CIAT's Annual Report, 1976. pp. B-25 and B-66.

CIAT (1981). CIAT series No. 07EC-1 (2nd ed.). In: J.C. Lozano; A. Bellotti; J.A. Reyes; R. Howeler; D. Leihner; J. Doll (eds.). Field Problems in Cassava. pp. 16-19.

CIAT (1985). CASSAVA: Research Production and Utilization. Cassava Program. Preliminary edition. CIAT, Cali, Colombia. pp. 341-617.

COCK, J.H. (1974). Agronomic Potential for Cassava Production. In: Araullo, E.V.; Barry Nestel; and M. Campbell (eds.). Cassava processing and storage. Proceedings of an interdisciplinary workshop, Pattaya, Thailand, 17-19 April pp. 21-26.

COCK, J.H. (1985). CASSAVA. New Potential for a neglected crop. Westview Press/Boulder and London. pp. 66 and 108-110.

COLLINS, C.H. and LYNE, P.M. (1976). Microbiological Methods. 4th ed. Butterworths. pp. 199.

COSTA, F. (1940). Regioes infestadas pela bacteriose de mandioca. Notas e Informacoes. Portaria do Ministerio Agricultura 573: 446.

DANIEL, J.F. and BOHER, B. (1985). Epiphytic phase of Xanthomonas campestris pv. manihotis on aerial parts of cassava. Agronomie, 5(2) pp. 111-116.

DRUMMOND-GONCLAVES, R. (1948). Bacteriose da mandioca. O. Biologico (Sao Paulo). 14:145-146.

DRUMMOND, O.A. and GONCLAVES, R. (1953). A bacteriose e a mandioca guaxupe. O. Biologico, Sao Paulo 19 114-117.

DRUMMOND, O.A. and HIPOLITO, O. (1940-41). Notas sobre bacterioses de mandioca. Boletin Escola Superior de Agricultura. Minas Gerais 4: 86-124.

DUNCAN, D.M. (1955). Multiple Range and Multiple F tests. Biometrics 11: 1-42.

EFFENDI, S. (1979). Cassava intercropping patterns and management practices in Indonesia. In: E. Weber, B. Nestel, and M. Campbell (eds.). Intercropping with cassava. Proceedings of an interdisciplinary workshop held in Trivandrum, India, Nov. 27-Dec. 1, 1978. pp. 35-41.

ERINLE, I.D. (1981). A short guide to bacterial diseases of Nigerian plants. Hamdan Express Printers, Zaria, Nigeria. pp. 1.

EZEILO, W.N.O. (1979). Intercropping with cassava in Africa. In: E. Weber, B. Nestel, and M. Campbell (eds.). Interdisciplinary workshop held in Trivandrum, India, Nov. 27-Dec. 1, 1978. pp. 49-56.

EZUMAH, H.C. and TERRY, E.R. (1974). Cultural considerations in the control of cassava bacterial blight. In: Glaser, H.J. (ed.). Proceedings of the first workshop on cassava bacterial blight in Nigeria. 28th April-1st May 1974, Rural Agricultural Research and Training Station, Umudike, Nigeria pp. 25-32.

FAO (1973). Production Year book. FAO, Rome, Italy, 1973. (FAO = Food and Agricultural Organisation).

FAO (1980). FAO, Food balance sheets 1975-1977 average.

FAO (1990). Production Yearbook. FAO. Rome, Italy, Vol. 44.

FAO (1991). Food Outlook. FAO, Rome, Italy, May 1991.

GONCLAVES, R.D. (1948). Bacteriose de mandioca. Notas e Informacoes O. Biologico, Sao Paulo 14: 145-146.

HAHN, S.K. and WILLIAMS, R.J. (1973). Investigation on cassava in the Republic of Zaire. Report to the commissaire d'etat a' 1' agriculture. Republic of Zaire, 1973.

HAHN, S.K. (1978). Breeding cassava for resistance to bacterial blight. PANS 24: 482-485.

HAHN, S.K.; TERRY, E.R.; LEUSCHNER, K.; AKOBUNDU, I.O.; OKALI, C.; and LAL, R. (1979). Cassava improvement in Africa. Reprint from: Field Crops Res. 2 (1979): 193-226.

HAHN, S.K. (1984). Tropical root crops: their improvement and utilization. Paper presented at a conference organized by the Commonwealth Agricultural Bureau on Advancing Agricultural Production in Africa held 13-17 Feb. 1984 at Arusha, Tanzania.

HAHN, S.K. and THEBERGE, R.L. (1985). Techniques and advances in breeding cassava for disease resistance in Africa. In: Clair, H. (ed.) Cassava breeding. A multidisciplinary review pp. 105-115.

HAHN, S.K.; ISOBA, J.C.G. and IKOTUN, T. (1989). Resistant breeding in root and tuber crops at the Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Crop Protection Vol. 8. 147-168.

HEYS, G. (1975). Cassava: bacterial blight in Nigeria. Shell in Agriculture. Span 18: No 2 (Supplement).

IITA, (1972). 1972 Report of root, tuber and vegetable improvement program. (IITA = International Institute of Tropical Agriculture, Ibadan, Nigeria). pp. 48.

IITA, (1974). 1974 annual report. IITA, Ibadan, Nigeria. pp. 125-152.

IITA (1976). IITA Annual report 1975. Ibadan, Nigeria, pp. 219.

IITA (1985). Common African Pests and Diseases of cassava, yam sweet potato and cocoyam. Theberge, R.L. (ed) IITA, Ibadan, Nigeria pp. 2-4.

IITA (1990). Cassava in Tropical Africa. A Reference Manual pp. 53-68 and 135.

IKOTUN, T. (1975). Cassava bacterial blight disease caused by Xanthomonas manihotis (Arthaud-Berthet, Bondar) Starr. Ph.D. Thesis. University of London pp. 242.

IKOTUN, T. (1977). Survival of Xanthomonas manihotis in cassava tissues. Nigerian Journal of Plant Protection. vol. 3 1977. pp. 31-38.

IKOTUN, T. (1982). The survival of Xanthomonas manihotis (Arthaud Berthet) Starr in the soil. Fitologia Brasileira 7: 29-36.

JENNINGS, D.L. (1959). Manihot melanobasis Muell - Arg.: a useful parent for cassava breeding. Euphytica 8: 157-162.

JONES, W.O. (1959). Manioc in Africa. Stanford University Press, Stanford, Calif. pp. 315.

KLEMENT, Z. (1975). "Rapid detection of the pathogenicity of some phytopathogenic bacteria by the Hypersensitive Reaction of plants" In: Goodman, R.N. (ed.) Proceedings of the first workshop on phytobacteriology, 3rd edition, pp. 61-62.

LEBEN, C. (1974). Survival of plant pathogenic bacteria. Ohio Agric. Res. Dev. Cent. Spec. Circ. 100 pp. 21.

LEON, J. (1977). Origin, evolution and early dispersal of root and tuber crops. In: Cock, J.H.; McIntyre, R.; and Graham, M. (eds.). Proceedings of 4th Symp. Int. Soc. Trop. Root crops, Cali. Colombia, 1976. Report No. IDRC-080e. IDRC, Ottawa, Canada. pp. 277.

LEU, L.S. and CHEN, C.T. (1972). Bacterial wilt of cassava (Manihot utilissima caused by Xanthomonas manihotis (Arthaud-Berthet) Starr. Plant Bull. 14: 17-26.

LOZANO, J.C. (1972). Bacterial blight of cassava (Manihot esculenta Crantz) in Colombia. Etiology, epidemiology and control. Ph.D. Thesis, Univ. Wis., Madison. pp. 114.

LOZANO, J.C. and SEQUEIRA, L. (1974a). Bacterial blight of cassava in Colombia: I, Etiology. Phytopathology 64: 74-82.

LOZANO, J.C. and SEQUEIRA, L. (1974b). Bacterial blight of cassava in Colombia: II, Epidemiology and control. Phytop. 64: 74-82.

LOZANO, J.C. (1975). Bacterial blight of cassava. PANS. vol. 21 No. 1. March 1975. pp. 38-43.

LOZANO, J.C. and BOOTH, R.H. (1974). Diseases of cassava (Manihot esculenta Crantz). PANS 20 (1): 30-54.

LOZANO, J.C. (1977). General considerations on cassava pathology. In: Brekelbaum, T.; Bellotti, A.C.; and Lozano, J.C. (eds.). Proceeedings cassava production workshop. CIAT, Cali. Colombia. 7-12 Nov. 1977. pp. 17-27.

LOZANO, J.C. and LABERRY, R. (1993). Biological control of cassava diseases using Fluorescent Pseudomonads. In: Roca, W.M. and Thro, A.M. (eds.). Proceedings of the first international scientific meeting of the Cassava Biotechnology Network, Cartegena, Colombia, 25-28 August 1992-Cali, Colombia: CIAT, 1993. pp 344-348 (Working Document; No 123).

LUC, M. and DEGUIRAN, G. (1968). Nematological problems in the French African tropical territories and Madagascar. In: Smart, G.C. and Perry, V.G. (eds.). Tropical Nematology. Univ. of Florida Press, Gainesville, Fla. pp. 93-112.

MARAITE, H. and MEYER, J.A. (1975). Xanthomonas manihotis (Arthaud-Berthet) Starr, causal agent of bacterial wilt, blight and leaf spots of cassava in Zaire. PANS 21: 27-37.

MATTOS, L.L. (1977). Bacteriosis del tallo de la yuca (Manihot esculenta Crantz). Tesis Mag. Sc. Universidad Nacional Agraria, La Molina, Lima, Peru. pp. 73.

MAUNY, R. (1953). Notes historiques autour des principales plantes cultivees d'Afrique occidentale. Bull Inst. Fr. Afr. Noire 15: 684-730.

MBANASO, E.N.A.; NWACHUKWU, E.C. and ENE, L.S.O. (1993). Progress on cassava improvement through biotechnology at the National Root Crops Research Institute, Umudike. In: Roca, W.M.; Thro, A.M. (eds.). Proceedings of the first international scientific meeting of the Cassava Biotechnology Network, Cartegena, Colombia, 25-28 August 1992 - Cali, Colombia: CIAT, 1993. pp 111-113 (Working document; no 123).

MORENO, R.A. and HART, R.D. (1979). Intercropping with cassava in Central America. In: E. Weber, B. Nestel, and M. Campbell (eds.). Proc. Int. Workshop held in Trivandrum, India, Nov 27-Dec. 1, 1978. pp. 17-30.

OKEKE, J.E. and ENE, L.S.O. (1985). Advanced cassava lines to farmers: Nigeria. In: Clair H. Hershey (eds.). Cassava Breeding: A multidisciplinary review. Proc. of a workshop held in the Philippines, 4-7 March 1985. pp. 241-250.

OKIGBO, B.N. (1977). Preliminary cassava interplanting trials. Paper presented at the first NAFPP National cassava workshop, Umudike, IITA. pp. 20.

OKPALA, E.U. (1974). Review of the economic importance of the bacterial blight of cassava caused by Xanthomonas manihotis. Proc. of the first workshop on cassava bacterial blight in Nigeria. 28th April-1st May 1974. Umudike, Nigeria. pp 15-17.

OTOO, J.A. (1989). IITA Africa-wide cassava improvement program. In: Natalie D. Hahn (ed.). In praise of cassava. Proceedings of the inter-regional experts' group meeting on the exchange of technologies of cassava. Processing equipment and Food products. IITA, Ibadan, Nigeria. April 1988. pp. 67-75.

PEREIRA, A.L.G. and ZAGATTO, A.G. (1967). Etiology of angular leafspot of cassava (Manihot utilissima). Archives do Institute Biologico, Sao Paulo 34: 153-160.

PERSLEY, G.J. (1977). Distribution of CBB in Africa. In: G. Persley, E. Terry, and R. MacIntyre (eds.). Report of an interdisciplinary workshop held at IITA, Ibadan, Nigeria. 1-4 Nov. 1976. pp 9-14. IDRC, Ottawa, Canada.

PERSLEY, G.J. (1978). Studies on the epidemiology and ecology of cassava bacterial blight. In: Cassava bacterial blight in Africa. Past, present and future. Report of an interdisciplinary workshop held at IITA, Ibadan, Nigeria. 26-30 June, 1978, pp. 5-7.

PORTO, M.C.M.; P.A. de ALMEDIA; P.L.P. MATTOS; and R.F. SOUZA. (1979). Cassava intercropping in Brazil. In: E. Weber, B. Nestel and M. Campbell (eds.). Intercropping with cassava: Proc. Int. Workshop held in Trivandrum, India, Nov. 27-Dec. 1, 1978. pp. 57-65.

RENVOISE, B.S. (1973). The area of origin of cassava as a crop plant: a review of the evidence. Econ. Bot. 26(4), 352-360.

SILVESTRE, P. (1989). The Tropical Agriculturist. Cassava. Translated by Paul Skinner. CTA/MACMILLAN Publishers, London & Basingstoke. pp. 1-2.

SINTHUPRAMA, S. (1979). Cassava and cassava-based intercrop systems in Thailand. In: E. Weber, B. Nestel, and M. Campbell (eds.). Intercropping with cassava: Proc. Int. Workshop held in Trivandrum, India, Nov. 27-Dec 1, 1978. pp. 57-65.

SNEDECOR, G.W. and COCHRAN, W.G. (1967). Statistical methods. 6th edition. Published by Iowa State University Press. pp. 120-122.

STARR, M.P. (1946). The nutrition of phytopathogenic bacteria. I. Minimal nutritive requirements of the genus Xanthomonas. Journal of Bacteriology 51: 131-143.

TAKATSU, A.; FUKUDA, S. and PERIN, S. (1979). Epidemiological aspects of bacterial blight of cassava in Brazil. In: Maraite, H. and Meyer, J.A. (eds.). Proceedings of the international symposium on diseases of tropical food crops held in 1978 at Louvain-la-Neuve, Belgium. pp. 141-150.

TERRY, E.R. (1973a). Cassava Diseases - East African Region. IITA Report, Oct. 1973 (Mimeo).

TERRY, E.R. (1973b). Report on cassava disease epidemic-East Central State of Nigeria. IITA. Report, August 1973 (Mimeo).

TERRY, E.R. (1974a). A mode of survival and spread of Xanthomonas manihotis, the cassava bacterial blight pathogen. Niger. J. Plant Protection (Ocassional Publication) (Abstract).

TERRY, E.R. (1974b). Some epidemiological factors affecting the survival and dissemination of Xanthomonas manihotis. Proceedings of the first workshop on cassava bacterial blight in Nigeria, IITA, May 1974. pp. 39-41.

TERRY, E.R. (1975). Cassava bacterial blight in Africa. In: Terry, E. and MacIntyre, R. (eds.). The international exchange and testing of cassava germ plasm in Africa. Proc. int. workshop held at IITA, Ibadan, Nigeria 17-21 Nov. 1975. pp. 23-25.

TERRY, E.R. (1976). Article in 1975 Ann. Rep. of Root and Tuber Improvement Program. IITA, Ibadan, Nigeria.

TERRY, E.R. and McINTYRE, R. (1976). The international exchange and testing of cassava germ plasm in Africa. Proc. int. workshop held at IITA, Ibadan, Nigeria. pp. 35.

TERRY, E.R. (1982). Review of cassava and sweet potato diseases with special reference to germplasm exchange. Paper presented at the CAB's first scientific conference on advancing agricultural population in Africa, Arusha, Tanzania, 12-18 Feb. 1982. CAB (Commonwealth Agricultural Bureaux), Slough, England.

THUNG, M. and COCK, J.H. (1979). Multiple cropping cassava and field beans; status of present work at the Centro Internacional de Agricultura Tropical (CIAT). In: E. Weber, B. Nestel, and M. Campbell (eds.). Intercropping with cassava. Proc. Int. Workshop held in Trivandrum, India Nov. 27-Dec 1, 1978, pp 7-16.

UCL/IITA (1980). Report for 1980 of the collaborative research project between UCL and IITA on diseases of tropical root and tuber crops. Lab. de phytopath., Universite' Catholique de Louvain, Louvain-la-Neuve, Belgium pp 24.

VERDIER, V.; SCHMIT, J. and BOHER, B. (1993). Microscopic study of the establishment of Xanthomonas campestris pv. manihotis on in vitro microcuttings of cassava: In: Roca, W.M. and Thro, A.M. (eds.). Proc. of the first int. scientific meeting of the cassava Biotech. Network, Cartegena, Colombia, 25-28 August 1992- Cali, Colombia: CIAT, 1993. pp.358-365 (Working document; no 123).

VIEGAS, A.P. (1940). Mofo dos afideos e alerirodoes. Revista Agricultura Piracicaba 15: 475-485.

VIEGAS, A.P. (1976). Estudios sobre a Mandioca, Instituto Agronomico do Estado de Sao Paulo. pp. 214.

WHYTE, J.B.A. (1985). Breeding cassava for adaptation to environmental stress. In: Clair H. Hershey (ed.). Cassava Breeding. A multidisciplinary Review. Proceedings of a workshop held in the Philippines, 4-7 March 1985. pp. 147-176.

WIEHE, P.O. and DOWSON, W.J. (1953). A bacterial disease of cassava (Manihot utilissima) in Nyasaland. Empire Journal of Experimental Agric. 21 141-143.

WILLIAMS, R.J; S.D. AGBOOLA; and R.W. SCHNEIDER (1973). Bacterial wilt of cassava in Nigeria. Plant Disease Rept. 57: 824-827.

9. APPENDICES

9.1 Analysis of variance (ANOVA) of parameters used in the evaluation of cassava bacterial blight in the 1993 disease area survey.

9.1.1 Location visited

9.1.1.1 Mean disease incidence

Source of variation	DF	SS	MS	F
Location	39	8.2033	0.2103	5.7874**
Error	41	1.4901	0.0363	
Total	80	9.6934		

9.1.1.2 Mean disease severity score

Source of variation	DF	SS	MS	F
Location	39	36.0429	0.9242	7.3960**
Error	41	5.1232	0.1250	
Total	80	41.1661		

9.1.2 Areas visited

9.1.2.1 Mean disease incidence

Source of variation	DF	SS	MS	F
Area	3	1.0294	0.3431	3.2125*
Error	77	8.2244	0.1068	
Total	80	9.2538		

9.1.2.2 Mean disease severity score

Source of variation	DF	SS	MS	F
Area	3	6.0667	2.0222	4.5964**
Error	77	33.8770	0.4400	
Total	80	39.9437		

9.2 Analysis of variance (ANOVA) of parameters used in determining the effects of planting date and intercropping of local cassava variety on the incidence and severity of cassava bacterial blight (CBB) in the 1993 field experiments.

9.2.1 Mean* disease incidence

Source of variation	DF	SS	MS	F
Replication	8	2.0244	0.2531	
Sole vs intercrops	1	1.6762	1.6762	8.7348**
Within intercrops	3	5.9237	1.9746	10.2897**
Error	32	6.1419	0.1919	
Total	44	15.7662		

9.2.2 Mean* disease severity score

Source of variation	DF	SS	MS	F
Replication	8	11.7911	1.4739	
Sole vs intercrops	1	8.4500	8.4500	8.5096**
Within intercrops	3	28.8128	9.6043	9.6720**
Error	32	32.7772	0.9930	
Total	44	80.8311		

9.3 ANOVA of parameters used in determining the effects of planting date and intercropping of improved cassava variety TMS 4(2)1425 on the incidence and severity of CBB in the 1993 field experients.

9.3.1 Mean* disease incidence

Source of variation	DF	SS	MS	F
Replication	5	2.3585	0.4717	
Sole vs. intercrops	1	3.2875	3.2875	13.6800**
Within intercrops	2	0.5197	0.2599	1.0815NS
Error	15	3.6047	0.2403	
Total	23	9.7704		

9.3.2 Mean* disease severity score

Source of variation	DF	SS	MS	F
Replication	5	8.2330	1.6466	
Sole vs. intercrops	1	12.6253	12.6253	12.6684**
Within intercrops	2	1.7733	0.8867	0.8897NS
Error	15	14.9488	0.9966	
Total	23	37.5804		

9.4 ANOVA of parameters used in the evaluation of 6 cassava varieties for resistance to bacterial blight in the 1992 field trial.

9.4.1 Mean disease incidence

Source of variation	DF	SS	MS	F
Replication	2	0.0966	0.0483	
Treatment	5	4.4092	0.6813	6.0230**
Error	10	1.1323	0.1132	
Total	17	4.6381		

9.4.2 Mean disease severity score

Source of variation	DF	SS	M	F
Replication	2	0.2133	0.1067	
Treatment	5	13.7482	2.7496	5.4052*
Error	10	5.0867	0.5087	
Total	17	19.0482		

9.5 ANOVA of parameters used in the evaluation of 29 cassava varieties for resistance to bacterial blight at the University farm, Shika, 1992 wet season.

9.5.1 Mean disease incidence

Source of variation	DF	SS	MS	F
Treatment	28	1.8372	0.0656	3.9832**
Error	21	0.3459	0.0165	
Total	49	2.1831		

9.5.2 Mean disease severity score

Source of variation	DF	SS	MS	F
Treatment	28	12.7448	0.4552	3.6237**
Error	21	2.6378	0.1256	
Total	49	15.3826		

9.5.3 Mean number of main shoot die-back per stand:

Source of variation	DF	SS	MS	F
Treatment	28	5.1259	0.1831	3.1999**
Error	21	1.2014	0.0572	
Total	49	6.3263		

9.6 ANOVA of parameters used in the evaluation of 53 cassava varieties for resistance to bacterial blight at the University farm, Shika; 1992 wet season.

9.6.1. Mean disease incidence

Source of variation	DF	SS	MS	F
Treatment	52	26.2568	0.5049	12.7125**
Error	2.901	115.2276	0.0040	
Total	2,963	141,4844		

9.6.2 Mean disease severity score

Source of variation	DF	SS	MS	F
Treatment	52	280.1035	5.3866	97.6076**
Error	2,901	160,0955		
Total	2,953	440,1990		

9.7 ANOVA of parameters used in the evaluation of 6 cassava varieties for resistance to bacterial blight in the 1993 pot experiment.

9.7.1 Mean disease incidence

Source of variation	DF	SS	MS	F
Treatment	5	1.0020	0.2004	1.8198NS
Error	30	3.3036	0.1101	
Total	35	4.3056		

9.7.2 Mean disease severity score

Source of variation	DF	SS	MS	F
Treatment	5	10.5853	2.1171	3.8175**
Error	30	16.6369	0.5546	
Total	35	27.2222		

9.8 ANOVA of parameters used in the evaluation of 8 cassava varieties from *in-vitro* establishment for resistance to bacterial blight at the University farm, Shika; 1993 wet season.

9.8.1 Mean disease incidence

Source of variation	DF	SS	MS	F
Treatment	7	0.8078	0.1154	7.9531**
Error	283	4.1063	0.0145	
Total	290	4.9141		

9.8.2 Mean disease severity score

Source of variation	DF	SS	MS	F
Treatment	7	4.5971	0.6567	4.5794**
Error	283	40.5850	0.1434	
Total	290	45.1821		

9.8.3 Mean number of main shoot die-back per stand

Source of variation	DF	SS	MS	F
Treatment	7	0.2141	0.0306	4.8831**
Error	283	1.7722	0.0063	
Total	290	1.9863		

9.9 ANOVA of parameters used in the evaluation of 30 cassava genotypes for resistance to bacterial blight at the University farm, Shika; 1993 wet season.

9.9.1 Mean disease incidence

Source of variation	DF	SS	MS	F
Treatment	29	1.5131	0.0522	1.6690**
Error	601	18.7880	0.0313	
Total	630	20.3011		

9.2.2 Mean disease severity score

Source of variation	DF	SS	MS	F
Treatment	29	18.6952	0.6447	2.3308**
Error	601	166.2271	0.2766	
Total	630	184.9223		

9.9.3 Mean number of main shoot die-back per stand

Source of variation	DF	SS	MS	F
Treatment	29	10.8860	0.3754	3.8377**
Error	601	58.7859	0.0978	
Total	630	69.6719		

BIOGRAPHY: Samuel Tabot Duala

Name	:	S.T. DUALA
Date of Birth	:	28 January 1962
Business Address	:	Department of Crop Protection, Faculty of Agriculture, Ahmadu Bello University, ZARIA, NIGERIA.
Home Address	:	c/o Mr. R.N. Duala, P.C. Azire, P.O. Box 49, Bamenda, CAMEROON.
Previous Qualifications	:	B.Sc. (Botany) University of Yaounde.

Institutions attended	From	To	Cert./degree
R.C.M School, Mundum I	1972	1975	F.S.L.C.
B.G.S. Molyko, Buea	1976	1981	O/L G.C.E.
CCAST Bambili, Bamenda	1981	1983	A/L G.C.E.
University of Yaounde, Cameroon	1983	1987	B.Sc. (Botany).

Post Held since the Award of First Degree

Organisation	From	To	Position
N.C.H.S. Bamenda	1987	1989	Head, Biology Dept.
C.C.C. Mankon, Bamenda	1991	1991	Senior Lecturer, Biology Dept.

Year of Admission for Postgraduate Studies : 1992

Admission Number : M.Sc./Agric/1870/91-92.