FACTORS INFLUENCING INFECTION, SPREAD AND SEVERITY OF TWO COLLETOTRICHUM SPECIES ON COWPEA (VIGNA UNGUICULATA (L.) WALP.) UNDER DIFFERENT CROPPING SYSTEMS

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WAS ACCEPTED IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY
IN THE FACULTY OF AGRIC. & FORESTRY
OF THIS UNIVERSITY
THE EFFECTIVE DATE OF THE AWARD IS

18 April, 1991

21 Nov., 1991
DATE

SECRETARY
POSTGRADUATE SCHOOL

FACTORS INFLUENCING INFECTION, SPREAD AND SEVERITY OF TWO *COLLETOTRICHUM* SPECIES ON COWPEA (*VIGNA UNGUICULATA* (L.) WALP.) UNDER DIFFERENT CROPPING SYSTEMS

BY

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A thesis in the Department of Agricultural Biology
Submitted to the Faculty of Agriculture and Forestry in
partial fulfilment of the requirements
for the degree of
DOCTOR OF PHILOSOPHY
UNIVERSITY OF IBADAN

APRIL, 1991

ABSTRACT

Screenhouse and field experiments were conducted between 1987 and 1989 to investigate the factors affecting infection, severity, and spread of two diseases, anthracnose, caused by *Colletotrichum lindemuthianum*, and brown blotch, caused by *Colletotrichum truncatum*. The following factors were studied: reaction of cowpea genotypes to infection, methods and time of inoculation in screening cowpea seedlings for resistance; plant spacing, genotype, and cropping pattern in mono-cowpea and cowpea-maize intercrop; and time of cowpea introduction into cowpea-maize association.

Cowpea varieties IT82E-60, IT81D-1137, and Vita-7 were most susceptible to anthracnose whereas TVx 3236, IT81D-994 and IT81D-975 were most resistant. Varieties IT82E-60, IT82D-699 and Ife Brown were most susceptible to brown blotch whereas TVx 3236, Vita-7, and IT81D-1137 were most resistant.

Wrapping of wounded seedlings with inoculum meal of *Colletotrichum* at 21 days after seedling emergence enhanced optimal conditions for infection and disease development with a clear distinction between susceptible and resistant varieties.

Significantly lower incidence and severity of the diseases occured on intercropped cowpea than monocrop. Though incidence values of 25 and 43% on pods from intercropped cowpea and sole cowpea infected with *C. lindemuthianum* were recorded, the results indicated that the sole cowpea had higher seed yield than the intercropped. Yield averages of 458 and 678 kg/ha were obtained from intercropped and sole cowpea with anthracnose infection.

Increasing cowpea spacing, between- and within-rows, reduced the infection and severity of both *Colletotrichum* species on cowpea in maize and non-maize stands. Infection rates for the pathogens were lower on cowpea intercropped than on sole, and infection rates increased as plant spacing decreased.

Disease infection, severity and spread significantly increased with increase in age among all the tested varieties. Infection rates were highest on IT82E-16 (semi-erect type) and lowest on IT84S-2246-4 (erect type). Thus, the erect variety proved more suitable than the spreading type in reducing the spread of both diseases.

Cropping pattern significantly affected the incidence and severity of the fungi on cowpea decreasing generally in the order Sole > Strip > Intrarow > Doublerow > Interrow.

Planting cowpea one week before maize and planting both crops simultaneously reduced the incidence and severity of the two fungi on cowpea more than when it was introduced later into maize. Infection rates were lowest on cowpea planted simultaneously with maize.

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to Dr. T. Ikotun, my major supervisor in the Department of Agricultural Biology, University of Ibadan, for his encouragement, guidance, constructive counselling during the course of this work and for recommending me for a fellowship. I am also grateful to Dr. K.E. Dashiell, International Institute of Tropical Agriculture (IITA), Ibadan who co-supervised the work and assissted tremendously in other aspects of it.

Special thanks go to the other members of my supervisory committee including; Dr. B. Fawole, Department of Agricultural Biology, Dr. A.O. Oladiran , Botany Department, University of Ibadan, and Dr. K.F. Cardwell, a plant pathologist, at IITA, for their suggestions and criticisms during the preparation of this thesis. I am also thankful for the contributions of Dr. G.L. Hartman, my former IITA co-supervisor.

I am greatly indebted to Drs. S.R. Singh and H. Gasser, Directors of Grain Legume Improvement and Training Programmes, respectively, for making the award of the fellowship which gave me all I needed for the study possible. Their fatherly encouragement during the study is deeply appreciated.

My profound gratitude goes to my sister, Chief (Mrs.) T. F. Adewumi and her husband for being my mentors and for their financial support. I also gratefully acknowlegde the encouragement of Auntie Titi Durojaiye, the contributions of my office colleague, Mrs. Rita Noameshie and the free editorial service provided by Mrs. Rose Umelo of the Publications on the thesis.

My appreciation goes to all staff of GLIP and Training Programme who jointly and/or severally assisted. Special thanks are expressed to Messrs. E.O.

Adenekan, S.N. Odoemene, T. Oyelakin, K. Ojo, C. Okafor, J. Akinbebije and Mrs. Deola Peters for their inspiration and assistance in their respective capacities. I thankfully remember Mrs. V.O. Ojo for her supportive role.

Great thanks go to the entire people working in the bindery, reprographic and circulation sections of the IITA Library for their remarkable assisstance.

I sincerely express my deep appreciation for the concern and patience of my mother. My younger ones, especially Mrs. D. Olatunbosun, and her husband, are thanked for their visits which normally eliminate my nostalgic feelings in the course of the study.

Finally, I thank God who kept me going up on the road to success amidst potholes of distress.

CERTIFICATION

We certify that this work was carried out by Mr. S. A. Adebitan of the Department of Agricultural Biology, University of Ibadan at the University and International Institute of Tropical Agriculture, Ibadan.

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TABLE OF CONTENTS

		Page
Title Page		1
Abstract		2
Acknowledgement		4
Certification		6
Table of contents		7
List of plates		12
List of figures		13
List of tables		16
Dedication		21
CHAPTER ONE		
1.	Introduction	22
CHAPTER TWO		
2.	Review of literature	27
2.1	The diseases	27
2.1.1	Anthracnose disease of cowpea	27
2.1.2	Brown blotch disease	33
2.1.3	Screening for resistance techniques	39
2..2	Status of intercropping in cowpea production	41
2.2.1	Relevance, concepts and definitions of intercropping	41
2.2.2	Advantages of intercropping in cowpea production	43

		Page
2.2.3	Effect of intercropping on the spread of cowpea diseases in intercropping systems	46

CHAPTER THREE

3.	Materials and methods	49
3.1	The pathogens	49
3.1.1	Isolation of pathogens	49
3.1.2	Preparation of spore suspension	49
3.1.3	Pathogenicity tests	50
3.1.4	Inoculation of cowpea plants	50
3.2	The host plant (cowpea)	51
3.2.1	Experimental sites and conditions	51
3.2.2	Land preparation, planting and cultural management	51
3.2.3	Experimental plots: size and design	54
3.2.4	Sampling and data collection	65
3.2.5	Statistical analyses	70

CHAPTER FOUR

4.	Results	71
4.1	Susceptibility test on cowpeas using three inoculation methods	71
4.1.1	Reaction of cowpea varieties to infection by *Colletotrichum lindemuthianum* and *C. truncatum.*	71
4.1.2	Effect of inoculation methods on *Colletotrichum lindemuthianum* and *C. truncatum.*	75
4.1.3	Effect of the variety and inoculation method interaction on both species of *Colletotrichum* used	76

Page

4.2. Effect of time of inoculation on the reaction of cowpea varieties to *Colletotrichum lindemuthianum* and *C. truncatum*. 78

4.2.1 Symptom appearance on cowpea seedlings at different times of inoculation 78

4.2.2 Effect of time of inoculation on the infection of both *Colletotrichum* diseases on cowpea seedlings 81

4.2.3 Effects of interaction between time and method of inoculation on the incidence of anthracnose and brown blotch diseases on cowpea seedlings 82

4.2.4 Severity of anthracnose and brown blotch diseases on cowpea seedlings 86

4.3 Effect of spacing on anthracnose and brown blotch diseases of cowpea in different cropping systems 91

4.3.1 Incidence of the cowpea pathogens 92

4.3.2 Severity of the diseases on cowpeas 99

4.3.3 Incidence of anthracnose and brown blotch diseases on cowpea pods 109

4.3.4 Severity of anthracnose and brown blotch diseases on cowpea pods 115

4.3.5 Infection of cowpea seed by anthracnose and brown blotch diseases 117

4.3.6 Viability of cowpea seeds following infection from anthracnose and brown blotch diseases 120

4.3.7 Effect of anthracnose and brown blotch diseases on cowpea seed weight. 120

4.3.8 Effect of anthracnose and brown blotch diseases on cowpea seed yield 121

4.3.9 The spread of anthracnose and brown blotch diseases on cowpea plants grown in two cropping systems at different spacings 124

		Page
4.4	The influence of cowpea genotypes and cropping patterns on anthracnose and brown blotch diseases of cowpea	130
4.4.1	Incidence of the diseases on cowpeas	130
4.4.2	Severity of anthracnose and brown blotch diseases on cowpeas	138
4.4.3	Incidence of anthracnose and brown blotch diseases on cowpea pods	146
4.4.4	Severity of anthracnose and brown blotch diseases on cowpea pods	148
4.4.5	Percent seed infection of cowpea by anthracnose and brown blotch diseases	151
4.4.6	Seed viability in cowpea following infection by anthracnose and brown blotch diseases	157
4.4.7	The effect of anthracnose and brown blotch diseases on cowpea seed weight	160
4.4.8	Effect of two *Colletotrichum* diseases on cowpea seed yield	162
4.4.9	The effects of cropping patterns and varietal difference on the spread of anthracnose and brown blotch diseases of cowpea	168
4.5	Effects of anthracnose and brown blotch diseases on cowpea introduced at different times in cowpea/maize association	176
4.5.1	Incidence of the diseases on cowpea	176
4.5.2	Severity of the diseases on cowpea	179
4.5.3	Incidence of anthracnose and brown blotch diseases on cowpea pods	179
4.5.4	Severity of the diseases on cowpea pods	182
4.5.5	Effects of anthracnose and brown blotch diseases on cowpea seed infection, viability and seed weight	185

Page

4.5.6 Influence of anthracnose and brown blotch diseases on cowpea seed yield due to different time of cowpea introduction into maize 185

4.5.7 The effects of varying times of cowpea introduction into maize plants on the spread of anthracnose and brown blotch diseases on cowpea 189

CHAPTER FIVE

5. Discussion 192

CHAPTER SIX

6. Summary and conclusion 207

REFERENCES 210

APPENDICES 226

LIST OF PLATES

Plate		Page
1.	*Colletotrichum lindemuthianum* showing acervuli with setae (A) and numerous rod-shaped conidia (B).	29
2.	*Colletotrichum truncatum* showing acervuli with setae (A) and numerous boat-shaped conidia (B).	35
3.	Symptoms of anthracnose disease appearing as tiny brown spots on the leaf (A) and covering the entire leaf (B)	92
4.	Characteristic symptoms of brown blotch disease on the leaf (A) and pods (B) of cowpea plant	97
5	Symptoms of brown blotch disease on cowpea: distortion and shrivelling of pods (A) and dry pods covered with acervuli of the disease incitant (B)	113

LIST OF FIGURES

Figure | Page

1a. Summary of IITA, Ibadan weather data showing the mean monthly relative humidity, mean monthly temperature and monthly total rainfall in 1987 — 52

b. Summary of IITA, Ibadan weather data showing the mean monthly relative humidity, mean monthly temperature and monthly total rainfall in 1988 and from January to March, 1989. — 53

2a. Plant arrangement and population from different combinations of between- and within-row spacings: under cowpea sole cropping (Numbers in parentheses represent cowpea plant population in a plot) 61

b. Plant arrangement and population from different combinations of between- and within-row spacings: under intercropping of cowpea = o with maize = o. (Numbers in parentheses represent cowpea plant population in a plot). — 62

3. A schematic diagram showing the different cropping patterns used in testing the effect of two *Colletotrichum* species on cowpeas. (Numbers in parentheses represent plant population). — 64

4. Seasonal variability in the severity of anthracnose disease during three growing seasons: F = first season, S = second season and T = third season, in 1987/88 — 101

5. Seasonal variability in the severity of brown blotch disease during three growing seasons: F = first season, S = second season and T = third season, in 1987/88 — 107

6. Disease spread by *Colletotrichum lindemuthianum* and incidence on cowpea in two cropping systems and at different interrow and intrarow spacing. — 125

7. The rates of anthracnose disease spread by *Colletotrichum lindemuthianum* and severity on cowpea in two cropping systems, and at different interrow and intrarow spacings. — 126

LIST OF FIGURES (contd.)

Figure		Page
8.	Rate of disease spread by *Colletotrichum truncatum* and incidence on cowpea in two cropping systems, at different interrow and intrarow spacings.	127
9.	The rate of spread by *Colletotrichum truncatum* as reflected in severity on cowpea in two cropping systems and at different interrow and intrarrow spacings.	128
10.	Effect of different cropping patterns on the severity of anthracnose disease on cowpea in three planting seasons in 1988/89. Bars with the same letter(s) are not significantly different at 5% level for each date of sampling.	139
11.	Effect of variety on the severity of anthracnose disease of cowpea during three planting seasons in 1988/89. Bars with the same letter(s) are not significantly different at 5% level for each sampling date.	140
12.	Effect of different cropping patterns on the severity of brown blotch disease on cowpea in three planting seasons in 1988/89. Bars with the same letter(s) are not significantly different at 5% level for each date of sampling.	144
13.	Effect of variety on the severity of brown blotch disease of cowpea during three planting seasons in 1988/89. Bars with the same letter(s) are not significantly different at 5 % level for each sampling date.	145
14.	The effect of the interaction between cropping pattern and variety on percent seed viability of cowpea infected by brown blotch disease during the second and third growing seasons in 1988/89	161
15.	Seed yield from cowpea varieties infected by anthracnose under different cropping patterns during three growing seasons (F = first season, S = second and T = third season) in 1988/89.	166
16.	Seed yield from cowpea varieties infected by brown blotch under different cropping patterns during three growing seasons (F = first season, S = second and T = third season) in 1988/89.	167

LIST OF FIGURES (contd.)

Figure **Page**

17. Patterns of disease spread by anthracnose disease on three varieties of cowpea and in five cropping patterns during three growing seasons in 1988/89. 169

18. The progress of *Colletotrichum lindemuthianum* and incidence on three cowpea varieties and in five different cropping patterns (Logarithmic transformation). 170

19. The rates of anthracnose disease by *Colletotrichum lindemuthianum* and severity on three cowpea varieties grown in different cropping systems. 171

20. Patterns of disease spread by brown blotch disease on three varieties of cowpea and in five cropping patterns during three growing seasons in 1988/89. 172

21. The progress of *Colletotrichum truncatum* and incidence on three cowpea varieties and in five different cropping patterns (Logarithmic transformation). 174

22. The rates of spread of brown blotch disease caused by *Colletotrichum truncatum* as reflected and its severity on three cowpea varieties grown in different cropping systems. 175

23. Seasonal variability in the severity of anthracnose and brown blotch diseases on cowpea introduced at different times into maize in 1988/89. 180

24. The progress of *Colletotrichum lindemuthianum* and *C. truncatum* as shown by its infection of cowpea planted at different times in cowpea/maize association (Logarithmic transformation). 190

25. The rate of disease spread caused by *Colletotrichum lindemuthianum* and *Colletotrichum truncatum* on cowpea introduced at different times into maize (Arithmetic transformation). 191

LIST OF TABLES

Table		Page
1.	Characteristics of the twelve varieties of cowpea screened for resistance to both *Colletotrichum* species.	55
2.	Disease incidence, severity and susceptibility class of 12 cowpea varieties inoculated with *Colletotrichum lindemuthianum*, 21 days after inoculation.	73
3.	Disease incidence, severity and susceptibility class of 12 cowpea varieties inoculated with *Colletotrichum truncatum*, 21 days after inoculation.	74
4.	Effect of inoculation methods on percent incidence and severity of anthracnose and brown blotch diseases on cowpea	77
5	Incidence (%) of *Colletotrichum lindemuthianum* and *Colletotichum truncatum* on cowpeas as affected by the interaction of cowpea varieties and inoculation methods in the screenhouse.	79
6	Mean estimates for the interaction effect between inoculation method and cowpea variety on the severity of *Colletotrichum lindemuthianum* and *Colletotrichum truncatum* on cowpea in the screenhouse.	80
7.	Effect of time of inoculation on percent incidence of anthracnose and brown blotch diseases of cowpea.	83
8.	Incidence (%) of anthracnose disease on twelve cowpea varieties inoculated at different times in the screenhouse.	84
9.	Incidence (%) of brown blotch disease on twelve cowpea varieties inoculated at different times in the screenhouse.	85
10.	Interaction effect of time x method of inoculation on the incidence (%) of anthracnose and brown blotch on cowpea.	87
11.	Effect of time of inoculation on the severity of anthracnose and brown blotch diseases on cowpea	88
12	Effects of interaction between time and method of inoculation on the severity of the *Colletotrichum* diseases on cowpea.	90

LIST OF TABLES (contd.)

Table		Page
13.	Mean estimates of the incidence (%) of anthracnose disease of on cowpea as affected by cropping pattern, interrow and intrarow spacing in1987/88.	93
14.	Effect of cropping pattern and interrow spacing on the incidence (%) of anthracnose disease on coowpea at 40 DAP during the irrigated off-season - 1987T.	95
15.	Effect of interaction between interrow and intrarow spacing on the incidence (%) of cowpea infected by *Colletotrichum lindemuthianum* during two growing seasons in 1987/88.	96
16.	Percent incidence of brown blotch disase of of cowpea as affected by cropping pattern, interrow and intrarow spacing in 1987/88.	98
17.	Effect of interaction between intrarow spacing and cropping pattern on the incidence (%) of brown blotch disease on cowpea at 54 and 68 DAP in the first season of 1987.	100
18.	Interaction effect of cropping pattern and interrow spacing on the severity (%) of anthracnose disease on cowpea at 54 DAP in the first and second seasons in 1987.	103
19.	Interaction effect on interrow and intrarow spacing on the severity (%) of anthracnose disease on cowpea at 54 DAP in the first season of 1987.	104
20.	Effect of the interaction among cropping pattern, interrow and intrarow spacing on the severity (%) of anthracnose on cowpea at 68 DAP in the first and second seasons in 1987.	105
21.	Interaction effect of cropping pattern and spacing on the severity (%) of cowpea brown blotch disease 68 DAP in the second season of 1987/88.	108
22.	Effect of the incidence (%) of anthracnose disease on cowpea pods as affected by cropping pattern, interrow and intrarow spacing during three growing seasons in 1987/88.	110
23.	Effects of the interaction among cropping pattern, interrow and intrarow spacing on the incidence (%) of anthracnose disease on cowpea pods during the third season in 1987/88.	112

LIST OF TABLES (contd.)

Table		Page
24.	Effect of the incidence (%) of brown blotch disease on cowpea pods as affected by cropping pattern, interrow and intrarow spacing during three growing seasons in 1987/88.	114
25.	Severity (%) of anthracnose disease on cowpea pods as affected by cropping pattern, interrow and intrarow spacing in three growing seasons in 1987.	116
26.	Severity (%) of brown blotch disease on cowpea pods as affected by cropping pattern, interrow and intrarow spacing in three growing seasons in 1987/88.	118
27.	Seed weight (100/g), percent seed infection and seed viability of cowpea infected by anthracnose and brown blotch respectively, under different cowpea- maize intercrops and spacings in 1987/88.	119
28.	Seed yield (kg/ha) from cowpea infected by anthracnose under different cowpea- maize cropping patterns, interrow and intrarow spacings during three growing seasons in 1987/88.	122
29.	Seed yield (kg/ha) from cowpea infected by brown blotch under different cowpea- maize cropping patterns, interrow and intrarow spacings during three growing seasons in 1987/88.	123
30.	Effect of variety x cropping pattern on the incidence (%) of anthracnose on cowpea at 54 DAP during three growing seasons in 1988/89.	131
31.	Effect of variety x cropping pattern on the incidence (%) of brown blotch disease of cowpean at 68 DAP during three growing seasons in 1988/89.	132
32.	Influence of cowpea varieties and cropping patterns on the incidence (%) of anthracnose of cowpea at three sampling times during three seasons in 1988/89.	134
33.	Effect of cowpea varieties and cropping patterns on the incidence (%) of brown blotch disease of cowpea at 54 DAP during the first and second cropping seasons in 1988/89.	135

LIST OF TABLES (contd.)

Table **Page**

34. Effect of cowpea varieties and cropping patterns on the incidence (%) of brown blotch disease of cowpea at 68 DAP during the first and second cropping seasons in 1988. 137

35. Interaction effect between variety and cropping pattern on the severity (%) of anthracnose disease of cowpea at 68 DAP during three seasons in 1988/89. 141

36. Effect of variety x cropping pattern interaction on the severity (%) of brown blotch disease of cowpea at three sampling times during the first growing season in 1988. 143

37. Mean squares for the effect of cropping pattern and variety on the incidence of anthracnose disease on cowpea pods during three growing seasons in 1988/89. 147

38. Incidence (%) of brown blotch disease on cowpea pods as influenced by cropping pattern and variety during three seasons in 1988/89. 149

39. Severity (%) of anthracnose disease on cowpea pods as influenced by cropping pattern and variety during three seasons in 1988/89 and across the seasons. 150

40. Analyses of variance for the effect of cropping pattern and variety on the severity of brown blotch disease on cowpea pods during three growing seasons in 1988/89. 152

41. Brown blotch disease severity (%) on cowpea pods as influenced by cropping pattern and variety during three seasons in 1988/89 and across the seasons. 153

42. Effect of variety and cropping pattern on infection (%) on cowpea seed by anthracnose disease in 1988/89. 154

43. The effect of interaction between cropping pattern and variety on infection (%) of cowpea seeds by brown blotch disease during three cropping seasons in 1988/89. 156

44. Effect of anthracnose on cowpea seed viability due to varietal and cropping pattern differences in the 1988/89 seasons. 158

LIST OF TABLES (contd.)

Table		Page
45.	Mean squares showing percent seed viability of cowpea due to the effect of anthracnose disease on cowpea varieties planted under different cropping patterns in three growing seasons in 1988/89.	159
46.	Seed weight (100/g) of cowpea varieties infected by anthracnose under different cropping patterns during three growing seasons in 1988/89.	163
47.	Seed weight (100/g) of cowpea varieties infected by brown blotch under different cropping patterns during three growing seasons in 1988/89.	164
48.	Effect of cowpea introduction into maize at different planting times on the incidence (%) of anthracnose disease on cowpea during three growing seasons in 1988/89.	177
49.	Effect of cowpea introduction into maize at different planting times on the incidence (%) of brown blotch disease cowpea during three growing seasons in 1988/89.	178
50.	Incidence (%) of anthracnose disease on pods of cowpea introduced into maize at different times in 1988/89	181
51.	Incidence (%) of brown blotch caused by *Colletotrichum truncatum* on pods of cowpea introduced into maize at different times in 1988/89.	183
52.	Severity (%) of anthracnose disease on pods of cowpea introduced into maize at different times in 1988/89.	184
53.	Severity (%) of brown blotch disease on pods of cowpea introduced into maize at different times in 1988/89.	186
54.	Cowpea seed yield (kg/ha) after anthracnose disease infection on cowpeas introduced at different times into maize during three growing seasons in 1988/89.	187
55.	Cowpea seed yield (kg/ha) after brown blotch disease infection on cowpeas introduced at different times into maize during three growing seasons in 1988/89.	188

DEDICATION

This work is dedicated to the evergreen memory of my father

late MR. MICHAEL A. ADEBITAN.

I stood on his shoulders, while he painstakingly bore me to see more than what he had seen.

May his gentle soul continue to rest in perfect peace.

TO GOD BE THE GLORY.

CHAPTER ONE

INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp) is grown throughout the tropics and sub-tropics (Johnson, 1970). Okigbo (1986) reported that the crop is grown on over 8 million hectares world wide. It is cultivated all over the southern fringes of the Sahara from the west coast to East Africa. Over 75% of world production of this crop is obtained from Africa, principally in Nigeria, Burkina Faso, Uganda, Niger and Senegal (Rachie and Rawal, 1976). Nigeria produces 0.85 million metric tonnes of dry seeds or 37.4% of the 2.2 million metric tonnes produced in the world (Okigbo, 1986).

In the West African countries, cowpea is the most important indigenous grain legume which is utilized for several purposes because of its numerous nutritive qualities. Platt (1962), Liener (1969), Rachie and Roberts (1974) and Rachie and Silvestre (1977) gave the various constituents of dry cowpea pulse which probably account for its preferred choice when compared with other legumes.

Cowpea is eaten in the form of dry seeds, green pods, and green seeds while tender green leaves are often used as pot herbs in most parts of Africa (Rachie and Roberts, 1974). It supplies most of the plant proteins which are not only the main, but also the cheapest, source of dietary proteins in the developing countries where meat is scarce and too expensive for the people (Allen, 1983). Luse (1973) reported that the total dietary protein intake from legumes in West Africa is 80% for adults (mostly from cowpeas) and it is nearly a sole source of protein for children. Cowpea is eaten in various ways, either alone or in association with the basic staple such as preparations of maize, rice, yams, plantain, or cassava cooked with vegetables, spices and other ingredients to make a thick soup or gruel. Other favourite food types made from cowpea flour include fried balls and steamed paste (Adeniji and Porter, 1980). Cowpea is also used for green manure as a catch crop, as a cover crop and in mixed crops (Agboola and Fayemi, 1972; Jain and Mehra, 1980), fodder (Saunders, 1935; Johnson, 1970; Adebowale, 1981) and medicinal purposes (Burkill, 1966; Kayumbo, 1975). The haulm of cowpea is used as feedstuff for livestock. In the southern United States of America and some other large scale livestock producing regions of the world including Australia, India and Morocco, the crop is used mainly for soil hay, silage and pastoral forage. Saunders (1935) showed the value of cowpea as a milk-producing crop and feed for sheep.

Despite the numerous uses of cowpea, its production is sharply declining (IITA, 1982). Concerted efforts are being made to increase the production area in the developing countries but almost all parts of cowpea are attacked by a range of diseases and insect pests (Taylor, 1965; Singh and Allen, 1979; Singh and Rachie, 1985).

Of the fungal diseases, anthracnose and brown blotch are highly devastating diseases of cowpea (Bailey, 1966; Onesirosan and Barker, 1971; Williams, 1975; Singh and Allen, 1979; Emechebe, 1981; Okpala, 1981; Oladiran and Oso, 1983). Anthracnose is caused by *Colletotrichum lindemuthianum* (Sacc. and Magn.) Bri. and Cav., while brown blotch, a more recent disease in Nigeria, is caused by *Colletotrichum truncatum* (Schw.) Andrus and Moore, in the southern forest zones in Nigeria, and *Colletotrichum capsici* (Syd.) Butler and Bisby in the drier guinea savanna zones (Singh and Allen, 1979; Emechebe, 1981; Oladiran and Oso, 1983). The two diseases may occur separately or jointly and where they occur together, especially under humid conditions, they cause severe losses in production.

Control of *C. lindemuthianum* and *C. truncatum* on host crops including beans *Phaseolus vulgaris* (L.) and soybeans *Glycine max* (L.) Merrill is successful with the use of chemicals and resistant varieties (Cox, 1957; Singh *et al*, 1973; Hassan and Khan, 1979; Backman *et al.*, 1979; Castro *et al* 1982; Miller and Roy, 1982; Lee, 1984; Gomez *et al.*, 1986). However these methods are fraught with many problems which make them economically unfeasible for adoption. Biological explanations for cultural and natural methods of control (Smith *et al*, 1976) have introduced another dimension in controlling cowpea pests and diseases. This new approach involves intercropping which is the growing of two or more crops simultaneously in the same field.

Extensive work has been done to demonstrate the advantages of intercropping especially in the agronomic aspects (Enyi, 1973; Haizel, 1974; Weber *et al*, 1979). In the area of crop protection, except for reports demonstrating the influence of intercropping system on major insect pests affecting cowpea (Taylor, 1965; Raheja, 1973; Norton, 1975; Perrin, 1977; Altieri *et al*, 1978; Karel *et al*, 1980; Ezueh and Taylor, 1984; Jackai *et al* 1985), scanty reports (Allen, 1976; Mukiibi, 1976; Shoyinka, 1976; Sumner *et al*, 1981; Van Rheenen *et al* 1981; Egunjobi, 1984) exist on the impacts of cropping system on cowpea diseases, and little attempt has yet been made to draw parallels between natural plant communities and agricultural ecosystems in this respect

(Browning, 1974; Burdon, 1978). There is no report on incidence and severity of anthracnose and brown blotch diseases of cowpea in cowpea - maize association.

It is postulated that the incidence and severity of both fungi will vary under intercropping systems of cowpea and maize at different densities of cowpea, using different varieties of cowpea under different cropping patterns and by varying times of introducing cowpea into maize. The use of host resistance to disease under the integrated pest management programme could minimize the loss caused by both *Colletotrichum* species. In order to identify resistant varieties for onward breeders' work, different cowpea genotypes have to be screened. In screening, the knowledge of the differences in the reaction of the cowpea genotypes is not only necessary but equally important if evoked through a very effective method of inoculation at the most susceptible stage of the plant growth. Thus, the aims and objectives of this study were to:

i. determine the reaction of cowpea genotypes to infection by *C. lindemuthianum* and *C. truncatum* by screening the genotypes for resistance in the screenhouse.

ii. develop a screening technique for preliminary screening of cowpea genotypes for resistance to *C. lindemuthianum* and *C. truncatum* in the screenhouse.

iii. investigate the best times, with respect to number of days after seedling emergence, for inoculation in screening cowpea genotypes for resistance to *C. lindemuthianum* and *C. truncatum* in the screenhouse.

iv. examine the effect of different spacings on the incidence, spread and severity of anthracnose and brown blotch diseases on cowpea grown in the field.

v. examine the effect of intercropping on the incidence and severity of the two diseases on cowpea.

vi. investigate the influence of genotypes and cropping patterns on the incidence, spread and severity of anthracnose and brown blotch diseases on cowpea.

vii. observe the effect of time of introducing cowpea into maize on the incidence, spread and severity of both diseases on cowpea.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 The Diseases

2.1.1 Anthracnose Disease of Cowpea

2.1.1. i. The pathogen, historical background and nomenclature

Cowpea anthracnose is caused by *Colletotrichum lindemuthianum* (Sacc. and Magn.) Bri. and Cav. Onesirosan and Barker (1971) observed that anthracnose is principally a stem disease of cowpeas. Before the time it was first reported on *Phaseolus* beans by Lindemuth at Bonn, (Germany), in 1875, it had occurred in France and other parts of Europe where mycologists had collected specimens as early as 1843 (Walker, 1969). The pathogen was found to be of such a notable importance on most legumes, especially *Phaseolus* beans and soybeans, all over the United States of America that it attracted serious studies from various investigators (Heald, 1933).

The pathogen is in the Order Melanconiales and the perfect stage, originally called *Glomerella lindemuthiana* Shear, is now known as *G. cingulata* (Stonem.) Spauld. and V. Schrenk (Walker, 1969).

2.1.1. ii. Occurrence and etiology

The anthracnose disease occurs worldwide on susceptible cultivars (Heald, 1933). It was first reported on cowpea in Nigeria by Onesirosan and Barker in 1971.

Colletotrichum produces septate, branched mycelium which is localized in the tissue of a lesion and does not spread internally to other parts. Its colour changes from hyaline to nearly black upon maturity (Schwartz and Galvez, 1980). Heald (1933) established that the mycelium produces the fruit bodies or acervuli (Plate 1A), below the epidermis, in the center of the lesions. Simple, erect, hyaline and continuous conidiophores, which are closely packed together, are produced by each fruit. Their conidiophores are 40-60 microns in length (Zaumeyer and Thomas, 1957). Conidia are produced at their tips (Heald, 1933). Pointed, unbranched, septate, brown hairs or setae, 30 to 90 microns long are formed between the conidiophores. The size of unicellular hyaline conidia ranges from 13 by 4.44 to 22 by 5.33 microns (Walker, 1969). *En masse*, they appear salmon, ochraceous or pink. Conidia shape may be oval, oblong or straight (Plate 1B) and are produced in numerous numbers. It has been reported by Heald (1933) that a single lesion may contain a few to 50 or more acervuli which may continue to form new crops of conidia after the old spores are washed away by rain.

2.1.1. iii. <u>Epidemiology and symptomatology</u>

Sources of primary inoculum consist of mycelial fragments and conidia which respectively, survive in the infected plant debris and the seeds (Onesirosan and Baker, 1971; Esuruoso, 1975; Emechebe and McDonald, 1979; Frank, 1983) for several years (Onesirosan and Sagay, 1975; COPR, 1981). Inoculation is mainly through the planting material. Inoculum can also be transported by wind-blown rain or spattering rain drops or moisture on the surface of affected structures may be filled with spore suspension which reach new host parts. Under favourable environmental conditions, conidia germinate 6 to 9 hours to form a germ tube and appressorium which are attached to the host cuticle by a gelatinous layer (Zaumeyer and Thomas, 1957).

Plate 1: *Colletotrichum lindemuthianum* showing acervuli with setae (A) and numerous rod-shaped conidia (B).

Penetration into the host tissue is by mechanical means applied by the apresorium and infection hyphae which develop from it (Leach, 1923). The infection hypha produces a small enlargement from which branches that spread through the tissue are formed within short distance of entry. With time and depending on the prevailing environmental conditions, acervulus formed from mycelium aggregation within the lesion site ruptures the host cuticle. The conidia so released serve as secondary inocula and are available for the disease to spread from plant to plant throughout the field. Spores may be disseminated by processes involving transference of moisture from one infected plant to another healthy one (Heald, 1933).

Symptoms of anthracnose infection may appear on all aerial parts of the host abpve the ground from the seedling stage to mature plants, depending on the time of infection and source of inoculum (Schwartz and Galvez, 1980). Sporulation can occur in lesions on the petiole and larger leaf veins leading to the production of secondary inoculum (Zaumeyer and Thomas, 1957). Leach (1923) observed that infections may be confined to the wall of the pod or penetrate the endocarp forming sunken cankers (1-10 mm in diameter). The fungus also invades developing seeds within the pods. The cotyledons and seedlings can also be infected (Heald, 1933).

2.1.1. iv. <u>Factors influencing development of anthracnose</u>

Infection and pathological development of disease take place under conducive temperatures, high humidities, and free moisture. Three important factors have been highlighted to influence the prevalence or severity of this disease. These are age of the host tissue, temperature and moisture (Wheeler, 1969). Infection occurs at two stages of the plant growth: when the plant is young and during the early stages of pod development. Infection occurs at temperatures from about 7 to 33°C, the optimum being from 22 to 25°C. Moisture is known to be essential for spore formation and germination. Rain splash is also indispensable to spore dispersal. Mathur *et al.* (1950) showed that there was no conidial formation below pH 3.0 though sporulation occurred at a range of pH 3.6 to 7.7; the optimum being between pH 5.2 and 6.5. In general, low night temperature, scanty rainfall, meagre dews and an abundance of sunshine do not favour the growth of the fungus (Heald, 1933).

2.1.1. v. Effects and economic importance

Cowpea stem anthracnose is regarded as the third most important fungal disease of the crop in the low latitude, rainforest ecological zone of Africa (IITA, 1985). Losses from anthracnose are attributed to reduced viability of infected seed, poor stands due to death of affected seedlings, reduced yields as a result of direct pod infections or to retarded growth and poor quality of the harvested crop (Heald, 1933). Infected seed may fail to germinate or the young seedlings may be killed before they emerge from the soil, or soon after, with resultant poor stands. The disfigured pods are unmarketable or may attract poor price.

Severely affected dry beans are of poor quality because of the shrunken and discoloured seed. In the rainforest areas of Nigeria, a grain yield reduction of 35-50% has been reported in a monoculture of cowpea when the disease was introduced at an early growth stage (William, 1974; Maramba, 1983). Onesirosan and Barker (1971) also reported that about 89% of the pods harvested in a trial were infected with the disease while a high reduction in dry weight of the entire plant was observed (Wong and Thrower, 1978).

2.1.1 vi. Control

The fungus exists in different pathogenic races posing the problem of control (Allen, 1983). Bailey (1974) and Preston (1975) observed that some antifungal compounds are produced by cowpea. These phytoalexins include vignafuran, kievitone, phaseollin and phaseollidin. They further found out that when cowpea producing these compounds were inoculated with *C. lindemuthianum*, conidial germination of the isolates of the fungus were totally inhibited.

Sorting and discarding diseased seed by hand picking or floatation, selecting seed from anthracnose-free fields, avoidance of conditions favourable for infection or the dissemination of the spores and growth of the pathogen, roguing, rotation of crops to avoid residual contaminations have been suggested for control (Zaumeyer and Meiners, 1975; Zaumeyer and Thomas, 1957; Copeland *et al.,* 1975).

Seed treatment with disinfectants has given variable results because of the internal mycelium which cannot be killed without damaging the seed (Wheeler, 1969). Also spraying with protectants or systemic fungicides has been attempted (Stevenson, 1956; Simbwa-Bunnya, 1972). Benomyl, Maneb, Difolatan and Dithane are among other fungicides which have proved very successful in controlling the disease (Sohi and Rawal, 1974).

Laboratory investigations revealed that *Actinomycetes albus* inhibited the growth of *C. lindemuthianum* on dextrose agar and maize meal agar (Alexopoulos *et al.*, 1938).

A lot of success has been achieved through breeding for resistance. Wheeler (1969) reported that resistance in the tested varieties is based on a hypersenstive reaction of the host tissue. As a result of this, host resistance is found unreliable, since there are many pathogenic races of *C. lindemuthianum* (Schreiber, 1932, cited by Walker, 1969).

2.1.2 <u>Brown Blotch Disease</u>

2.1.2 i. <u>The pathogen, historical background and nomenclature</u>

Brown blotch is incited by two species of *Colletotrichum*. These are *C. capsici* (Syd.) Butler and Bisby and *C. truncatum* (Schw.) Andrus and Moore (Singh and Allen, 1979; Singh and Rachie, 1985). It was first reported on beans grown near Kyoto and Osaka in Japan where it caused a great deal of damage (Hemmi, 1952). It is relatively new in Nigeria where it has gained an important recognition since its discovery. It has been also reported on other crops.

Like *C. lindemuthianum*, the incitant of brown blotch is in the Order Melanconiales and not much is yet known about it. Hence, information regarding its nomenclature and possession of synonyms is very scanty.

2.1.2 ii. <u>Occurrence and etiology</u>

In southern Nigeria where there is higher relative humidity, *C. truncatum* is the incitant (Singh and Allen, 1979; Oladiran and Oso, 1983). In the drier guinea savanna zones, *C. capsici* is reported as the incitant (Singh and Allen, 1979; Emechebe, 1981).

C. truncatum is septate with branched mycelium of varying colour from hyaline to nearly black when mature. The fungus produces numerous black spherical or hemispherical acervuli, with a few being conical, linear or oval rugulose (Oladiran and Oso, 1983). Nik and Lin (1984) had observed that while mycelia occurred in all three layers of soybean seed coat, the acervuli were present in the palisade layer and were found on the outer surface of the infected regions (Wajid and Singh, 1972). The acervuli are borne on clearly developed stomata and may either be scattered or gregarious in nature. Wajid and Singh (1972) have shown that the acervuli are variable in length, comprising short and long types which are intermixed (95-360 by 3.6-9.0 microns in length and diameter, respectively). There are many black spine-like setae of variable lengths (60-300 microns) and diameter (2.5-8 microns) amidst which the conidiophores are produced (Plate 2A). The conidiophores form oblong (nearly cylindrical) unicellular boat-shaped to fusoid conidia (Plate 2B) which are 18-30 microns in length by 3-4 microns in width (Westcotts, 1979). Other investigators obtained different measurements while working on different isolates: Saxena and Sinha (1977) found them to be 16-20 microns in length and 3.0-3.5 microns in width, while Oladiran and Oso (1983) recorded a length ranging from 20.5 to 22.0 microns by 3.2 to 4.0 microns in width.

In general, while it was reported by Ridings (1973) and Lenne *et al.* (1984) that conidia produced by setae are not different from those produced by conidiophores on beans, Southworth (1891), however, had observed that conidia produced from setae were somewhat smaller than those borne on

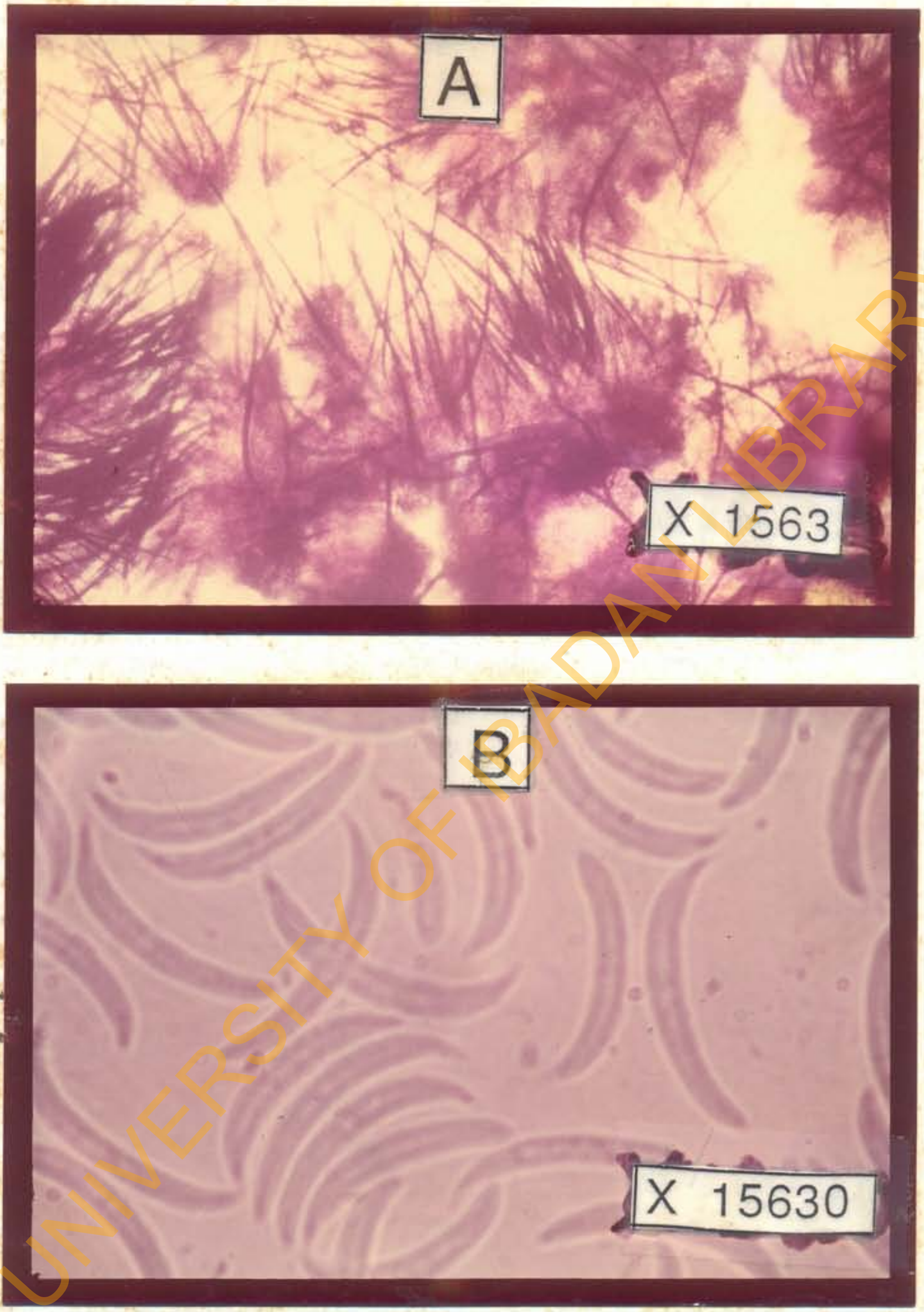


Plate 2: *Colletotrichum truncatum* showing acervuli with setae (A) and numerous boat-shaped conidia (B).

conidiophores on the same host. Two types of setae were observed in the acervuli (Lenne *et al.*, 1984): fertile which produce conidia, and sterile that do not. Lenne *et al.* (1984) further distinguished the fertile setae which have truncate and near hyaline apices (Southworth, 1891) from those that are sterile having darker and usually obscure apices.

2.1.2 iii. Epidemiology and symptomatology

Sources of primary inoculum are mycelial fragments and conidia which are carried over to the following season in infested plant debris and seed (Emechebe and McDonald, 1979; Emechebe, 1981). Westcotts (1979) reported that conidia are held together by a gelatinous coating and appear pinkish in mass. He also reported that they are not wind-borne but can be disseminated by wind-splashed rain. Rain-drop splash was reported to restrict the spread of the pathogen to a relatively short distance (Walker,1969; Westcotts,1979). However, they also observed that conidia produced on setae are readily dislodged by air movement so that during humid windy conditions, they are dispersed over longer distances than when dislodged by raindrops.

On French beans, *P. vulgaris*, conidia germinate to form brown appressoria. Dey (1919) observed that appressoria produce peg-like infection hypha which penetrate into the cuticle through mechanical pressure normally initiated by appressorium. After penetration, Tiffany (1951) observed that hyphae grow between the cell walls and protoplasts for 2 to 4 days without apparent damage to the host cells under natural conditions.

At flowering, the peduncles and leaves show symptoms (Emechebe, 1981). Saxena and Sinha (1977) reported that there may be coalescence of a number of spots resulting in bigger spots which occupy a major portion of the lamina. Observations made by Wajid and Singh (1972) revealed that tiny black brown cankers are found on hypocotyls and cotyledons of soybean seedlings. They also noticed the cankers gradually enlarge in a round to irregular outline measuring about 1-5 mm in diameter. Ling (1940) showed that *C. truncatum* causes pre- and post-emergence damping off of soybean seedlings, within two or four days of sowing. Within two days of inoculation of *C. truncatum* on soybean seedlings, hyphae and acervuli are produced on the seedlings with resultant discrete veinal necrosis of inoculated leaves (Manandhar *et al*, 1985). The acervuli, sclerotia and stromatic bodies appear on dead plant debris at the end of the growing season (Tiffany, 1951).

2.1.2 iv. **Effect and economic importance of brown blotch**

Though relatively new in Nigeria, brown blotch is regarded as the second most important cowpea disease in four of the five ecological zones of cowpea production in Africa (Anon., 1985). Emechebe (1985) stated that the disease became important in the mid-1970s when it was found causing severe damage to pods of improved varieties of cowpea in the savanna, from where it spread to other parts of the country. It has been estimated to cause up to 75% crop loss under protracted wet field conditions (Emechebe, 1981), whereas in 16 southern U.S. states, losses incurred from the disease in 1983 ranged from 0.5 to 6% (Mulrooney, 1985). As a potential pathogen on soybean in the field, Roy (1982) reported that *C. truncatum* appears to be the most important, resulting in 4-26% reductions in seed yield (Backman *et al*, 1982; Saxena, 1984). While working on soybean, Lee (1984) showed that the disease led to reduced seed germination.

2.1.2 v. **Factors influencing development of brown blotch disease**

Dey (1919) and Lauritzen (1919) individually demonstrated that relative humidity ranging between 92-100% was necessary for infection while a temperature range of 13-21°C was found suitable; 17°C was optimum (Westscotts, 1959). Adebitan (1984) observed a wider temperature range, from 15° - 30°C. He also found 28°and 25°C to be optimum for growth and sporulation respectively, while growths on all cultures stopped at 35°C.

The role of testa has been associated with the susceptibility to *C. truncatum*. Presser (1966) showed that in inoculation tests on mature seeds, those with coloured testa were seldom attacked compared to those with white testa. Herbicides have been shown to enhance the development of acervuli. Cerkauskas and Sinclair (1980) showed that field application of paraquat resulted in a greater number of acervuli of *C. truncatum* on stems of soybean cultivars than in unsprayed plants. Increased incidence of the disease was also shown to occur earlier in sprayed plants than in unsprayed plants (Cerkauskas *et al*, 1983).

2.1.2 vi. **Control of brown blotch disease**

Adebitan (1984) showed that the growth of *C. truncatum* was inhibited by *Cercospora kikuchi* and *Fusarium oxysporium* f. sp. *tracheiphilum*. He also reported that there was neither eradicant nor protective effect *in vitro* on the growth of *C. truncatum*. Other reports of inhibition have been shown separately by Singh *et al* (1973) and Yen and Sinclair (1980) who demonstrated the growth inhibition of the pathogen in cultures of *Acremonium sordidulum* and *Chaetomium cupreum* respectively.

There are reports on the chemical control of this fungus on cowpea (Adebitan, 1984) and other crops (Cox, 1957; Hassan and Khan, 1979; Backman *et al.*, 1979; Miller and Roy, 1982; Lee, 1984; Gomez *et al.*, 1986). Fungicides including Plygon, Captan, Thiram, Difolatan, Dithane and Benlate have been tested and found effective in controlling the disease (Singh and Rachie, 1985).

2.1.3 Techniques in screening for resistance

Spraying a conidial suspension of spores onto strawberry seedlings in the screenhouse had been reported to be effective in screening strawberry seedlings for resistance to *Colletotrichum fragariae* (Smith and Spiers, 1982).

A variety of methods have been used to inoculate strawberry plants artificially with *C. fragariae* and evaluate disease levels. Brooks (1931) observed that high temperature and high humidity favoured disease development and that wounding was necessary during inoculation to obtain lesions on petioles and leaves. Disease development was evaluated based on lesion development (Howard, 1972; Howard and Albregts, 1973), percentage of infected plants (Horn *et al.*,1976) and percentage loss or dead plants (Horn and Carver, 1968).

The assay method of Van Wert *et al.* (1984) is a useful tool for rapid selection of *Cephalosporium gramineum* resistant winter wheat germplasm before field trials. Their procedure is useful in differentiating between highly susceptible and highly resistant lines, but less effective for discriminating between lines with intermediate reactions. Seedlings were directly placed in conidial suspensions of *C. gramineum* for 15 minutes before transference to pots containing autoclaved soil. Conidial suspension was also poured into holes in which seedlings were planted in the pots. Pots were placed in a controlled environmental chamber and symptoms rated after 24 days.

Intact and excised stems of container and field-grown *Banksia* plants were used while Dixon *et al.* (1984) attempted to obtain a technique for rapid assessment of tolerance of the plants to root rot caused by *Phytophthora cinnamoni*. They showed that inoculated intact stems and excised stem cuttings developed characteristic lesion lengths. Similar stem inoculation techniques have been used in the selection of root stocks in apples for resistance to stem canker caused by *Phytophthora cactorum* (Borecki and Millikan, 1969; Dakwa and Sewell, 1981).

Rubbing is another inoculation technique that has been used for testing *Phaseolus* bean lines for resistance to anthracnose. Inoculation was done at primary leaf stage in the screenhouse by rubbing individual leaves with a piece of cottonwool previously dipped in the spore suspension (Shao and Teri, 1981). Similar method has been used by other workers (Fisher *et al.*, 1976).

Kruger *et al.* (1977) used the dipping method to examine sources of resistance to *Colletotrichum lindemuthianum* in *Phaseolus* beans. Newly germinated bean seeds were inoculated by dipping in a spore suspension and planted in a layer of sand. They were incubated at 15-18°C in the greenhouse for about 3 days. Cotyledons and hypocotyls of highly susceptible cultivars were severely infected and death resulted a few days later while slightly susceptible cultivars survived and developed distinct stem and leaf necrosis. Symptoms appeared on seedlings of resistant cultivars when spore suspension was sprayed following emergence of the seedlings.

The method of Tu and Aylesworth (1980) is an effective method of screening (white) seedlings for resistance to *C. lindemuthianum*. It is said to provide a distinct differentiation between susceptible and resistant seedlings - a quality lacking in the method of Kruger *et al.* (1977). The spore suspension of anthracnose fungus was brushed gently onto the upper and lower sides of the primary leaves and the hypocotyl. The inoculated seedlings were then covered with a transparent plastic bag.

An *in vitro* method has been used (Tu, 1986), involving the brushing of inoculum onto the underside of excised leaves and leaflets which were placed, inoculated side up, on several layers of wet paper towels in a tray. One important advantage of using this method is that one plant can be assayed several times, either for the same race or for different races of the pathogen. The use of electrophoretic differences in the peroxidase and esterase systems has been demonstrated between the resistant and susceptible lines of *Phaseolus* beans (Okafor *et al.*, 1982). This method has been suggested to be a useful screening aid in breeding programmes.

2.2 Status of intercropping in cowpea production

2.2.1 Relevance, concepts and definitions of intercropping

There is increasing interest in methods which would increase food production as a result of the recent world food shortage, protein deficiency and prospects of inadequate supplies in future (Papendick *et al.*, 1976). Beets (1982) stressed that crop production can be increased by expanding the area planted to crops, raising the yield per unit area of individual crops and by growing more crops per year in time and/or space. Andrews and Kassam (1976) opined that there should be a marked departure from methods involving cultivation of more land to those that will employ the use of smaller parcels of farmland with comparatively great yield per unit area, as emphasized in the developed countries (Sanchez, 1976). They later suggested that a way through which this could be achieved was through a wider and more intensive use of multiple cropping, out of which intercropping plays an integral part (Andrews and Kassam, 1976). Preliminary research has established that a possible means of increasing the productivity on these farms would be achieved through intercropping (Enyi, 1973; Andrews and Kassam, 1976).

Harwood (1973) defined intercropping as the interplanting or mixing of a number of different crops on the same piece of land at the same time such that the period of overlap is long enough to include the vegetative state. This definition agrees with that of Andrews and Kassam (1976) who further classified the term into four different subdivisions as follow:

- mixed intercropping: growing two or more crops simultaneously only in a random order or in no distinct row arrangement. It is characteristic of peasant farming systems throughout the tropics as the farmers do not usually plant in rows;
- row intercropping: growing two or more crops simultaneously where one or more crops are planted in rows;
- strip intercropping: growing two or more crops simultaneously in different strips wide enough for the crops to interact agronomically;

- relay intercropping: growing two or more crops simultaneously during part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage of growth but before it is ready for harvest.

In all, intercropping is one of the components of multiple cropping which embraces relay and sequential planting of the same or different species of crops (Dalrymple, 1971; Beets, 1977). It is a common characteristic of present farming in many parts of Africa and Asia (Papendick *et al*, 1976; Okigbo and Greenland, 1976). Beets (1977) established that specific intercropping systems have evolved over the years in different regions, owing to the prevailing ecological and socio-economic factors in the tropics where it is widely practised. About 98% of cowpea grown in Africa are intercropped (Arnon, 1972) while in Nigeria alone, Lundborg (1982) estimated that about 80% of the country's production takes place in the region in a mixed intercropping system. Thus, differences exist in intercropping systems from one area to another under different soil and climatic conditions (Steiner, 1982).

2.2.2 Advantages of intercropping in cowpea production

Cowpea is rarely planted as a sole crop in Northern Nigeria because of severe pest and disease attack (Litzinger and Moody, 1976). Cowpea is mostly intercropped with maize, sorghum, millet and cassava, but occasionally with cotton and groundnut (Barker and Norman, 1975). It has been established that cowpea grown as a monocrop is subjected to heavy attack from insect pests and diseases, resulting in a low yield (Singh and Rachie, 1985). Norman (1974) therefore asserts that the peasant cowpea farmers are not ready to give up their age-old system of farming and that for a considerable number of years to come, will continue the practice of mixed intercropping even though this militates against the adoption of innovation packages for the farmer (Bartlett *et al*, 1976). Many advantages are associated with intercropping (Ssekabembe, 1985). These include:

2.2.2 i. <u>High productivity: magnitude of inputs and output</u>

Generally, the farmers exploit intercropping mainly for higher productivity if the crops are complementary, as are most crops commonly used in population combinations. Andrews (1972) reported that a higher yield per plant was obtained in cowpea intercropped with maize than when it was monocropped. This report was corroborated by Olafare and Ojomo (1986) who showed that maize-cowpea intercrop has higher yielding potential either as a early or late season crop than when the component crops were grown separately in monocultures. Isenmilla *et al* (1980) reported that yield losses of cowpeas intercropped with maize could be reduced from 68 to 48%.

However, growing cowpea in mixtures can be a low or nil - input way of increasing cowpea production. Even though the yield of maize was significantly enhanced when cowpea was intercropped with it than in sole maize cropping, the yield of cowpea was drastically reduced in intercrop (Das and Mathur, 1980; Gangwar and Kalva, 1982). In some reports, cowpea yields were equally reduced under intercropping situation but with no effect on maize (Ahmed and Kobayashi, 1976; Mongi *et al*, 1982).

2.2.2 ii. <u>Risk avoidance</u>

Farmers normally employ crop mixtures as risk precautions. Willey (1979a) stated in his review of the importance of intercropping that a major reason for the predominance of the method in poorly developed agriculture is that it can offer greater stability. It has been proved (Ruthenberg, 1971; Ogunfowora and Norman, 1973) that at low levels of production in the tropics, the adoption of sole cropping gives less dependable returns. Poor performance of some of the component crops in intercropping may be compensated by the yields of other crops. In support of this, Fisher (1976) showed that greater bean growth, producing high Land Equivalent Ratios (LERs), was still obtained from some used sites, despite the loss caused by hail damage.

2.2.2 iii. <u>Better utilization of environmental resources</u>

A mixture of crops of similar maturity has been demonstrated to give higher total productivity than when grown separately as monocrops through effective utilization of resources within their limit (Andrews and Kassam, 1976). In 1976, Willey and Roberts showed that intercropping can increase efficient utilization of light, land, nitrogen and other inputs. They further observed that light is probably the most important factor when better temporary use of resources is to be achieved. Also, it was demonstrated that component crops may exploit different soil layers, thus utilising a greater total volume of soil for nutrients and water (Willey, 1979b). This was considered the cause of yield gains in some mixtures of oat varieties by Trenbath (1974), because of disparities in rooting patterns and of the 'mutual avoidance' of different root systems (Raper and Barber, 1970; Baldwin *et al*, 1977).

2.2.2 iv. Soil protection and improvement of soil fertility

Intercropping, compared with conventional systems, has been associated with high beneficial effects in terms of coverage and protection of the soil against erosion resulting from heavy downpour, wind and sun heat (Siddoway and Barnett, 1976). Better soil coverage, produced by intercropping systems, is regarded as highly desirable on typical unstable soils of the tropics (Agboola, 1982). Soil fertility has been shown by Agboola and Fayemi (1972) to be more enhanced under intercropping systems than under sole cropping.

2.2.3 Effect of intercropping on the spread of cowpea diseases

The environment of the cowpea plant is drastically modified by intercropping since there are immune or resistant plants in the mixtures which impede pathogen spread and increase the separation between susceptible plants (Altieri and Liebman, 1986).

Larios and Moreno (1977) proved that the agroecosystems which best avoid disease damage in tropical areas are multiple cropping systems which simulate the local natural system. They further observed that *Ascochyta phaseolorum* was less prevalent in cowpea interplanted with maize than in cowpeas grown alone (Altieri and Liebman, 1986). A similar report was made by Moreno (1979). Luthra *et al* (1935) showed that chickpea blight (*Ascochyta rabiei*) was less severe when the crop was inter-sown with a cereal.

Before maize populations are sufficiently dense to shade cowpea, thus providing a favourable environment for the rapid spread of powdery mildew (*Erysiphe polygoni*) of cowpea in association with maize (Allen, 1977), Moreno

(1979) reported that the disease initially developed more rapidly in sole-crop cowpea than when intercropped with maize. In support of this finding, Keswani and Mreta (1980) also showed that the severity of powdery mildew on green-gram was higher under monoculture than when green-gram was intercropped with other crops. Likewise, Mora (1978) noticed less incidence of angular leaf spot (*Isariopsis griseola*) and rust (*Uromyces appendiculatus*) in beans grown in association with maize in Costa Rica. This report, however, contradicts that of Moreno (1977) which showed that the severity of angular leaf spot of beans was more in bean polycultures that included maize than in bean monocultures.

Among other diseases found to show low incidence in beans grown in association with maize when compared with monocultures generally are bean common mosiac virus, anthracnose (*C. lindemuthianum*), scab (*Elsinoe phaseoli*), black node disease (*Phoma exigua* var. *diversispora*), powdery mildew (*Erysiphe polygoni*) and to a lesser extent, angular leaf spot (Van Rheenen *et al.*, 1981). Singh (1954) recorded a susbtantial reduction in the mortality rate of intercropped component crops from *Rhizoctonia solani* which causes root rot, seedling rot and leaf blight; and from wilt caused by *Fusarium coeruleum*. Greater damage from these pathogens resulted when compared with what happened in intercrop.

In 1976, Shoyinka (in Monyo *et al.*, 1976) observed that cowpeas in Nigeria were less attacked by virus when intercropped with maize, rice or soybean than when grown alone, probably due to reduced vector populations in the mixture (Altieri *et al.*, 1978) or by their impeded mobility (Kayumbo, 1976). In mixtures of groundnuts and beans, a similar trend was recorded; the spread of the vector of groundnut rosette disease (*Aphis craccivora* Koch.) decreased because the aphids were trapped by the hooked trichomes of the beans (Farrell, 1976; Thresh, 1982).

Disease reduction also occurred when it was observed that the severity of halo blight (*Pseudomonas syringae* pv. *phaseolicola*) and common blight (*Xanthomonas campestris* pv. *phaseoli*) was shown to be significantly less when beans were grown in association with maize (Van Rheenen *et al.*, 1981; Msuku and Edje, 1982). On the other hand, Egunjobi (1984) recorded higher populations of *Pratylenchus brachyurus* when maize was grown with cowpea and other legumes. However, no difference was found in the soil population level of root-knot nematodes - *Meloidogyne* species - under sole crop of cowpea and intercrop combinations cowpea and maize (Idowu, 1988).

CHAPTER THREE

MATERIALS AND METHODS

3.1 The Pathogens

3.1.1 Isolation of pathogens

Naturally infected cowpea plant parts including stems, petioles and pods were cut into several pieces for isolation of *Colletotrichum lindemuthianum* and *C. truncatum*. The pieces were dipped in 1:9 solution of sodium hypochlorite for 30-50 seconds for surface sterilization. The pieces were rinsed in five changes of sterile distilled water, dried in folded sterile tissue paper and then plated on acidified Difco potato dextrose agar (APDA) for 10-15 days at 25°C. When fungal growths had been fully formed on agar, subcultures grown on the same medium were made to obtain pure cultures of both pathogens. These were further grown on APDA slants and preserved as stock cultures at 5°C. Subcultures were made from the stock cultures as needed.

3.1.2 Preparation of spore suspension

Subcultures were prepared from the different stock cultures of *C. lindemuthianum* and *C. truncatum* and plated on APDA for 10-15 days when the pathogens were fully grown and sporulated. The contents of the Petri dishes were scooped out into a Waring blendor containing distilled water (1 liter) and a drop of Teepol detergent was added to aid the dislodgement of the spores from the medium (APDA). Blending was done for 40 seconds. The spores were strained off the mycelial and medial fragments using two-fold Muslin cheese cloth inside a funnel. The spore suspension was poured into a Hills Porta's garden sprayer (7 litres) after standardization to 5×10^5 spores/ml using a hemacytometer, for subsequent inoculation in the field.

3.1.3 Pathogenicity tests

Koch's postulates were followed to confirm that the isolated micro-organisms were actually responsible for inciting anthracnose and brown blotch diseases, respectively. Apparently healthy seeds of cowpea lines known to be highly susceptible to the two diseases naturally in the field were sown in perforated plastic pots (of 1.12 dm^3 volume) filled with sterilized soil. Ten pots containing five seeds each,were kept inside the screenhouse.

Ten day-old disease-free seedlings of the potted lines were inoculated by spraying leaves and stems with conidial suspension (5.0 x 10^5 conidial/ml) of 10-15 day-old culture of the respective pathogens. The inoculated seedlings were covered up with moistened polyethylene bags to provide high relative humidity for optimum infection. They were kept under the greenhouse bench for 48 hours after which they were uncovered and replaced on the bench. Symptoms that developed on the seedlings were compared with and compared to those that developed naturally on the field. The organisms were re-isolated on APDA and confirmed to be those formerly isolated from field infected plants.

3.1.4 Inoculation of cowpea plants

Cowpea plants were inoculated in the field using two methods which were spraying of spore suspension and hanging of infected plant parts on the growing crop. At the seedling stage and three weeks later, the plants were sprayed to run-off with the standardized spore suspension (as prepared in 3.1.2) of the individual causal organisms of anthracnose and brown blotch. The plants were usually sprayed in the evening for optimum infection a week before the application of insecticide.

3.2 The Host Plant (Cowpea, *Vigna unguiculata* (L.) Walp.)

3.2.1 Experimental sites and conditions

The experiments were conducted variously at IITA and on the Agricultural Farm of the University of Ibadan in 1987, 1988 and 1989. Each field experiment was conducted in three separate growing seasons. The first season designated as F, spanned April to August while the second (S) was from August to November. The third season designated as T, was the dry off-cropping period spanning from November to March in the following year. The summary of the weather conditions recorded at the meteorological station IITA, Ibadan for 1987, 1988 and the first three months in 1989 is presented in Figures 1a and 1b.

The experiments conducted in the third season were under irrigation. The field was irrigated for 4 hours each week. The rate of water supply was 8.6 mm per hour, an equivalent of 35 mm of rainfall per week. This adequately simulated the normal water requirement for the growth of both cowpea and maize plants besides other overall needs.

3.2.2 Land preparation, planting and cultural management

The experimental plots were mowed. To ensure minimum tillage practices, paraquat at the dosage of five litres per hectare was uniformly sprayed to destroy the weeds and make ploughing and harrowing unnecessary.

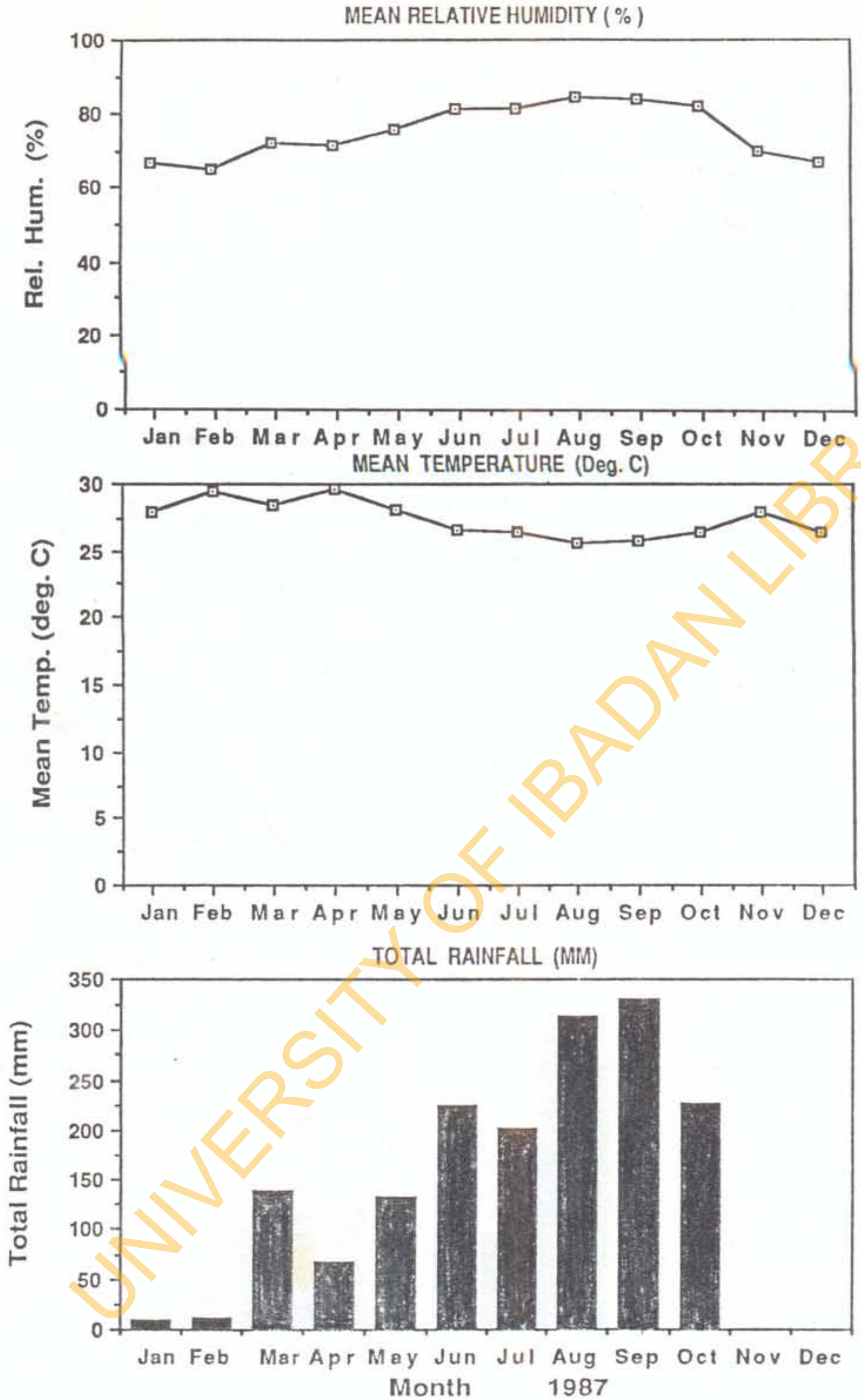


Fig. 1a: Summary of IITA,Ibadan weather data showing the mean monthly relative humidity, mean monthly temperature and monthly total rainfall in 1987

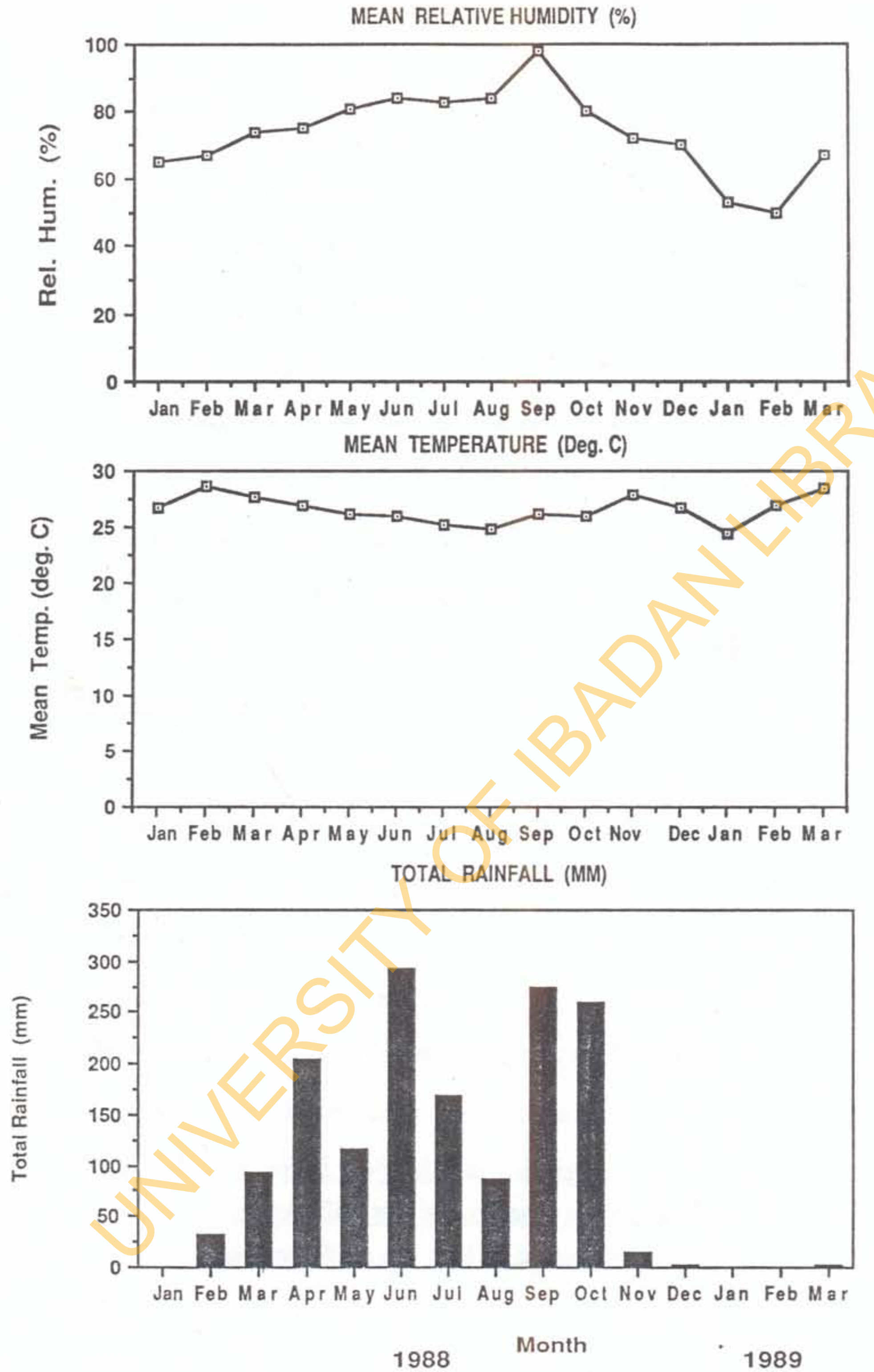


Fig. 1b: Summary of IITA, Ibadan weather data showing the mean monthly relative humidity, mean monthly temperature and monthly total rainfall in 1988 and from January to March, 1989.

The plots were properly marked out and labelled according to the respective treatments. Planting was done on the flat. Two seeds were sown per stand. All missing stands were replanted 5 days after emergence. The seedlings were later thinned to one per hill 15 days after planting. Subsequent weed control, after the initial application of 2.3 litres per hectare of paraquat immediately after sowing the seeds, was by hoeing on 3 weekly basis. Routine 3-weekly insect control with Sherpa Plus (a combination of dimethoate and cypermethrin) sprayed from a knapsack sprayer at 50 ml per 10 litres of water was applied during each experiment until maturity beginning 10 days after sowing.

In the field, each experimental plot layout was duplicated at each location in the same season. The cowpea plants in the duplicates, which were separated from each other by a distance of 6m, were inoculated with either *C. lindemuthianum* or *C. truncatum* respectively. This was to avoid any possible cross-contamination of one pathogen by the other in response to the various treatments. Besides this, the Waring blendor, sprayer and other equipment used in preparation and spraying of spore suspension were thoroughly washed with detergent and rinsed several times under tap water and finally in distilled water before any subsequent use for inoculation.

3.2.3 Experimental plots: size and design

i Susceptibility test on cowpeas to infection by *Colletotrichum lindemuthianum* and *C. truncatum* using three inoculation methods

The experiment was performed in the screenhouse. The test varieties were obtained from IITA, Ibadan and chosen on the basis of their high grain productivity. Their characteristics are as shown in Table 1.

Table 1. Characteristics of the twelve varieties of cowpea screened for resistance to both *Colletotrichum* species.

Varieties	Seed testa	Seed colour	Maturity+	Plant type
IT81D-975	Rough	Brown	Medium	Semi erect
IT81D-994	Rough	White	Medium	Spreading
IT81D-1137	Smooth	White	Medium	Spreading
IT82D-699	Rough	White	Medium	Spreading
IT82E-16	Smooth	Red	Early	Semi-erect
IT82E-32	Smooth	Mottled black	Early	Erect
IT82E-60	Smooth	White	Early	Erect
IT84S-2246-4	Rough	Red	Early	Erect
Ife Brown	Rough	Brown	Medium	Semi erect
TVx 3236	Rough	Cream	Medium	Semi erect
Vita-7	Smooth	Brown	Medium	Semi erect
IT84E-124	Rough	Brown	Extra-early	Erect

+Medium = 70-80 days to maturity
Early = 65-70 days to maturity
Extra early = 55-65 days to maturity.

The experiment was set up in a split plot design in the screenhouse during three growing seasons. Seeds were planted respectively in April, August and November in 1987. Each cowpea variety represented a main plot consisting of four perforated plastic pots (1.12 dm^3) which were the subplots. For each disease, the experiment was carried out three times. The pots were filled with top soil. Three seeds were sown in each pot. To avoid cross contamination from either anthracnose or brown blotch, experiments involving the two pathogens were separated across location and time in a screenhouse.

There were four subtreatments, consisting the control, which involves spraying sterile deionized distilled (SC) water on seedlings using Hill's hand sprayer and three others consisting of the following inoculation methods:

a) spraying of spore suspension on seedlings (SS), prepared as described in 3.1.3 above, using Hill's hand sprayer (0.5 litre).

b) injecting spore suspension into seedling stems using hypodermic syringe with needles (SI).

c) wrapping seedling stems with inoculum meal (MW) prepared by mixing 10 agar plates containing well sporulated growths of the pathogen with 40g of ground cowpea seeds.

The seedlings were inoculated with spore suspension of *C. lindemuthianum* and *C. truncatum* respectively, at 20 days after emergence (6-8 trifoliate leaf stage) using the various methods already defined. All seedlings were removed from the top of the screenhouse bench and placed under, in an enclosure of polyethylene sheet immediately after inoculation. A mist blower, regulated at 15 minutes mist cycles/hr, was placed inside to provide high relative humidity for optimum infection for 48 hours, after which the pots were replaced on top of the bench.

For the different diseases, the first day of symptom appearance was recorded following observation from the first day of inoculation till the seventh day when the plants were scored for disease severity.

The severity of anthracnose and brown blotch on cowpea seedlings in the screenhouse was scored and classified according to modified Emechebe's (1985) scale:

a) Anthracnose;

0. No symptom of disease
1. Few discrete non-coalescing lesions
2. Many lesions occasionally coalescing
3. Coalescing lesions, continuous on more than 40 but less than 61%
4. Coalescing lesions, continuous on more than 60 but less than 81%
5. Collapse of affected part, fall of leaflet, buckling or fall of petiole, death of stem.

b) Brown blotch;

0. No symptom of disease
1. Up to 20% of seedling stem affected by brown blotch
2. 21-40% of seedling stem affected by brown blotch
3. 41-60% of seedling stem affected by brown blotch
4. 61-80% of seedling stem affected by brown blotch
5. More than 80% of seedling stem affected by brown blotch

The reactions of the genotypes based on the 0-5 visual scale were grouped in the following classes:

0.0 - 1.4 = highly resistant

1.5 - 2.4 = moderately resistant

2.5 - 3.0 = moderately susceptible

More than 3.0 = highly susceptible.

Percentage infection was recorded on the basis of the number of plants which were infected by disease among the total number of plants in a pot. A plant having evidence of disease, however slight or severe, was considered infected.

ii Investigation into the best time for inoculation while screening cowpea for resistance to *C. lindemuthianum* and *C. truncatum* in the screenhouse

The experiment was conducted in the screenhouse in two separate studies with each involving one of the pathogens. Twelve varieties of cowpea as formerly presented in Table 1 were used.

This experiment consisted of a randomized split plot design with three replicates. There were three main factors comprising variety, method of inoculation and time of inoculation. The main treatment was a combination of twelve cowpea varieties and three methods of inoculations: spraying of spore suspension (SS), wrapping of seedling stem with inoculum meal (MW) and control where seedling plants were left uninoculated (SC). Inoculation done at five different stages of seedling growth: 7, 14, 21, 28 and 35 days after emergence (DAE) respectively, served as the sub-treatments.

Altogether, 180 pots containing 1.2 dm^3 volume of sterilised top soil were used. Three seeds, from each of the cowpea varieties, were sown per pot. The seeds were sown in three pots per variety at five different times based on a regular weekly interval. Using 60 pots each for a method, the same inoculation procedures, as previously described in the first experiment were followed. Inoculation of all seedlings was done simultaneously at 7th DAE of the last set of seeds sown. This coincided with 35th DAE of the first set of seeds sown in the experiment. Observation and scoring were made on the seedlings as previously stated in 3.2.3.

iii The effect of plant spacing on the incidence, spread and severity of *C. lindemuthianum* and *C. truncatum* on cowpeas

A 2 x 3 x 4 factorial experiment in completely randomized block of 24 plots was designed with the following factors: cropping patterns (monoculture cowpea and intercropped cowpea), between row spacing (50, 75 and 100 cm) and within row spacing (10, 20, 30 and 40 cm). The experimental plots were each 3m long and 6m wide. A clear border of 1m was maintained between plots consisting of the 24 treatments, each of which was replicated three times. The cowpea variety used was Ife Brown which is high yielding and susceptible to infection from both pathogens. Its other characteristics have been described earlier.

In the sole cowpea plots, 50, 75 and 100 cm between-row levels gave 12, 8, and 6 rows per plot respectively. Plant population decreased in the order of 30, 15, 10 and 7 plants approximately as a result of 10, 20, 30 and 40 cm within-rows in the plots respectively. The combination of the two factors under sole cropping is shown in Figure 2a.

In the intercropped plots, TZESR-Y variety of maize which is high yielding with a maturity period of about 65-70 days was grown with cowpea. A constant population of approximately 53,000 plants ha^{-1} was maintained in each plot by adjusting the within-row distance ina maize row appropriately in each plot (Figure 2b).

In this experiment since a single plant of one species may not necessarily be equivalent to a single plant of another species, a replacement series technique was used. The plant equivalence in the cowpea/maize mixtures was calculated according to the ratio of the estimated optimum plant population of the component crops in pure stands. On this basis, plant equivalence has been calculated to be three cowpea plants to one maize plant (Karel *et al.*, 1980). In the intercropped plots, two-thirds of cowpea was employed by replacing every second row of maize by a pair of cowpea rows to keep the total population constant in both mixture and pure stand. Subsequently, two-thirds of cowpea planted in each sole cowpea plots was maintained in the intercrop by replacing every third row of cowpea with maize (Figure 2b).

iv <u>Effects of cultivar and cropping pattern on cowpea anthracnose and brown blotch</u>

Three varieties of cowpeas (IT84S-2246-4, Ife Brown and IT82E-16), with characters already described in Table 1, were evaluated for susceptibility to anthracnose and brown blotch under five different cropping patterns. The combination of these two factors (variety and cropping pattern) gave 15

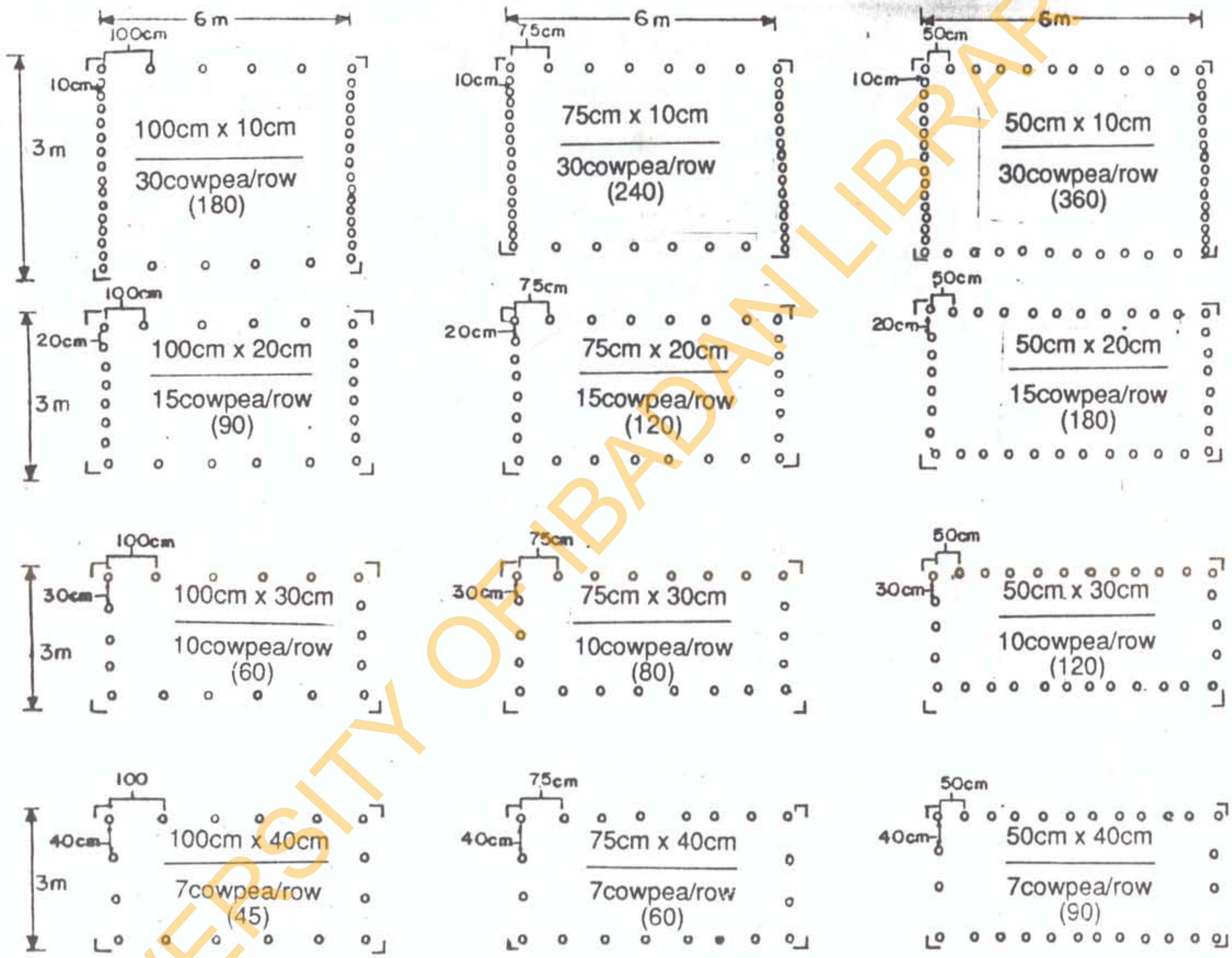


Fig. 2a: Plant arrangement and population from different combinations of between- and within-row spacings: under cowpea sole cropping. (Numbers in parentheses represent cowpea plant population in a plot).

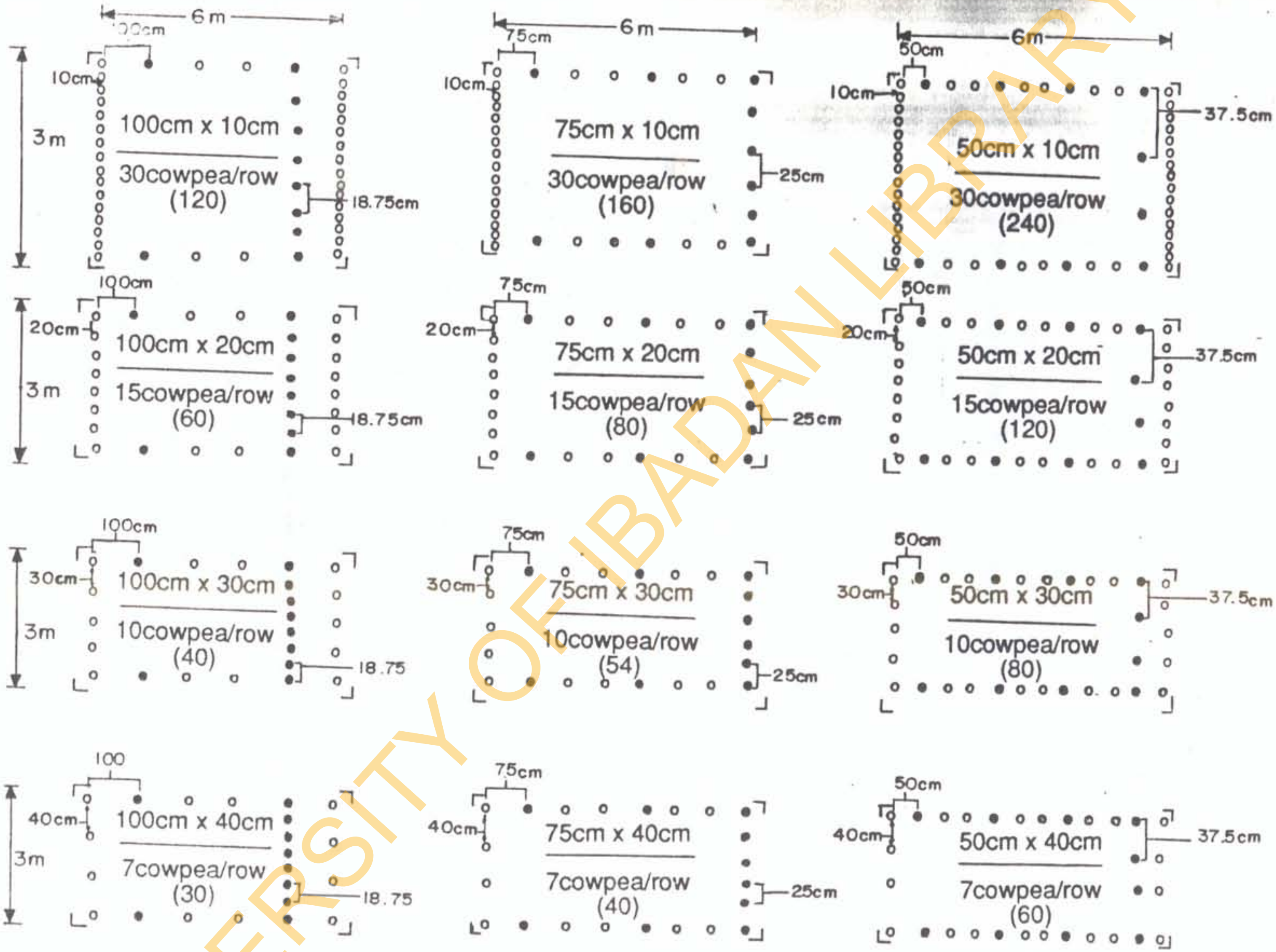


Fig. 2b: Plant arrangement and population from different combinations of between- and within-row spacings under intercropping of cowpea = o with maize = •. (Numbers in parentheses represent cowpea plant population in a plot).

treatments which were completely randomized in blocks, each consisting of 15 plots. Each of these blocks was 23m by 19m with 1m distance between two blocks. Each plot was 6m by 4m with 0.5m space between two of them. The experiment was replicated three times. Plant spacing within rows was 20 cm whereas it was 75 cm between rows in each of the plots. The cropping patterns were as follows:

i. inter-row mixed cropping (Interrow): rows of cowpea were alternately planted with rows of maize (Figure 3);

ii. double-row intercropping (Doublerow): two rows of cowpea planted between single rows of maize.

iii. strip-cropping (Strip): four rows of cowpea sandwiched between two rows of maize on either side;

iv. intra-row mixed cropping (Intrarow): cowpea and maize were planted in alternate hills within each of the rows;

v. sole-cropping (Sole): every row was planted to cowpea.

All these cropping patterns gave approximately the same cowpea population of 66,000 plants per hectare in the plots.

v **Effects of varying times of cowpea introduction into maize**

The experimental design was a split-plot randomized layout with three replications. Three varieties of cowpea (cv. Ife Brown, IT84S-2246-4 and IT82E-16) were used as the main plots. The subplots consisted of the introduction of cowpea into maize at five different intervals: cowpea planted one week before maize establishment and cowpea planted 0, 1, 2 and 3 weeks after maize establishment (WAM).

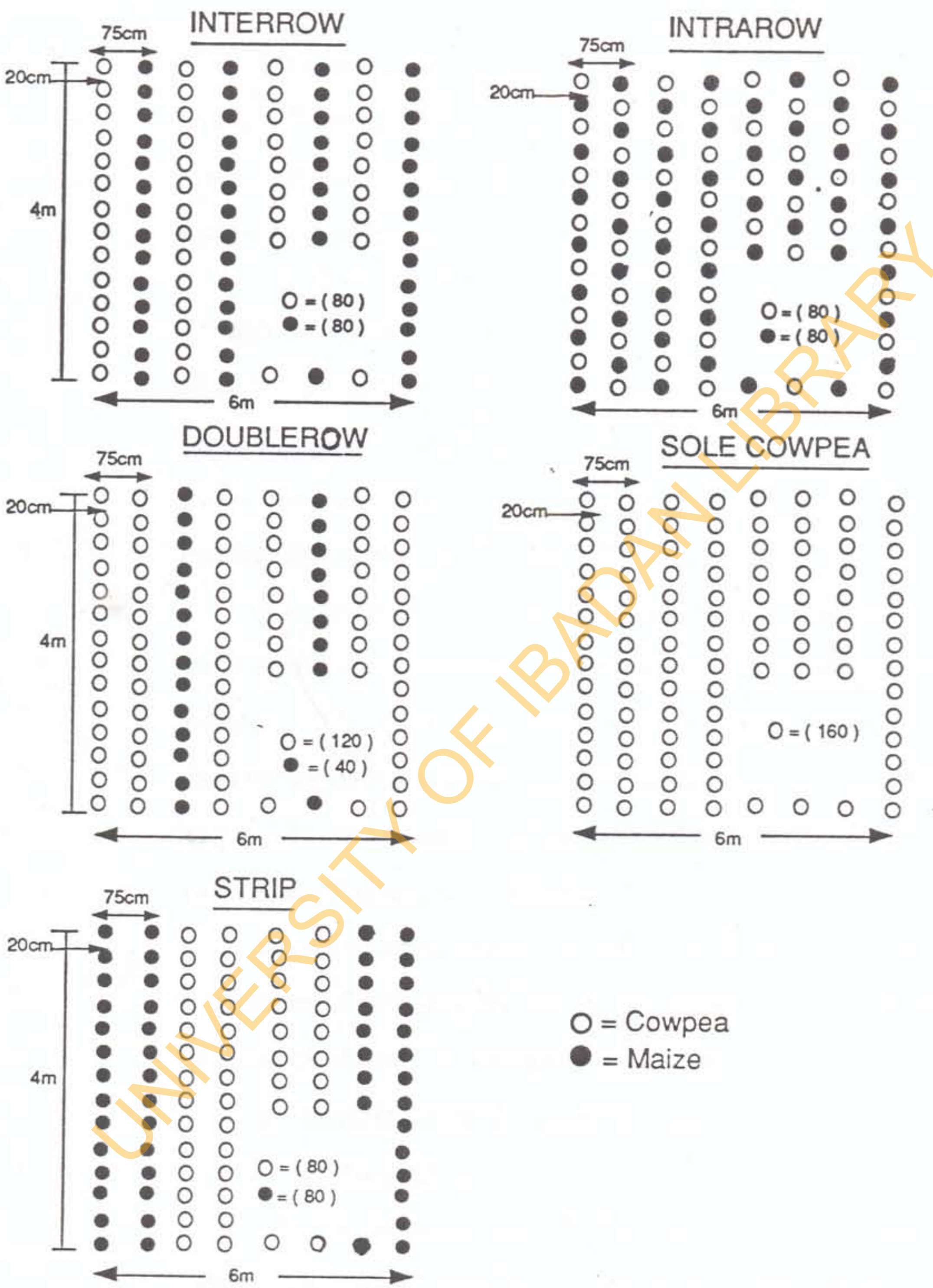


Fig. 3: A schematic diagram showing the different cropping patterns used in testing the effect of two *Colletotrichum* species on cowpeas. (Numbers in parentheses represent plant population).

The main plots, each 27m long x 7.5m wide, were randomized within the blocks. The subplots (5m long x 7.5m wide each) with 1m space between them were randomized within the main plots. The subplots consisted of 10 rows spaced at 75cm.

The planting distance for cowpea was 20 cm by 75 cm while 25 cm by 75 cm was for maize. This gave an approximate population density of 66,000 and 53,000 plants ha^{-1} for cowpea and maize respectively. In the intercrop, doublerow intercropping pattern with every second row of maize replaced by a pair of cowpea rows to keep the optimum population pressure constant in the mixture and pure stand was used (Karel *et al.*, 1980).

A separate unreplicated block comprising of three main plots (same as in the intercrop) was sown with sole cowpea for comparison of disease development on the sole and intercropped cowpea in relation to the different dates of cowpea introduction. Each of the main plots consisted of 5 subplots (5m long by 7.5m wide) where cowpea was planted at the five different dates.

3.2.4 Sampling and data collection

Except otherwise stated, the effective plot size in all trials was 2m by 4m at the center of each plot. This area was divided into two equal halves which were separately used for disease and yield assessments.

(i) Assessment of the diseases on cowpea

a) In the field

Disease assessment started from the first day when symptoms of the disease appeared and continued thereafter at 2-week intervals. This first day of symptom appearance was recorded for all plots.

Twenty plants randomly selected from half of the effective plant area per plot were examined for disease symptoms. Disease incidence was calculated from the total number of plants examined that had symptoms of anthracnose or brown blotch as the trial was set up. Percentage disease intensity was calculated by dividing the number of diseased plants by total number of plants examined and multiplying the result by 100 (Sohi and Rawal, 1984).

The severity of anthracnose and brown blotch diseases on cowpeas in all plots was scored on a 0 - 5 modified scale of Mukunya and Keya (1978) thus:

0. No infection
1. Light flecking infections resulting in small black lesions without spores (1-20% infection)
2. Lesions definite, small and restricted to veins and ridges of vein and stems. Plants apparently unaffected in vigour (21-40% infection)
3. Many, shallow lesions on stems, leaves and pods. Plants considerably vigorous (41-60% infection)
4. Abundant, large and deep lesions on epicotyl, petioles, veins and pods; seedling survives but reduced in vigour (61-80% infection)
5. Seedling usually dies. Lesions very large and deep on all aerial parts, and pods if any, with deep lesions and rarely mature seed (more than 80% infection)

A disease severity index for each plot was calculated by multiplying the proportion of the plants in each disease category by the rating of that category and adding the products together in the formula:

$$D.S.I\% = \frac{0n_0 + 1n_1 + 2n_2 + \text{---------} + 5n_5 \times 100}{(n_t(n_c - 1))}$$

n = number of diseased plants in each category,
n_t = total number of plants
n_c = total number of disease categories (Oladiran and Oso, 1983).

A graph of disease severity index (DSI) was plotted against age of plant. Total possible infections were calculated using the formula for the simple interest disease:

$$\text{Log}_e \frac{x}{1-x_t}$$

where x equals the proportions of diseased plants in each plot at a time- t denoting the disease incidence rating date. Values of total possible infection were linearly regressed over time to obtain the rate of spread of disease (Zadok and Schein, 1979). A total of three disease assessments was made for each experiment within the season, tagging each plant having evidence of disease, no matter how slight or severe, each time disease incidence readings were taken at intervals of two weeks, starting from 40 days after planting (DAP) when symptoms of infection started to manifest on the plant.

(ii) Laboratory detection and assessment of anthracnose and brown blotch pathogens on cowpea

a) Leaves, petioles and peduncles

Following the immediate appearance of disease symptoms 40 DAP, that is around 30% flowering stage, samples of leaves, petioles and peduncles were taken three times from five randomly selected plants per plot. The sampling procedures were repeated at 54 and 68 DAP respectively. During sampling, pieces measuring 2-3 cm were cut from the lower and upper parts of the petioles and peduncles (20 pieces in all). Plugs (12 mm) were removed from the centre-most part of the middle leaflet of the leaves taken from the field. These samples were wrapped in cheese cloth, washed for 15 minutes under running water and sterilized in 1:9 sodium hypochlorite solution for 5 minutes. After being rinsed twice with sterile distilled water, they were dipped in an aqueous solution of paraquat (28.1% a.i.) diluted 1.40 for 1 min (Cerkauskas and Sinclair, 1980; Hartman *et al.*, 1986). Plant parts were placed on moist filter papers inside Petri dishes and incubated at 25°C. After 10 days, plant parts were examined for evidence of fruit structures of *C. lindemuthianum* and *C. truncatum* under a Wild Heerbrugg dissecting microscope. Records of disease incidence and severity were based on a subjective visual rating scale from 0 to 5, where 0 indicated absence of symptoms and 5, plant part totally covered with fruit bodies.

b) <u>Pods</u>

Before threshing, 25 dry mature pods selected randomly from each plot were examined for disease incidence and severity on a modified Horsfall and Barrett's (1945) scale based on visual observation as presented below:

0 = no fruit structures of pathogen on pod

1 = 1-20% of pod surface was covered by fruit bodies of pathogen.

2 = 21-40% of pod surface covered by fruit bodies of pathogen

3 = 41-60% of pod surface covered by fruit bodies of pathogen

4 = 61-80% of pod surface covered by fruit bodies of pathogen.

5 = More than 80% of pod surface covered by fruit bodies of pathogen.

c) **Seed assay for germination and presence of anthracnose and brown blotch diseases**

Fifty seeds were randomly collected from well shaken paper bags containing seeds from the plots and wrapped in cheese cloth. Procedure for sterilization was observed. The seeds were plated on 12 mm - plugs of APDA in Petri dishes and incubated for 10 days at 25°C.

Germination is defined as the protrusion of the radicle through the testa by more than 2.0 mm. Data on percent seed germination was expressed by the formula:

$$\% \text{ seed germination} = \frac{\text{number of germinated seeds}}{\text{total number of seeds plated}} \times 100\%$$

Data were taken on % seed germination and on proportion of seeds on which there were structures of *C. lindemuthianum* and *C. truncatum*. This was to associate viability of seed expressed by seed germination - with the disease microorganisms.

In order to test whether differences existed between seeds obtained from apparently 'clean' pods, which had less than 5% of its length infected with disease as already defined, and seeds from badly infected pods with more than 70% infection, fifty seeds each were randomly picked from seeds obtained from clean and infected pods. These were sterilized, plated on 12 mm-plugs of APDA in petri dishes and incubated for 10 days at 25°C and 100% relative humidity. This trial was replicated four times. Data were obtained on percent disease intensity.

(iii) Yield assessment of cowpea

Cowpeas from the second half of the effective plot area in the trial were harvested. Data were taken on the yield weight per plot and on the weight of 100 seeds randomly taken from the plot.

These data were correlated with and regressed on the disease severity index to show whether there was any relationship between the seed quality, the yield and disease severity, and the magnitude of loss resulting from disease infection.

3.2.5 Statistical Analysis

The statistical analysis of the data collected was done by computer using the Crops Research Integrated Statistical Package (CRISP) programme. Data were recorded for various characters examined in each plot/subplot and per plant means for each plot/subplot were computed. These data were analysed separately to answer the various hypotheses set for the different experiments, each of which had the same design for *C. lindemuthianum* and *C. truncatum* (Appendices 1 - 5).

Where applicable, the means were separated using the Duncan's multiple range test (DMRT) or the least significant difference (LSD), both at 5% level of significance. The standard errors and coefficients of variation were also computed to assess the reliability of the data and the result of analysis of variance according to Gomez and Gomez (1984).

CHAPTER FOUR

RESULTS

4.1 Susceptibility test on cowpeas using three inoculation methods

4.1.1 Reaction of cowpea varieties to infection by *Colletotrichum lindemuthianum* and *C. truncatum*

i. Days to symptom appearance

Cowpea varieties IT82E-60, IT82D-699, IT81D-994 and IT81D-975 were first to show symptoms of infection by *Colletotrichum truncatum* within 2-3 DAI (Appendix 6). Other susceptible varieties developed symptoms of infection from the respective pathogens later on an irregular daily basis. While symptoms of infection from *C. lindemuthianum* appeared late on varieties IT84S-2246-4, IT82D-699 and IT82E-16 on 10, 12 and 15 DAI respectively, using the injection method of inoculation, symptoms of brown blotch disease were observed 10 DAI on IT82E-32 generally for almost all the different inoculation techniques used.

ii. Incidence and severity of the diseases on cowpea

a. Anthracnose disease

There was a significant difference (P < 0.05) in the incidence and severity of anthracnose disease on the different cowpea varieties (Appendix 7). Cowpea varieties IT82E-60, IT82E-32, VITA-7 and IT81D-1137 were most susceptible to the disease within 22 days after inoculation (Table 2). More than 40% of the seedlings of these varieties were infected by the pathogen, resulting in severe damage which subsequently culminated in the lodging of some seedlings.

There was elongation of necrotic lesions from the point of inoculation first, apically and basally, before radial extension along the seedling stems. Small dark-brown to black lesions were observed on the cotyledons. Lesions also appeared on the leaves, petioles and veins as small angular brick-red spots which later became dark-brown to black. During microscopic examination of the fungus *in situ*, macerated and mashed aerial plant tissues showed the presence of the pathogen, while pathogenicity tests confirmed that the isolated pathogen was actually responsible for inciting anthracnose disease. Variety IT82E-60 shows the highest incidence (58.44%) of the pathogen. No disease symptom was observed on TVx 3236, IT81D-994 and IT81D-975. The susceptibility class of these varieties is shown (Table 2).

b. Brown blotch disease

ANOVA result for the incidence and severity of brown blotch disease (Appendix 8) shows that the varieties differed significantly ($P \leq 0.05$) in their reaction to infection by the pathogen. Compared to anthracnose, a higher percentage occurrence of brown blotch (61-73%) was recorded on IT82E-60, IT82D-699, Ife Brown, IT81D-994 and IT84S-2246-4 seven DAI (Table 3). From this table, the severity of brown blotch followed almost the same pattern in relation to its incidence on the host plants. Within 2 DAI, there were tiny brownish to dark spots around the point of inoculation. These spots further extended sideways binding up the entire stem part.

On most susceptible varieties including IT82E-60, the seedlings toppled over at the point of inoculation 7 DAI. The acervuli were seen in black dots

Table 2. Disease incidence, severity and susceptibility class of 12 cowpea varieties inoculated with *Colletotrichum lindemuthianum*, 21 days after inoculation.

Cowpea variety	Incidence[1](%)	Severity[2]	Susceptibility class
TVx 3236	0 a[3]	0.0 a	Highly resistant
IT81D-994	0 a	0.0 a	Highly resistant
IT81D-975	0 a	0.0 a	Highly resistant
IT84S-2246-4	26 cd	1.7 b	Moderately resistant
IT82D-699	9 b	1.8 bc	Moderately resistant
Ife Brown	20 c	2.0 cd	Moderately resistant
IT84E-124	33 e	2.1 cd	Moderately resistant
IT82E-32	43 f	2.3 d	Moderately resistant
IT82E-16	30 de	2.3 d	Moderately resistant
VITA 7	45 f	2.9 e	Moderately susceptible
IT81D-1137	45 f	3.0 e	Moderately susceptible
IT82E-60	58 g	3.5 f	Highly susceptible
Overall mean	26	2.05	
CV (%)	14	11.02	

[1]Average of three replicates and four inoculation methods

[2]Based on: 0-5 rating scale, where
- 0 = no symptom of disease
- 1 = few discrete non-coalescing lesions on the leaf surface
- 2 = many lesions on the leaf surface occasionally coalescing
- 3 = coalescing lesions on the leaf surface, and continuous on more than 40 but less than 61%
- 4 = coalescing lesions on the leaf surface, and continuous on more than 60 but less than 81%
- 5 = collapse of affected part, fall of leaflet, buckling or fall of petiole, death of stem

[3]Means followed by the same letter in a column are not significantly different at P = 0.05 (DMRT).

Table 3. Disease incidence, severity and susceptibility class of 12 cowpea varieties inoculated with *Colletotrichum truncatum*, 21 days after inoculation.

Cowpea variety	Incidence[1](%)	Severity[2]	Susceptibility class
TVx 3236	0 a[3]	0.0 a	Highly resistant
VITA 7	0 a	0.0 a	Highly resistant
IT81D-1137	0 a	0.0 a	Highly resistant
IT82E-16	6 b	1.8 bc	Moderately resistant
IT84E-124	11 b	1.8 bc	Moderately resistant
IT82E-32	19 c	1.4 b	Moderately susceptible
IT81D-975	59 d	2.8 e	Moderately susceptible
IT84S-2246-4	61 de	2.6 de	Moderately susceptible
IT81D-994	64 d-f	2.1 cd	Moderately resistant
Ife Brown	66 ef	3.1 ef	Highly susceptible
IT82D-699	70 fg	3.7 f	Highly susceptible
IT82E-60	72 g	3.9 f	Highly susceptible
Overall mean	35	2.19	
CV (%)	10	17.39	

[1]Average of three replicates and four inoculation methods

[2]Based on: 0-5 rating scale, where
0 = no symptom of disease
1 = up to 20% of seedling stem affected
2 = 21 - 40% of seedling stem affected
3 = 41 - 60% of seedling stem affected
4 = 61 - 80% of seedling stem affected
5 = more than 80% of seedling stem affected

[3]Means followed by the same letter in a column are not significantly different at P = 0.05 (DMRT).

either scattered or clustered together on the basal part of the stem a few centimetres above the soil line. Some of the leaves drooped while a few others had already dropped from the seedling. At maturity, the mummified seedling stem became dry and the acervuli appeared as black dots on a white background. Numerous spots consisting of hyphae and acervuli were also found on the stem, petiole, veins and interveinal areas of the leaf leading to discrete necrosis of these various parts.

The fungus was most severe on IT82E-60, IT82D-699 and Ife Brown, on which a severity index of more than 3 was recorded. Though a higher incidence (61%) of the pathogen was recorded on IT84S-2246-4 which is an erect variety when compared with IT81D-975, a semi-erect type, the difference was not significant at the seedling stage.

Generally, a smaller number of cowpea varieties 7:9 cultivars were assessed to be resistant, to brown blotch than anthracnose disease (Tables 2 and 3). These varieties are IT82E-32, IT81D-1137, VITA-7 and TVx 3236. Varieties IT81D-994, IT82E-124 and IT82E-16 were classified as moderately resistant while both IT81D-975 and IT84S-2246-4 were susceptible.

4.1.2 Effect of inoculation methods on the development of anthracnose and brown blotch diseases on cowpea

i. Days to symptom appearance

Susceptible cowpea varieties showed symptoms of disease more quickly when slightly wounded seedlings were wrapped with inoculum meal (MW) than where other methods were used (Appendix 6). Following inoculation by *C. lindemuthianum*, spraying of spore suspension (SS) was next to MW method in inducing the seedlings to show disease symptoms within the shortest time after inoculation. Different observation was recorded for *C. truncatum*, where injection of spore suspension using a hypodermic needle (SI) was next to MW in predisposing the seedling to infection with subsequent symptom manifestation. In both cases of fungus inoculation, though seedlings of some previously classified moderately resistant or resistant varieties showed symptoms, the symptoms appeared 7 DAI or longer.

ii. **Incidence and severity of anthracnose and brown blotch diseases using different inoculation methods.**

Disease incidence and severity of both diseases on cowpea was highest when seedlings were wrapped with inoculum meal of the respective pathogens (Table 4). Generally, disease incidence resulting from inoculation by *C. lindemuthianum* followed the same pattern in the order MW > SS > SI > SC. Disease incidence for *C. truncatum* was in the order MW > SI > SS > SC.

4.1.3 Effect of the variety x inoculation method interaction on both species of *Colletotrichum* used.

i. **Incidence and severity of both diseases on cowpea**

There was a significant ($P \leq 0.05$) interaction effect of variety x inoculation method on the incidence and severity of anthracnose and brown blotch diseases on cowpea. This indicates that the percentage incidence of both diseases on the cowpea varieties and the susceptibility of the latter to the diseases are not the same across the various inoculation methods tested.

Table 4. Effect of inoculation methods on percent[1] incidence and severity of anthracnose and brown blotch diseases on cowpea

Inoculation method[2]	Anthracnose		Brown blotch	
	Incidence (%)	Severity[3]	Incidence (%)	Severity[4]
SS	34 ± 4 b[5]	2.06 ± 0.16 b	40 ± 6 b	2.01 ± 0.43c
SI	20 ± 3 c	1.89 ± 0.12 b	32 ± 5 c	2.31 ± 0.36b
MW	43 ± 5 a	2.94 ± 0.24 a	49 ± 6 a	3.17 ± 0.44a
SC	7 ± 1 d	1.25 ± 0.08 c	21 ± 4 d	1.28 ± 0.16d
CV %	25	26.67	16	32.54

[1]Average of three replicates and twelve varieties

[2]Based on: SS = Spraying of spore suspension; SI = Injection of spore suspension using hypodermic syringe; MW = Wrapping of wounded seedling stems with inoculum meal, and SC = Spraying of sterile deionized distilled water as the control.

[3]Based on: 0-5 rating scale, where
- 0 = no symptom of disease
- 1 = few discrete non-coalescing lesions on the leaf surface
- 2 = many lesions on the leaf surface occasionally coalescing
- 3 = coalescing lesions on the leaf surface, and continuous on more than 40 but less than 61%
- 4 = coalescing lesions on the leaf surface, and continuous on more than 60 but less than 81%
- 5 = collapse of affected part, fall of leaflet, buckling or fall of petiole, death of stem

[4]Based on: 0-5 rating scale, where
- 0 = no symptom of disease
- 1 = up to 20% of seedling stem affected
- 2 = 21 - 40% of seedling stem affected
- 3 = 41 - 60% of seedling stem affected
- 4 = 61 - 80% of seedling stem affected
- 5 = more than 80% of seedling stem affected

[5]Means followed by the same letter in a column are not significantly different at P = 0.05 (DMRT).

Among the susceptible varieties, the lowest incidence (20-23%) and the highest incidence (86.67%) of infection by *C. lindemuthianum* were observed on IT82E - 60 using SC and MW respectively (Table 5). On the same variety, brown blotch infection rose up to 41.33% and 70-63% using SC and MW inoculation methods respectively.

A similar trend of results was observed for the severity of the respective diseases on the host crop with just a slight difference (Table 6). The highest severity score of 5 was obtained on IT82E-60 inoculated by *C. lindemuthianum* through MW method of inoculation. On IT82D-699 and IT81D-975, a score of 5 was also observed using SS and MW methods respectively while *C. truncatum* was the inoculum. The lowest value of 1 was observed for the resistant varieties and on others where SC was used.

4.2 Effect of time of inoculation on the reaction of cowpea varieties to anthracnose and brown blotch diseases

4.2.1 Symptom appearance on cowpea seedlings at different times of inoculation

Results in Appendix 9 showed that the appearance of symptoms due to infection by both fungi followed the same trend respectively on the varieties as well as for the different methods of inoculation used as already observed and reported in Section 4.1.1. (i). Seedlings of variety IT82E-60 inoculated 14 DAP were earliest in showing symptoms of infection 1-2 days following inoculation by both fungi. However, other cowpea varieties susceptible to anthracnose after IT82E-60 were IT81D-1137 > VITA-7 > IT82E-16 >IT82E-32 and IT82E-124 in that

Table 5. Incidence (%)* of *Colletotrichum lindemuthianum* and *Colletotrichum truncatum* on cowpeas as affected by the interaction of cowpea varieties and inoculation method in the screenhouse.

Cowpea varieties	*C. lindemuthianum*				*C. truncatum*			
	SS**	SI	MW	SC	SS	SI	MW	SC
IT81D-975	0.00	0.00	0.00	0.00	48.57	67.87	80.23	38.10
IT81D-994	0.00	0.00	0.00	0.00	55.70	68.47	85.70	43.97
IT81D-1137	61.67	38.00	69.00	12.67	0.00	0.00	0.00	0.00
IT82D-699	19.67	1.67	13.00	0.00	63.33	82.17	89.83	44.10
IT82E-16	35.33	19.67	56.33	7.67	0.00	3.33	19.33	0.00
IT82E-32	53.33	35.33	74.00	11.00	14.33	20.00	38.00	1.67
IT82E-60	68.33	58.00	86.67	20.33	70.63	84.50	92.70	41.33
IT84S-2246-4	34.67	17.69	46.67	3.00	60.50	66.10	83.60	31.97
VITA 7	54.00	37.67	74.33	12.67	0.00	0.00	0.00	0.00
TVx 3236	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ife Brown	31.67	10.67	36.00	2.33	62.50	75.17	80.07	45.33
IT84E-124	46.00	20.67	54.67	9.00	6.00	11.67	23.00	0.00
$LSD_{0.05}$ for same method			11.03				10.18	
same variety			10.35				9.42	

*Average of three replicates and twelve varieties

**SS = Spraying of spore suspension; SI = Injection of spore suspension using hypodermic syringe; MW = Wrapping of wounded seedling stems with inoculum meal, and SC = Spraying of sterile deionized distilled water as the ontrol.

Table 6. Mean estimates[*] for the interaction effect of inoculation methods and cowpea varieties on the severity[**] of *Colletotrichum lindemuthianum* and *Colletotrichum truncatum* on cowpea in the screenhouse

Cowpea varieties	*C. lindemuthianum*				*C. truncatum*			
	SS[****]	SI	MW	SC	SS	SI	MW	SC
IT81D-975	1.0	1.0	1.0	1.0	4.5	3.5	5.0	2.5
IT81D-994	1.0	1.0	1.0	1.0	1.0	3.0	2.3	1.0
IT81D-1137	3.3	2.7	4.7	1.3	1.0	1.3	1.5	1.5
IT82D-699	2.0	1.7	2.3	1.0	5.0	1.3	4.3	1.0
IT82E-16	2.3	2.0	2.3	1.0	1.0	2.0	3.3	1.0
IT82E-32	2.0	2.3	3.7	1.0	1.0	1.0	1.0	1.0
IT82E-60	3.3	2.3	5.0	3.3	3.3	4.3	4.8	2.4
IT84S-2246-4	1.7	1.7	2.3	1.0	2.5	3.0	4.0	1.0
VITA 7	2.7	2.3	4.7	2.0	1.0	1.0	1.3	1.0
TVx 3236	1.0	1.1	1.0	1.0	1.0	2.3	4.3	1.0
Ife Brown	1.7	2.7	2.7	1.0	1.0	4.3	4.8	1.0
IT84E-124	2.3	2.0	3.0	1.0	1.8	1.0	1.8	1.0
$LSD_{0.05}$ for same method			0.86				1.03	
same variety			0.89				1.00	

[*]Average of three replications

[**]Based on: 0-5 rating scale, where 0 = asymptomatic; 1=1 - 20% infection; 2 = 21-40% infection; 3 = 41-60%; 4 = 61-80%; and 5 = more than 80% infection

[***]SS = Spraying of spore suspension; SI = Injection of spore suspension using hypodermic syringe; MW = Wrapping of wounded seedling stems with inoculum meal, and SC = Spraying of sterile deionized distilled water as the control.

order of daily symptom appearance at 14 DAP. Also at 14 DAP, varieties IT84S-2246-4, IT81D-699 and Ife Brown were among the susceptible varieties which followed IT82E-60 in early manifestation of symptoms of infection from the pathogen.

The cowpea varieties reacted in a similar way to different times of inoculation. Seedlings of each susceptible variety inoculated 14 DAP were earliest in manifesting symptoms of both diseases when compared with those inoculated at other times of inoculation. Seedlings inoculated at 21 > 28 > 7 DAP in that order were first to show disease symptoms after those inoculated at 14 DAP. Others inoculated 35 DAP were similar in haphazard exhibition of symptoms due to infection from both diseases.

No symptom of infection was observed on cowpea varieties IT81D-975, IT81D-994 and TVx 3236 already found to be highly resistant to *C. lindemuthianum*. Cowpea varieties IT81D-1137, VITA-7 and TVx 3226 showed no symptoms of disease caused by *C. truncatum*, following inoculation using any of the methods. Uninoculated susceptible varieties were the latest in showing symptoms of infection by both fungi in rare cases where this occurred.

4.2.2 Effect of time of inoculation on the infection of both *Colletotrichum* diseases on cowpea seedlings

The effect of time of inoculation on the infection of the different cowpea varieties tested was highly significant at $P \leq 0.05$ (DMRT). The percentage infection of cowpea was consistently highest at 21 days after seedling emergence (DAE) with averages of 33.8% and 28.2% for anthracnose and brown blotch diseases respectively (Table 7). Inoculation of cowpea seedlings with *C.*

lindemuthianum at 14, 7 and 28 DAE resulted in descending values of infection from this fungus after those inoculated at 21 DAE. However, following inoculations of cowpea seedlings with *C. truncatum* at 21, 28, 14 and 7 DAE, the magnitude of infection descended in values in that order.

The interaction effect between the varieties and time of inoculation on the incidence of the two pathogens was significant at P = 0.01 DMRT (Appendix 10). No incidence of anthracnose infection was observed on varieties IT81D-975, IT81D-994 and TVx 3236. Also, varieties IT81D-1137, VITA-7 and TVx 3236 showed no symptoms of infection by *C. truncatum*. The incidence of anthracnose infection was highest on IT82E-60 seedlings inoculated 21 DAE and was lowest on IT82E-32 seedlings inoculated 35 DAE (Table 8). Variety IT82E-60 equally showed the highest incidence (62.3%) of *C. truncatum* infection, while the lowest incidence of 2.11% was observed on IT84E-124, also as a result of inoculation at 35 DAE (Table 9).

4.2.3 Effects of interaction between time and method of inoculation on the incidence of anthracnose and brown blotch diseases

The effects of interaction between time and method of inoculation on the incidence of both pathogens was significant at P = 0.05 level of probability indicating that the inoculation methods differed appreciably across the different times of inoculation. The various techniques of inoculation followed the same trend for the different times of inoculation. The values obtained for the two methods (MW and SS), when inoculation was done at 7, 14, 21 and 28 DAE, with respect to the two diseases, were significantly higher than those of control, SC

Table 7. Effect of time of inoculation on percent[1] incidence of anthracnose and brown blotch diseases of cowpea.

Time of inoculation, DAE[2]	Anthracnose	Brown blotch
7	23.22 ± 3.8 c[3]	17.52 ± 3.99 d
14	28.36 ± 4.5 b	24.80 ± 4.72 b
21	33.76 ± 5.1 a	28.22 ± 5.14 a
28	19.97 ± 3.5 d	19.10 ± 4.63 c
35	6.49 ± 2.4 e	4.62 ± 1.04 e
Mean	19.39	16.31

[1]Means of three replications, twelve varieties and three inoculation methods.

[2]Days after seedling emergence

[3]Means followed by the same letter in the column are not significantly different at P = 0.05 (DMRT).

Table 8. Incidence (%)[a] of anthracnose disease on twelve cowpea varieties inoculated at different times in the screenhouse

Cowpea variety	Time of inoculation, DAE[b]				
	7	14	21	28	35
TVx 3236	0.00	0.00	0.00	0.00	0.00
IT81D-975	0.00	0.00	0.00	0.00	0.00
IT81D-994	0.00	0.00	0.00	0.00	0.00
IT84S-2246-4	17.56	30.11	33.11	8.78	0.00
IT82D-699	18.56	19.56	30.44	16.33	0.00
IT84E-124	22.22	25.44	36.11	20.89	0.00
Ife Brown	27.22	31.11	39.78	25.00	0.00
IT82E-32	30.00	35.33	40.00	17.22	1.67
IT82E-16	32.78	37.78	41.00	30.56	0.00
VITA 7	35.44	43.78	59.78	35.33	3.11
IT81D-1137	38.78	56.00	59.56	35.56	35.00
IT82E-60	56.11	61.22	65.33	50.00	38.11

LSD at 0.05 for same treatment = 4.03
same variety = 3.63

[a]Average of three replications and three inoculation methods

[b]Days after emergence

Table 9. Incidence (%)[a] of brown blotch disease on twelve cowpea varieties inoculated at different times in the screenhouse

Cowpea variety	Time of inoculation, DAE[b]				
	7	14	21	28	35
VITA 7	0.00	0.00	0.00	0.00	0.00
TVx 3236	0.00	0.00	0.00	0.00	0.00
IT81D-1137	0.00	0.00	0.00	0.00	0.00
IT82E-16	0.56	17.67	19.67	0.56	0.00
IT84E-124	5.78	23.67	25.11	2.22	2.11
IT82E-32	8.33	10.22	15.89	0.00	0.00
IT81D-975	16.89	25.22	28.67	20.44	4.33
IT81D-994	25.11	32.78	43.56	31.56	6.44
IT84S-2246-4	25.44	31.67	60.56	28.00	9.44
Ife Brown	36.22	47.11	48.33	44.56	10.78
IT82E-60	44.89	56.56	62.33	51.22	11.67
IT82D-699	47.00	52.67	54.56	50.67	10.67

LSD at 0.05 for same treatment = 2.58
same variety = 2.39

[a]Average of three replications and three inoculation methods

[b]Days after emergence

(Table 10).

Seedlings inoculated 21 DAE by wrapping the stem with inoculum meal (MW) had the highest percentage incidence value averaging, 48.89 for *C. lindemuthianum* while it was 44.36 for *C. truncatum*. Those inoculated with *C. lindemuthianum* 35 DAE had the least incidence value averaging 3.19, while in the case of *C. truncatum*, seedlings inoculated at 28 DAE had the least incidence value.

Generally, it was observed that the pathogens still manifested their symptoms of infection on some of the control seedlings and those inoculated when they were more than 28 days old.

4.2.4 Severity of anthracnose and brown blotch diseases on cowpea seedlings

The pathogens were most severe on seedlings inoculated 21 DAE (Table 11). In both cases, the level of disease severity decreased from seedlings inoculated at 21 DAE to those inoculated at 14 < 28 < 7 < 35 DAE in that order. No statistical difference was observed in the severity of both diseases on seedlings inoculated at 28 and 7 DAE and between those inoculated at 35 DAE.

The effect of cowpea variety x time of inoculation was significant (P = 0.05) regarding the severity of anthracnose and brown blotch diseases respectively on cowpea. For the susceptible varieties, the highest level of disease severity was observed in seedlings inoculated at 21 DAE whereas no value was recorded on the resistant varieties following inoculation with both pathogens. The highest values of 3.2 and 3.7 were scored for *C. lindemuthianum* and *C. truncatum* respectively on IT82E-60 while the lowest values were scored for the

Table 10. Interaction effect of time x method of inoculation on the incidence[a] (%) of anthracnose and brown blotch on cowpea

Inoculation method[b]	Time of inoculation, DAE[c]				
	7	14	21	28	35
			Anthracnose		
MW	36.31	43.36	48.89	31.36	6.36
SS	27.56	33.83	42.22	23.86	4.03
SC	5.81	7.89	10.17	4.69	3.19

$LSD_{0.05}$ same method = 2.39
same time = 2.65

			Brown blotch		
MW	30.08	39.36	44.36	30.28	7.81
SS	20.75	32.36	37.19	24.61	4.58
SC	1.72	2.67	3.11	0.42	1.47

$LSD_{0.05}$ same method = 1.57
same time = 1.70

[a]Average of three replications and twelve varieties

[b]MW = Wrapping of seedling with stem with inoculum meal, SS = Spraying of stem with spore suspension and SC = Control.

[c]Days after seedling emergence.

Table 11. Effect of time of inoculation on the severity[1] of anthracnose and brown blotch diseases on cowpea.

Time of inoculation, DAE[2]	Anthracnose	Brown blotch
7	1.56 ± 0.01 c[3]	1.75 ± 0.16 c
14	1.88 ± 0.16 b	2.12 ± 0.19 b
21	2.06 ± 0.17 a	2.33 ± 0.22 a
28	1.70 ± 0.13 c	1.63 ± 0.13 c
35	1.18 ± 0.06 d	1.35 ± 0.08 d
Mean	1.59	1.74

[1]Based on 0-5 rating scale, where 0 = asymptomatic; 1=1 - 20% infection; 2 = 21-40% infection; 3 = 41-60%; 4 = 61-80%; and 5 = more than 80% infection

[2]Days after emergence

[3]Means followed by the same letter in a column are not significantly different at P = 0.05 (DMRT).

cowpea seedlings inoculated at 35 DAE.

The severity of both diseases due to method of inoculation x time of inoculation interaction, also followed a similar pattern to that observed for the incidence of these pathogens on cowpea (Table 12). Seedlings inoculated using inoculum meal at 21 days after seedling emergence were most susceptible to infection by the respective pathogens. An average score of 2.72 and 3.17 were recorded for the seedlings which were most severely attacked following infection by *C. lindemuthianum* and *C. truncatum* respectively.

Seedlings inoculated 35 DAE were the least infected by the individual fungi. Generally, the reaction of the seedlings to infection by the fungi using different inoculation methods was significantly different from one another across time of inoculation, 7, 14, 21 and 28 DAE.

Table 12. Effects of interaction between time and method of inoculation on the severity[a] of the *Colletotrichum* diseases on cowpea.

Inoculation method[b]	Time of inoculation, DAE[c]				
	7	14	21	28	35
			Anthracnose		
MW	2.00	2.53	2.72	2.22	1.14
SS	1.58	2.03	2.22	1.72	1.31
SC	1.08	1.08	1.22	1.74	1.08
LSD 0.05 same method = 0.17; same time = 0.19					
			Brown blotch		
MW	2.26	2.78	3.17	2.03	1.53
SS	1.86	2.31	2.53	1.72	1.39
SC	1.14	1.25	1.31	1.14	1.14
LSD 0.05 same method = 0.14; same time = 0.14					

[a]Based on 0-5 rating scale, where 0 = asymptomatic; 1=1 - 20% infection; 2 = 21-40% infection; 3 = 41-60%; 4 = 61-80%; and 5 = more than 80% infection

[b]MW = Wrapping of seedling stem with inoculum meal, SS = Spraying of spore suspension and SC = Control.

[c]Days after seedling emergence.

4.3 Effect of spacing on anthracnose and brown blotch diseases of cowpea in different cropping systems

4.3.1 Incidence of the pathogens on cowpeas

i Anthracnose

The symptoms of infection were generally in form of lesions which developed on the leaf petiole, the lower surface of leaves and leaf veins as small angular brown spots (Plate 3A). These spots became joined together to produce brick red to brown discolouration of the entire leaf (Plate 3B).

The cropping pattern significantly affected the incidence of anthracnose on cowpea at various stages of the plant growth during the three seasons when the experiment was conducted (Table 13). A lower incidence of the disease was recorded on cowpeas intercropped with maize than on sole cowpea. Equally, both interrow and intrarow significantly influenced its incidence on cowpea.

At various growth stages, incidence of the disease on plants grown 100 cm apart between rows was more significantly reduced than on other plants spaced 50 and 75 cm apart. Up till 54 DAP and 40 DAP in the first and second growing seasons respectively, cowpeas planted 50 and 75 cm apart between rows did not significantly show any difference in their reaction to infection from the pathogen. Lowest values of disease incidence were observed on cowpeas planted 40 cm within rows while these values increased with decreasing intrarow spacing, with the plants spaced 10 cm apart in the same row having the highest incidence values.

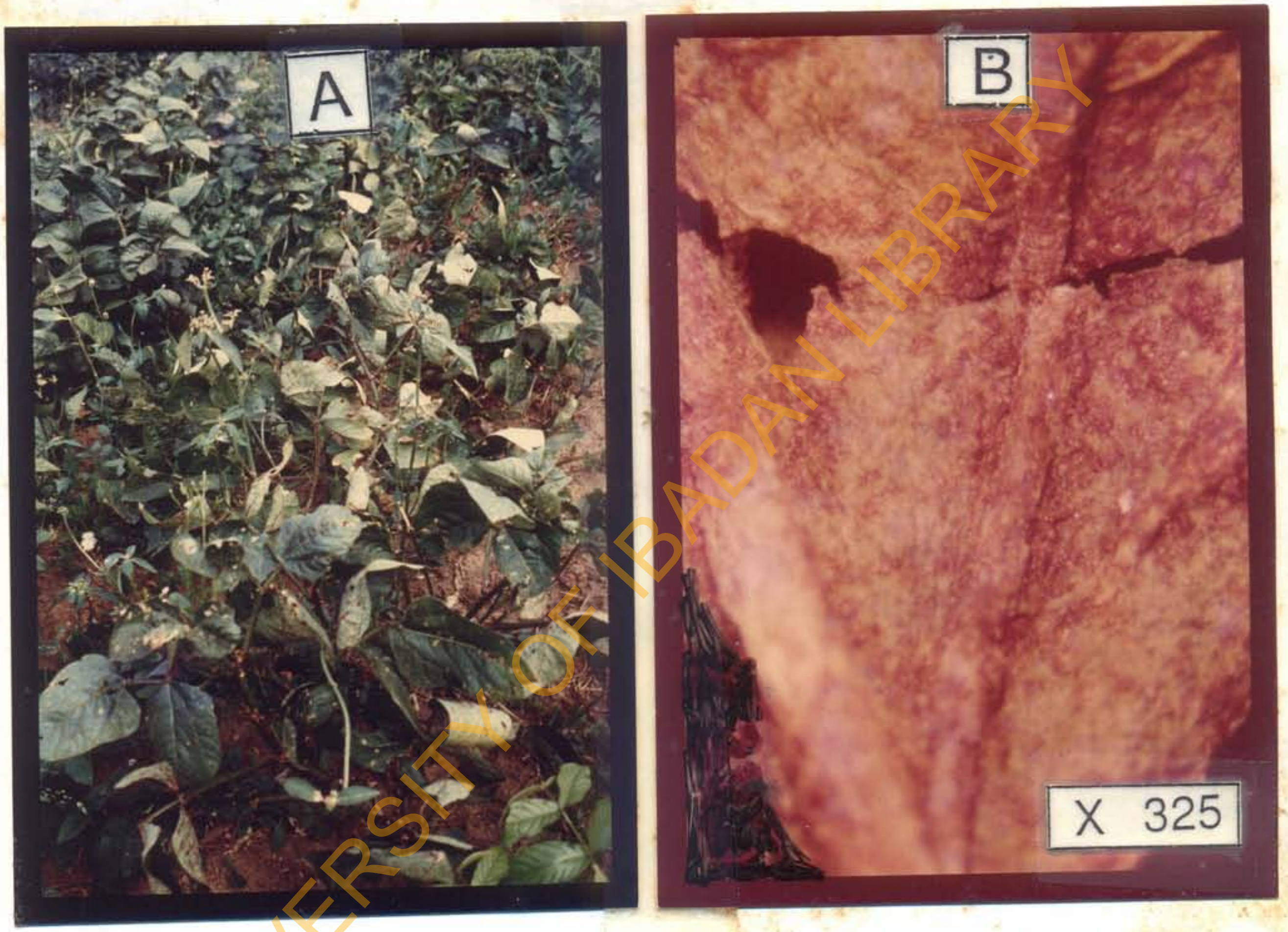


Plate 3. Symptoms of anthracnose disease as tiny brown spots on the leaf (A) and covering the entire leaf (B).

Table 13. Mean estimates of the incidence[1] (%) of anthracnose disease of cowpea as affected by cropping pattern, interrow and intrarow spacing in 1987/88[2].

	1987F			1987S			1987T		
Treatments	40 DAP[3]	54 DAP	68 DAP	40 DAP	54 DAP	68 DAP	40 DAP	54 DAP	68 DAP
Cropping pattern									
Cowpea + maize	24.6 a[4]	40.4 a	50.8 a	29.0 a	35.6 a	43.6 a	8.1 a	24.0 a	33.1 a
Sole cowpea	28.8 b	62.0 b	71.9 b	33.3 b	51.7 b	61.3 b	11.8 b	42.4 b	56.3 b
Interrow spacing (cm)									
100	21.5 a	42.2 a	52.5 a	29.9 a	36.8 a	44.8 a	7.0 a	24.8 a	34.5 a
75	26.2 a	49.8 a	59.6 b	29.1 a	41.7 b	50.0 b	10.3 b	32.2 b	44.1 b
50	32.5 b	61.7 b	71.9 c	37.5 b	52.5 c	62.5 c	12.6 c	42.5 c	55.6 c
Intrarow spacing (cm)									
40	18.4 a	38.8 a	47.6 a	23.8 a	33.3 a	39.3 a	4.2 a	21.3 a	31.2 a
30	23.8 a	45.4 b	54.6 b	28.2 b	38.1 a	46.1 b	6.5 b	28.1 b	38.7 b
20	30.4 b	57.5 c	66.7 c	33.3 c	49.0 b	58.6 c	12.1 c	39.2 c	50.8 c
10	34.0 b	63.2 d	76.4 d	39.3 d	54.2 b	65.7 d	17.1 d	44.2 d	58.1 d

[1]Average of three replications.
[2]Three seasons in 1987/88: F = First season (April-July, 1987); S = Second season (August-November, 1987; and T = Third season (December 1987 - March 1988).
[3]DAP = Days after planting
[4]Only means followed by different letter(s) within a column for each factor differ significantly at P ≤ 0.05 (DMRT).

There was a significant interaction ($P \leq 0.05$) between cropping pattern and interrow spacing 40 DAP (Appendix 11). This indicates that the incidence of the pathogen on cowpeas in the mixture and sole cropping systems were not the same across the interrow spacing levels (Table 14). Interrow x intrarow interaction was also significant at 40 and 64 DAP in the first growing season and at 40 and 68 DAP in the third irrigated season respectively (Tables 15). Appreciable differences existed in the incidence of the pathogen on plants at various within-row spacings across the interrows. There was no significant interaction among the main factors in the second growing season, indicating that the reaction of cowpeas at any of the tested spacing levels was independent of whether cowpea was intercropped with maize or not.

ii Brown blotch

Incidence of disease was noticeable on the cowpea plant two weeks before flowering. Symptoms of infection were initially tiny localised tan lesions. These later increased in size as they became enlarged and were merged together, forming reddish, later brown discoloration on all the aerial parts including petioles, leaves and flower stalks (Plate 4A) from where the pods were infected (Plates 4B) and became purplish and later brown in colour.

In the first growing season, the incidence of brown blotch on cowpeas in mixture was significantly lower than that observed on the sole crop (Table 16). However, the reduction in incidence as a result of intercropping at 40 DAP in the second season at both 40 and 54 DAP in the third season was insignificant even though significant differences were seen at 68 DAP.

Table 14. Effects of cropping pattern and interrow spacing on the incidence[1] (%) of anthracnose disease on cowpea at 40 DAP[2] during the irrigated off-season of 1987, (1987T).

Interrow spacing (cm)	Cropping pattern		
	Sole	Inter	Difference
100	8.1 a[3]	5.8 a	2.3 ns
75	11.5 ab	9.2 a	2.3 ns
50	15.8 b	9.4 a	6.4+

[1]Average of three replications and four intrarow spacing levels.
[2]Days after planting
[3]Mean separation in a column by DMRT at 5% level.
+Significant at 5% level
ns = Not significant.

Table 15. Effects of interaction between interrow and intrarow spacing on the incidence[a] (%) of cowpea infected with anthracnose disease during two growing seasons[b] in 1987.

Intrarow spacing (cm)	Interrow spacing (cm)											
	1987F						1987T					
	40 DAP[c]			54 DAP			40 DAP			68 DAP		
	50	75	100	50	75	100	50	75	100	50	75	100
40	11.6	7.3	3.3	21.0	14.5	11.0	9.2	3.3	6.0	46.3	31.3	16.3
30	13.0	9.5	6.0	24.0	17.0	13.5	11.7	6.2	1.7	53.8	36.3	26.3
20	13.5	12.0	11.0	26.0	23.0	20.0	15.0	11.3	10.0	57.5	51.3	43.8
10	14.0	13.2	13.7	27.7	25.2	23.0	14.6	20.4	16.3	65.0	57.5	51.7
LSD 0.05 for means												
in a column			1.4			1.0			2.0			4.4
for means in a row			1.2			1.4			1.7			3.8

[a]Average of three replications and two cropping patterns.

[b]Two seasons in1987/89: F = first season (April-July 1988) and T = third season (December,1988 - March,1988).

[c]Days after planting

Plate 4. Brown blotch disease symptoms on the leaf (A) and pods (B) of cowpea plant.

Table 16. Percent incidence[1] (%) of brown blotch disease of cowpea as affected by cropping pattern, interrow and intrarow spacing in 1987/88[2].

Treatments	1987F			1987S			1987T		
	40 DAP[3]	54 DAP	68 DAP	40 DAP	54 DAP	68 DAP	40 DAP	54 DAP	68 DAP
Cropping pattern									
Cowpea + maize	18.5 a[4]	36.5 a	47.2 a	22.9 a	27.9 a	35.8 a	18.1 a	35.8 a	45.8 a
Sole cowpea	20.8 b	49.4 b	60.8 b	24.7 a	41.7 b	52.2 b	20.5 a	39.1 a	50.4 b
Interrow spacing (cm)									
100	18.0 a	33.1 a	44.1 a	17.2 a	23.2 a	35.0 a	13.9 a	27.5 a	40.6 a
75	19.4 ab	43.1 b	55.7 b	24.2 b	35.1 b	43.5 b	20.3 ab	37.2 b	45.9 b
50	21.5 b	52.6 c	62.2 c	30.0 c	46.1 c	53.3 c	23.7 b	47.7 c	57.7 c
Intrarow spacing (cm)									
40	17.5 a	33.6 a	37.5 a	17.5 a	21.3 a	28.3 a	16.9 a	35.0 ab	38.6 a
30	18.3 a	36.0 a	45.1 b	19.0 a	33.2 b	37.4 b	17.9 a	32.9 a	47.1 b
20	21.4 b	49.3 b	63.9 c	26.4 b	41.7 c	49.6 c	21.0 a	39.4 bc	51.3 bc
10	21.3 b	52.9 c	69.1 d	32.2 c	43.2 c	60.6 d	21.3 a	42.5 c	55.4 c

[1]Average of three replications.

[2]Three seasons in 1987/88: F = First season (April-July, 1987); S = Second season (August-November, 1987; and T = Third season (December 1987 - March 1988).

[3]DAP = Days after planting

[4]Only means followed by different letter(s) within a column for each factor differ significantly at P $\leq$ 0.05 (DMRT).

Significant differences occurred among the three interrow spacings. Plants spaced at 100 cm rows apart had the least incidence of the disease while those spaced 50 cm had the highest incidence irrespective of the growth stage of the plant. Cowpeas planted 10 cm apart within rows showed highest values of incidence and those spaced at 40 cm showed the lowest values, indicating that at any stage of the plant growth, and regardless of the seasons, incidence of brown blotch on cowpea increases as the planting space between the two adjacent plants within the row decreases.

There were remarkable differences in the incidence of the pathogen on cowpea across the interrow levels, regardless of the cropping pattern. Equally, a significant cropping pattern x intrarow spacing interaction effect was observed at 54 DAP and 68 DAP during the first growing season with the reaction of the crop in both cropping patterns to infection from the fungus being significantly dissimilar across the various within row spacings as presented in Table 17. Just as it was observed previously for anthracnose, there was no significant interaction among the main factors in the second growing season regarding the incidence of brown blotch disease on cowpea.

4.3.2 Severity of the diseases on cowpeas

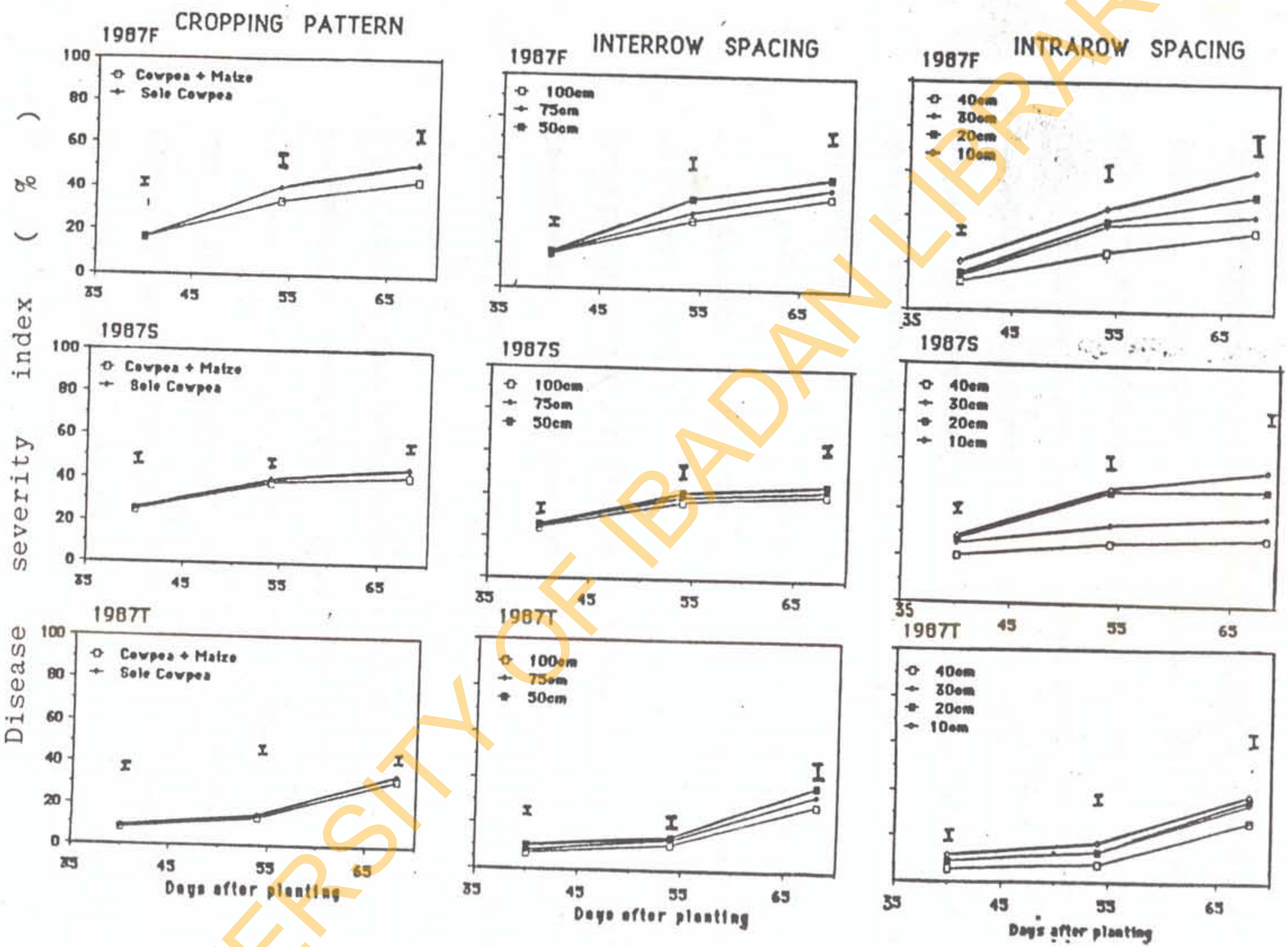
i. Anthracnose disease

Significant differences existed among the cropping patterns and spacings at all the stages of growth, except at the first sampling stages within the seasons when there was no appreciable difference between the severity of the pathogen on intercropped cowpea and on sole cowpea (Appendix 12, Figure 4).

Table 17. Effects of interaction between intrarow spacing and cropping pattern on the incidence[1] (%) of brown blotch disease on cowpea at 54 and 68 DAP in the first season of 1987.

Intrarow spacing (cm)	54 DAP[2]			68 DAP		
	Cropping pattern			Cropping pattern		
	Sole	Inter	Difference	Sole	Inter	Difference
40	36.1 a[3]	31.1 a	5.0 ns	41.9 a	33.1 a	8.8+
30	45.6 b	26.4 a	19.2++	52.8 b	37.5 a	15.3++
20	60.3 c	38.3 b	22.0++	74.4 c	53.3 b	21.1++
10	55.8 c	50.0 c	5.8+	73.9 c	65.0 c	8.9+
CV		12.5			13.1	

[1]Average of three replications and four intrarow spacing levels.
[2]Days after planting
[3]Mean separation in a column by DMRT at 5% level.
+Significant at 5% level
++Significant at 1% level.
ns = Not significant.



101

Fig. 4: Seasonal variability in the severity of anthracnose disease during three growing seasons: F = first season, S = second season and T = third season, in 1987/88.

The trend observed for the incidence of the pathogen was also observed for severity of this disease on cowpea. The disease was more severe on cowpea plants which were most closely spaced than on those which were more widely spaced. Significantly lower values of disease severity were recorded for plants spaced 100 cm apart between rows than for those 50 cm apart at various stages of growth. Similarly, lower estimates of the severity of the pathogen were recorded on cowpea spaced 40 cm apart within the row than on those spaced at 10 cm within row.

At 54 DAP in the first and second seasons, there was a significant cropping pattern x interrow spacing interaction (Table 18), showing that there were differences in the severity of anthracnose on cowpeas across the various levels of interrow spacing. The effect of intrarow spacing on disease severity on cowpea was observed to be dependent on interrow spacing (Table 19). The effect of cropping pattern x interrow spacing x intrarow spacing interaction was significant at 68 DAP both in the first and second seasons (Table 20). Results in Figure 4 show that there was a general increase in severity of the pathogen on cowpea in all treatments across the three seasons. At 54 DAP, there was a sharp rise from an apparent gradual mode of disease development earlier observed during the third irrigated off season. Contrary to this observation, the mode of disease development had become gradual at 54 DAP until maturity in the preceeding (second) season.

ii. Brown blotch

Regarding the severity of brown blotch disease on the host crop, the cropping pattern was not significant at the initial stages of growth in the three

Table 18. Interaction effect of cropping pattern and interrow spacing on the severity[1](%) of anthracnose disease on cowpea at 54 DAP[2] in the first and second seasons in 1987.

Intrarow spacing (cm)	1987 F			1987 T		
	Sole-cowpea	Inter-cropped cowpea	Difference	Sole-cowpea	Inter-cropped cowpea	Difference
100	34.8 a[3]	29.0 a	5.8+	37.0 a	36.7 a	0.3 ns
75	38.5 b	32.2 b	5.8+	40.0 b	38.6 b	1.4 ns
50	45.0 c	37.9 c	7.1+	43.0 c	39.4 c	3.5+

[1]Average of three replications and four intrarow spacing levels.
[2]Days after planting
[3]Mean separation in a column by DMRT at 5% level.
+Significant at 5% level
ns = Not significant.

Table 19. Interaction effect of interrow and intrarow spacing on the severity[1](%) of anthracnose disease on cowpea at 54 DAP[2] in the first season of 1987.

Intrarow spacing (cm)	Interrow spacing (cm) 100	75	50
40	19.5 ax[3]	25.0 ay	31.5 az
30	35.0 bx	36.5 by	38.5 bz
20	33.0 cx	37.5 by	45.8 cz
10	40.2 dx	42.5 cy	50.0 dz

[1]Average of three replications and two cropping patterns
[2]Days after planting
[3]Mean separation by DMRT at 5% level. Letters a to d for means in a column and x to z for those in a row.

Table 20. Effect of the interaction among cropping pattern, interrow and intrarow spacing on the severity[1] (%) of anthracnose on cowpea at 68DAP[2] in the first and second seasons in 1987.

Spacing (cm)		1987 F			1987 S		
Interrow	Intrarow	Sole-cowpea	Inter-cropped cowpea	Difference	Sole-cowpea	Inter-cropped cowpea	Difference
100	40	30.0 a[3]	32.0 a	-2.0ns	27.0 a	26.0 a	1.0ns
	30	39.0 bc	37.0 bc	2.0ns	38.0 c	34.0 b	2.0ns
	20	48.0 e	39.0 cd	9.0+	46.0 d	47.6 c	-1.6ns
	10	66.0 g	48.0 f	18.0+	58.0 g	53.0 d	5.0+
75	40	38.0 b	34.0 ab	4.0ns	29.0 a	28.7 a	0.3ns
	30	43.0 cd	40.0 cd	3.0ns	38.0 c	36.0 b	2.0ns
	20	56.0 f	43.0 de	13.0+	50.0 e	49.0 c	1.0ns
	10	68.0 g	54.0 g	14.0+	58.0 g	53.0 d	5.0+
50	40	40.0 bc	37.0 bc	3.0ns	34.0 b	27.0 a	7.0+
	30	46.0 de	46.0 ef	0.0ns	45.0 d	35.7 b	9.3+
	20	68.0 g	48.0 f	20.0+	53.0 f	49.0 c	4.0+
	10	70.0 g	60.0 h	10.0+	60.0 g	58.6 d	1.4ns

[1] Average of three replications and four intrarow spacings.
[2] Days after planting.
[3] Mean separation in a column by DMRT at 5% level.
+Significant at 5% level
ns = Not significant.

growing seasons (Appendix 13). But, towards the flowering and podding stages of growth, significant differences were observed, with the cowpea in mixture being less severely attacked, with averages of 23.9 and 47.6% at 54 and 68 DAP respectively in the first season, than those grown in sole cropping which had averages of 7.0 and 53% (Figure 5). There was no significant difference in the severity on cowpea plants grown at 50 and 75 cm apart between rows of infections from *C. truncatum* during plant growth, except at the latter stage, 58 DAP. However, except in the first season, plants spaced at 100 cm apart between rows were infected than those planted at a closer interrow spacing.

The effect of intrarow spacing on disease severity on cowpea also followed the pattern observed for anthracnose. At 40 DAP, during the growing seasons, the fungus was not significantly severe on cowpeas at the various levels of intrarow spacing, except for plants spaced at 40 cm apart within row which were significantly infected compared with other intrarow spacing levels. In the first and third seasons, planting cowpea at 30 and 20 cm apart within row resulted in no significant difference. In general, the severity of the disease increased as the space between plant stands in a row decreased.

There was no significant interaction either among the three main factors or between the combination of any two of them, except at 68 DAP in the second season when the severity of the pathogen varied significantly across interrow and intrarow spacings in both sole- and intercropped cowpeas (Table 21). This indicated that the effect of the cropping pattern, interrow or intrarow

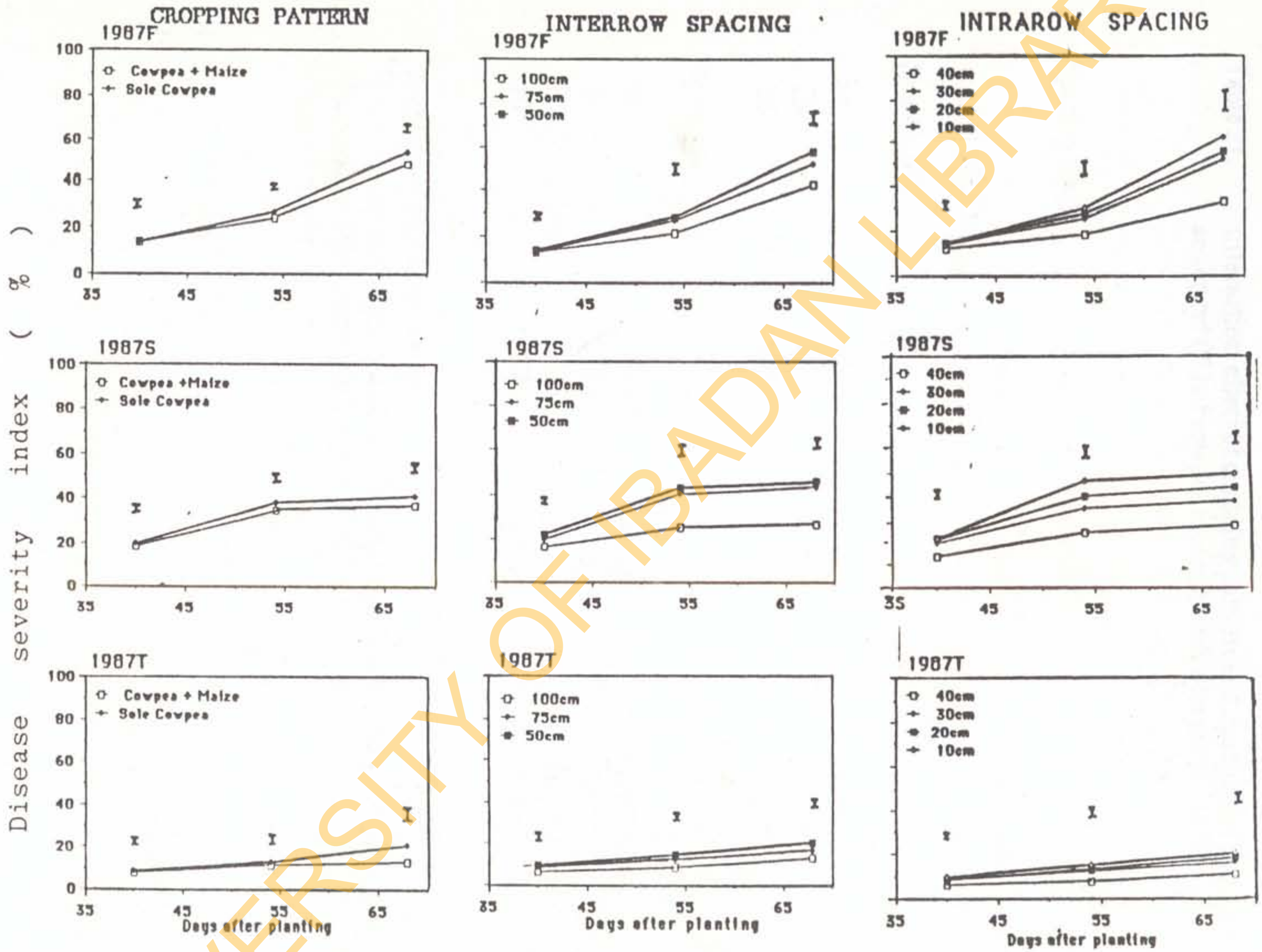


Fig. 5 : Seasonal variability in the severity of brown blotch disease during three growing seasons: F = first season, S = second season and T = third season, in 1987/88.

Table 21. Interaction effect of cropping pattern and spacing on the severity* (%) of cowpea brown blotch disease 68 DAP in the second cropping season of 1987.

Spacing (cm)	Cropping pattern		
	Sole	Inter	Difference
Interrow			
100	32.8 a	4.2 a	28.6++
75	41.3 b	8.8 ab	32.5++
50	50.9 c	11.7 b	39.2++
Intrarow			
40	28.1 a**	2.9 ab	25.2++
30	33.2 a	2.3 a	30.9++
20	47.8 b	9.6 c	38.2++
10	57.7 c	18.1 d	39.6++

*Average of three replications

**Only means followed by different letter(s) within a column for each factor differ significantly at $P \leq 0.05$ (DMRT).

++Significant at 1% level.

spacing in the severity of *C. truncatum* on field grown cowpeas depended on the presence of the other two factors for each and any one of the factors considered.

In the first growing season, there was a sharp rise in the severity of the pathogen on cowpea notwithstanding the various treatments at 54 DAP (Figure 3). At the same stage of plant growth, there was a gradual decrease in the rate of infection from the pathogen until maturity. The disease was least severe in the third season and the rate of increase in the severity was gradual from the beginning of the plant growth until maturity.

4.3.3 Incidence of anthracnose and brown blotch diseases on cowpea pods

i. Anthracnose disease

Intercropping cowpea with maize resulted in significant reductions in the incidence of the pathogen on pods in all seasons (Table 22). The total seasonal mean estimate of disease incidence on cowpea pods harvested from intercropping plots was 24.5% while an equivalent estimate of 42.7% was observed on pods from cowpea in monoculture with an average difference of 18.2%.

Across the seasons, spacing cowpea at 50 cm apart between rows resulted in consistently higher damage from cowpea anthracnose than spacing at 75 cm or 100 cm apart between rows. Plants spaced 100 cm apart between rows had the lowest incidence of disease symptom on their pods. Anthracnose disease infection was highest on pods harvested from plants most closely spaced together within the same row. Cowpea plants sown 30 and 40 cm between hills did not differ as a result of disease incidence on their pods in the

Table 22. Effect of the incidence[1] (%) of anthracnose disease on cowpea pods as affected by cropping pattern, interrow and intrarow spacing during three growing seasons[2] in 1987/88.

Treatments	1987F	1987S	1987T	Across seasons
Cropping pattern				
Cowpea + maize	30.6 a[3]	19.2 a	23.7 a	24.5 a
Sole cowpea	51.4 b	32.7 b	44.1 b	42.7 b
Interrow spacing (cm)				
100	31.8 a	19.5 a	26.5 a	25.9 a
75	41.7 a	25.5 b	32.3 b	38.2 b
50	49.5 c	32.8 c	42.8 c	41.7 c
Intrarow spacing (cm)				
40	29.6 a	18.0 a	20.9 a	22.8 a
30	34.7 a	20.6 a	28.0 b	27.8 b
20	44.9 b	30.0 b	39.1 c	38.0 c
10	54.9 c	35.1 c	47.6 d	45.9 d

[1]Average of three replications
[2]Three seasons in 1987/88: F = First season (April - July 1987); S = Second season (August - November 1987) and T = Third season (December 1987 - March 1988).
[3]Only means followed by different letter(s) within a column for each factor differ significantly at $P \leq 0.05$ (DMRT).

first two growing seasons. During the dry season (1987T) the cropping pattern x interrow x intrarow spacing effect on the incidence of *C. lindemuthianum* was significant (Appendix 14). This indicates that each of the main factors depends at least on the other two in influencing the incidence of the pathogen on cowpea pods in that season. The interaction between 75 cm x 20 cm and that between 50 cm x 40 cm was independent of the cropping pattern (Table 23).

ii. Brown blotch disease

Generally, infected seeds were discolored and contained dark-brown to black lesions. Where these lesions were numerous, fusion occurred, leading to the formation of irregular and extended spots.

Infection of the pods resulted in brown to purplish discoloration, distortion and mummification of immature pods. Shrivelling of these pods subsequently developed (Plate 5A). Laboratory examination of the infected pods showed that there were many acervuli on them (Plate 5B).

Except for the irrigated off-season, significant difference (at $P \leq 0.05$) DMRT) was observed for the incidence of *C. truncatum* on pods from cowpeas intercropped with maize and those grown in sole crop (Table 24). The effect of interrow spacing on the incidence of *C. truncatum* on cowpea pods in the first and second growing seasons was remarkably significant, with incidence level decreasing with increasing interrow spacing level. Though the incidence of brown blotch disease was lowest on pods from cowpea planted 40 cm apart within row, and increased with decreasing intrarow spacing, the incidence on pods did not vary significantly at different levels of spacing tested.

Table 23. Effects of the interaction among cropping pattern, interrow and intrarow spacing on the incidence[1](%) of anthracnose disease on cowpea pods during the third season in 1987.

Spacing (cm)				
Interrow	Intrarrow	Sole cowpea	Intercropped cowpea	Difference
100	40	17.5 gh[2]	0.0 j	17.5++
	30	22.5 d-h	0.0 j	22.5++
	20	25.0 d-g	15.0 hi	10.0++
	10	32.5 bc	20.0 f-h	12.5++
75	40	20.0 f-h	0.0 j	20.0++
	30	22.5 d-h	10.0 i	10.5++
	20	28.4 b-f	20.9 e-h	7.5ns
	10	35.0 ab	25.0 d-g	10.0++
50	40	22.5 d-h	18.4 f-h	4.1 ns
	30	30.0 b-d	20.0 f-h	10.0++
	20	35.0 ab	22.5 d-h	12.5++
	10	40.0 a	25.9 c-f	14.1++

[1]Average of three replications
[2]Mean separation in a column by DMRT at 5% level.
++Significant at 1% level
ns = Not significant.
Means with the same letter are not significantly different at 5% level.

Plate 5. Symptoms of brown blotch disease on cowpea: distortion and shrivelling of pods (A) and acervular structures on dry pods.

Table 24. Effect of the incidence[1] (%) of brown blotch disease on cowpea pods as affected by cropping pattern, interrow and intrarow spacing in three seasons[2] of 1987/88.

Treatments	1987F	1987S	1987T	Across seasons
Cropping pattern				
Cowpea + maize	62.1 a[3]	49.3 a	31.5 a	47.6 a
Sole cowpea	69.2 b	61.2 b	36.0 a	55.5 b
Interrow spacing (cm)				
100	60.0 a	50.1 a	29.2 a	46.5 a
75	65.8 b	55.6 b	33.4 a	51.6 b
50	71.1 c	60.1 b	38.7 a	56.6 c
Intrarow spacing (cm)				
40	54.0 a	46.6 a	26.9 a	42.5 a
30	66.2 b	55.3 b	31.2 ab	50.9 b
20	69.7 bc	56.8 bc	36.2 bc	54.2 c
10	72.6 c	62.3 c	40.8 c	58.6 d

[1]Average of three replications

[2]Three seasons in 1987/88: F = First season (April - July 1987); S = Second season (August - November 1987) and T = Third season (December 1987 - March 1988).

[3]Only means followed by different letter(s) within a column for each factor differ significantly at $P \leq 0.05$ (DMRT).

4.3.4 Severity of anthracnose and brown blotch diseases on cowpea pods

i. Anthracnose disease

While cropping pattern had significant effect on disease severity due to infection by *C. lindemuthianum* on cowpea pods during the first season, it had no effect in the second and third growing seasons (Table 25). However, higher severity values were recorded for pods harvested from sole cowpea plots than from those carrying cowpeas in mixture with maize.

Significant difference existed among the levels of interrow spacing with the highest values for pods from cowpeas sown 50 cm apart between rows while the fungus was least severe on pods from cowpea grown 100 cm apart. There was no consistent effect of intrarow spacing on the severity of *C. lindemuthianum* on cowpea pods from season to season. Cowpea anthracnose damage on pods seemed to be most severe on pods from plants most closely grown together within the row.

The disease was most severe in the first season with an average of 43.9% while it was least severe during the cowpea off-growing season (1987T) with an average of 33.5%. There was no significant difference in the severity of the fungus on pod between the first and second growing seasons.

ii Brown blotch disease

All the main factors had significant influence on the severity of brown blotch disease on cowpea pods even though each factor was independent of the other (Appendix 15). However, the disease severity on the cowpea pods obtained

Table 25. Severity[1*] (%)of anthracnose disease on cowpea pods as affected by cropping pattern, interrow and intrarow spacing in three growing seasons[2] in 1987/88.

Treatments	1987F	1987S	1987T	Across seasons
Cropping pattern				
Cowpea + maize	42.6 a[3]	41.9 a	32.2 a	48.9 a
Sole cowpea	45.3 b	42.0 a	33.5 a	53.2 b
Interrow spacing (cm)				
100	38.9 a	37.4 a	27.8 a	44.6 a
75	44.8 b	42.1 b	32.6 b	51.9 b
50	48.1 c	46.4 c	38.1 c	56.6 c
Intrarow spacing (cm)				
40	35.9 a	37.7 a	27.1 a	38.2 a
30	41.7 b	39.9 a	31.8 bc	47.5 b
20	45.7 c	41.9 a	34.7 c	56.2 d
10	52.3 d	48.3 b	37.8 d	62.2 d

[1]Average of three replications

*Based on 0-5 rating scale, where 0 = asymptomatic; 1=1 - 20% infection; 2 = 21-40% infection; 3 = 41-60%; 4 = 61-80%; and 5 = more than 80% infection.

[2]Three seasons in 1987/88: F = First season (April - July 1987); S = Second season (August - November 1987) and T = Third season (December 1987 - March 1988).

[3]Only means followed by different letter(s) within a column for each factor differ significantly at $P \leq 0.05$ (DMRT).

from intercropped and sole plots was not significantly different regardless of the spacing in the dry off-season designated as 1987T (Table 26).

Following the same trend which was observed for the incidence of the disease on cowpea pods, disease severity on pods also increased with decreasing levels of both interrow and intrarow spacing. A mean seasonal range of 44.6 - 56.6% and 38.0 - 61.0% was recorded for cowpea spaced 100 cm between rows and those spaced 10 cm within rows, respectively.

4.3.5 Infection of cowpea seed by anthracnose and brown blotch diseases

Usually, blackened and shrivelled seeds were produced following infection of cowpea, while the seed testa of the healthy seeds were smooth.

Seeds harvested from cowpea intercropped with maize consistently had a lower level of infection from the individual diseases across the three growing seasons compared with those harvested from monocropped cowpea (Table 27). Spacing cowpea at different interrow and intrarow levels also significantly affected the infection of cowpea seeds by the respective diseases. Seeds from cowpea spaced 50 cm apart between rows were most infected.

Mean seasonal values of 49 and 68% infection from anthracnose and brown blotch diseases respectively were recorded from cowpea seeds grown 50cm between rows, whereas those from 100 cm apart between rows appeared to be most "healthy". Seeds from cowpea planted at 10 cm apart within a row were most infected, while fewer seeds became infected as the space between the neighbouring hills in a row was increased. There was no interaction between

Table 26. Disease severity[1]*(%) of brown blotch on cowpea pods as affected by cropping pattern, interrow and intrarow spacing during three growing seasons[2] in 1987/88.

Treatments	1987F	1987S	1987T	Across seasons
Cropping pattern				
Cowpea + maize	66.0 a[3]	45.9 a	34.8 a	48.9a
Sole cowpea	70.7 b	51.9 b	37.1 a	53.2b
Interrow spacing (cm)				
100	61.9 a	39.3 a	32.7 a	44.6a
75	68.9 b	50.0 b	36.9 ab	51.6b
50	74.2 c	57.4 c	38.2 b	56.6c
Intrarow spacing (cm)				
40	59.3 a	36.0 a	19.2 a	38.2a
30	63.4 a	46.3 b	32.9 b	46.9b
20	72.7 b	54.8 c	41.2 c	56.3c
10	77.9 c	58.4 c	50.3 d	62.2d

[1] Average of three replications

*Based on 0-5 rating scale, where 0 = asymptomatic; 1=1 - 20% infection; 2 = 21-40% infection; 3 = 41-60%; 4 = 61-80%; and 5 = more than 80% infection

[2] Three seasons in 1987/88: F = First season (April - July 1987); S = Second season (August - November 1987) and T = Third season (December 1987 - March 1988).

[3] Only means followed by different letter(s) within a column for each factor differ significantly at $P \leq 0.05$ (DMRT).

Table 27. Means[1] of the effect of anthracnose and brown diseases on cowpea seed weight (100/g), percent seed infection and seed viability as influenced by intercropping and spacing across three growing seasons in 1987/88.

	Anthracnose			Brown blotch		
	Seed weight	Seed infection	Seed viability	Seed weight	Seed infection	Seed viability
Cropping pattern						
Cowpea + maize	12.2a[2]	29.5 a	81.5 a	11.8 a	57.4 a	62.9 a
Sole cowpea	10.8 b	54.4 b	62.7 b	10.9 b	64.1 b	56.3 b
Interrow spacing (cm)						
100	12.0 a	35.7 a	76.2 a	11.6 a	52.3 a	64.3 a
75	11.7 b	41.5 b	72.7 b	11.3 ab	61.8 b	61.4 b
50	11.1 c	49.0 c	67.5 c	11.2 b	68.1 c	53.1 c
Intrarow spacing (cm)						
40	11.7 a	29.3 a	82.1 a	11.6 a	43.4 a	70.8 a
30	11.5 a	35.3 b	76.0 b	11.5 ab	56.6 b	64.5 b
20	11.5 a	47.3 c	68.9 c	11.2 ab	65.5 c	55.7 c
10	11.4 a	56.3 d	61.2 d	11.1 b	77.5 d	47.5 d

[1] Average of three replications

[2] Only means followed by different letter(s) within a column for each factor differ significantly at $P \leq 0.05$ (DMRT).

any two or more of the three main factors indicating that each factor is independent of the others in affecting the pathogens' infection of the seed.

4.3.6 Viability of cowpea seeds following infection from anthracnose and brown blotch diseases

Significantly, more viable seeds were produced from cowpea intercropped than in sole crop across the seasons (Table 27). Cowpea spaced more widely apart along adjacent rows produced more viable seeds than those more closely spaced together between rows.

There were significant differences among the various levels of intrarow spacings. Cowpea plants spaced 40 cm apart within rows produced the largest number of viable seeds, while those spaced 10 cm apart within rows were the least viable with a seasonal mean of 61.2 and 47.5% following infection from anthracnose and brown blotch diseases respectively. In general, while the largest number of viable seeds were produced during the off-growing season, the smallest number of viable seeds were produced in the first growing season.

4.3.7 Effect of anthracnose and brown blotch diseases on cowpea seed weight

Seed weights from cowpea in mixtures were significantly higher in all the seasons than seeds from sole cowpea (Table 27). Seeds produced in rows where cowpea was grown 100 cm apart between the rows were heavier than from those more closely spaced together between adjacent rows.

Though the effect of intrarow spacing regarding the weight of cowpea seeds was insignificant in all the seasons for the diseases, mean estimates showed that seeds from cowpea more widely spaced within rows weighed slightly more than those more closely spaced out from one another within rows.

4.3.8 Effect of anthracnose and brown blotch diseases on cowpea yield

i. Anthracnose disease

On the average, a higher seed yield was consistently obtained from cowpea grown in sole than from those in the mixture during each of the seasons (Table 28). There was significant difference in seed yield from cowpea grown at various interrow and intrarow levels. The highest seed yield was produced from cowpea spaced at 50 cm between rows, while the lowest was from those spaced 100 cm apart. Similarly, the highest seed yield was produced from cowpea plants more closely spaced within rows than those that were relatively less closely grown together in a row.

The range between the highest and lowest seed yield from cowpea spaced respectively at 50 and 100 cm apart between rows was smaller in the first season with an average of 82 kg/ha as compared to the second or third season with averages of 102 and 104 kg/ha respectively. The same observation was recorded in the intrarow treatment in the seasons at the same location.

ii. Brown blotch disease

Significantly, more seed yield was obtained from sole cowpea than from cowpea in mixture. Seed yield increased with decreasing interrow and intrarow spacing levels (Table 29).

In general, the seasonal ranges between the highest and lowest cowpea yield produced from the most and the least closely spaced plants were also consistently low in the first season. However, these ranges were

Table 28. Seed yield[1] (kg/ha) from cowpea infected by anthracnose under different cowpea- maize cropping patterns, interrow and intrarow spacings during three growing seasons[2] in 1987/88.

Treatments	1987F	1987S	1987T	Across seasons
Cropping pattern				
Cowpea + maize	444.9 a[3]	514.6 a	415.0 a	458.2 a
Sole cowpea	657.3 b	752.4 b	623.1 b	677.6 b
Interrow spacing (cm)				
100	502.1 a	574.7 a	454.4 a	510.4 a
75	567.2 b	649.0 b	544.7 b	587.0 b
50	584.0 b	676.9 b	558.0 b	606.3 b
Intrarow spacing (cm)				
40	501.5 a	562.8 a	466.3 a	510.2 a
30	545.8 b	626.2 b	506.8 ab	559.6 b
20	574.5 c	668.3 c	529.8 bc	590.9 c
10	582.7 c	676.9 c	574.4 c	661.3 c

[1]Average of three replications

[2]Three seasons in 1987/88: F = First season (April - July 1987); S = Second season (August - November 1987) and T = Third season (December 1987 - March 1988).

[3]Only means followed by different letter(s) within a column for each factor differ significantly at $P \leq 0.05$ (DMRT).

Table 29. Seed yield[1] (kg/ha) from cowpea infected by brown blotch under different cowpea- maize cropping patterns, interrow and intrarow spacings during three growing seasons[2] in 1987/88.

Treatments	1987F	1987S	1987T	Across seasons
Cropping pattern				
Cowpea + maize	397.3 a[3]	441.2 a	302.6 a	380.4 a
Sole cowpea	633.8 b	673.9 b	471.3 b	593.0 b
Interrow spacing (cm)				
50	490.1 a	532.9 a	306.9 a	433.3 a
75	524.9 b	560.9 b	419.0 b	501.6 b
100	531.6 b	578.9 c	435.2 b	515.2 c
Intrarow spacing (cm)				
10	498.3 a	526.6 a	344.9 a	456.6 a
20	501.2 a	559.8 b	381.8 ab	480.9 b
30	527.8 b	562.6 bc	389.8 bc	493.4 c
40	534.9 b	581.2 c	431.3 c	515.8 d

[1]Average of three replications

[2]Three seasons in 1987/88: F = First season (April - July 1987); S = Second season (August - November 1987) and T = Third season (December 1987 -March 1988).

[3]Only means followed by different letter(s) within a column for each factor differ significantly at $P \leq 0.05$ (DMRT).

equally low in the second season when averages of 41.5 and 36.6 kg/ha were recorded for cowpeas harvested from the most and the least closely spaced in the interrow and the intrarow respectively.

4.3.9 The spread of anthracnose and brown blotch diseases on cowpea plants grown in two cropping systems at different spacings

i. Anthracnose disease

The linear regression equations of the incidence and severity of anthracnose disease of cowpea on plant growth showed that disease spread is gradual (Figures 6 and 7). Disease steadily increased with increase in the age of the plant, regardless of the differential treatments.

The correlation coefficients (R) of the relationship between the incidence of anthracnose disease and plant growth were positive and highly significant at $P \leq 0.05$ level of probability (Figure 6). Intercropping of cowpea with maize showed a more gradual slope of disease incidence on cowpea than monocropping. Infection rates of 0.80 and 1.38 were obtained for intercropped and monocropped cowpea respectively. The rates of disease spread decreased with increase in the spacing of cowpea plants between and within rows. The lowest infection rate obtained on cowpea plants spaced 40 cm apart within rows was 0.85 whereas it was 1.30 for the highest rate for cowpea spaced 10 cm apart. Similar results were observed for the severity of the disease on cowpea (Figure 7).

Brown blotch disease similarly spread more readily on cowpea grown under sole cropping than when intercropped with maize (Figures 8 and 9). Infection rates increased with a decrease in plant spacing. Hence, cowpea

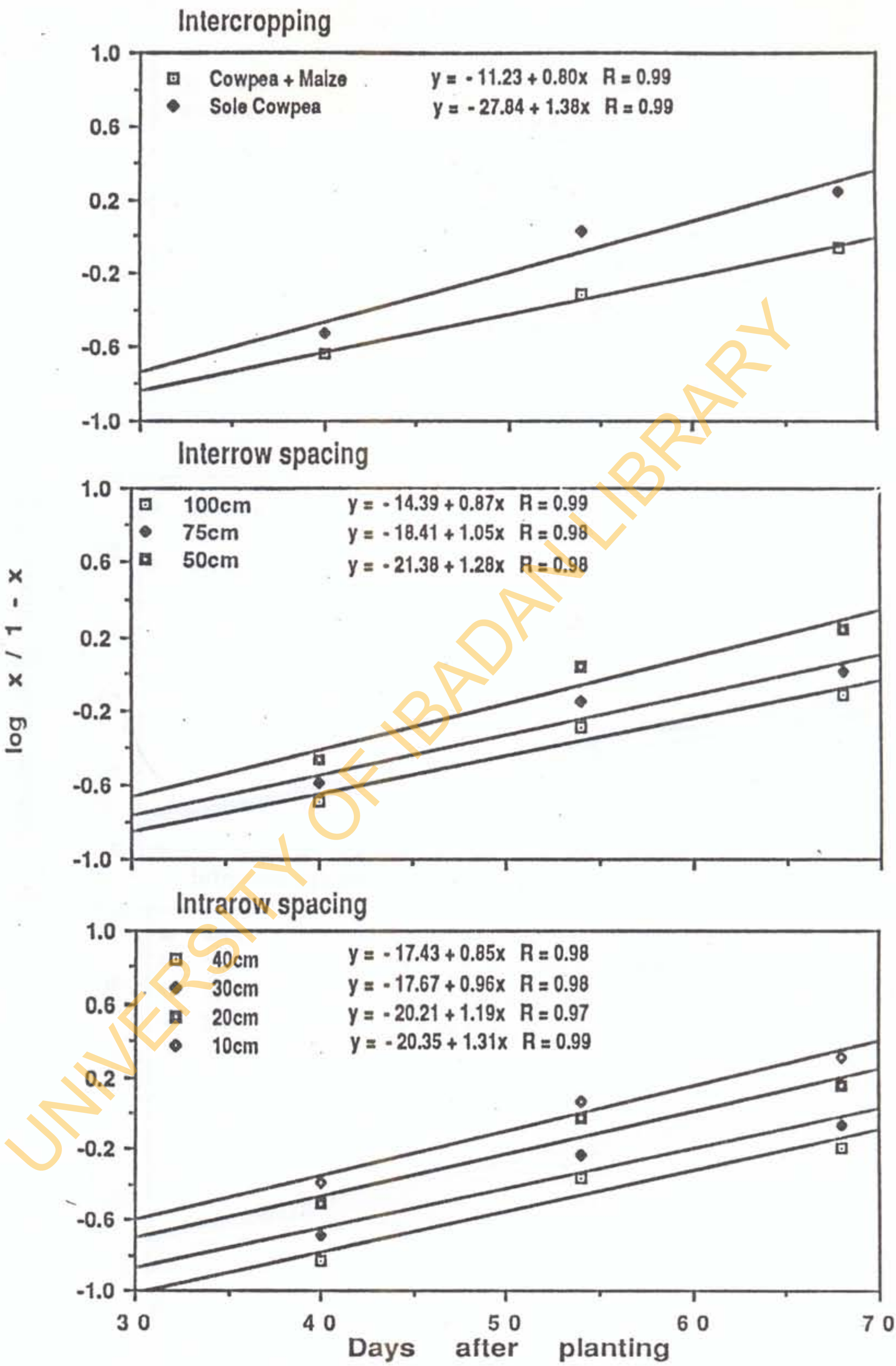


Fig. 6: Disease spread by *Colletotrichum lindemuthianum* and incidence on cowpea in two cropping systems and at different interrow and intrarow spacing.

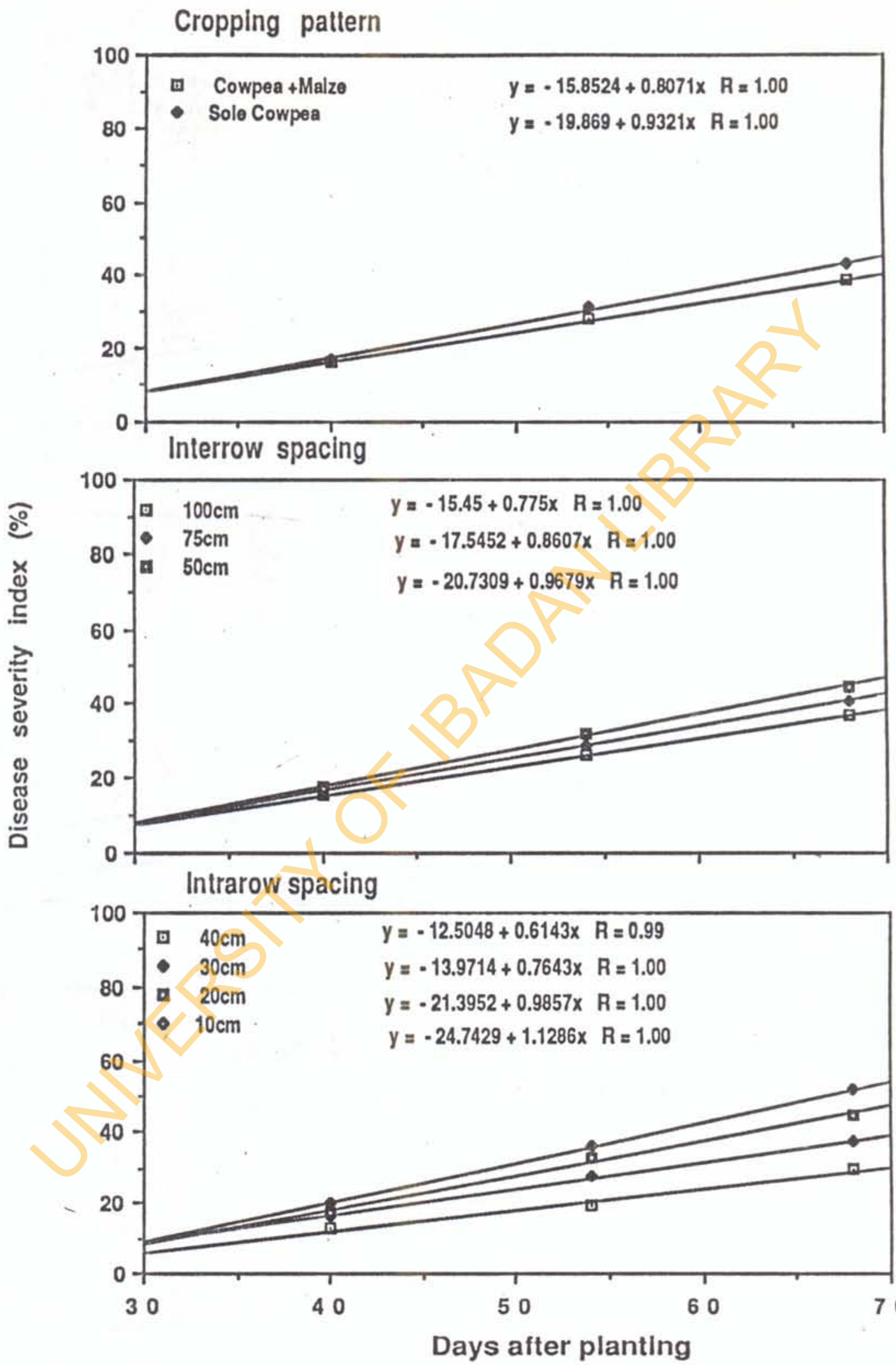


Fig. 7: The rate of anthracnose disease spread by *Colletotrichum lindemuthianum* and severity on cowpea in two cropping systems, and at different interrow and intrarow spacings.

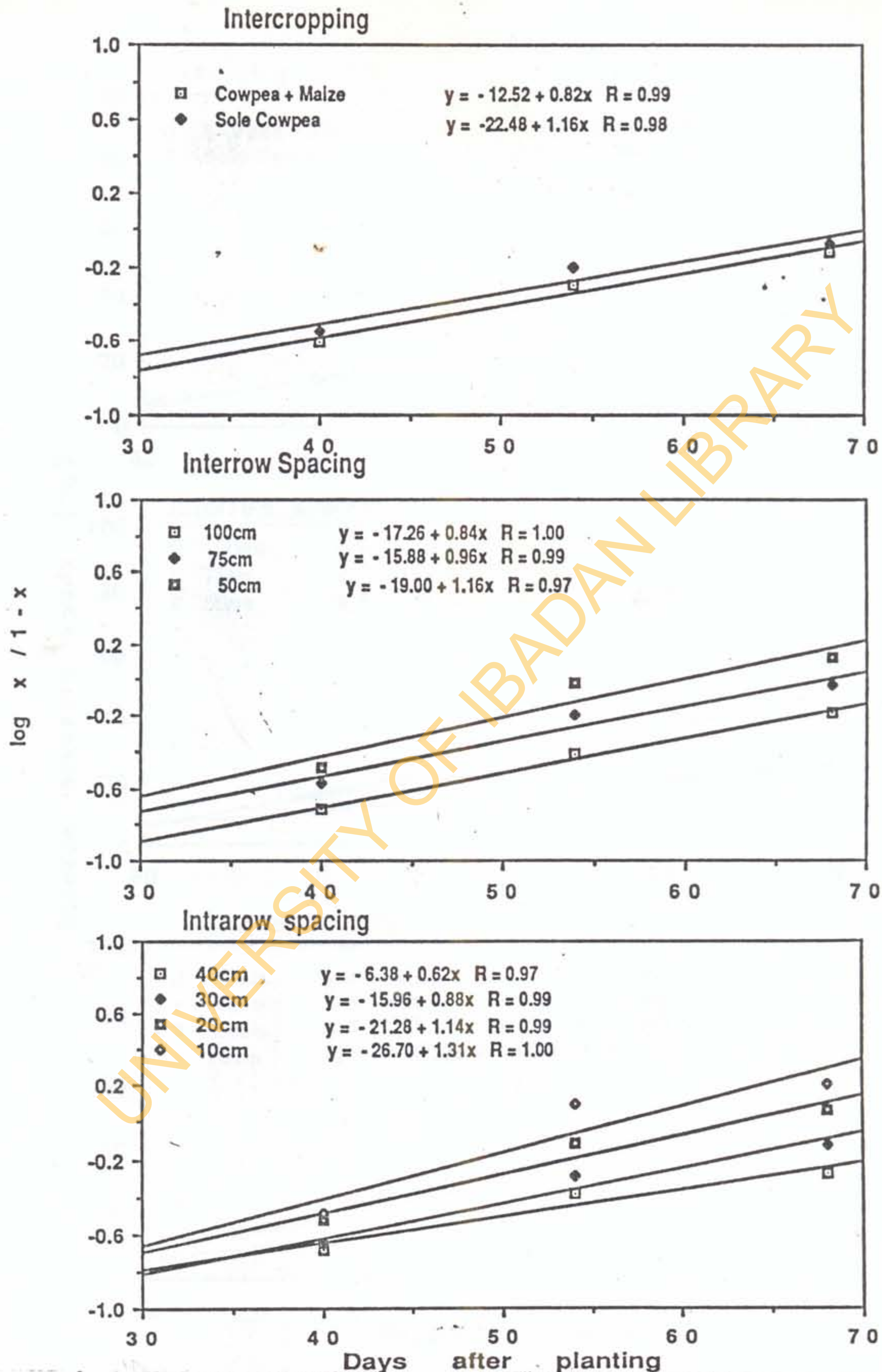


Fig. 8: Rate of disease spread by *Colletotrichum truncatum* and incidence on cowpea in two cropping systems, at different interrow and intrarow spacings.

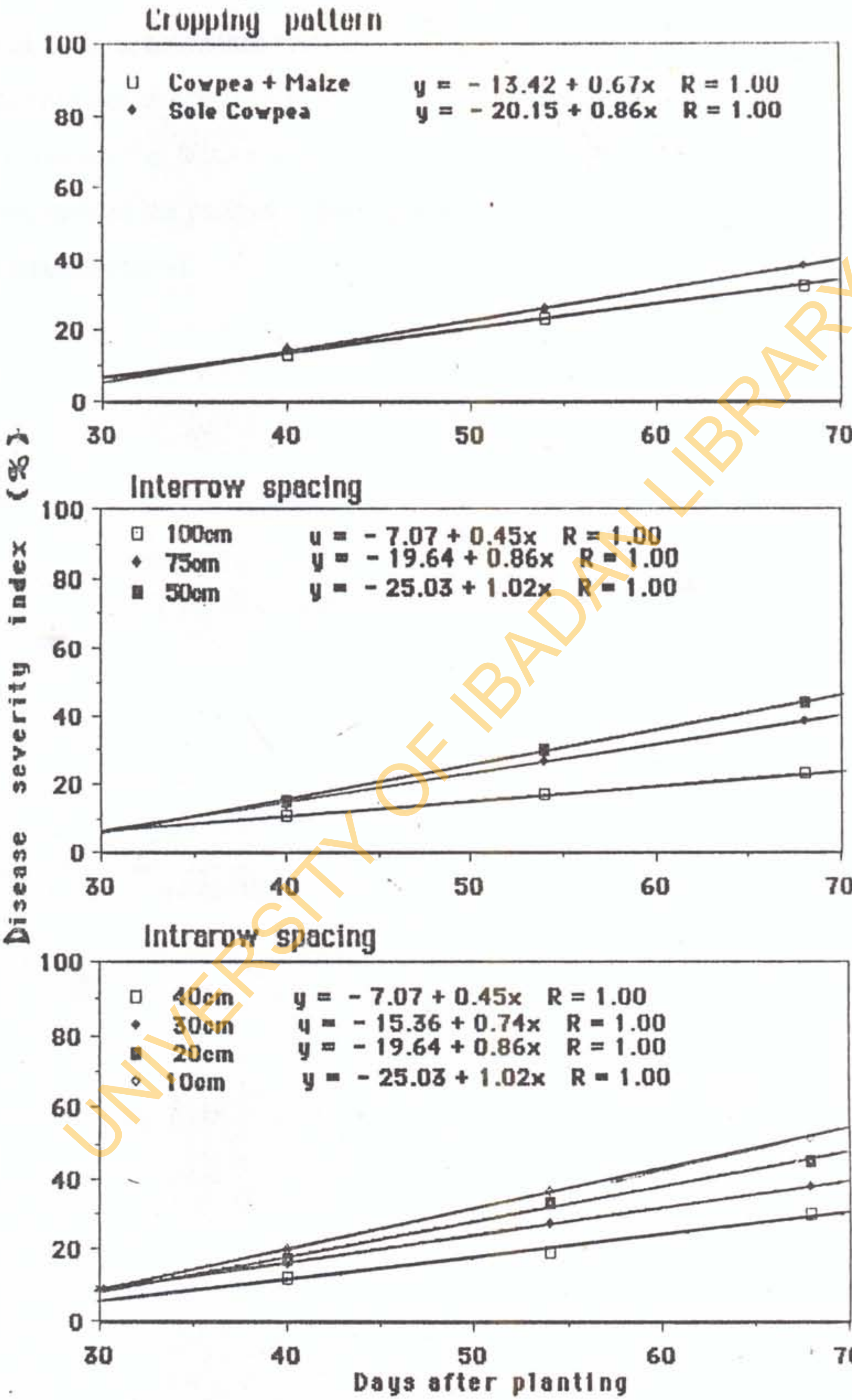


Fig. 9: The rate of spread by *Colletotrichum truncatum* as reflected in its severity on cowpea in two cropping systems and at different interrow and intrarrow spacings.

planted 10 cm apart within rows and those planted 50 cm apart between rows had the highest infection rates of 1.16 and 1.31 respectively.

The scaling factors (the intercepts), in each disease case, were constants that partly fixed the position of the regression lines. They were all negative for each treatment level.

4.4 The influence of cowpea genotypes and cropping patterns on anthracnose and brown blotch diseases of cowpea

4.4.1 Incidence of the diseases on cowpea

i. Anthracnose disease

The cowpea varieties and the cropping pattern showed significant variations at all three sampling periods during each of the three seasons; 1988F, 1988S and 1988T (Appendix 16). Except at 40 DAP in the second season, the effect of the interaction between variety and cropping pattern on the incidence of anthracnose on cowpea was highly significant.

At 54 DAP in the first season (1988F), IT82E-16 increased in disease incidence in order interrow < doublerow<intrarow<strip<sole (Table 30). The incidence of anthracnose on Ife Brown was, however, more pronounced when the crop was grown doublerow than in intrarow. Also, in the strip cropping pattern, a higher incidence of the disease was recorded on IT84S-2246-4 grown in intrarow than when grown in strip. Other cases of the interaction effects of these two factors were observed in the two other seasons (Table 31).

At 68 DAP, IT82E-16 was the most susceptible to infection from anthracnose disease among other varieties grown under the various cropping patterns, except in interrow where Ife Brown was most susceptible among other varieties during the first season, 1988F (Table 32). In 1988S, IT82E-16 was more susceptible in doublerow, while other two varieties were less. Conversely, the two varieties were more susceptible than IT82E-16 in intrarow pattern. Equally, IT84S-2246-4 was more susceptible in intrarow pattern than in strip where the other two varieties were more susceptible. In the third season, the

Table 30. Effect of variety x cropping pattern on the incidence[1] (%) of anthracnose disease of cowpea at 54 DAP[2] during three growing seasons in 1988/89[3].

	1988F			1988S			1988T		
Cropping pattern	IT84S-2246-4	Ife Brown	IT82E-16	IT84S-2246-4	Ife Brown	IT82E-16	IT84S-2246-4	Ife Brown	IT82E-16
Interrow	25.4	30.0	27.5	35.0	35.0	35.0	17.5	10·0	32.5
Doublerow	27.5	52.5	55.0	47.5	57.5	57.5	27.5	32.5	37.5
Intrarow	37.5	40.0	65.0	52.5	67.5	75.0	27.5	40·0	45.0
Strip	35.0	67.5	70.0	47.5	70.0	85.0	37.5	47.5	50.0
Sole	50.0	70.0	97.5	60.0	87.5	95.0	45.0	57.5	85.0
LSD 5% variety			5.3			3.6			5.1
LSD 5% cropping pattern			6.7			4.7			6.6

[1]Average of three replications.
[2]DAP = Days after planting
[3]Three seasons in 1988/89: F = First season (April - July 1988); S = Second season (August - November 1988) and T = Third season (December 1988 - March 1989).

Table 31. Effect of variety x cropping pattern on the incidence[1] (%) of brown blotch disease of cowpea at 68DAP[2] during three growing seasons in 1988/89[3].

Cropping pattern	1988F			1988S			1988T		
	IT84S-2246-4	Ife Brown	IT82E-16	IT84S-2246-4	Ife Brown	IT82E-16	IT84S-2246-4	Ife Brown	IT82E-16
Interrow	35.0	40.0	37.5	40.0	37.5	42.5	25.0	32.5	40.0
Doublerow	45.0	65.0	90.0	47.5	62.5	85.0	37.5	37.5	52.8
Intrarow	55.0	70.0	95.0	52.5	67.5	77.5	42.5	65.0	65.0
Strip	65.0	85.0	97.5	50.0	72.5	95.0	50.0	70.0	75.0
Sole	90.0	95.0	100.0	70.0	97.5	100.0	57.5	82.5	92.5
LSD 5% variety			4.2			4.0			3.5
LSD 5% cropping pattern			5.4			5.1			4.5

[1] Average of three replications.
[2] DAP = Days after planting
[3] Three seasons in 1988/89: F = First season (April - July 1988); S = Second season (August - November 1988) and T = Third season (December 1988 - March 1989).

Table 32. Influence of cowpea varieties and cropping patterns on the incidence[1] (%) of anthracnose of cowpea at three sampling times during three seasons in 1988/89[2].

Treatments	1988F			1988S			1988T		
	40 DAP[3]	54 DAP	68 DAP	40 DAP	54 DAP	68 DAP	40 DAP	54 DAP	68 DAP
A. Varieties									
IT84S-2246-4	28.5 a[4]	35.0 a	58.0 a	40.0 a	48.5 a	52.0 a	25.0 a	31.0 a	42.5 a
Ife Brown	37.5 b	52.0 b	71.0 b	50.0 b	63.5 b	67.5 b	28.0 a	37.5 b	67.5 b
IT82E-16	45.0 c	63.0 c	84.0 c	55.5 c	69.5 c	80.0 c	32.5 b	50 c	65.0 c
B. Cropping pattern									
Interrow	22.5 a	27.5 a	37.5 a	25.0 a	35.0 a	40.0 a	12.5 a	20 a	32.5 a
Doublerow	37.5 b	45.0 b	66.7 b	45.0 b	54.2 b	65/0 b	26.7 b	32.5 b	42.5 b
Intrarow	37.5 b	47.5 b	73.3 c	52.5 c	65.0 c	65.8 b	30.8 bc	37.5 b	57.5 c
Strip	42.5 bc	57.5 c	82.5 d	57.5 d	67.5 c	72.5 c	35.0 cd	45.0 c	65.0 d
Sole	45.0 c	72.5 d	95.0 c	62.5 e	80.8 d	89.2 d	37.5 d	62.4 d	77.5 e
C.V. %	15.4	13.9	7.9	10.4	8.0	8.0	8.2	17.4	8.5

[1]Average of three replications.
[2]Three seasons in 1988/89: F = First season (April - July 1988); S = Second season (August - November 1988) and T = Third season (December 1988 - March 1989).
[3]DAP = Days after planting
[4]Only means followed by different letter(s) within a column for each factor differ significantly at $P \leq 0.05$ (DMRT).

same incidence value of 37.5% was recorded on IT84S-2246-4 and Ife Brown in the interrow whereas, in other cropping patterns, Ife Brown was more susceptible to the disease than IT84S-2246-4.

Throughout the growing seasons, IT82E-16 was the most susceptible to infection by *C. lindemuthianum* with a seasonal mean value of 76.3% while IT84S-2246-4 was the least susceptible (50.8%) at 68 DAP. All the cowpea varieties were significantly less susceptible to the fungus attack when intercropped with maize than when grown alone. However, cowpeas grown in interrow pattern were the least susceptible, while there were inconsistent differences in significance when cowpeas were planted in doublerow, intrarow and in strip.

ii. Brown blotch disease

There were significant differences among the genotypes and cropping patterns (Appendix 17). Though there were highly significant interactions between varieties and cropping pattern, these were not consistent over the various sampling times within the seasons (Table 33).

In the first season, IT82E-16 was more susceptible to brown blotch infection in intrarow intercropping of cowpea with maize than in strip compared to other varieties which were more susceptible in strip than in intrarow. Equally, both IT84S-2246-4 and IT82E-16 were both less susceptible in doublerow than in intrarow compared with Ife Brown, which was less susceptible in intrarow than in doublerow.

In the second growing season, both Ife Brown and IT84S-2246-4 were significantly different in their reaction to *C. truncatum* in each of the cropping

Table 33. Effect of cowpea varieties and cropping patterns on the incidence[a] (%) of brown blotch disease of cowpea at 54 DAP[b] during the first and second cropping seasons in 1988/89.

Cropping pattern	1988F			1988S		
	Ife Brown	IT84S-2246-4	IT82E-16	Ife Brown	IT84S-2246-4	IT82E-16
Interrow	35.0	22.0	17.5	40.0	30.0	27.5
Doublerow	45.0	30.0	22.5	72.5	50.0	50.0
Intrarow	42.5	37.5	32.5	67.5	40.0	35.0
Strip	67.5	45.0	30.0	80.0	55.0	49.0
Sole	75.0	62.5	42.5	90.0	62.5	52.5
L.S.D. 5% Variety			2.1			3.1
L.S.D. 5% Cropping pattern			2.7			4.0

[a]Average of three replications
[b]DAP = Days after planting

patterns. However, IT82E-16 had significantly lower incidence values only in interrow and intrarow compared to other cropping patterns where it had relatively higher incidence values which were not significantly different. In comparing the varieties across the cropping patterns, Ife Brown was significantly the most susceptible while IT82E-16 was the least susceptible except in doublerow where it had the same value asIT84S-2246-4.

In the third season, there was no significant cowpea variety x cropping pattern interaction effect. From the mean estimates, Ife Brown was the most susceptible. It was followed by IT84S-2246-4, while IT82E-16 was the most resistant. Among the cropping patterns tested, infection of cowpea by *C. truncatum* was lowest in interrow, while it was highest in sole cropping system. There was no significant difference between cowpea planted in strip and intrarow cropping patterns, whereas a higher incidence value was recorded in doublerow intercropping of cowpea.

At 68 DAP, there was no signifcant interaction between the main factors during the first and second growing seasons. In both seasons, mean estimates (Table 34) show that Ife Brown was the most susceptible variety, while IT82E-16 was the least. Sole cropping system provided the most conducive situation for infection by *C. truncatum*. It was followed by strip > intrarow > doublerow > interrow in that order. The incidence of *C. truncatum* on cowpea varied significantly from one level to the other among the cropping patterns in the first season, whereas in the second season there was no significant difference between doublerow and intrarow.

Table 34. Effect of cowpea varieties and cropping patterns on the incidence[1] (%) of brown blotch disease of cowpea at 68 DAP[2] during the first and second cropping seasons in 1988/89.

Cropping pattern	1988F				1988S			
	Ife Brown	IT84S-2246-4	IT82E-16	Mean	Ife Brown	IT84S-2246-4	IT82E-16	Mean
Interrow	35.0	28.3	25.0	29.4 a[3]	57.5	37.5	32.5	42.5 a
Doublerow	52.5	45.0	37.5	45.0 b	75.0	52.5	52.5	60.0 b
Intrarow	62.0	50.0	45.0	52.5 c	77.0	55.0	55.0	62.5 b
Strip	72.5	67.5	62.5	67.5 d	90.0	62.5	57.5	70.0 c
Sole	95.0	90.0	85.0	90.0 e	100.0	92.5	77.5	90.0 d
Variety mean	62.5 a	57.2 b	51.0 c		80.0 a	60.0 b	55.0 c	
C.V. %		6.9				8.1		

[1]Average of three replications.
[2]DAP = Days after planting
[3]Only means followed by different letter(s) within a column for each factor differ significantly at $P \leq 0.05$ (DMRT).

4.4.2 Severity of anthracnose and brown blotch diseases on cowpeas

i. Anthracnose disease

Anova result showed that there were significant differences in the severity of anthracnose on the cowpea varieties and cropping patterns at all the sampling times in 1988/89 cropping seasons (Appendix 18). At almost all growth stages during the three cropping seasons, the disease was least severe on cowpea grown in interrow and most severe on those grown in sole crop (Figure 10). Cowpea grown in strip cropping ranked next to those grown in sole in susceptibility to anthracnose, whereas those in doublerow and interrow were not significantly different ($P \leq 0.05$) in susceptibility to the disease in certain cases.

Except in the first cropping season (1988F), there was no appreciable difference in the reaction of the cowpea genotypes to infection from the pathogen 40 DAP (Figure 11). At 54 DAP, IT82E-16 was significantly more susceptible to the pathogen than the other two varieties (IT84S-2246-4 and Ife Brown) which had non-significantly lower severity values across the seasons. At 68 DAP, the three varieties significantly differed in severity from one another, with IT82E-16 being the most severely attacked while IT84S-2246-4 was the least infected.

There was significant variety x cropping pattern interaction effect on the severity of anthracnose disease on cowpea, indicating that the severity of this disease on cowpea differed significantly across the different cropping patterns. Clear evidence is shown in Table 35. In 1988F, *C. lindemuthianum* was more severe on IT82E-16 grown in doublerow than when grown in intrarow compared with the other two varieties which were less susceptible to the disease in

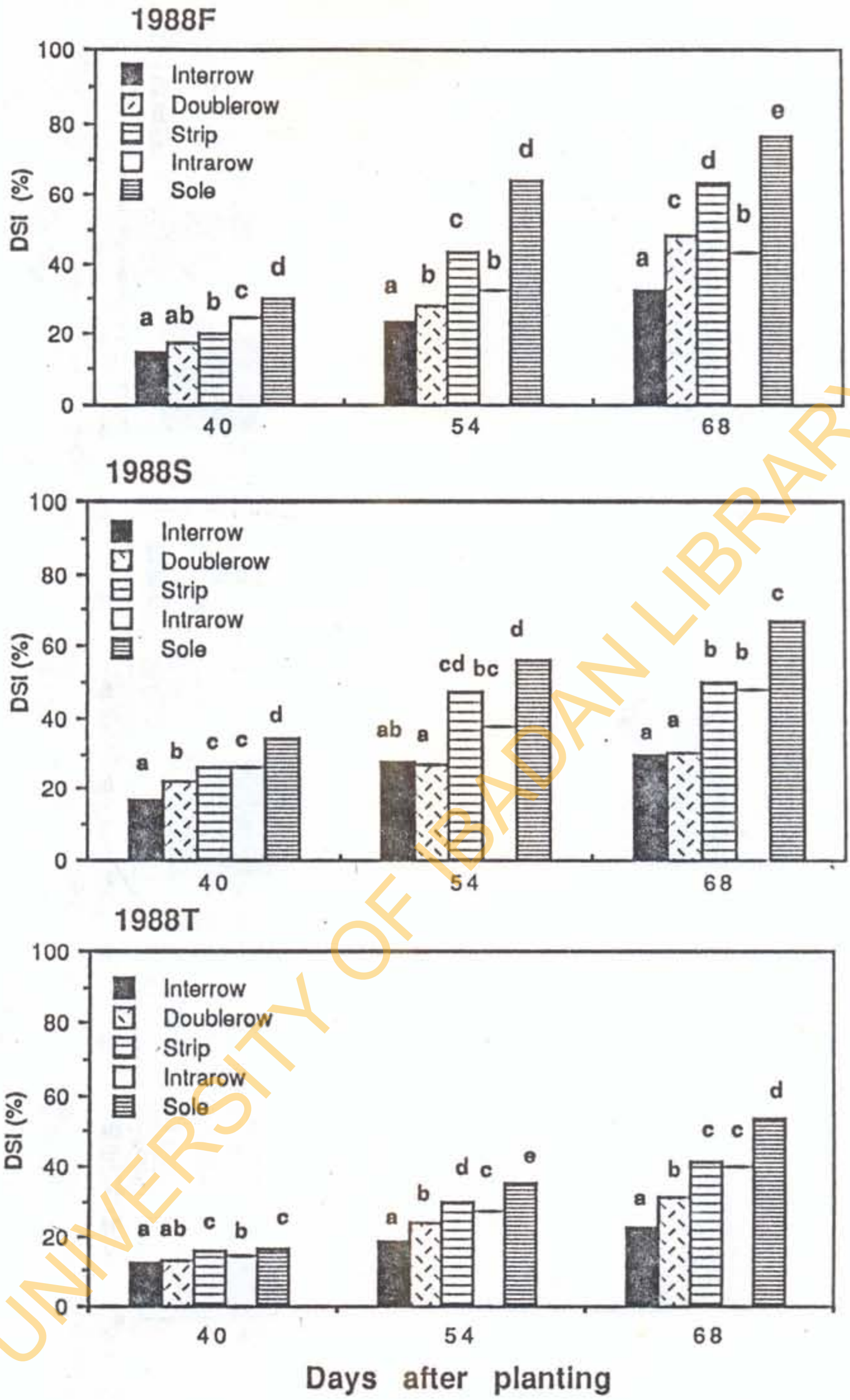


Fig. 10: Effect of different cropping patterns on the severity of anthracnose disease on cowpea in three planting seasons (F = first season, S = second and T = third season) in 1988/89. Bars with the same letter(s) are not significantly different at 5% level each sampling date.

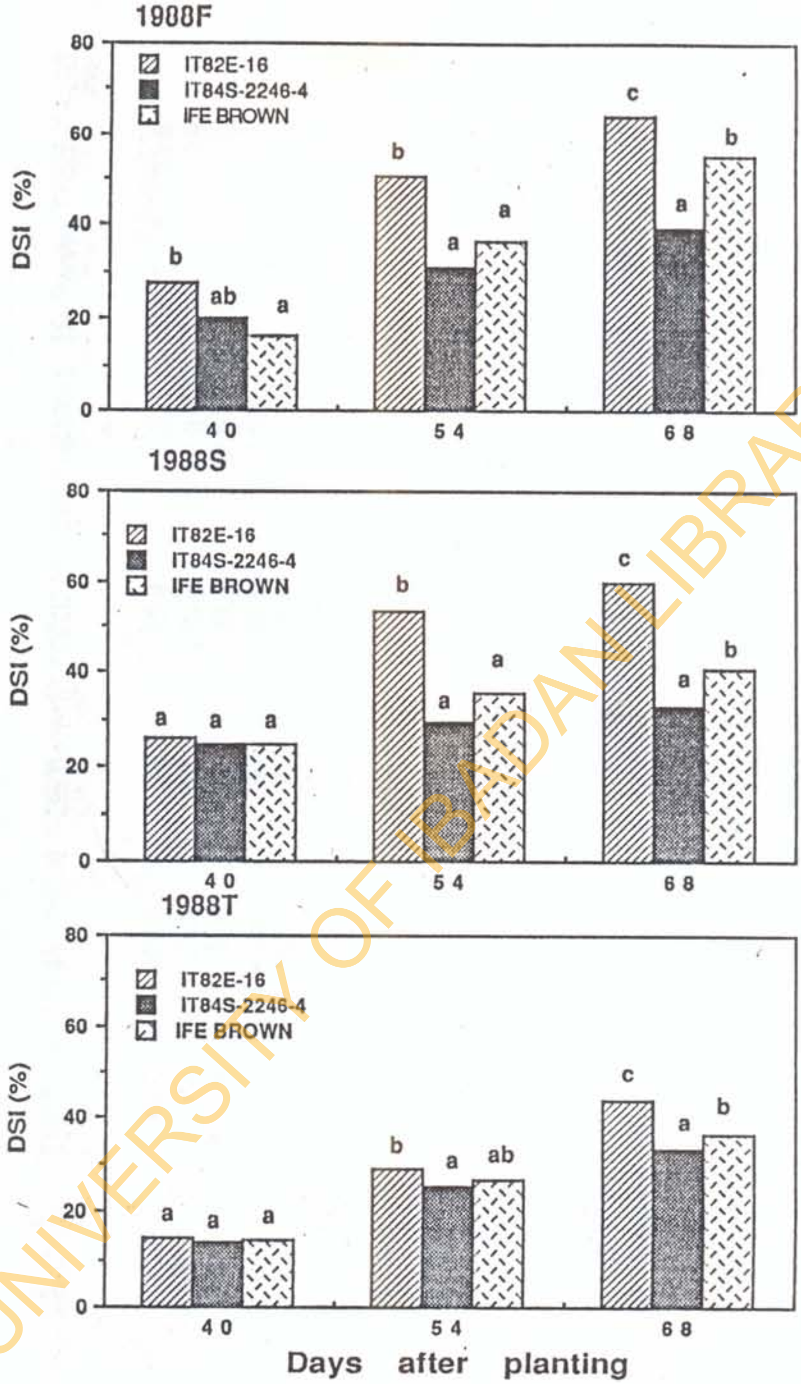


Fig.11: Effect of variety on the severity of anthracnose disease of cowpea during three planting seasons (F = first season, S = second and T = third season) in 1988/89. Bars with the same letter(s) are not significantly different at 5 % level for each sampling date.

Table 35. Interaction effect of variety x cropping patterns on the severity[1] (%) of anthracnose disease of cowpea at 68 DAP[2] during three seasons in 1988/89[3].

	1988F			1988S			1988T		
Cropping pattern	IT84S-2246-4	Ife Brown	IT82E-16	IT84S-2246-4	Ife Brown	IT82E-16	IT84S-2246-4	Ife Brown	IT82E-16
Interrow	26.0	31.0	42.0	32.0	24.0	35.0	31.2	21.0	30.0
Doublerow	37.0	47.0	61.0	25.0	29.0	38.0	17.0	29.9	33.6
Intrarow	30.0	49.0	51.0	30.0	42.0	73.0	27.9	38.8	53.6
Strip	40.0	71.0	78.0	52.0	48.0	67.0	38.0	40.0	47.1
Sole	64.0	77.0	89.0	52.0	60.0	89.0	52.0	53.3	56.7
LSD 5% variety			3.4			3.8			1.9
LSD 5% cropping pattern			4.4			4.9			2.4

[1]Average of three replications.
[2]DAP = Days after planting
[3]Three seasons in 1988/89: F = First season (April - July 1988); S = Second season (August - November 1988) and T = Third season (December 1988 - March 1989).

doublerow than in intrarow. In the second and third seasons, IT82E-16 was more severely attacked when grown in intrarow than in strip, whereas both Ife Brown and IT84S-2246-4 were more severely attacked than when they were grown in intrarow. Values obtained for Ife Brown in both cropping patterns did not differ significantly from each other during the third growing season.

ii. Brown blotch disease

There were significant variations in the severity of brown blotch disease on the cowpea varieties grown in different cropping patterns (Appendix 19). There was significant interaction between the two factors at all the sampling times in the first season as presented in Table 36. However, there was no significant variety x cropping pattern interaction in the second season. During the dry irrigated seasons though there was no significant interaction between the factors at 40 DAP, significant interactions were noticeable at 54 and 68 DAP.

In contrast to observation of the varietal response to the anthracnose severity on cowpea, IT82E-16 was the least susceptible while Ife Brown was the most susceptible (Figure 12). The severity of the disease on cowpea grown in different cropping patterns of maize and cowpea association at three sampling times in three seasons is shown in Figure 13. The same results recorded as for infection by *C. lindemuthianum* were obtained, severity being lowest in an interrow cropping system and highest where there was sole-cropping, with inconsistent variations among other cropping patterns.

Table 36. Effect of variety x cropping pattern on the severity[1] (%) of brown blotch disease of cowpea at three sampling times during the first growing season in 1988/89[2].

	40 DAP[3]			54 DAP			68 DAP		
Cropping pattern	IT84S-2246-4	IT82E-16	Ife Brown	IT84S-2246-4	IT82E-16	Ife Brown	IT84S-2246-4	IT82E-16	Ife Brown
Interrow	7.0	8.6	9.7	8.0	15.0	28.0	10.3	19.0	37.0
Doublerow	13.8	13.1	20.7	13.5	16.0	28.0	15.8	31.0	51.0
Intrarow	13.8	15.0	23.7	24.0	49.5	75.0	36.2	62.0	87.0
Strip	14.0	13.4	22.7	18.2	46.0	65.0	21.0	68.0	98.1
Sole	13.0	15.5	26.0	39.8	75.0	87.5	68.0	81.5	96.0
LSD 5% variety			1.7			2.6			2.3
LSD 5% cropping pattern			2.2			3.3			3.0

[1]Average of three replications.

[2]Three seasons in 1988/89: F = First season (April - July 1988); S = Second season (August - November 1988) and T = Third season (December 1988 - March 1989).

[3]DAP = Days after planting

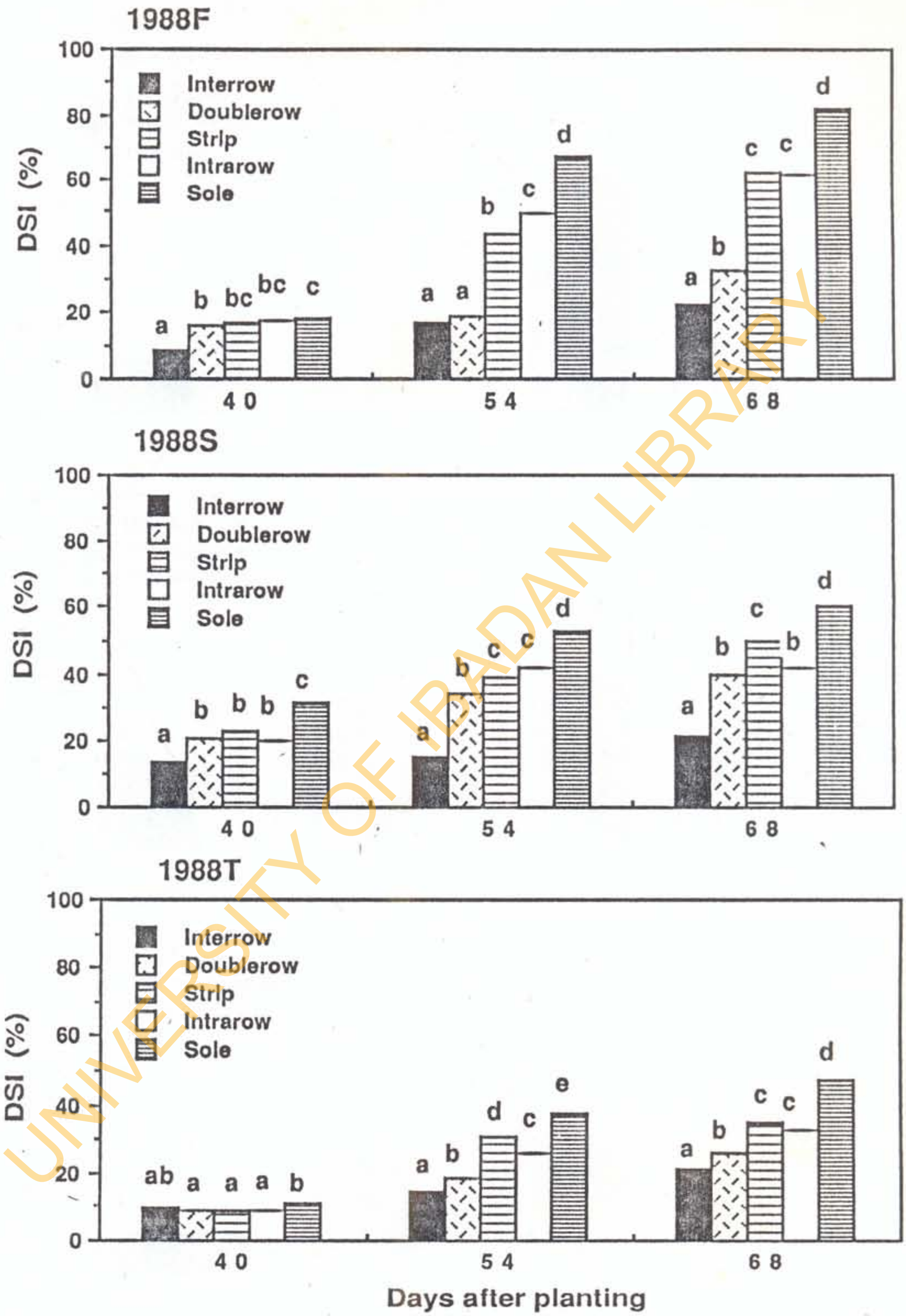


Fig.12: Effect of different cropping patterns on cowpea brown blotch severity in three planting seasons in1988/89. Bars with the same letter(s) are not significantly different at 5% level for each sampling date .

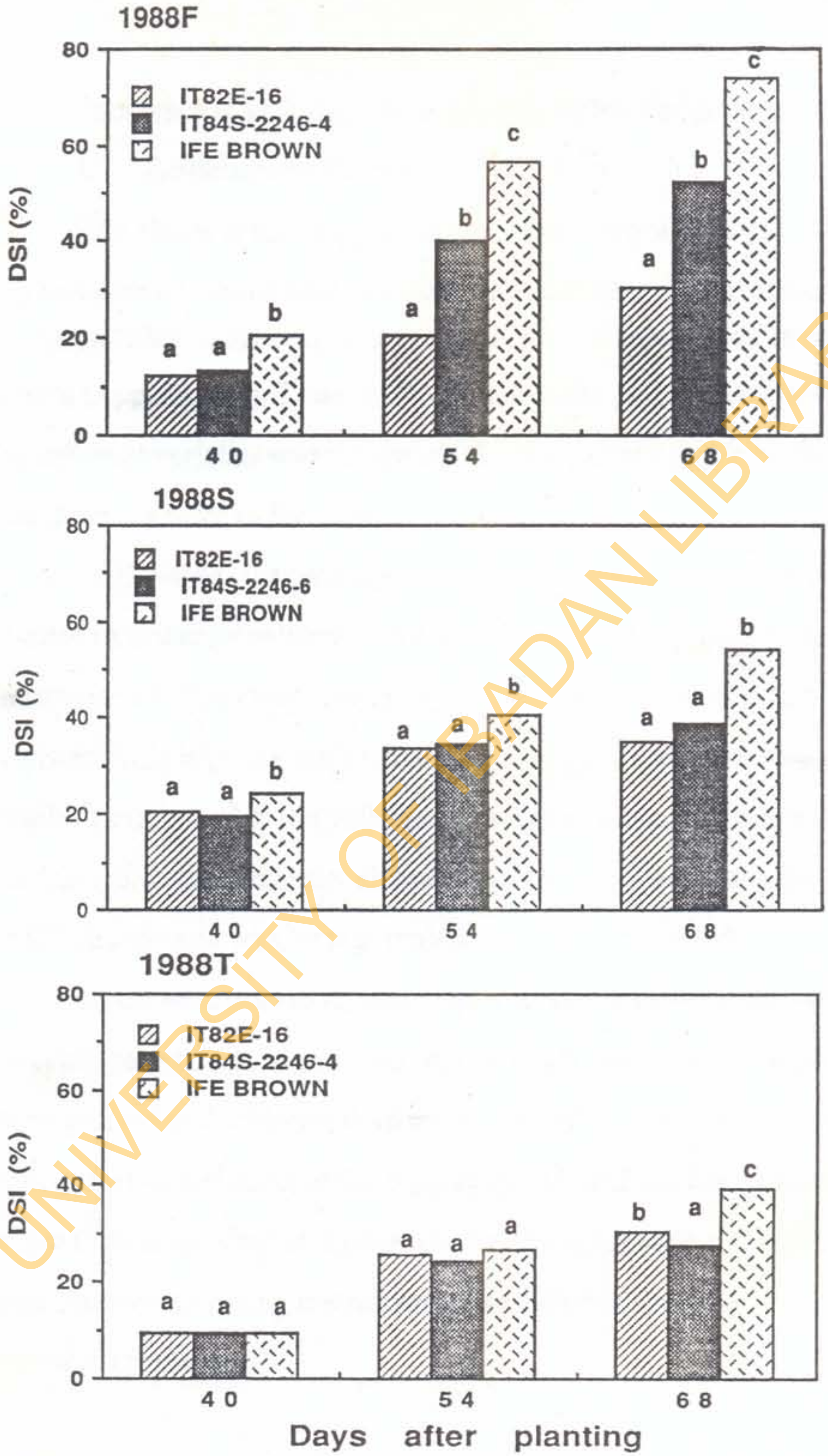


Fig.13: Effect of variety on the severity of brown blotch disease of cowpea during three planting seasons (F = first season S = second and T = third season) in 1988/89. Bars with the same letter(s) are not significantly different at 5 % level for each sampling date.

4.4.3 Incidence of anthracnose and brown blotch diseases on cowpea pods

i. Anthracnose disease

The effects of the cropping pattern and cowpea genotype on the infection of plant pods by *Colletotrichum lindemuthianum* were significant (Table 37). Except in 1988S, there was no significant effect of interaction between the two factors (Appendix 20). Thus, the incidence of the pathogen on cowpea pods from the different varieties was independent of the pattern in which the cowpea plants were grown in the field.

However, the pathogen was least prevalent on pods from cowpea planted in interrow pattern, while pods from cowpea in sole cropping were the most infected. Pods from cowpea grown two rows between maize rows and in alternate hills with the maize (doublerow and intrarow) were statistically similar in infection by the pathogen. Varietal response to infection by *C. lindemuthianum* generally showed that the pathogen was most prevalent on IT82E-16 pods and was least prevalent on IT84S-2246-4 pods.

In the second season, when the interaction between the variety and cropping pattern was significant, the pathogen occurred more on IT84S-2246-4 when planted in doublerow than when planted in intrarow. Contrary to this, other varieties had more of their pods infected with anthracnose when planted in intrarow than when in doublerow. In the same season, IT84S-2246-4 pods from interrow cropping system were less infected compared with IT82E-16 pods from sole cropping.

Table 37. Mean squares for the effect of cropping pattern and variety on the incidence of anthracnose disease on cowpea pods during three growing seasons[a] in 1988/89.

Source of variation	Degrees of Freedom	Mean squares		
		1988F	1988S	1988T
Cropping pattern	4	1203.8++	654.1++	1449.5++
Variety	2	583.8++	663.4++	368.6++
Interaction	8	16.3ns	44.5++	20.3ns
Error	28	20.5	12.0	20.6

[a]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November, 1988) and T = Third season (December 1988 - March 1989).

++Significant at 1% level
ns - Not significant.

ii. Brown blotch disease

Brown blotch disease was most prevalent on pods harvested from cowpea grown sole, whereas pods from cowpea intercropped with maize had a lower incidence of infection (Table 38). Pods from the interrow planting system had the lowest disease incidence in all seasons. Except in 1988F, there was no significant difference in the incidence of the pathogen on pods of Ife Brown and IT84S-2246-4 (Appendix 21). In the other two seasons, the greatest incidence of *C. truncatum* was recorded on IT84S-2246-4 while IT82E-16 pods had the lowest values.

Cowpea pods harvested from interrow planting pattern showed the lowest level of incidence due to *C. truncatum* with a seasonal mean value of 52.4%. Those from sole-cropped cowpea had the highest level of infection with a seasonal mean estimate of 87.3%. Cowpea variety x cropping pattern interaction was significant ($P \leq 0.05$) only in the first growing season. In this season, the pathogen's incidence level on Ife Brown and IT84S-2246-4 pods was significantly lower when cowpea was planted in intrarow pattern than in double row. The converse was the case for the incidence of the pathogen on pods from IT82E-16 grown in doublerow compared with the incidence when this variety was grown in intrarow cropping pattern.

4.4.4 Severity of anthracnose and brown blotch diseases on cowpea pods

i. Anthracnose disease

Cowpeas planted in interrow system were the least susceptible to infection by *C. lindemuthianum*, as shown by the severity of the pathogen on the pods (Table 39). Those planted in cropping patterns; doublerow, intrarow

Table 38. Incidence[a] (%) of brown blotch disease on cowpea pods as influenced by cropping pattern and variety during three seasons in 1988/89[b].

Cropping pattern	1988F			1988S				1988T			
	IT82E-16	Ife Brown	IT84S-2246-4	IT82E-16	Ife Brown	IT84S-2246	Cropping pattern mean	IT82E-16	Ife Brown	IT84S-2246	Cropping pattern mean
Interrow	44.5	67.0	56.5	31.0	41.0	48.4	40.1 a*	56.1	60.4	67.0	61.2 a
Doublerow	70.3	75.0	75.3	52.2	56.5	64.3	57.7 b	66.3	68.0	75.7	70.0 b
Intrarow	54.0	79.5	81.3	47.6	63.7	69.0	60.1 b	63.7	75.5	79.2	72.8 bc
Strip	75.7	83.6	86.2	58.0	67.4	72.5	66.0 c	71.8	78.2	83.7	77.9 c
Sole	89.6	94.2	98.6	74.0	81.7	85.0	80.2 d	84.3	87.0	91.7	87.7 d
Variety mean				52.6 a	62.0 b	67.9 c		68.4 a	73.8 b	79.4 c	
Interaction		+			ns				ns		
CV %		8.2			8.3				8.6		

[a]Average of three replications
[b]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November, 1988; and T = Third season (December, 1988 - March, 1989)
*Only means followed by different letter(s) within a column for each factor differ significantly at P ≤ 0.05 (DMRT).
+Significant at 5% level.
ns = Not significant.

Table 39. Severity[1] (%) of anthracnose on cowpea pods as influenced by cropping pattern and variety during three seasons[2] in 1988/89 and across the seasons.

Treatments	1988F	1988S	1988T	Across seasons
Cropping pattern				
Interrow	40.3 a[3]	29.2 a	31.0 a	33.5 a
Double row	48.5 b	36.3 b	40.0 b	41.6 b
Intrarow	49.1 b	37.0 b	40.4 b	42.2 b
Strip	55.9 c	41.8 c	44.9 b	47.5 c
Sole	68.2 d	52.7 d	64.3 c	61.7 d
Cowpea variety				
Ife Brown	47.5 a	47.0 a	58.7 a	51.1 a
IT84S-2246-4	52.2 b	53.2 b	64.0 b	56.5 b
IT82E-16	57.5 c	58.0 c	70.2 c	61.9 c

[1]Average of three replications

[2]Three seasons in 1988/89: F = First season (April - July 1988); S = Second season (August - November 1988) and T = Third season (December 1988 - March 1989).

[3]Only means followed by different letter(s) within a column for each factor differ significantly at $P \leq 0.05$ (DMRT).

and strip, had lower values, compared with the observation in interrow, and were not statistically different with reference to the severity of the pathogen on their pods. Pods from cowpea plants not intercropped were most severely attacked by the pathogen. Generally, in all the seasons, pods of IT84S-2246-4 were the least susceptible to infection, while IT82E-16 pods were the most severely infected.

ii. Brown blotch disease

Significant differences existed in the effect of the varieties and cropping patterns on the severity of brown blotch disease on cowpea pods (Table 40). A trend of results similar to that seen in the severity of anthracnose on cowpea pods, due to the influence of the two factors, was also obtained even though numerically higher severity percentages were recorded for brown blotch disease (Table 41).

In the first season, there was a significant cowpea variety x cropping pattern effect on the severity of the disease on the pods. It was observed that except for IT84S-2246-4 which was significantly less susceptible in intrarow (42.2%) than in doublerow (62.8%), other varieties were more susceptible in intrarow than in doublerow.

4.4.5 Percent seed infection of cowpea by anthracnose and brown blotch diseases

i. Anthracnose disease

There were significant differences in the effects of the various cropping patterns and cowpea varieties on the infection of cowpea seed by anthracnnose disease (Table 42). Cowpea seeds from IT82E-16 were the most infected with a

Table 40. Analyses of variance for the effect of cropping pattern and variety on the severity of brown blotch disease on cowpea pods during three growing seasons* in 1988/89.

Source of variation	Degrees of Freedom	Mean squares		
		1988F	1988S	1988T
Cropping pattern	4	2142.6++	1709.0++	12038.6++
Variety	2	803.3++	341.4++	786.6++
Interaction	8	135.1++	11.8 ns	26.0ns
Error	28	32.7	25.5	10.5

*Three seasons in 1988/89: F = First season (April - July 1988); S = Second season (August - November 1988) and T = Third season (December 1988 - March 1989).

++Significant at 1% level
ns - Not significant.

Table 41. Brown blotch disease severity[1] (%) on cowpea pods as influenced by cropping pattern and variety during three seasons[2] in 1988/89 and across the seasons.

Treatments	1988F	1988S	1988T	Across seasons
A. Cropping pattern				
Interrow	45.1 a[3]	29.5 a	37.0 a	37.2 a
Double row	63.4 b	46.9 b	58.2 b	57.4 b
Intrarow	67.1 b	47.6 b	61.7 c	57.5 b
Strip	76.9 c	54.9 c	66.7 d	68.2 c
Sole	86.1 d	67.4 d	78.1 e	77.2 d
B. Cowpea variety				
Ife Brown	59.3 a	44.3 a	53.5 a	52.4 a
IT84S-2246-4	71.4 b	49.6 b	59.6 b	60.2 b
IT82E-16	72.5 b	53.8 c	67.9 c	64.8 c

[1]Average of three replications

[2]Three seasons in 1988/89: F = First season (April - July 1988); S = Second season (August - November 1988) and T = Third season (December 1988 - March 1989).

[3]Only means followed by different letter(s) within a column for each factor differ significantly at $P \leq 0.05$ (DMRT).

Table 42. Effect of variety and cropping pattern on infection[1] (%) of cowpea seed by anthracnose disease in 1988/89[2].

Treatments	1988F	1988S	1988T	Across seasons
Cropping pattern				
Interrow	41.8 a[3]	27.0 b	28.8 a	32.5 a
Double row	45.2 ab	37.1 b	35.1 b	39.1 b
Intrarow	48.0 bc	40.4 bc	39.7 bc	42.7 bc
Strip	46.7 a-c	37.1 b	37.4 b	40.4 b
Sole	52.1 c	42.2 c	44.3 c	46.2 c
Cowpea variety				
Ife Brown	42.3 a	34.7 a	32.0 a	36.3 a
IT84S-2246-4	47.3 b	36.7 ab	39.3 b	41.1 b
IT82E-16	50.7 b	39.0 b	39.9 b	43.2 b

[1]Average of three replications

[2]Three seasons in 1988/89: F = First season (April - July 1988); S = Second season (August - November 1988) and T = Third season (December 1988 - March 1989).

[3]Only means followed by different letter(s) within a column for each factor differ significantly at $P \leq 0.05$ (DMRT).

a seasonal mean of 36.3%, while those of IT84S-2246-4 were the least infected (43.2%). Cowpea planted in interrow cropping pattern produced seeds which were the least infected, compared with those from the other cropping patterns. A seasonal mean of 46.2% was the highest infection value recorded for seeds from cowpea plants which were not intercropped. Varying degrees of infection were observed on cowpea planted using other types of planting patterns between the interrow cropping pattern at one extreme and sole cropping at the other. There was no significant interaction between cropping pattern and the varieties.

ii. Brown blotch disease

There were significant cropping pattern x cowpea variety interaction effects at $P \leq 0.05$ DMRT on the infection of seeds of the different varieties of cowpea by the fungus, depending on the type of cropping pattern adopted in planting the cowpea in the field.

In the first season (1988F), IT82E-16 was significantly the most susceptible to infection when planted in strip compared with the other planting patterns, whereas both IT84S-2246-4 and Ife Brown were most susceptible when grown in sole cropping (Table 43). Similarly, in the second and third seasons, more seeds of IT84S-2246-4 were infected when the variety was grown in doublerow cropping pattern than when it was grown in intrarow pattern. However, significantly more seeds of both Ife Brown and IT82E-16 were infected than when the two varieties were grown in doublerow intercrop with maize.

Table 43. The effect of interaction between cropping pattern and variety on infection[1] (%) of cowpea seeds by brown blotch disease during three cropping seasons in 1988/89[2].

	1988F			1988S			1988T		
Cropping pattern	IT82E-16	IT84S-2246-4	Ife Brown	IT82E-16	IT84S-2246-4	Ife Brown	IT82E-16	IT84S-2246-4	Ife Brown
Interrow	34.6 ax[3]	56.8 az	43.5 ay	22.4 ax	26.7 ay	29.4 ay	27.4 ax	32.0 ay	37.0 az
Doublerow	39.2 ax	60.5 ay	61.7 by	30.5 bx	44.8 cz	38.8 by	37.1 bx	67.3 cz	52.9 by
Intrarow	59.1 bx	58.7 ax	72.2 cy	42.0 cy	38.2 bx	46.7 cz	60.2 cy	39.1 bx	70.8 cz
Strip	68.7 cx	71.8 bxy	74.6 cdy	47.5 dx	46.5 cx	48.0 cx	65.4 dx	70.9 cdy	73.7 cy
Sole	60.7 bx	73.8 by	79.3 dz	47.8 dx	52.7 dy	54.0 dy	68.2 dx	72.8 dy	74.6 cy
CV%			8.2			9.9			8.6

[1]Average of three replications.

[2]Three seasons in 1988/89: F = First season (April - July 1988); S = Second season (August - November 1988) and T = Third season (December 1988 - March 1989).

[3]Letters a-e for comparing means in a column; Letters x-z comparing means in a row: only means followed by different letter(s) within a column for each variety and in a row for a level of cropping pattern differ significantly at $P \leq 0.05$ (DMRT).

4.4.6 <u>Seed viability in cowpea following infection by anthracnose and brown blotch diseases</u>

i Anthracnose disease

There were significant differences ($P \leq 0.05$) in seed viability of different cowpea varieties following infection by *C. lindemuthianum* and using the different cropping patterns (Table 44). In all seasons, viability of seeds decreased in percentage values from cowpea planted in interrow > doublerow > strip > intrarow > in this order for those planted in sole with the seasonal mean values ranging from 43.4% for those in interrow to 25.0% for the ones in sole.

Seed germination was highest in Ife Brown among other varieties tested in this experiment, while lower viability percentages were recorded for both IT84S-2246-4 and IT82E-16 seeds which appeared to be more susceptible to infection from *C. lindemuthianum*. Except in the first season, seed viability resulting from infection by *C. lindemuthianum* was not statistically different in IT82E-16 and IT84S-2246-4 though numerically the former produced more viable seeds.

ii. Brown blotch disease

Significant differences occurred in the viability of cowpea seeds due to varietal difference and the different cropping patterns used (Table 45). Except in the first season, the effect of cowpea variety x cropping pattern interaction was significant.

Table 44. Effect of anthracnose on cowpea seed viability[1] (%) due to variety and cropping pattern differences in the 1988/89 seasons[2].

Treatments	1988F	1988S	1988T	Across seasons
Cropping pattern				
Interrow	34.7 a[3]	50.6 a	45.0 a	43.4 a
Double row	32.4 ab	46.9 a	41.6 a	40.3 a
Intrarow	29.9 b	40.2 b	34.9 b	35.0 b
Strip	31.7 ab	45.7 ab	39.4 ab	38.9 ab
Sole	25.2 c	26.7 c	23.2 c	25.0 c
Cowpea variety				
Ife Brown	34.1 a	48.7 a	40.2 a	41.1 a
IT84S-2246-4	30.7 b	40.9 b	35.7 b	35.8 b
IT82E-16	27.6 c	36.4 b	34.6 b	32.8 c

[1]Average of three replications

[2]Three seasons in 1988/89: F = First season (April - July 1988); S = Second season (August - November 1988) and T = Third season (December 1988 - March 1989).

[3]Only means followed by different letter(s) within a column for each factor differ significantly at $P \leq 0.05$ (DMRT).

Table 45. Mean squares showing percent seed viability[1] of cowpea due to the effect of anthracnose disease on cowpea varieties planted under different cropping patterns during three growing seasons[2] in 1988/89.

Source of variation	Degrees of Freedom	1988F	1988S	1988T
Cropping pattern	4	1346.8++	2718.3++	2029.8++
Variety	2	136.6+	802.9+	1208.6++
Interaction	8	11.7ns	70.4++	87.2++
Error	28	25.9	19.2	12.6

[1]Average of three replications.

[2]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November, 1988) and T = Third season (December 1988 - March 1989).

++Significant at 1% level
+Significant at 5% level
ns - Not significant.

In the first season, seeds from cowpea planted in the interrow were the most viable, while cowpea seeds produced from doublerow > intrarow > strip > sole in that order decreased in viability, ranging from 48.0 to 16.7%. In this season, Ife Brown and IT82E-16 seeds respectively produced the smallest and largest number of viable seeds averaging 25.0 and 31.0%.

Results from Figure 14 show that in the second season, in the different cropping patterns, seed viability decreased from IT8E-16 > IT84S-2246 > Ife Brown in that order, except in doublerow where Ife Brown produced significantly more viable seeds than IT84S-2246-4. Equally, there was an appreciable difference in the viability of seeds from IT84S-2246-4 when grown in doublerow and when grown in intrarow. The reaction of this cowpea variety in the two cropping patterns was at direct variance with other varieties when grown in the same cropping patterns.

In the third season (1988T), the trend of seed viability among the cowpea varieties was similar across the different cropping patterns. While in interrow, intrarow and in sole cropping systems, there was no significant difference in seed viability of IT82E-16 and IT84S-2246, significant differences occurred between these varieties.

4.4.7 <u>The effect of anthracnose and brown blotch diseases on cowpea seed weight</u>

i. Anthracnose disease

Except in the first cropping season (1988F), there was no significant difference in seed weight due to growing cowpea in different cropping patterns

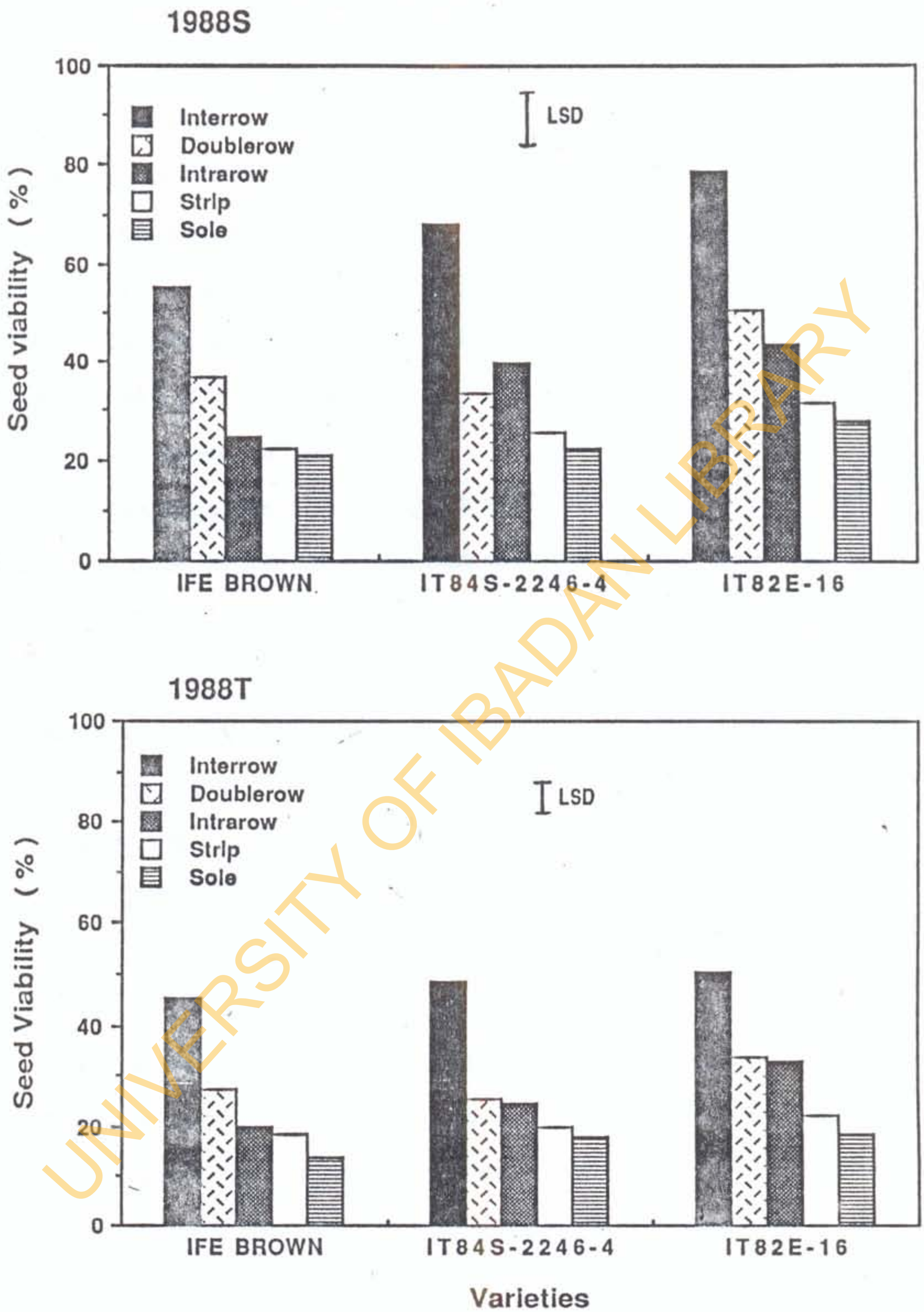


Fig.14: The effect of the interaction between cropping pattern and variety on percent seed viability of cowpea infected by brown blotch disease during the second and third growing seasons in 1988/89.

following infection by the pathogen (Appendix 22, Table 46). However, cowpea grown in interrow cropping pattern numerically produced the heaviest seeds.

There were significant differences ($P \leq 0.05$) in the weight of seeds from the different cowpea varieties following infection by *C. lindemuthianum*. IT84S-2246-4 produced the heaviest seeds and Ife Brown the lightest with seasonal means of 14.4 as 12.2g respectively.

ii. Brown blotch disease

Cropping pattern had no significant ($P \leq 0.05$) effect on seed weight of cowpea infected with brown blotch disease (Appendix 23, Table 47), an observation which had already been made for anthracnose disease. However, significant differences were seen in the weight of the seeds caused by varietal dissimilarities. Variety IT84S-2246-4 produced the heaviest seeds, while Ife Brown produced the lightest. The interaction effect between cropping pattern and variety was not significant, indicating that the differences in seed weight of the varieties is independent of the cropping patterns.

4.4.8 <u>Effect of two *Colletotrichum* diseases on cowpea seed yield</u>

i. Anthracnose disease

The analyses of variance for the effects of cropping pattern and varietal genotype on the yield of cowpea infected with *C. lindemuthianum* during three growing seasons in 1988/89 show that there were the significant differences in cowpea seed yield due to the influence of the two factors (Appendix 24). Except in the first seasons, there were significant interaction effects on yield during the seasons.

Table 46. Seed weight[1] (100 seeds/g) of cowpea varieties infected by anthracnose under different cropping patterns during three growing seasons[2] in 1988/89.

Treatments	1988F	1988S	1988T	Across seasons
Cropping pattern				
Interrow	12.9 a[3]	14.3 a	13.1 a	13.5 a
Double row	12.9 a	14.3 a	13.0 a	13.4 a
Intrarow	12.6 ab	14.2 a	12.8 a	13.2 ab
Strip	12.5 ab	13.8 a	12.8 a	13.1 b
Sole	12.2 b	14.1 a	12.8 a	13.0 b
Cowpea variety				
Ife Brown	14.0 a	15.0 a	14.1 a	14.4 a
IT84S-2246-4	12.4 b	14.1 b	12.9 b	13.1 b
IT82E-16	11.4 c	13.4 c	11.7 c	12.2 c

[1]Average of three replications

[2]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November 1988) and T = Third season (December 1988 - March 1989).

[3]Means with the same letter(s) are not significantly different within a column for each factor at $P \leq 0.05$ (DMRT).

Table 47. Seed weight[1] (100 seeds/g) of cowpea varieties infected by brown blotch under different cropping patterns during three growing seasons[2] in 1988/89.

Treatments	1988F	1988S	1988T	Across seasons
Cropping pattern				
Interrow	13.2 a	14.2 a	13.9 a	13.8 a
Double row	13.1 a	14.2 a	13.9 a	13.7 a
Intrarow	13.0 a	13.9 a	13.6 a	13.5 a
Strip	12.9 a	13.9 a	13.5 a	13.4 a
Sole	12.8 a	14.0 a	13.5 a	13.4 a
Cowpea variety				
Ife Brown	14.9 a	15.0 a	14.6 a	14.8 a
IT84S-2246-4	12.7 b	14.0 b	13.5 b	13.4 b
IT82E-16	11.4 c	12.4 c	12.8 c	12.2 c

[1]Average of three replications

[2]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November 1988) and T = Third season (December 1988 - March 1989).

[3]Means with the same letter(s) are not significantly different within a column for each factor at $P \leq 0.05$ (DMRT).

In the first season (1988F), the highest yield was obtained from sole cropping system (Figure 15) and was not significantly different from that obtained from the strip. The lowest yield was obtained in plots where cowpea was intercropped with maize in alternating hills within the rows. This value was not statistically different from the values obtained in doublerow and interrow.

In the second season, Ife Brown, grown in strip arrangement with maize, produced the smallest yield averaging 337.6 kg/ha (Figure 15). In the third season, only 266.7 kg/ha was obtained from the same vaariety grown under intrarow system. Cowpea variety IT84S-2246-4 grown in sole cropping produced the highest yields of 772.9 and 780.5 kg/ha respectively in the second and third seasons. In the second season, IT82E-16 and IT84S-2246-4, planted in doublerow and intrarow, produced similar yields statistically.

ii. Brown blotch disease

Seed yield differed significantly among the cowpea varieties and in the different cropping patterns (Figure 16). Seed production by the varieties depended on the type of cropping pattern used in planting the crop (Appendix 25). In the first season, IT82E-16 planted in doublerow and intrarow produced the poorest yield, whereas the lowest yields obtained from Ife Brown and IT84S-2246-4 resulted from growing them in interrow and intrarow respectively. A similar result was also obtained in the third season, though the poorest yield for IT82E-15 was from planting it in interrow. For each of the sampling periods, the highest yielding varieties followed almost the same trend across the cropping patterns.

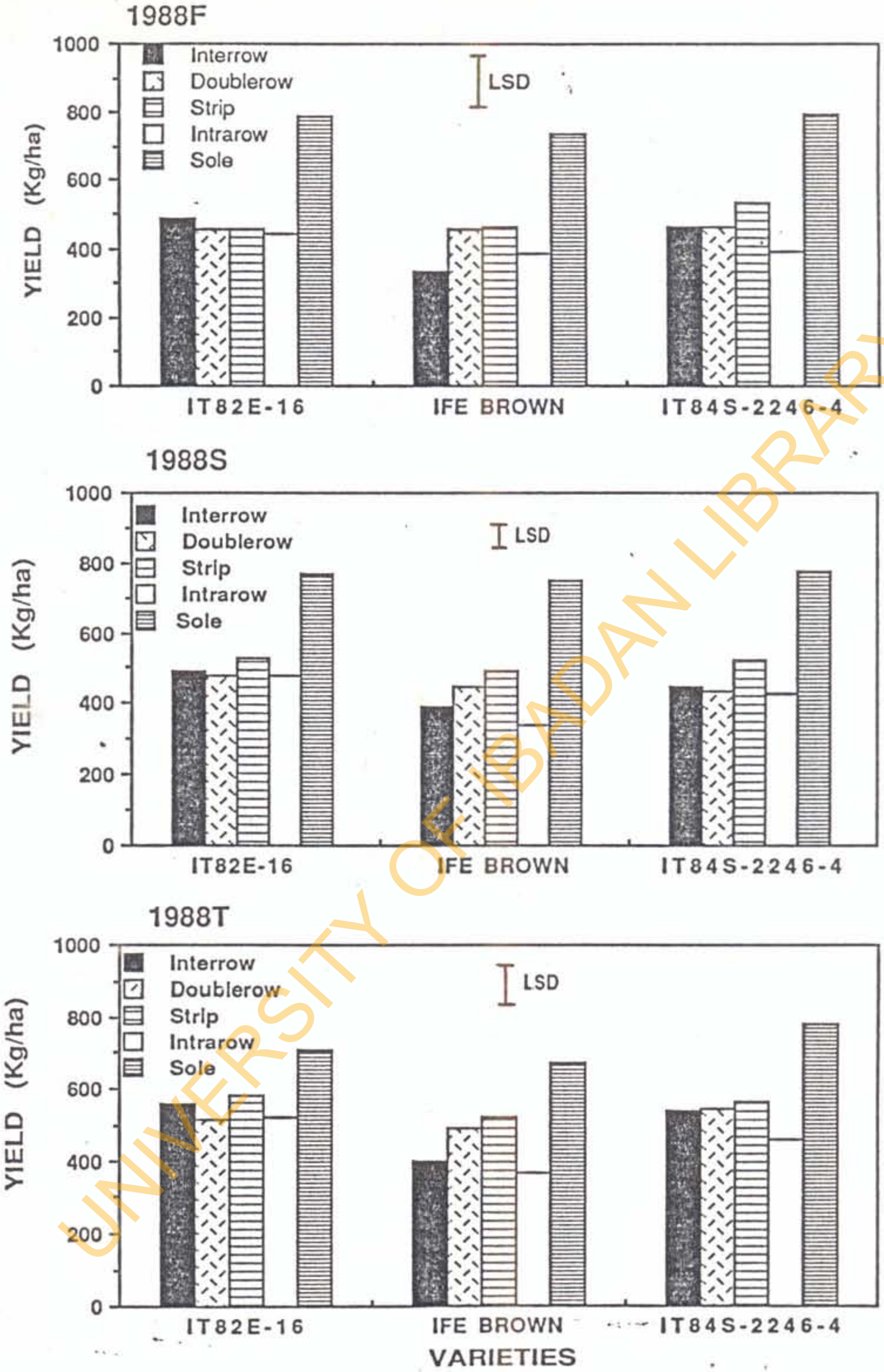


Fig.15: Seed yield from cowpea varieties infected by anthracnose under different cropping patterns during three growing seasons (F = first season, S = second and T = third season) in 1988/89.

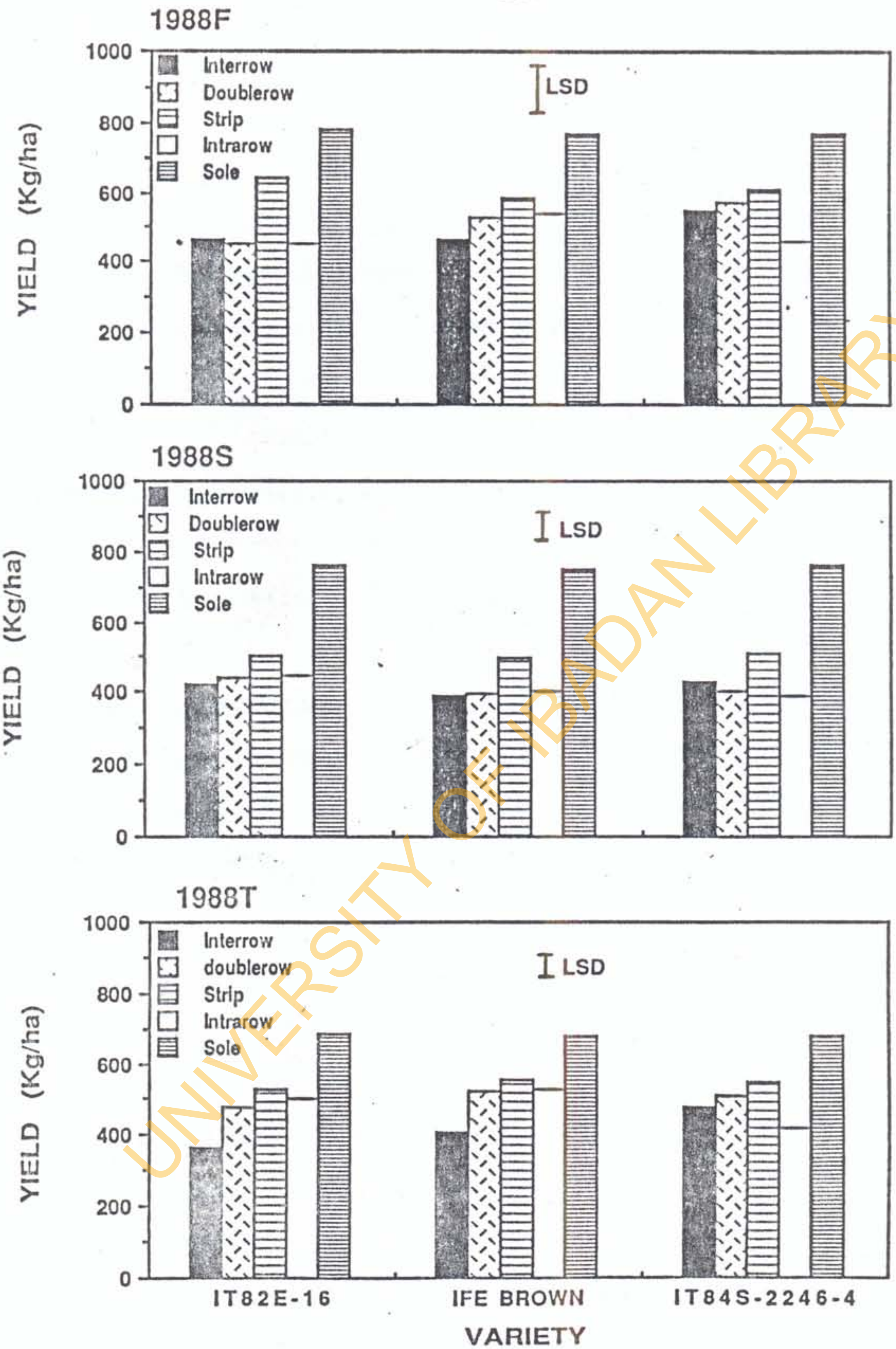


Fig.16: Seed yield from cowpea varieties infected by brown blotch under different cropping patterns during three growing seasons (F = first season, S = second and T = third season) in 1988/89.

4.4.9 The effects of cropping patterns and varietal difference on the spread of anthracnose and brown blotch diseases of cowpea

i. Anthracnose disease

The rates of spread of the disease steadily increased with increasing plant age for all the various levels of treatment (Figure 17). The highest infection rate was recorded on IT82E-16 with respect to the incidence and severity of the pathogen on cowpea (Figures 18 and 19). The lowest rate was on IT84S-2246-4. However, the rate at which the disease became severe on IT82E-16 was greater than that on Ife Brown (Figure 19).

Infection rate was highest on cowpea grown in sole cropping than in any of the different patterns tested among the intercrop. The rates of disease spread in relation to the incidence and severity for cowpea grown in sole cropping were both 1.39. In the different intercrops, infection rate on cowpea was highest in strip with 0.60, while it was lowest in interrow cropping system with 0.49 values. Significantly high R values were recorded with reference to disease incidence and severity, indicating the closeness of the relationship between the incidence and severity of the disease and the age of the cowpea plant.

ii. Brown blotch disease

Results from Figure 20 show that, generally, there was an increase in the rates of disease spread by brown blotch with the increase in plant age of the different cowpea varieties in all the cropping patterns. In the first season, there was a sharp rise in disease spread at 40 DAP among all the treatments, except for the interrow cropping pattern. In the second and third seasons, the rate of disease spread was gradual and it was almost equal for IT84S-2246 and IT82E-16

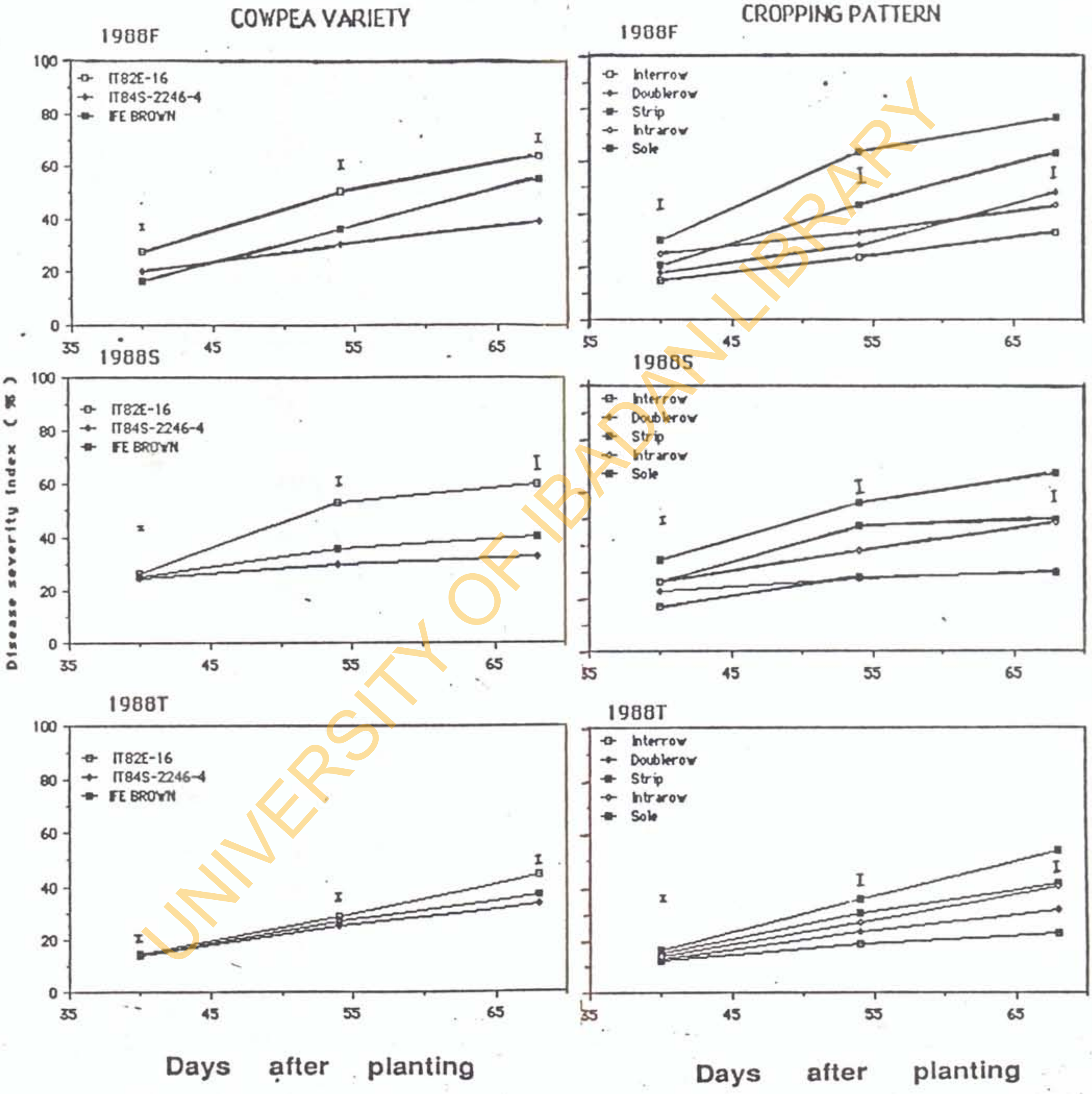


Fig.17: Patterns of disease spread by anthracnose disease on three varieties of cowpea and in five cropping patterns during three growing seasons (F = first season, S = second and T = third season) in 1988/89.

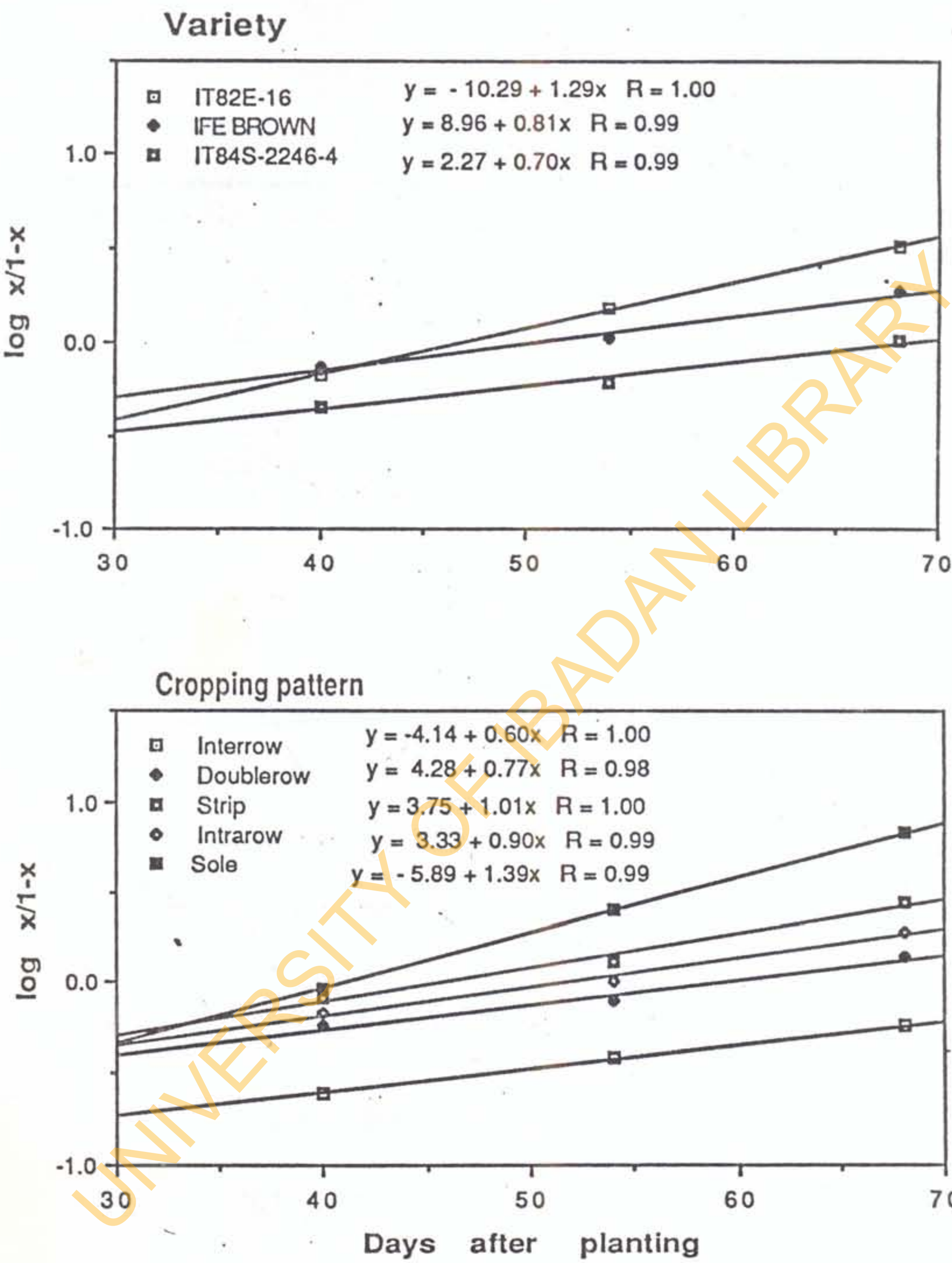


Fig.18: The progress of *Colletotrichum lindemuthianum* and its incidence on three cowpea varieties and in five different cropping patterns (Logarithmic transformation).

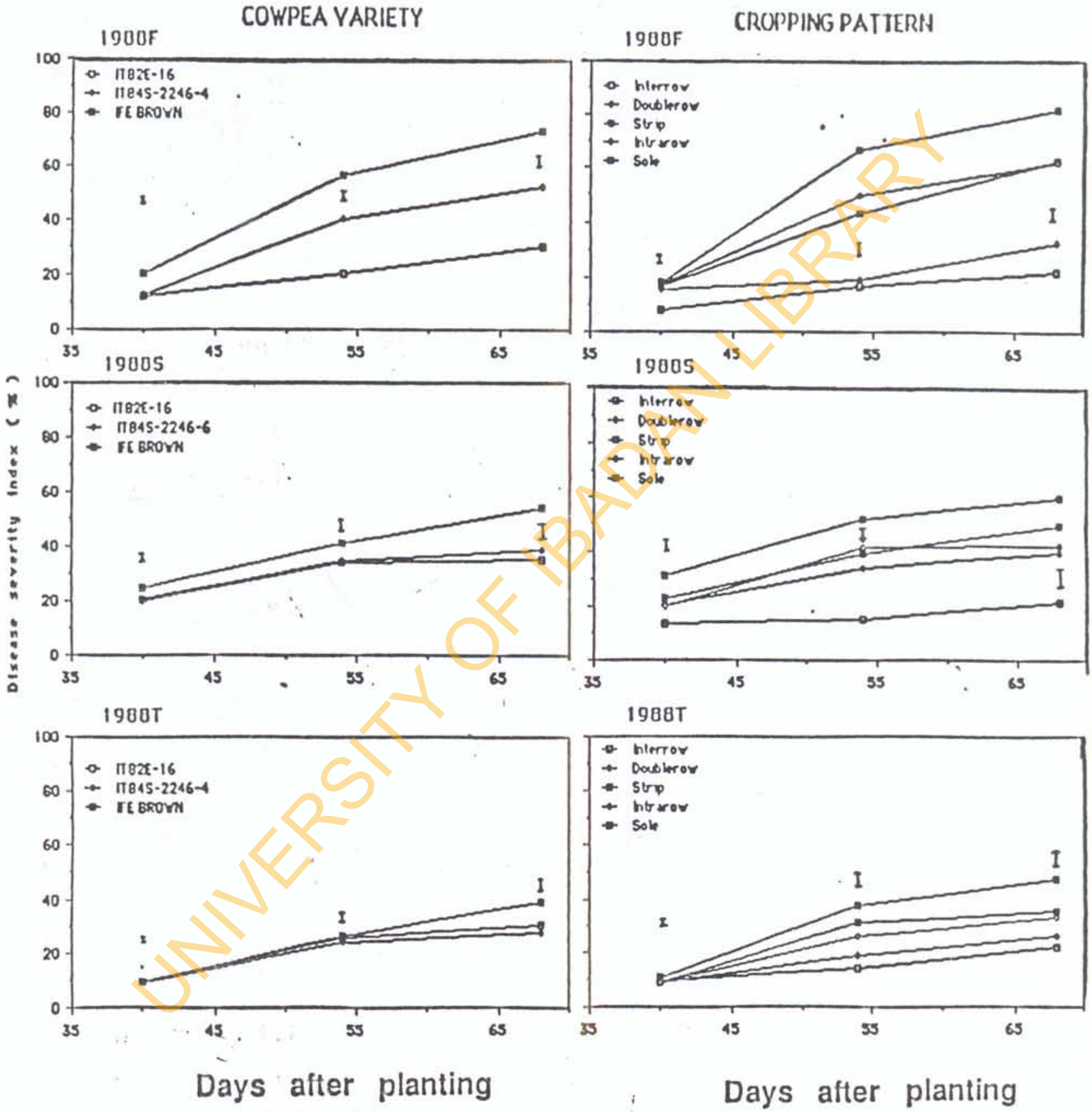


Fig.20: Patterns of disease spread by brown blotch disease on three varieties of cowpea and in five cropping patterns during three growing seasons (F = first season, S = second and T = third season) in 1988/89.

with values of 0.86 and 0.89 respectively (Figure 21). The highest infection rate was recorded on Ife Brown whereas the lowest was obtained on IT82E-16.

Among the cropping patterns, the progress of the pathogen was highest in sole followed by strip > intrarow > doublerow > interrow in that order (Figures 21 and 22).

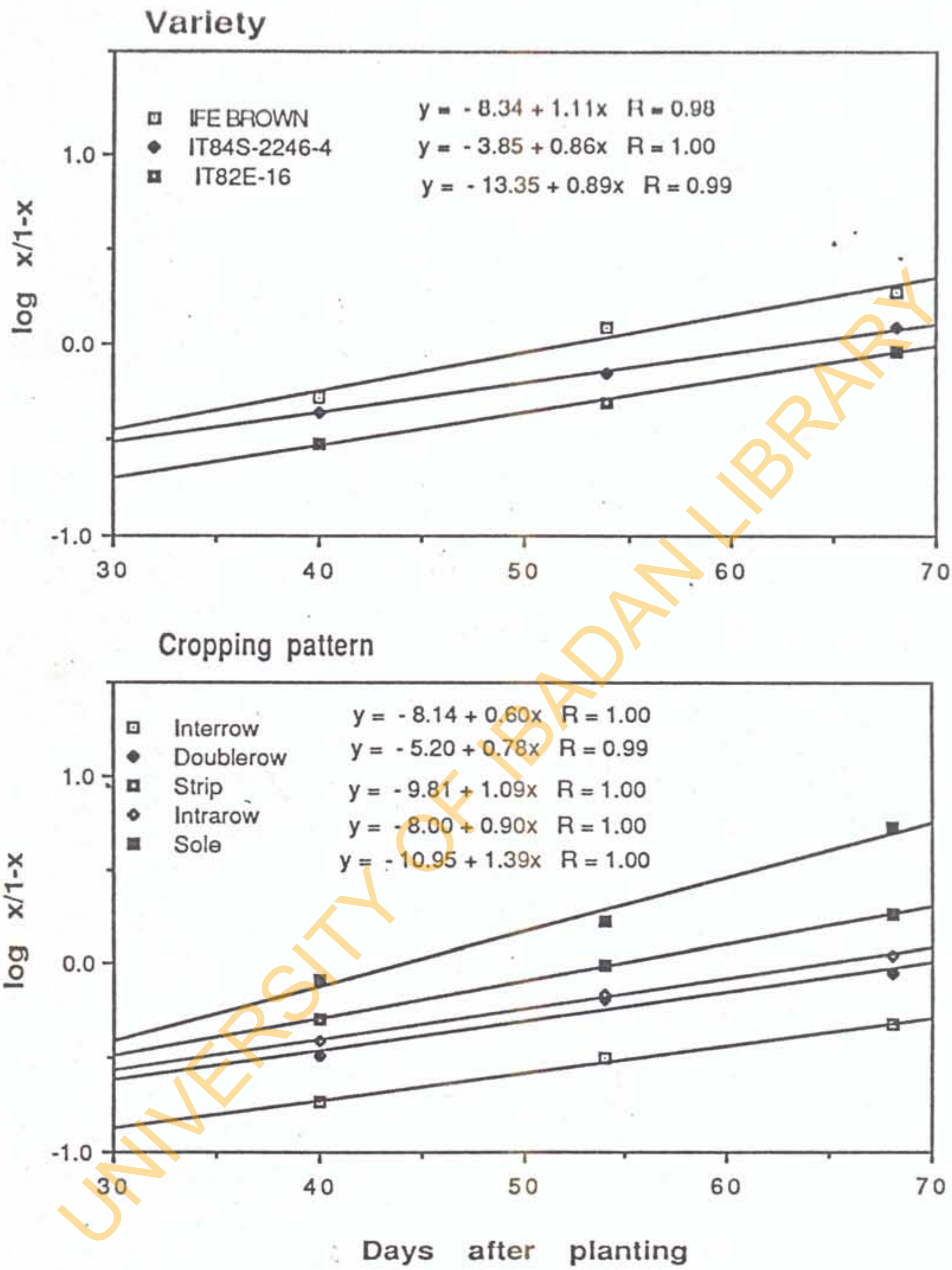


Fig.21: The progress of *Colletotrichum truncatum* and its incidence on three cowpea varieties and in five different cropping patterns (Logarithmic transformation).

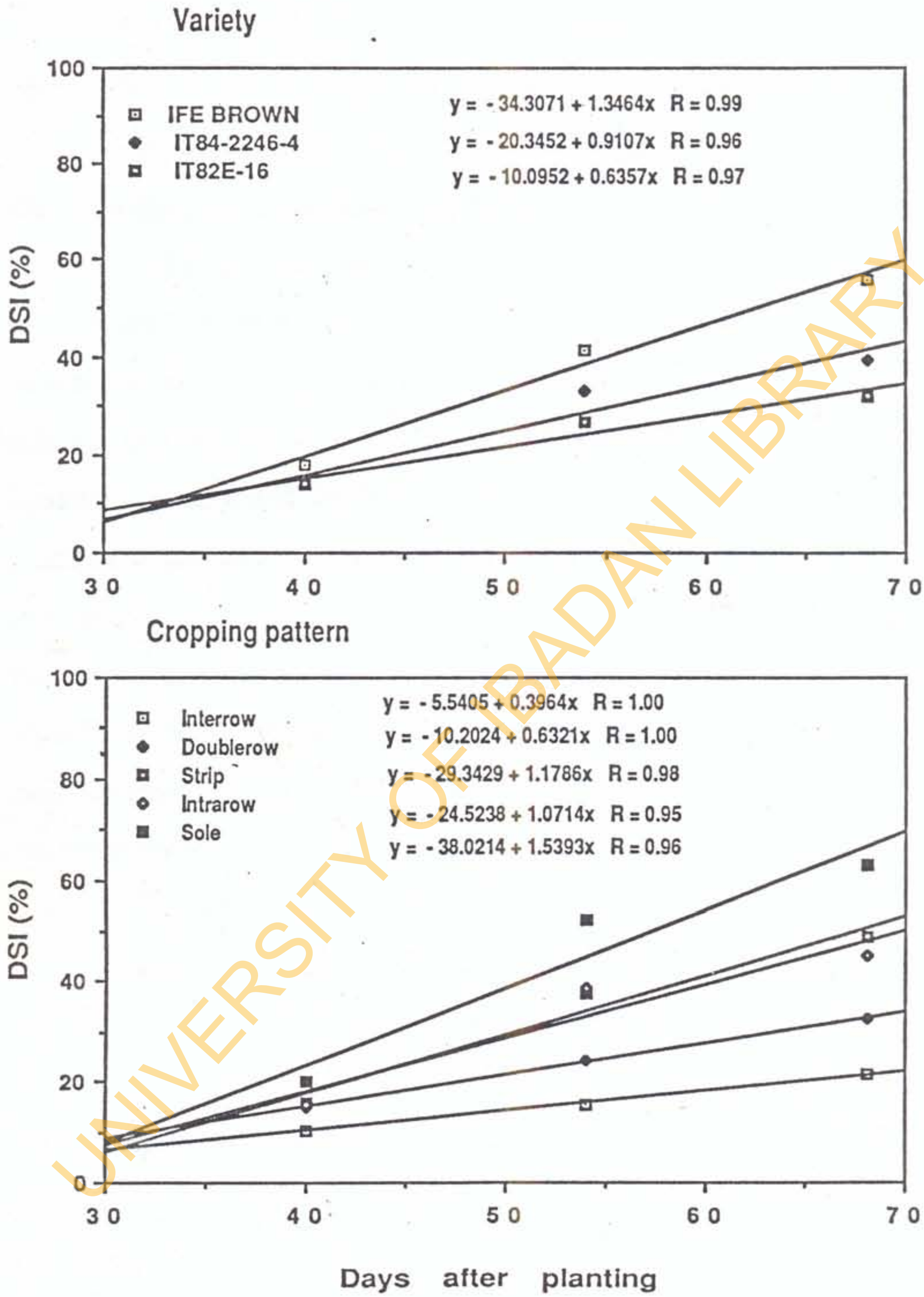


Fig.22: The rate of spread of brown blotch disease caused by *Colletotrichum truncatum* and its severity on three cowpea varieties grown in different cropping systems.

4.5 Effect of anthracnose and brown blotch diseases on cowpea introduced at different times in cowpea/maize association

4.5.1 Incidence of the diseases on cowpea

i. Anthracnose disease

Results show that there was a significant difference ($P < 0.05$) in the incidence of anthracnose disease on cowpea at all sampling dates caused by the different time of cowpea introduction in cowpea-maize intercrop (Table 48). Consistently, the lowest incidence level of infection was recorded on cowpea planted simultaneously with maize, while the highest incidence value was recorded on cowpea planted three weeks after maize (WAM). Disease incidence was significantly higher on cowpea planted one week before maize (WBM) than when both crops were planted simultaneously. Generally, disease incidence level increased, though inconsistently, with increasing gap between planting of the two crops after simultaneous sowing.

ii. Brown blotch disease

A trend of results similar to that for the anthracnose disease was obtained for brown blotch (Table 49). Significant differences were obtained in the incidence of the disease on cowpea at varying times of cowpea introduction in cowpea-maize association. The lowest incidence was recorded on cowpea planted simultaneously with maize, while the highest was on cowpea introduced 3 WAM. There was no significant interaction effect between cowpea variety and dates of cowpea introduction into maize on the incidence of the pathogen on cowpea except at 54 DAP during the second season, 1988S (Appendix 25).

Table 48. Effect of cowpea introduction into maize at different planting times on the incidence[1](%) of anthracnose on cowpea during three growing seasons[2] in 1988/89.

Time of introduction	1988F			1988S			1988T		
	40 DAP[3]	54 DAP	68 DAP	40 DAP	54 DAP	68 DAP	40 DAP	54 DAP	68 DAP
1 WBM*	22.5 b**	33.3 b	47.5 b	31.7 b	35.8 b	40.0 b	18.3 b	22.5 b	27.5 b
0 WAM	17.2 a	21.9 a	35.0 a	21.7 a	23.3 a	27.5 a	10.0 a	12.5 a	20.0 a
1 WAM	27.5 c	47.5 c	60.8 c	34.2 b	37.2 c	51.9 c	20.0 b	29. 2c	40.0 c
2 WAM	35.0 d	60.0 d	66.7 c	37.5 c	51.9 d	62.8 c	22.5 c	32.8 c	40.3 c
3 WAM	40.3 e	63.3 d	74.7 d	45.0 d	62.5 e	70.5 e	25.0 d	38.6 d	44.7 d
CV %	15.1	12.7	10.5	9.6	8.9	8.7	13.2	15.1	11.2

[1]Average of three replications.

[2]Three seasons in 1988/89: F = First season (April - July 1988); S = Second season (August - November 1988) and T = Third season (December 1988 - March 1989).

[3]DAP = Days after planting

*WBM = Weeks before maize; WAM = Weeks after maize establishment.

**Only means followed by different letter(s) within a column differ significantly at P $\leq$ 0.05 (DMRT).

Table 49. Effect of cowpea introduction into maize at different planting times on the incidence[1](%) of brown blotch disease on cowpea during three growing seasons[2] in 1988/89.

Time of introduction	1988F			1988S			1988T		
	40 DAP[3]	54 DAP	68 DAP	40 DAP	54 DAP	68 DAP	40 DAP	54 DAP	68 DAP
1WBM*	25.8 b**	30.0 b	34.7 b	23.3 b	26.1 a	30.3 b	15.0 b	17.5 b	22.5 b
0 WAM	9.7 a	13.6 a	25.8 a	14.4 a	21.4 a	24.7 a	8.6 a	9.4 a	15.0 a
1 WAM	37.5 c	49.2 c	57.2 c	35.8 c	42.2 b	52.2 c	17.5 b	25.8 c	35.0 c
2 WAM	38.3 c	45.0 c	61.7 d	39.7 cd	45.3 bc	63.3 d	23.3 c	32.5 d	42.5 d
3 WAM	40.8 c	55.8 d	69.7 e	44.7 d	50.3 c	65.8 d	22.5 c	37.5 d	50.0 e
CV %	13.9	10.2	17.2	16.4	14.4	10.4	18.0	24.0	21.1

[1]Average of three replications.

[2]Three seasons in 1988/89: F = First season (April - July 1988); S = Second season (August - November 1988) and T = Third season (December 1988 - March 1989).

[3]DAP = Days after planting

*WBM = Weeks before maize; WAM = Weeks after maize establishment.

**Only means followed by different letter(s) within a column differ significantly at P ≤ 0.05 (DMRT).

4.5.2 Severity of the diseases on cowpea

i. Anthracnose disease

Intercropping cowpea with maize by planting the crops at different times affected the severity of anthracnose disease on cowpea significantly ($P < 0.05$). The disease was least severe on cowpea sown simultaneously with maize; and values obtained were not statistically different from those obtained on cowpea sown 1 WBM when samples were taken at 68 DAP in the second and third seasons (Figure 23). The disease was most severe on cowpeas planted 3 WAM. Across the seasons, there was no significant cowpea variety x time of cowpea introduction effect, indicating that the effect of time of cowpea introduction into maize on the severity of anthracnose disease on cowpea is independent of the differences in the cowpea varieties used in the experiment.

ii. Brown blotch disease

The brown blotch disease was least severe on cowpea sown simultaneously with maize in cowpea-maize intercrop while it was most severe on those planted 3 WAM (Figure 23). There were no significant differences in the disease severity on cowpea sown at the same time with maize and that sown 1 WBM. There was also no statistical difference on its severity on cowpeas sown 1 WAM and 2 WAM at almost all the sampling periods in the experiment.

4.5.3 Incidence of anthracnose and brown blotch diseases on cowpea pods

i. Anthracnose disease

Results showed that there were no significant differences in the severity of *C. lindemuthianum* on cowpea pods due to varying times of planting cowpea in cowpea/maize intercrop (Table 50). The incidence of the disease was highest

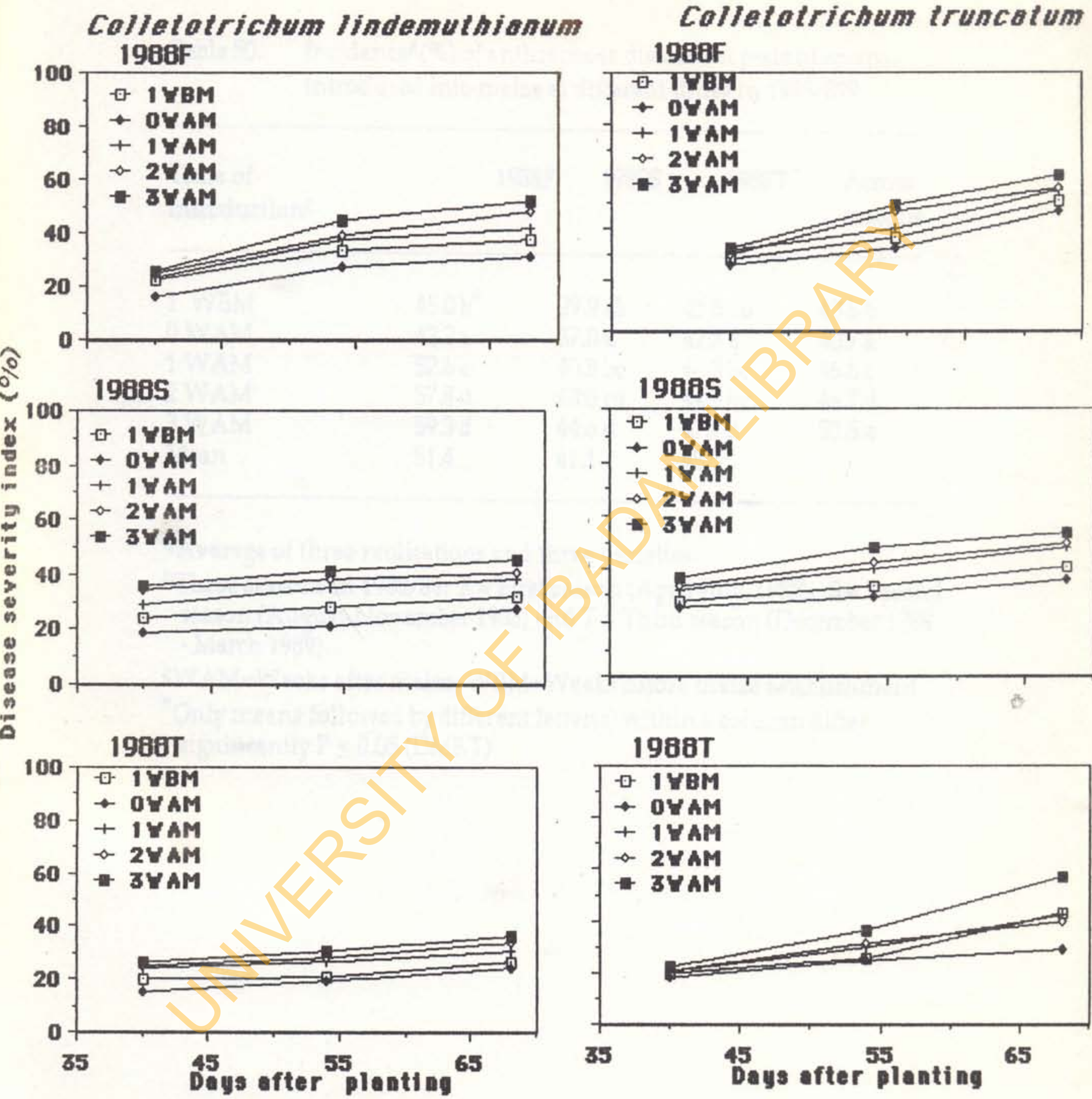


Fig.23: Seasonal variability in the severity of anthracnose and brown blotch diseases on cowpea introduced at different times into maize in 1988/89.

Table 50. Incidence[a](%) of anthracnose disease on pods of cowpea introduced into maize at different times in 1988/89[b]

Time of introduction[c]	1988F	1988S	1988T	Across seasons
1 WBM	45.0 b*	39.9 ab	45.5 ab	43.5 b
0 WAM	42.2 a	37.0 a	42.8 a	40.7 a
1 WAM	52.6 c	40.8 bc	46.5 bc	46.6 c
2 WAM	57.8 d	43.5 cd	44.9 bc	48.7 d
3 WAM	59.3 d	44.6 d	47.7 e	50.5 e
Mean	51.4	41.1	45.5	

[a]Average of three replications and three varieties.

[b]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November 1988) and T = Third season (December 1988 - March 1989).

[c]WAM=Weeks after maize; WBM=Weeks before maize establishment

*Only means followed by different letter(s) within a column differ significantly $P \leq 0.05$ (DMRT)

on pods harvested from cowpea planted at the same day with maize, while it was lowest on pods from cowpea planted 3 WAM with averages of 40.7 and 50.5% respectively across the seasons. For each of the three seasons, there were no significant (P< 0.05) differences in the incidence of the disease on pods from cowpeas planted 2 and 3 WAM. The highest values were recorded on cowpea during the first cropping season, and the lowest were recorded in the second season.

ii. Brown blotch disease

Averages over three growing seasons show that there were no significant differences in disease incidence on pods from cowpea planted with maize at 0 WAM and 1 WBM on one hand, and on those from cowpea planted 1 and 2 WAM on the other (Table 51). While the disease was least prevalent on pods from cowpea sown simultaneously with maize, it was most prevalent on the pods from cowpea sown 3 WAM. Generally, the disease was most common in the first season on cowpea, and least prevalent on this host crop in the second season.

4.5.4 Severity of the diseases on cowpea pods

i. Anthracnose disease

There were significant differences in the severity of anthracnose disease on cowpea pods attributable to the different sowing times of cowpea in maize (Table 52). These differences were inconsistent over the three seasons and were not because of varietal differences in the three cowpea varieties used for the experiment. Except in the second season (1988S), there was no difference in the

Table 51. Incidence[a] (%) of brown blotch disease caused by *Colletotrichum truncatum* on pods of cowpea introduced into maize at different times in 1988/89[b].

Time of introduction[c]	1988F	1988S	1988T	Across seasons
1 WBM	68.9 ab*	54.2 a	56.5 ab	59.8 a
0 WAM	65.9 a	54.2 a	54.8 a	58.3 a
1 WAM	72.9 bc	58.7 b	59.7 bc	63.8 b
2 WAM	74.2 c	60.0 b	61.8 cd	65.3 b
3 WAM	77.2 c	62.7 b	65.4 d	68.4 c
Mean	71.8	57.9	59.6	63.3

[a]Average of three replications and three varieties.

[b]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November 1988) and T = Third season (December 1988 - March 1989).

[c]WAM=Weeks after maize; WBM=Weeks before maize establishment

*Only means followed by different letter(s) within a column differ significantly $P \leq 0.05$ (DMRT)

Table 52. Severity[a] (%) of anthracnose disease on pods of cowpea introduced into maize at different times in 1988/89[b].

Time of introduction[c]	1988F	1988S	1988T	Across seasons
1 WBM	34.0 ab*	30.3 b	21.3 a	28.5 b
0 WAM	32.2 a	25.9 a	19.0 a	25.7 a
1 WAM	36.5 bc	31.8 b	22.0 c	31.4 c
2 WAM	38.6 c	35.1 c	30.0 d	34.6 d
3 WAM	41.2 d	37.6 c	32.5 d	37.1 a

[a]Average of three replications and three varieties.

[b]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November 1988) and T = Third season (December 1988 - March 1989).

[c]WAM=Weeks after maize; WBM=Weeks before maize establishment

*Only means followed by different letter(s) within a column differ significantly $P \leq 0.05$ (DMRT)

severity of the pathogen on cowpea sown at 0 WAM and on those sown 1 WBM. There was no significant difference (P< 0.05) in the severity of the anthracnose disease on cowpea planted 2 and 3 WAM due to infection in the second and third seasons.

ii. Brown blotch disease

Significant differences in the severity of brown blotch disease on cowpea pods resulted from planting cowpea in cowpea-maize association with different dates (Table 53). Pods harvested from cowpea planted simultaneously with maize were the least severely attacked, whereas those from cowpea sown 3 WAM were the most severely attacked. However, there was no significant difference (P < 0.05) in the severity of the fungus on the pods of cowpea sown 1, 2 and 3 WAM in the first and second seasons.

4.5.5 Effects of anthracnose and brown blotch diseases on cowpea seed infection, viability and seed weight

Introduction of cowpea into maize in cowpea-maize intercrop at varying times did not significantly affect the infection, viability and weight of cowpea seed by either anthracnose or brown blotch disease during the three growing seasons in 1988/89.

4.5.6 Influence of anthracnose and brown blotch diseases on cowpea seed yield due to different time of cowpea introduction into maize

There were inconsistent yield differences in cowpea infected with the respective diseases as a result of varying times of planting cowpea in the association with maize during the growing seasons (Tables 54 and 55). However, cowpea planted 1 WBM significantly outyielded the one planted 3

Table 53. Severity[a](%) of brown blotch disease on pods of cowpea introduced into maize at different times in 1988/89[b].

Time of introduction[c]	1988F	1988S	1988T	Across seasons
1 WBM	67.9 b*	44.3 a	51.6 ab	54.6 b
0 WAM	60.0 a	41.5 a	49.3 a	50.3 a
1 WAM	65.6 ab	49.3 b	52.1 ab	55.6 bc
2 WAM	68.7 b	50.3 b	53.2 bc	57.4 cd
3 WAM	70.4 b	50.7 b	55.7 c	58.9 d

[a]Average of three replications and three varieties.

[b]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November 1988) and T = Third season (December 1988 - March 1989).

[c]WAM=Weeks after maize; WBM=Weeks before maize establishment

*Only means followed by different letter(s) within a column differ significantly $P \leq 0.05$ (DMRT)

Table 54 Cowpea seed yield[a] (kg/ha) after anthracnose disease infection on cowpea introduced at different times into maize during three growing seasons in 1988/89[b].

Time of introduction[c]	1987F	1987S	1987T	Across seasons
1 WBM	479.4 a*	497.7 a	474.6 a	483.9 a
0 WAM	468.6 a	489.8 ab	453.7 a	470.7 ab
1 WAM	464.1 ab	476.0 a-c	451.2 a	463.8 b
2 WAM	458.9 ab	468.0 bc	453.6 a	460.2 b
3 WAM	437.5 b	455.0 c	410.0 b	434.5 c
CV (%)	5.7	4.8	8.6	6.2

[a]Average of three replications and three varieties.

[b]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November 1988) and T = Third season (December 1988 - March 1989).

[c]WAM=Weeks after maize; WBM=Weeks before maize establishment

*Only means followed by different letter(s) within a column differ significantly $P \leq 0.05$ (DMRT)

Table 55. Cowpea seed yield[a] (kg/ha) after brown blotch disease infection on cowpea introduced at different times into maize during three growing seasons in 1988/89[b].

Time of introduction[c]	1987F	1987S	1987T	Across seasons
1 WBM	458.9 a*	464.5 a	412.7 a	445.4 a
0 WAM	448.2 ab	459.8 ab	409.9 a	439.3 ab
1 WAM	432.1 bc	450.5 ab	400.8 a	427.8 bc
2 WAM	422.0 c	442.2 b	395.2 ab	419.8 c
3 WAM	385.0 d	413.5 c	380.5 b	393.0 d
CV (%)	4.2	4.6	4.5	5.1

[a] Average of three replications and three varieties.

[b] Three seasons in 1988/89; F = First season (April-July, 1988); S = Second season (August-November 1988) and T = Third season (December 1988 - March 1989).

[c] WAM=Weeks after maize; WBM=Weeks before maize establishment

*Only means followed by different letter(s) within a column differ significantly $P \leq 0.05$ (DMRT)

WAM. The delay in planting one month and a week after maize establishment resulted in yield reductions by 13.6 and 11.7% following infection with *C. lindemuthianum* and *C. truncatum* respectively. There was no significant interaction between time of cowpea introduction into maize and the variety of cowpea grown.

4.5.7 The effects of varying times of cowpea introduction into maize plants on the spread of anthracnose and brown blotch diseases

Figure 23 shows the pattern of disease spread on cowpea by both diseases on cowpea introduced into maize at different planting times. In the first and second seasons, both pathogens became gradually more severe with the increase in the age of the plant in each of the treatments. In the third season, the rate of the severity of brown blotch disease on cowpea introduced 3 WAM increased sharply.

From the regression equations given in Figure 24, the infection rates of the relative pathogens were apparently similar. However, the lowest infection rate was obtained on cowpea introduced 1 WBM and highest on the host crop introduced 3 WAM. Results from Figure 25 showed that the rates, at which the diseases were severe on the cowpea grown at different times in the intercrop, followed the same trend as those of disease spread relating to the incidence. However, the rate at which brown blotch disease became severe was slowest on cowpea planted simultaneously with maize, compared with other tested times of introduction.

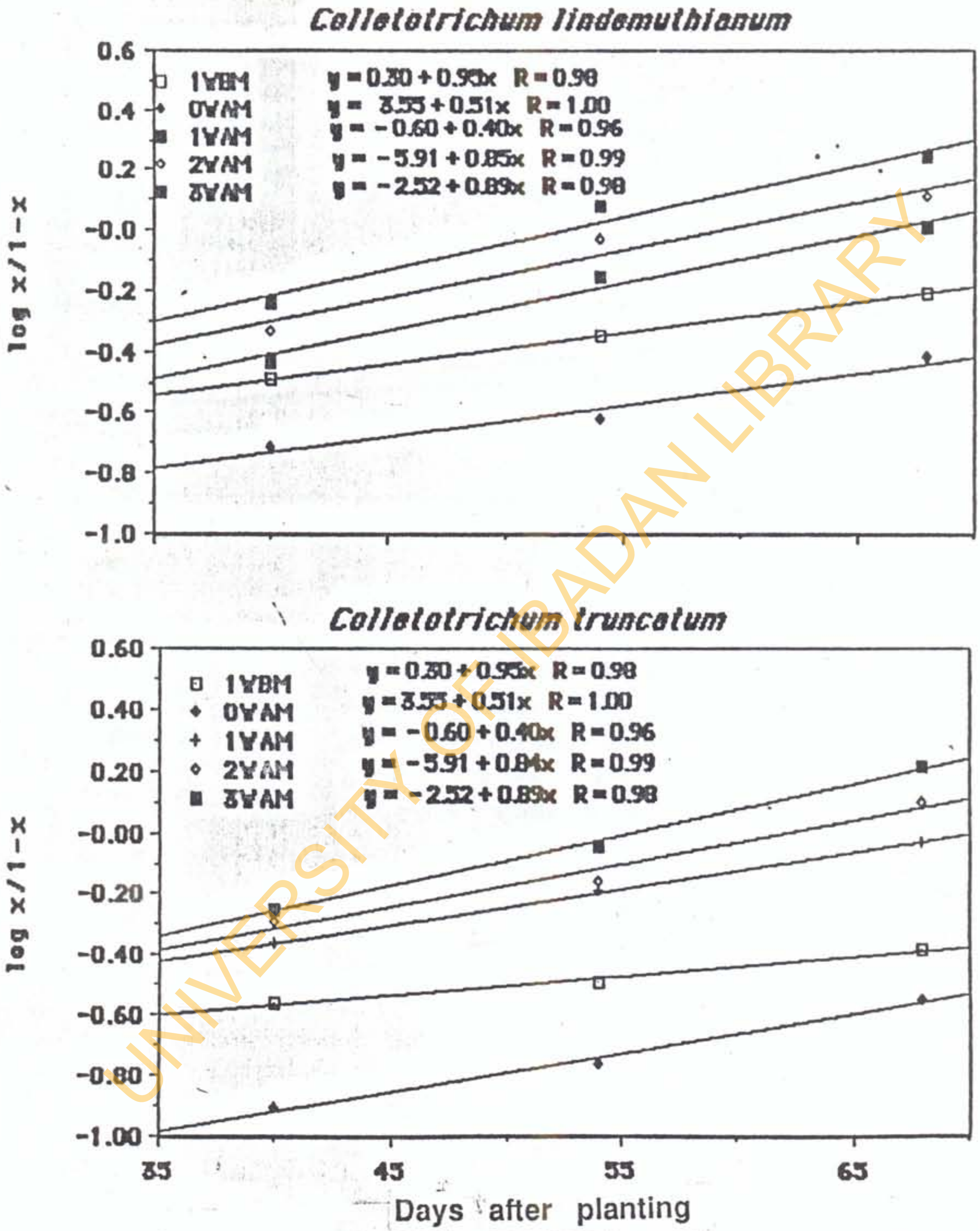


Fig. 24. The progress of *Colletotrichum lindemuthianum* and *C. truncatum* as shown by its infection of cowpea planted at different times in cowpea/maize association (Logarithmic transformation).

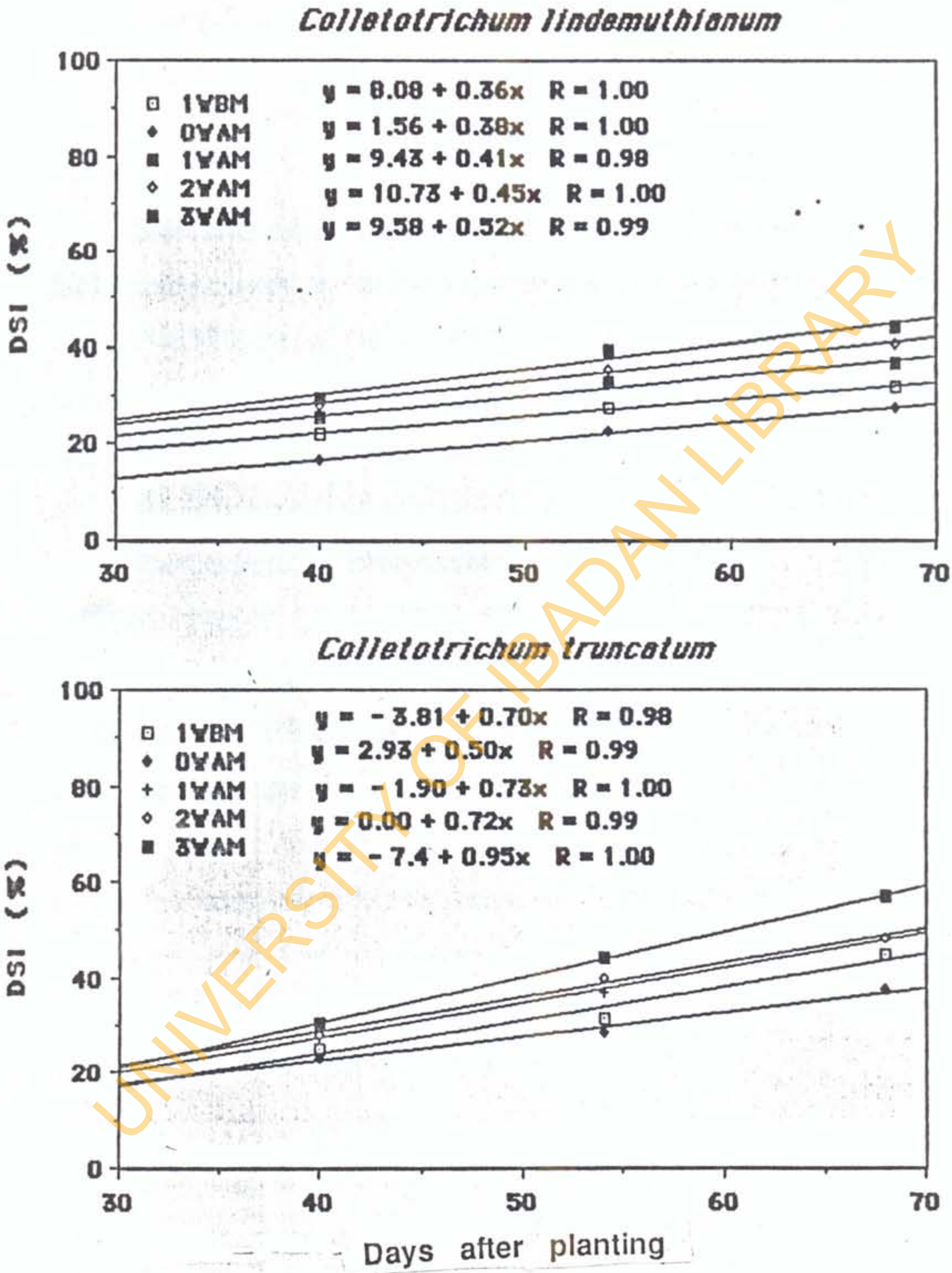


Fig.25: The rate of disease spread caused by *Colletotrichum lindemuthianum* and *Colletotrichum truncatum* on cowpea introduced at different times into maize (Arithmetical transformation).

CHAPTER FIVE

DISCUSSION

Under favourable environmental conditions in the screenhouse and in the field, susceptible cowpea varieties showed symptoms of infection following inoculation with the individual *Colletotrichum* species. These symptoms of infection were as described by several workers (Heald, 1933; Andrus and Moore, 1935; Tiffany, 1951, Onesirosan and Barker, 1971; Wajid and Singh, 1972; Saxena and Sinha, 1977; Singh and Allen, 1979; Emechebe, 1981; Manandhar *et al.*, 1985).

Results from the screenhouse experiment revealed that cowpea varieties IT82E-60, IT82E-32, IT81D-1137 and Vita-7 showed disease symptoms of anthracnose disease within 2-3 days after inoculation, while IT82E-60, IT82D-699, IT81D-994 and IT81D-975 were first to show symptoms of infection by brown blotch disease caused by *C. truncatum* within the same period. These same varieties which showed symptoms of infection within 2-3 days following inoculation later showed higher disease incidence than other varieties which showed symptoms later or not at all. These varieties were found to be more susceptible to infection. This finding is probably due to the build-up of inoculum which may be more rapid within the seeds of the more susceptible varieties than others that are less susceptible.

Both fungi are seed-transmitted. Thus, it is possible that there were differentials in inoculum carry-over by the seeds of the different varieties which might have influenced the added inoculum in causing variations in symptom manifestation with respect to days after inoculation. On the susceptibility scale, Ife Brown, among three other varieties, was susceptible to both pathogens. This finding agrees with that of an earlier report (Oladiran and Oso, 1983).

When screening cowpea varieties for resistance, lower incidence of both anthracnose and brown blotch diseases were recorded when spraying of spore suspension and injection of spore suspension methods were used as methods of inoculation, than when the seedlings were wounded or wrapped with inoculum meal. Besides this, the *Colletotrichum* pathogens were more severe on the seedlings wounded and wrapped with inoculum meal than on cowpea inoculated using other methods. This indicates that wrapping of wounded seedlings is the best method of inoculation in a screening trial. The reason for the inferiority of other methods has been suggested (Tu and Aylesworth, 1980). The spraying method (Kruger and Hoffman, 1978) led to variable infection because of non-uniform distribution of inoculum during spraying. The injection method resulted in inefficient deposition of the inoculum and restriction of the movement of the same inoculum within the tissue. The initial inoculum injected might not be enough to cause infection in the susceptible variety.

Since the aim of wrapping wounded seedling stems with inoculum was to predispose the host plant by creating a direct entry for the inoculum into the tissue, this method is similar to that of the brushing method used by Tu and Aylesworth (1980) when french bean seedlings, *Phaseolus vulgaris* (L.), were screened for resistance to *C. lindemuthianum*. In their finding, the method differentiated the susceptible backcross progenies from those that were resistant more precisely than the spraying or dipping methods. However, they found the method of inoculation by brushing more tedious. Similarly, the wound-wrapping method of inoculation proved significantly better than other methods tested in this study except that it was more labourious and time-consuming. The amount of work, facilities and time required in a breeding programme are reduced through accuracy and promptness in differentiating susceptible and resistant varieties. Therefore, it seems logical that for consistency and uniformity of the results which apparently eliminates the associated problems, wrapping of the wounded seedlings could be recommended in screening cowpea for resistance to these *Colletotrichum* pathogens.

It was observed that certain varieties had symptoms of infection despite the fact that they were not inoculated in the control. According to Tiffany (1951), this occurrence could be attributed to the successful establishment of the mycelium which was carried over the season within the seed from the field. Similar results were obtained in earlier studies with *C. lindemuthianum* even though the percentage of seeds transmitting the pathogen was small (Dhingra *et al.*, 1986).

High values of incidence of both diseases were recorded for seedlings inoculated at 7, 14, 21 and 28 days after seedling emergence, (DAE). Seedlings inoculated at these times were equally highly susceptible to attack by the two pathogens. On the contrary, lower incidence values were recorded for seedlings inoculated at 35 DAE. In screening cowpea seedlings for resistance to *C. lindemuthianum* and *C. truncatum*, it could be suggested that inoculation done within 7-28 DAE would give reliable results in differentiating susceptible varieties from those that are resistant. Though seedlings inoculated 21 DAE had the highest incidence values of 33.8 and 28.2% respectively following inoculation with *C. lindemuthianum* and *C. truncatum*, and were also most susceptible to the pathogens, the reason for this is not known. However, the fact that little or no infection occurred on seedlings inoculated 35 DAE could be explained on the basis of the fact that younger plants as well as younger tissues are more susceptible to the diseases than older plants or older tissues (Barrus, 1921).

Notwithstanding the fact that differences existed in the incidence and severity of the two *Colletotrichum* species due to different times of inoculation when screening cowpea seedlings for resistance to the pathogens, the reaction of the host crop to inoculation at different times depended on the varieties. Thus, it was observed that uniform non-significant values were recorded for some varieties across the levels of time of inoculation. This explains the fact that whereas certain varieties were resistant no matter the time of inoculation, others which were susceptible showed different levels of susceptibility.

Sampling of cowpea plants could not start until 40 DAP. This delay is due to the absence of visible disease symptoms on the plants until early production of flower buds. This occurred during all the three designated seasons. The phenomenon is consistent with Pacumbara's (1988) result and also agrees with Tiffany's (1951) finding of the characteristic delay of *Colletotrichum* sporulation on the host crop. The simultaneous appearance of the fruiting structures over the plant parts was explained as a resumption of active development by mycelium already present in the cells (Tiffany, 1951) as the pathogens are facultative parasites. The same observation was also made by Hartman *et al.*

(1986) who noticed the endophytic and symptomless situation (latent infection) of brown blotch disease and host weeds during the growing season.

Further results from this study show that lower incidence of both pathogens occurred on cowpea in mixtures than on those in sole cropping. Similarly, the pathogens were less severe on cowpeas planted in mixtures than those grown in monocropping. Other researchers (Allen, 1976; Shoyinka, 1976; Mukiibi, 1976; Moreno, 1977; Mora, 1978; Keswani and Mreta, 1980; Van Rheenen *et. al.*, 1981; Thresh, 1982) had earlier given the same reports. Thus, it appears that monocopping provides a more conduicive environment for disease development on cowpea than intercropping. Suggestions are that spore dissemination, modification of the microenvironment (humidity, light, free moisture, temperature, air movement), and differences in nutrient uptake in an intercropping system compared with a monoculture of a more diversified root system are factors influencing the effects of intercropping on pathogens and disease development (Okigbo and Greenland, 1976; Trenbath, 1976; Summer *et al.*, 1981).

Certain mechanism for disease reduction in mixed stands have been equally suggested (Burdon, 1978). These are as follow:

(a) in a pure stand of plants with uniform susceptibility to a particular pathogen, the replacement of a proportion of these plants by resistant ones reduces the amount of inoculum available for subsequent dispersal within the stand;

(b) replacement of susceptible plants by resistant ones results in a decline in the density of the remaining susceptible plant and thus, an increase in the average distance that inoculum has to travel between one susceptible plant and another. Increased distance is often associated with factors which reduced the spread of inoculum. This is in line with Mukiibi's (1976) report. However, it is only possible for simple interest diseases which are normally soil-borne, and therefore, of no importance for the compound interest diseases which are air-borne (Van der Plank, 1968);

(c) resistant plant may interfere with the passage of inoculum between susceptible plants. In the case of air-borne diseases, the foliage would act as a trap for the spores (Mukiibi, 1976). This would reduce the number of propagules available for infecting the susceptible crop;

(d) cross protection phenomena may play some part in a crop mixture. There are two conflicting phenomena affecting the disease level. These are pathogen filtration and high relative humidity;

(e) the resistant host provides an unsuitable environment for the development of the disease.

The observation that the rate of disease spread in intercrop was significantly lower than in monoculture could be explained. Immune or resistant plants, providing sheltering effect, in the mixtures may be responsible for impeding disease spread and increasing the separation between susceptible plants. This sheltering effect tends to offset the microclimatic advantage from which pathogens may benefit from the dense foliage of mixed crops (Palti, 1981). In his explanation, Van Rheenen *et al.* (1981) stated that the associated maize root causes temperature decrease, humidity increment, interception of light with subsequent formation of an umbrella over the legume and so, prevents the spreading of spores by rain splashing. Besides this, it operates as a sort of wind-break, decreasing the spread of spores by wind (Litsinger and Moody, 1976).

On the contrary to this explanation, it has been demonstrated that maize pollen could stimulate the germination of *C. lindemuthianum* and increase the incidence of anthracnose in cowpea (Allen and Skipp, 1982). However, the accuracy of this observation remains doubtful, as it has been demonstrated that maize pollen only causes spores to form long germ tubes instead of appressoria which are essential for entry of the pathogen into the plant (Heald, 1933). In effect, field studies indicated that diseases may either be enhanced or reduced, depending upon interplay between several factors (Anon, 1977).

It was also observed that the severity of infection by *Colletotrichum spp.* increases with age and that this increase was sharp at 54 DAP on the first season crop inoculated with *C. truncatum* whereas it was just mild, rising in a more gradual manner, in the third season for *C. lindemuthianum*. In the second season, however, there was also a gradual increase at 54 DAP to plant maturity following inoculation by the two pathogens individually. The sharp increase in disease severity for *C. truncatum* in the first growing season could be attributed to increasing rainfall experienced (Figures 1 A and B) within the years which resulted in more splashes aiding inoculum dissemination for greater infection on other erstwhile 'healthy' host plants, since incidence is favoured by plenty of rain (Lozano and Booth, 1976). In the second season, the pattern of disease severity over planting period could probably be linked to the dwindling rainfall towards the end of each year with consequent reduction in the rate of spore dissemination.

There was significant reduction in the yield of cowpea in intercropped plots compared with cowpeas in monoculture despite the lower incidence of the pathogens recorded in the former cropping system than the latter. According to Moreno (1979), the possible reasons for this are physiological effects such as tillering and/or light interception of sorghum and millet on green-gram. This report is corroborated by that of Keswani and Mreta (1980) who recorded a reduction of 60 percent in cowpea yield because less light was available to it under a different cropping system involving cowpea-cassava intercrop. Besides this, it is possible that the stocking capacity of cowpea could have been reduced by intercropping.

It was observed that there was a smaller range of difference between the yields from cowpea plants spaced most widely and those that were most closely spaced together in the first season than in the other two seasons. This could have been caused by higher disease infection, especially from anthracnose. Disease development was probably enhanced by the prevalent abundant rains.

Furthermore, results indicated that the level of incidence and severity of infection by the *Colletotrichum* species on cowpea crop in the cropping patterns used was influenced by the host plant spacing. Wider plant spacing led to reduced level of incidence and severity on plant aerial parts. The explanation for this is probably simply that the more the host crops there are per given area, the closer are the crop canopies resulting in more moist and humid environment (Steadman, *et. al.*, 1973).

Prime requisite factors for infection of cowpea by *Colletotrichum* species include high humidity, moderate temperature and heavy dew. Excessive plant growth and dense foliage favours reduced air circulation, promotes higher humidities, prolong dew periods and allows cooler soil surface temperatures (Schwartz and Steadman, 1978). Thus, it seems understandable that luxuriant plant growth, resulting from closer plant spacing, could enhance the incidence and severity of *Colletotrichum*. Open canopies could probably allow better penetration of sunlight and better circulation of air with subsequent inhibition of infection and colonization of the host crop by the pathogens.

It was shown that the wider the spacing between and within rows among the plants, the larger the number of viable seeds produced. On the other hand, the percentage of seeds which were infected increased with closer spacing. It appears therefore, that wider spacing reduces infection of seeds and subsequently, increases seed viability. Thus, to improve cowpea production beyond present limits, healthy seeds have to be obtained for use as planting materials. Planted seeds have been identified as the major and cheapest medium of inoculum transference from one growing season to the other. Seed weight was not significantly affected by spacing following infection from the pathogens. This could be due to the fact that even though the seed was infested by the fungi, no physical damage was done. *Colletotrichum* pathogen is a facultative parasite that can subsist inside the seed until favourable environmental conditions of growth are met (Barrus, 1921; Tiffany, 1951).

Agronomically, earlier studies have shown that closer spacing attained higher yields of seeds than wider spacing (Enyi, 1973). However, with disease involvement, it is expected that the closer the spacing, the smaller the yield would be. But results from this study revealed that despite the fact that the incidence and severity of anthracnose disease was reduced with increasing intrarow and interrow spacings, this was not reflected in the yield. In the converse, the yield increased with decreasing spaces between- and within- rows, as there were more plants to provide a greater yield per square area. In this study, since all the cowpea plots were inoculated, there was no yield determination from disease free plots in relation to spacing, so there was no basis for comparison with the yield resulting from disease-infected and disease-free plots as a result of differential spacing. However, it could be inferred that the increase in yield with closer spacings would be marginally lower with infection from the pathogens than when the cowpea plants were not infected. This is because field observation showed that following infection, the aerial plant parts, especially the leaves, were discoloured and this could have led to the impairment of the plants' physiological functions. Besides, discolouration of the aerial parts, the pods became disfigured and some of them were shrivelled and fell off from the plant.

Result from this study revealed that infection rates were higher on cowpea plants which were more closely grown together, both between and within rows, than those which were relatively more spaced out. These results are in agreement with those of Keyworth and Davies (1946); and Burdon and Chilvers (1975). In their findings, they observed that the planting density of the host population plays an important role in determining the rate of multiplication and the rate of advance of the disease. Furthermore, they noticed that disease spread occurred much more readily between plants which were closely spaced together than those widely spaced out. The explanation given for this was that at high seeding densities with closely spaced stands, the disease was transmitted readily between host plants. At wider spacings, the greater distance between adjacent plants reduced the probability of successful transmission as it was reflected in the parameters of multiplication and advanced in the present study. Thus, the wider the separation between individual host plants, the less likely it becomes that organisms infect new plants (Chilvers and Brittain, 1972).

It was found that the computed R values were not significant, though high and positive. This could have been indicative of a high relationship between the spread of the pathogens on the plants and the age of the plants. It could also be due to small sample size. However, it was observed that the curve for disease spread over time in the field experiment, though linear, did not start until later in the life cycle of the cowpea plant.

Generally, cowpea variety significantly affected the incidence and severity of both diseases on cowpea when intercropped with maize. Incidence and severity on cowpea in the field following infection from *C. lindemuthianum* increased in the order IT84S-2246-4 < Ife Brown < IT82E-16, while increase with *C. truncatum* infection was in the order IT82E-16 < IT84S-2246-4 < Ife Brown. This result clearly indicated that the cowpea varieties reacted differently to the pathogens. The reason for this difference could be provided. Every plant, like every human being, is resistant or susceptible to any disease according to its genetic constitution, although the environment on the long run plays an important modifying role. There is the innate tendency for resistance or susceptibility to any disease.

Though inconsistent over the sampling stages during the seasons, the result from this study showed that the interaction of cowpea variety x cropping pattern was significant. This implies that the reaction of the varieties to infection from the respective pathogens varies across the cropping patterns. Results showed that IT82E-16 was more susceptible in strip than in intrarow. This result is expected, since IT82E-16 is a spreading cowpea variety which easily covers the distance created between adjacent cowpea plants in the intrarow planting. Wider spaces were created by maize stands within other cowpea varieties, IT84S-2246-4 (erect) and Ife Brown(semi-erect). The extent to which both varieties could reduce the distance created by the maize plants is more limited than that of IT82E-16. The disease would probably be more easily spread by plant to plant contact. Thus, the explanation by Leonard (1969) that non-host crop may act in a way, so as to entrap either rain-splashed or wind-borne fungal spores with resultant reduction in the quantity of available inoculum, may not hold in this case.

Unlike what the result revealed on the reaction of the cowpea varieties to infection from the *Colletotrichum* species while still growing in the field, cowpea varietal reaction as reflected on the incidence and severity of both individual disease on cowpea pods and seeds was different. In both cases of pathogenic infection, Ife Brown was the least infected and IT82E-16 was the most infected. This could have been so, since with time, *Colletotrichum* symptoms of infection manifested more clearly at a latter stage of the plant growth (Tiffany, 1951). Hence, the spreading variety gets more infection from the pathogens' attack than the other varieties.

Cropping pattern significantly affected the effect of the pathogens on cowpea, because of the varying distances between the adjacent plants. In the interrow arrangement, the space between cowpea plant at adjacent rows is double that of any other cropping arrangement, thus sufferring the least attack from the pathogens. It appears therefore that by planting cowpea and maize in alternate rows at a spacing of 100 cm between rows and 40 cm within rows, damage from anthracnose and brown blotch attack could be drastically reduced. However, there is need for further research studies into the optimum plant spacing between and within rows which would give reasonable yield in the interrow arrangement under a cowpea-maize intercrop.

Differences in cropping patterns had no effect on the seed weight of cowpea infested by *Colletotrichum* species. The explanation for this occurrence was not studied in this trial. However, the significant differences due to varietal variations could be attributed to the level to which the plant aerial parts were infected, thereby facilitating the consequent entry into the seed cotyledon through the pods. Through the impairment of the physiological functions of the leaves, which were deprived of their chlorophyll through leaf and stem discolouration, it might be possible that less photosynthetic product than expected got to the seed during the seed-filling period. This might lead to the differential weight loss. Former results from the present study on pod infection of these cowpea genotypes supported this view.

Compared with any of the cowpea-maize cropping intercropped arrangement infection rates for *Colletotrichum* were highest on cowpeas in the sole cropping. Explanation for this has been that the non-host crop, maize, provides a sheltering effect in the mixture (Van Rheenen *et al.*, 1981). This sheltering effect does not exist in the monoculture. Among the intercrops involving different cowpea-maize association, the spread of the pathogen decreases in the order strip > intrarow > double row > interrow, indicating that the sheltering effect probably decreases in the same order from strip to interrow. Besides this, the distance between neighbouring host plants could also be a determining factor, as already shown by Leonard (1969); and Burdon and Chilvers (1975).

While the highest rate of infection was recorded on IT82E-16, the lowest was on IT84S-2246-4, indicating that differences in the plant architecture influenced the spread of the pathogens. IT82E-16 is a spreading variety of cowpea while Ife Brown is semi-erect and IT84S-2246-4 is an erect type. With increasing degrees in the spreading habit of these varieties, it appears that there was increase in the spread of disease which could be linked to the varieties' ability to reduce the distance between the stands (Thresh, 1982). In an earlier experiment by Oladiran and Oso (1983), among other varieties, the highest infection rate was found on Ife Brown, which placed second to IT82E-16 in this study.

In the present work, infection of cowpea in cowpea-maize intercrop varied with time of cowpea introduction into the maize plants. It was found that planting cowpea simultaneously with maize and planting cowpea one week before maize reduced the incidence and severity of both *Colletotrichum* pathogens more significantly than introducing cowpea into maize after the establishment of the maize plants. This indicates that the prospects of using cowpea and maize as intercrops in controlling infection by these pathogens may involve some manipulations in the time of sowing. In this respect; sowing both crops at the same time or one week before maize appear to be suitable timing. The biological reasons for this occurrence were not studied. However, it might be connected with the fact that, since cowpea matures faster than maize in the intercrop, it may escape more of the canopies which could have resulted from maize growth, thus providing more moist and humid environment (Steadman *et al.,* 1973) which is necessary for disease development (Wheeler, 1969). This reasoning sounds logical from the point of view of yield increment obtained by early introduction of cowpea into the intercrop.

Disease spread on cowpea in the cowpea-maize intercrop was not significantly different as a result of varying times of cowpea introduction until at later sampling stages. Thus, the highest infection rate was recorded on cowpeas introduced at 3 weeks after maize, compared with cowpea grown one week before maize in which the lowest infection rate was recorded. This means that infection rate of cowpea increases the longer the delay before sowing the crop after maize establishment in cowpea-maize association. This appears biologically logical in the sense that by the time symptoms of disease would start to be manifested on the cowpeas, depending on the stage of growth of maize plant at the time, canopy formation resulting from maize luxuriance could constitute a major determining factor. Thus, it is possible that cowpea sown a week earlier than maize may tend to escape much of this canopy and the rate of spread of diseases may be reduced.

CHAPTER SIX

SUMMARY AND CONCLUSION

Twelve cowpea genotypes were screened to determine their reaction to infection, to investigate the best method of inoculation, and to examine the best time of inoculation for the determination of resistance to *Colletotrichum lindemuthianum* and *C. truncatum*.

Results revealed that there was a range of plant reactions from resistant to susceptible and that not all the plants reacted similarly to the individual pathogens. While only IT82E-60 was susceptible to both pathogens, only TVx 3236 was resistant. The most susceptible varieties to *C. lindemuthianum* include IT82E-60, IT81D-1137 and VITA 7, while TVx 3236, IT91D-994 and IT81D-975 were most resistant. Varieties IT82E-60, IT82D-699 and Ife Brown were most susceptible to *C. truncatum*, while TVx 3236, VITA 7 and IT81D-1137 were most resistant.

In screening cowpea seedlings for resistance to *C. lindemuthianum* and *C. truncatum*, wrapping of wounded seedlings with the inoculum meal of the respective pathogens is the most reliable method of inoculation, among other methods studied, Even though it was somewhat laborious, it offers a clear differentiation between the resistant and susceptible varieties of cowpea.

Symptoms of disease were manifested on seedlings inoculated at 7, 14, 21 and 28 days after seedling emergence, DAE. However, the highest level of incidence and severity were obtained on seedlings inoculated 21 DAE, indicating that the most appropriate time for seedling inoculation while screening for resistance to anthracnose and brown blotch pathogens is 21 DAE.

Lower levels of incidence and severity of the *Colletotrichum* diseases were recorded on cowpea grown in mixtures than on those in sole cropping. Thus, intercropping of cowpea with maize could be a better control measure on the incidence of both diseases on cowpea, especially nowadays, when chemical control measure is both ecologically and economically unwise, even if the chemicals are available.

Despite the lower incidence of the pathogens on cowpea in the intercropped plots, seed yields were still significantly higher under monocropping than intercropping systems. However, seeds harvested from sole cowpea were more infected by disease than those harvested from cowpea planted in the intercropped plots. As the interrow and intrarow spacings in cowpea plots were increased, the incidence and severity of both diseases on cowpeas (whether grown in maize or non-maize based stands) became reduced and a higher percentage of seed viability was also recorded.

Cropping pattern significantly affected the incidence and severity of the different diseases on cowpea. Cowpeas grown in alternate rows with maize provided the best cropping pattern in the control of the individual disease. There were inconsistent variations among other cropping patterns which involved intercropping of cowpea with maize. Generally, cowpeas grown in monoculture were more infected by the respective diseases.

With increasing age, the incidence and severity of disease on susceptible cowpea varieties increased. Infection from anthracnose disease increased in the order of IT84S-2246-4 < Ife Brown < IT82E-16, while, IT82E-16 variety was most affected by brown blotch, followed by IT84S-2246-4 < Ife Brown in that order.

Planting of cowpea one week before maize or planting both crops simultaneously made no significant difference on the incidence and/or severity of the two *Colletotrichum* diseases. Planting done at these times could then be recommended as a control measure in minimizing infection of cowpea by these diseases under cowpea-maize intercrop arrangement. Plantings done later, other than simultaneous sowing of the two crops in association, resulted in a higher incidence level of disease.

The spread of both fungi was affected by season, age of the plant, intercropping and cropping arrangement, spacing, variety and introduction of cowpea into maize crop. The rate of disease spread was highest during the first growing season at which period the damage to the seeds was worst. With increase in the age of plant, right from the time the first disease symptoms were manifested, the rate at which the pathogen spread kept on increasing. Higher infection rates were recorded on cowpea grown under monocrop than on those under intercrop. Disease spread was faster among cowpeas which were more closely grown together than among those relatively more widely separated from one another in stands. Disease spread was faster on cowpeas which have the spreading habit than on those which were erect. Infection rates increased on cowpeas as the sowing of the crop in cowpea-maize intercrop was delayed in time after maize establishment.

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Appendix 1. Analysis of variance table for the experiments conducted in the screenhouse in 1987 showing cowpea (V, 12) reaction to four methods of inoculation (I).

Sources of variation	Degrees of freedom[a]			Sum of squares
Replication	r - 1	=	2	SS(R)
Variety (V)	v - 1	=	11	SS(V)
Error (a)	(r-1)(v-1)	=	22	SS(Ea)
Inoculation methods (I)	i - 1	=	3	SS(I)
V x I	(v-1) (i-1)	=	33	SS(V x I)
Error (b)	r(r-1)(i-1)	=	72	SS(Eb)
Total	rvi - 1	=	143	

[a]r = number of replication; v and i are levels of the two original factors and V and I, respectively.

Appendix 2. An outline of the analysis of variance for a 3 x 12 x 5 factorial experiment[a] in a split-plot design.

Sources of variation	Degrees of freedom[b]			Sum of squares
Replication	(r-1)	=	2	SS(R)
Main-plot factor	(vi-1)	=	35	SS(T1)
Variety (V)	(v-1)	=	11	SS(V)
Inoculation Method (I)	(i-1)	=	2	SS(I)
V x I	(v-1) (i-1)	=	22	SS(VxI)
Error (a)	(r-1)(vi-1)	=	70	SS(Ea)
Subplot factor (T)	(t-1)	=	4	SS_{T2}
Main-plot factor x sub- plot factor:	(vi-1) (t-1)	=	140	SS_T
T x V	(t-1) (v-1)	=	44	SS(TXV)
T x I	(t-1) (i-1)	=	8	SS(TxI)
T x V x I	(t-1)(v-1)(i-1)	=	88	SS(TxVxI)
Error (b)	vi(r-1)(t-1)	=	288	SS(Eb)
Total	rvit - 1	=	539	

[a]Experiment consists of:
Three inoculation methods(I); twelve varieties of cowpea (V)
Five times of inoculation; days after emergence (T).

[b]Applied to a stimulated two factor experiment with main-plot factor as a combination of two original factors V and I, and subplot factor representing the third original factor T.

r = number of replications; v, n, and w are levels of the three original factors V, N, and W, respectively.

Appendix 3a. Analysis of variance table for 2 x 3 x 4 factorial experiments[a] in randomized complete block design.

Sources of variation	Degrees of freedom[b]		Sum of squares
Replication	(r-1)	= 2	SS(R)
Treatment	cbw-1	=23	SS(T)
Cropping pattern (C)	(c-1)	= 1	SS(C)
Between row spacing (B)	(b-1)	= 2	SS(B)
Within row spacing (W)	(w-1)	= 3	SS(W)
W x B	(c-1)(b-1)	= 6	SS(WxB)
C x W	(c-1)(w-1)	= 3	SS(CxW)
C x W	(c-1)(w-1)	= 3	SS(CxW)
C x B x W	(v-1)(c-1(w-1)	= 6	SS(CxBxW)
Error	(r-1)(cbw-1)	=46	SS(E)
Total	rcbw-1	=71	

[a]Experiments consist of
Two cropping patterns (C)
Three between row spacings (B)
Four within row spacings (W)

[b]r = number of replications; c,b, and w are levels of the three original factors C, B and W, respectively.

Appendix 3b. Analysis of variance table for 2 x 3 x 4 factorial experiments[a] (C,2; B, 3 and W, 4) in randomized complete block design (across three seasons).

Sources of variation	Degrees of freedom[b]		Sum of squares
Replication	(r-1)	= 2	SS(R)
Treatment	cbws-1	= 71	SS(T)
Cropping pattern (C)	(c-1)	= 1	SS(C)
Between row spacing (B)	(b-1)	= 2	SS(B)
Within row spacing (W)	(w-1)	= 3	SS(W)
Season (S)	(s-1)	= 2	SS(S)
C x B	(c-1)(b-1)	= 2	SS(CxB)
C x W	(c-1)(w-1)	= 3	SS(CxW)
C x S	(c-1)(s-1)	= 2	SS(C x S)
B x W	(b-1)(w-1)	= 6	SS(BxW)
B x S	(b-1)(s-1)	= 4	SS(B x S)
W x S	(w-1)(s-1)	= 6	SS(WxS)
C x B x W	(c-1)(b-1)(w-1)	= 6	SS(CxBxW)
B x Wx S	(b-1)(w-1)(s-1)	= 12	SS(BxWxS)
C x B x W xS	(c-1)(b-1)(w-1)(s-1)	= 22	SS(CxBxWxS)
Error	(r-1)(cbws-1)	= 142	SS(E)
Total	rcbw-1	= 215	

[a]Experiments consist of
- Two cropping patterns (C)
- Three between row spacings (B)
- Four within row spacings (W)
- Three seasons (S)

[b]r = number of replications; c,b,w, and s are levels of the three original factors C, B, W and S, respectively.

Appendix 4a. An outline of the analysis for 3 x 5 factorial experiments[a] in randomized complete block design in three replications.

Sources of variation	Degrees of freedom[b]		Sum of squares
Replication	r-1	= 2	SS(R)
Treatments	vc-1	= 14	SS(T)
Variety (V)	(v-1)	= 2	SS(V)
Cropping pattern (C)	(c-1)	= 4	SS(C)
V x C	(v-1)(c-1)	= 8	SS(VxC)
Error	(r-1)(vc-1)	= 28	SS(E)
Total	rvc-1	= 44	

[a]Experiments consists of
Three varieties of cowpeas
Five cropping patterns.

[b]r = number of replications; v and c are levels of the two original factors; V and C, respectively.

Appendix 4b. An outline of the analysis for 3 x 5 factorial experiments[a] in randomized complete block design in three replications (across three seasons).

Sources of variation	Degrees of freedom[b]		Sum of squares
Replication	r-1	= 2	SS(R)
Treatments	vc-1	= 17	SS(T)
Variety (V)	(v-1)	= 2	SS(V)
Cropping pattern (C)	(c-1)	= 4	SS(C)
Season (S)	(s-1)	= 2	SS(S)
V x C	(v-1)(c-1)	= 8	SS(VxC)
V x S	(v-1)(s-1)	= 4	SS(VxC)
C x S	(c-1)(s-1)	= 8	SS(VxC)
V x C x S	(v-1)(c-1))(s-1)=	16	SS(VxC)
Error	(r-1)(vcs-1)	= 88	SS(E)
Total	rvc-1	= 134	

[a]Experiments consists of
Three varieties of cowpeas
Five cropping patterns.
Three seasons.

[b]r = number of replications; v, c and s are levels of the three original factors V, C and S, respectively.

Appendix 5a. Analysis of variance table for 3 x 5 factorial Experiments arranged in a split-plot design with three varieties (V) as main-plot treatments and five times of introduction of cowpea (T) as subplot treatments in three replications.

Sources of variation	Degree of freedom[a]		Sum of squares
Replication	r - 1	= 2	SS(R)
Varieties (V)	c - 1	= 2	SS(V)
Error (a)	(r-1)(v-1)	= 4	SS(Ea)
Time of introduction (T)	t - 1	= 4	SS(T)
V x T	(v-1)(t-1)	= 8	SS(VxT)
Error (b)	v(r-1)(t-1)	= 24	SS(Eb)
Total	rvt-1	= 29	

[a]r = number of replications, c and t are levels of the two original factors C and T, respectively.

Appendix 5b. Analysis of variance table for 3 x 5 factorial Experiments arranged in a split-plot design with three varieties (V) as main-plot treatments and five times of introduction of cowpea (T) as subplot treatments in three replications (across three seasons).

Source of variation	Degree of freedom[a]		Sum of squares
Replication	r - 1	= 2	SS(R)
Season (S)	s - 1	= 2	SS(S)
Error a	(r-1)(s-1)	= 4	SS(Ea)
Variety (V)	v-1	= 2	SS(V)
S x V	(s-1)(v-1)	= 4	SS(SxV)
Error b	s(r-1)(v-1)	= 12	SS(Eb)
Time of introduction (T)	d-1	= 4	SS(T)
S x T	(s-1)(t-1)	= 8	SS(SxT)
V x T	(v-1)(t -1)	= 8	SS(VxT)
Tx V x S	(v-1)(t-1)(s-1)	= 16	SS(VxTxS)
Error c	sv(r-1)(vts-1)	= 72	SS(Ec)
Total	rsvt-1	= 134	SS(Total)

[a]Experiments consist of:
Three seasons (S)
Three cowpea varieties (V)
Five times of cowpea introduction (T)
s,v, and t are levels of original factors S, V and T, respectively.

Appendix 6. Data showing symptom appearance (days after inoculation, DAI) on twelve cowpea varieties inoculated with two *Colletotrichum spp.* using four methods of inoculation

Variety	1st trial				2nd trial				3rd trial			
	SS[a]	SI	MW	SC	SS	SI	MW	SC	SS	SI	MW	SC
					C. lindemuthianum							
IT81D-975	0	0	0	0	0	0	0	0	0	0	0	0
IT81D-994	0	0	0	0	0	0	0	0	0	0	0	0
IT81D-1137	4	6	2	0	4	7	3	0	4	5	3	6
IT82D-699	5	7	5	0	6	0	3	0	5	0	3	0
IT82E-16	5	7	3	0	5	7	4	4	7	0	6	0
IT82E-32	0	6	3	0	6	4	3	0	5	6	3	0
IT82E-60	5	4	3	0	3	4	3	6	4	4	2	5
IT84S-2246-4	6	6	3	0	7	7	4	0	7	0	5	0
VITA 7	7	4	2	7	6	5	5	0	0	4	4	0
TVx 3236	0	0	0	0	0	0	0	0	0	0	0	0
Ife Brown	7	5	5	0	5	6	3	7	6	7	2	4
IT84E-124	6	7	6	0	6	7	4	7	7	6	4	0
					C. truncatum							
IT81D-975	5	3	2	5	5	6	3	7	6	4	4	7
IT81D-994	6	4	3	7	6	4	4	7	5	4	2	6
IT81D-1137	0	0	0	0	0	0	0	0	0	0	0	0
IT82E-16	7	6	5	7	7	7	5	0	5	6	5	0
IT82D-699	6	4	3	7	6	4	2	6	4	3	2	6
IT82E-32	7	0	0	0	0	7	0	0	0	0	0	0
IT82E-60	4	2	2	7	5	4	2	7	5	3	2	6
IT84S-2246-4	6	5	3	7	4	3	2	6	7	6	4	7
VITA 7	0	0	0	0	0	0	0	0	0	0	0	0
TVx 3236	0	0	0	0	0	0	0	0	0	0	0	0
Ife Brown	5	4	4	7	6	5	3	7	6	5	4	7
IT84E-124	0	6	5	0	0	6	4	0	5	5	3	0

[a]SS = Spraying of spore suspension, SI = Injection of spore suspension, MW = Wrapping of seedling stem with inoculum meal and SC = Control by spraying deionized sterile distilled water
0 = No disease symptom.

Appendix 7. Mean squares from the analyses of variance for the incidence and severity of anthracnose disease on cowpea using different inoculation methods.

Sources of variation	Degrees of freedom	Incidence	Severity
Variety	11	4901.35++	7.7039++
Error A	22	57.30	0.2039
Inoculation method	3	8977.22++	16.0810++
Interaction	33	395.94++	0.8789++
Error B	72	40.34	0.2986

++Significant at 1% level of probability.

Appendix 8. Mean squares from the analyses of variance for the incidence and severity of brown blotch disease on cowpea using different inoculation methods.

Sources of variation	DF	Incidence	Severity
Variety	11	11930.82++	15.1948++
Error A	22	51.66	0.5815
Inoculation method	3	5442.71++	29.1555++
Interaction	33	248.77++	3.5275++
Error B	72	33.40	0.5091

++Significant at 1% level of probability.

Appendix 9. Symptom appearance (DAI)[a] of *Colletotrichum spp.* on cowpea varieties inoculated at different stages of plant growth.

Varieties	Time of inoculation (DAP)[b]														
	7			14			21			28			35		
	SS	MW	SC	SS	MW	SC	SS	MW	SC	SS	MW	SC	SS	MW	SC
							C. lindemuthianum								
IT81D-975	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IT81D-994	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IT81D-1137	5.3	4.3	5.3	2.7	1.7	5.0	4.0	2.7	5.3	4.7	3.3	6.0	6.0	5.3	6.0
IT82D-699	6.7	5.7	0	5.7	4.7	0	6	5.0	0	6.3	5.3	0	0	0	0
IT82E-16	5.0	4.0	0	4.0	2.3	0	5.3	3.3	+	5.0	4.7	0	0	0	0
IT82E-32	6.7	5.3	0	3.7	2.7	0	4.7	3.3	0	+	4.7	0	0	0	0
IT82E-60	5.0	3.7	4.3	2.7	1.7	3.3	4.0	2.3	3.7	4.3	3.0	4.0	5.7	4.7	5.3
IT84S-2246-4	6.3	5.0	0	4.7	3.7	0	5.3	4.3	0	0	5	0	0	0	0
VITA 7	6.0	5.0	6.7	2.7	2.0	2.3	3.3	2.3	2.7	5.7	3.3	7.0	0	0	0
TVx 3236	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ife Brown	6.3	5.7	0	5.7	4.0	0	4.7	3.0	0	6.0	5.0	0	0	0	0
IT84E-124	6.7	6.0	0	3.7	3.0	0	4.7	4.0	0	6.0	4.7	0	0	0	0

Appendix 9 (contd.)

Varieties	Time of inoculation (DAP)[b]														
	7			14			21			28			35		
	SS	MW	SC	SS	MW	SC	SS	MW	SC	SS	MW	SC	SS	MW	SC
							C. truncatum								
IT81D-975	+	5.7	0	6.3	5.3	+	5.3	4.3	+	+	5.0	+	6.7	7	+
IT81D0994	+	6.3	0	5.7	5.3	0	5.7	4.7	0	6.7	5.7	0	0	+	0
IT81D-1137	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IT82D-699	5.3	4.0	+	3.7	2.7	5.7	4.7	3.3	+	4.0	3.3	+	+	5.3	0
IT82E-16	0	+	0	6.0	5.3	0	6.0	5.0	0	0	+	0	0	0	0
IT82E-32	+	6	0	+	5.0	0	6.3	5.3	0	0	0	0	0	0	0
IT82E-60	4.3	3.0	+	+	1.3	+	4.7	2.0	6.7	4.0	2.3	0	0	+	0
IT84S-2246-4	5.0	2.7	+	4.3	2.0	+	+	3.0	6.7	5.3	3.3	+	6.3	5.3	+
VITA 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TVx 3236	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ife Brown	5.7	4.7	0	4.3	3.0	0	5.7	3.7	0	5.0	4.3	0	+	6.0	0
IT84E-124	+	+	0	5.0	4.3	0	5.3	4.3	0	0	+	0	0	0	0

[a]Days after inoculation and data are average of three trials

[b]Days after planting.

[c]SS = Spraying of spore suspension, MW = Wrapping of seedling stem with inoculum meal and SC = Control by spraying deionized sterile distilled water

0 = No disease symptom

+ = Incomplete data due to lack of symptoms yet during the last day of observation.

Appendix 10. Mean squares for the analyses of variance for the incidence of anthracnose and brown blotch diseases on cowpea inoculated at different stages of growth

Source of variation	DF	Mean squares	
		Anthracnose	Brown blotch
Variety	11	13545.45++	11633.78++
Inoculation method	2	31232.01++	34819.95++
Variety x inoculation method	22	1074.50++	2247.76++
Error A	70	70.34	50.81
Time	4	14887.97++	11260.46++
Variety x time	44	623.55++	749.53++
Inoculation method x time	8	2461.54++	2453.08++
Variety x Inoculation method x time	88	154.15++	183.16++
Error B	288	29.35	25.52
CV %		27.9	31.00

++Significant at P = 0.01 (DMRT)

Appendix 11. Analyses of variance for the effect of cropping pattern, interrow and intrarow spacing on the incidence of anthracnose disease at three sampling times during three growing seasons[a] in 1987/88.

Source of variation	Degrees of freedom	Means squares								
		1987F			1987S			1987T		
		40 DAP[b]	54 DAP	68 DAP	40 DAP	54 DAP	68 DAP	40 DAP	54 DAP	68DAP
Cropping pattern (CP)	1	50.0++	1343.3++	1283.5++	323.0++	4552.2++	5600.3++	243.8++	6095.9++	9683.7++
Interrow spacing (INTER)	2	122.6++	370.1++	369.0++	755.4++	1554.9++	1987.9++	192.0++	1898.5++	2690.7++
Intrarow spacing (INTRA)	3	138.1++	357.1++	468.7++	808.6++	1663.5++	2558.0++	603.6++	1950.8++	2593.8++
CP x INTER	2	0.5 ns	5.9 ns	0.9 ns	26.1 ns	21.1 ns	12.8 ns	12.8 ns	0.6 ns	23.5 ns
CP x INTRA	3	0.6 ns	1.5 ns	1.1 ns	3.8 ns	16.5 ns	76.0 ns	76.0 ns	7.0 ns	8.0 ns
INTER x INTRA	6	20.7++	1.4+	12.2ns	38.7 ns	4.6 ns	35.1 ns	35.1 ns	45.1 ns	124.7+
CP x INTER x INTRA	6	6.9 ns	1.7 ns	0.8 ns	16.3 ns	16.9 ns	26.0 ns	14.3 ns	15.9 ns	6.2 ns
Error	46	4.6	5.7	7.3	29.5	68.9	56.8	9.4	53.8	42.0

[a]Three seasons in 1987/88: F = First season (April-July, 1987); S = Second season (August-November, 1987; and T = Third season (December 1987 - March 1988).
[b]DAP = Days after planting
++Significant at 1% level
+Significant at 5% level
ns = Not significant.

Appendix 12. Analyses of variance for the effect of cropping pattern, interrow and intrarow spacing on the severity of anthracnose disease on cowpea at three sampling stages during three growing seasons[a] in 1987/88.

Source of variation	Degrees of freedom	Means squares								
		1987F			1987S			1987T		
		40 DAP[b]	54 DAP	68 DAP	40 DAP	54 DAP	68 DAP	40 DAP	54 DAP	68 DAP
Cropping pattern (CP)	1	0.8 ns	734.7++	1112.3++	8.0 ns	57.2++	185.0++	169.0 ns	1168.0++	1417.8+
Interrow spacing (INTER)	2	10.0+	560.0++	526.9++	26.6++	115.5++	102.3++	155.1++	663.9++	843.2++
Intrarow spacing (INTRA)	3	185.5++	1135.8++	2245.0++	265.2++	2196.4++	2766.2++	183.6++	595.8++	1124.2++
CP x INTER	2	0.3 ns	2.43 ns	4.8 ns	0.7 ns	16.5+	22.3++	8.9 ns	18.6 ns	15.9 ns
CP x INTRA	3	0.4 ns	268.3++	230.2++	0.0 ns	7.3 ns	12.7++	6.1 ns	8.3 ns	27.0 ns
INTER x INTRA	6	1.7 ns	29.2++	18.3 ns	1.5 ns	6.6 ns	2.9 ns	3.0 ns	15.9 ns	21.8 ns
CP x INTER x INTRA	6	0.8 ns	8.1 ns	27.4++	2.6 ns	1.1 ns	12.6++	1.6 ns	10.9 ns	10.3 ns
Error	46	2.5	5.7	7.9	3.0	3.7	2.8	3.2	15.5	16.0

[a]Three seasons in 1987/88: F = First season (April-July, 1987); S = Second season (August-November, 1987; and T = Third season (December 1987 - March 1988).
[b]DAP = Days after planting
++Significant at 1% level
+Significant at 5% level
ns = Not significant.

Appendix 13. Analyses of variance for the effect of cropping pattern, interrow and intrarow spacing on the severity of brown blotch disease at 40, 54, and 65 DAP[a] during three growing seasons[b] in 1987/88.

Source of variation	Degrees of freedom	Means squares								
		1987F			1987S			1987T		
		40 DAP	54 DAP	68 DAP	40 DAP	54 DAP	68 DAP	40 DAP	54 DAP	68 DAP
Cropping pattern (CP)	1	1.2 ns	172.4^{+}	661.3^{++}	0.0 ns	14.0 ns	4544.2^{++}	15.1 ns	19.2 ns	1140.8^{++}
Interrow spacing (INTER)	2	9.2 ns	331.1^{++}	1390.4^{++}	45.4 ns	382.9^{++}	871.6^{++}	55.3^{+}	198.5^{++}	299.6^{++}
Intrarow spacing (INTRA)	3	59.1 ns	433.6^{++}	2875.5^{++}	239.7^{++}	1632.2^{++}	1773.4^{++}	43.4^{+}	69.2^{++}	335.1^{++}
CP x INTER	2	4.0 ns	3.9 ns	6.7 ns	9.3 ns	4.8 ns	231.1^{+}	1.4 ns	1.7 ns	4.1 ns
CP x INTRA	3	3.8 ns	10.2 ns	1.5 ns	0.6 ns	2.8 ns	238.3^{++}	0.4 ns	0.3 ns	3.8 ns
INTER x INTRA	6	6.6 ns	0.6 ns	15.1 ns	4.3 ns	5.9 ns	23.6 ns	0.9 ns	3.8 ns	2.9 ns
CP x INTER x INTRA	6	5.4 ns	6.6 ns	3.3 ns	3.2 ns	9.8 ns	28.4 ns	1.0 ns	1.3 ns	6.9 ns
Error	46	15.6	41.3	81.0	25.1	46.7	46.6	11.9	16.2	24.2

[a]DAP = Days after planting

[b]Three seasons in 1987/88: F = First season (April-July, 1987); S = Second season (August-November, 1987; and T = Third season (December 1987 - March 1988).

$^{++}$Significant at 1% level
$^{+}$Significant at 5% level
ns = Not significant.

Appendix 14. Analyses of variance for the effects of cropping pattern and spacing on the incidence of anthracnose disease on cowpea pods during three growing seasons[a] in 1988/89.

Sources of variation	Degrees of freedom	Sum of squares		
		1988F	1988S	1988T
Cropping pattern (CP)	1	490.9++	813.4++	1880.9++
Interrow spacing (INTER)	2	235.1++	535.1++	822.1++
Intrarow spacing (INTRA)	3	426.5++	861.5++	1879.8++
CP x INTER	2	28.4 ns	21.8 ns	56.8+
CP x INTRA	3	30.3 ns	68.2 ns	40.7 ns
INTER x INTRA	6	28.2 ns	52.0 ns	97.9 ns
CP x INTER x INTRA	6	50.7 ns	29.3 ns	186.8
Error	46	229.6	431.5	358.6

[a]Three seasons in 1987/88: F = First season (April-July, 1988); S = Second season (August-November, 1988; and T = Third season (December 1988 - March 1989).

++Significant at 1% level
+Significant at 5% level
ns = Not significant.

Appendix 15. Analyses of variance for the effect of cropping pattern and spacing on the severity of brown blotch disease on cowpea pods during three growing seasons[a] in 1988/89.

Sources of variation	Degrees of freedom	Sum of squares		
		1988F	1988S	1988T
Cropping pattern (CP)	1	172.9+	606.7+	10.9ns
Interrow spacing (INTER)	2	1492.5++	1234.5++	715.5+
Intrarow spacing (INTRA)	3	3612.4++	1303.7++	1965.8++
CP x INTER	2	7.4 ns	21.4 ns	22.5
CP x INTRA	3	6.4 ns	4.4 ns	3.0
INTER x INTRA	6	79.9ns	177.9 ns	104.9
CP x INTER x INTRA	6	28.9 ns	2.8 ns	39.3
Error	46	2148.5	86.9	2721.4

[a]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November, 1988; and T = Third season (December, 1988 - March, 1989).

++Significant at 1% level
+Significant at 5% level
ns = Not significant.

Appendix 16. Analyses of variance for the incidence of anthracnose disease on cowpea as affected by variety and cropping pattern at three sampling times during three growing seasons[a] in 1988/89.

Sources of variation	Degrees of freedom	Sum of squares		
		40 DAP[b]	54 DAP	68 DAP
1988F				
Cropping pattern	4	686.2++	2475.0++	4173.1++
Variety	2	1023.7++	2985.0++	2535.0++
Interaction	8	100.3+	317.8++	278.7++
Error	28	32.3	48.1	31.7
1988S				
Cropping pattern	4	1929.4++	2639.4++	823.1++
Variety	2	926.2++	1785.0++	2951.2++
Interaction	8	40.3ns	206.6++	240.3++
Error	28	25.5	23.4	28.2
1988T				
Cropping pattern	4	873.1++	2233.1++	2868.7++
Variety	2	213.7++	1398.7++	1968.7++
Interaction	8	95.0++	175.3++	107.8++
Error	28	24.2	47.0	21.8

[a]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November, 1988); and T = Third season (December, 1988 - March, 1989).

[b]Days after planting

++Significant at 1% level
+Significant at 5% level
ns = Not significant.

Appendix 17. Analyses of variance for the incidence of brown blotch disease on cowpea as affected by varietal and cropping pattern at three sampling times in three growing seasons[a] in 1988/89.

Sources of variation	Degrees of freedom	Sum of squares		
		40 DAP[b]	54 DAP	68 DAP
1988F				
Cropping pattern	4	1131.8++	1670.6++	4776.8++
Variety	2	1495.5++	2171.2++	496.8++
Interaction	8	139.3+	104.1++	35.9ns
Error	28	13.5	7.9	15.3
1988S				
Cropping pattern	4	1085.5++	1715.1++	2671.9++
Variety	2	190.5++	3165.1++	2625.0++
Interaction	8	32.7ns	96.4++	56.2 ns
Error	28	17.2	16.8	28.1
1988T				
Cropping pattern	4	1055.8++	2585.5++	2998.0++
Variety	2	372.6++	858.5++	1090.5++
Interaction	8	21.1 ns	94.9 ns	134.8++
Error	28	13.4	26.6	20.5

[a]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November, 1988); and T = Third season (December, 1988 - March, 1989).

[b]Days after planting

++Significant at 1% level
ns = Not significant.

Appendix 18. Analyses of variance showing severity of anthracnose disease on cowpea as affected by varietal and cropping pattern effects at three stages of plant growth in three growing seasons[a] of 1988/89.

Sources of variation	Degrees of freedom	Sum of squares		
		40 DAP[b]	54 DAP	68 DAP
1988F				
Varieties	2	986.3++	3041.2++	4715.2++
Cropping patterns	4	1311.7++	9850.8++	10577.2++
Interaction	8	196.6 ns	886.8++	756.8++
Error	28	542.6	589.1	581.6
1988S				
Varieties	2	19.9 ns	4607.9++	6144.4++
Cropping patterns	4	1461.5++	5174.9++	9407.2++
Interaction	8	60.1ns	756.1 ns	1289.6++
Error	28	303.5	2799.9	721.5
1988T				
Varieties	2	5.4 ns	91.9+	948.7++
Cropping patterns	4	98.0++	1496.7++	4955.4++
Interaction	8	69.0++	187.8+	509.3++
Error	28	58.4	276.3	178.8

[a]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November, 1988); and T = Third season (December, 1988 - March, 1989).

[b]Days after planting

++Significant at 1% level of probability
+Significant at 5% level of probability
ns = Not significant.

Appendix 19. Analyses of variance showing severity of brown blotch disease on cowpea as affected by varietal and cropping pattern effects at three stages of plant growth in three growing seasons[a] of 1988/89.

Sources of variation	Degrees of freedom	Sum of squares		
		40 DAP[b]	54 DAP	68 DAP
1988F				
Varieties	2	615.3++	9626.4++	143.7++
Cropping patterns	4	562.9++	15050.4++	21262.7++
Interaction	8	121.2+	2138.7++	2858.1++
Error	28	151.1	338.2	276.4
1988S				
Varieties	2	193.0++	448.4++	3076.0++
Cropping patterns	4	1459.8++	6670.0++	7321.8++
Interaction	8	73.2ns	159.5 ns	720.5 ns
Error	28	223.5	416.4	1020.8
1988T				
Varieties	2	0.3 ns	44.3ns	1123.1++
Cropping patterns	4	22.3 ns	3077.1++	3635.9++
Interaction	8	1.6 ns	576.4 ++	323.2++
Error	28	61.8	278.8	306.9

[a]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November, 1988); and T = Third season (December, 1988 - March, 1989).

[b]Days after planting

++Significant at 1% level
ns = Not significant.

Appendix 20. Incidence[a] (%) of anthracnose disease on cowpea pods as influenced by cropping pattern and cowpea variety during three seasons in 1988/89[b].

Cropping pattern	1988F				1988S			1988T			
	IT84S-2246-4	Ife Brown	IT82E-16	Mean	IT84S-2246-4	Ife Brown	IT82E-16	IT84S-2246-4	Ife Brown	IT82E-16	Mean
Interrow	4.0	45.7	51.7	45.8 ab*	26.0	39.6	39.2	34.0	39.0	46.5	39.8 a
Doublerow	59.7	58.7	74.2	64.2 bc	40.0	40.0	48.9	54.7	55.0	58.9	56.2 b
Intrarow	54.5	61.8	68.5	61.6 b	30.9	46.8	52.6	48.7	60.9	63.8	57.8 b
Strip	62.2	65.3	71.4	66.8 c	43.5	49.7	57.0	60.8	64.5	68.3	64.6 c
Sole	72.0	78.0	84.0	78.0 d	54.0	56.0	63.0	68.9	75.0	79.3	74.4 d
Variety mean	57.7 a	61.9 b	70 c					53.5 a	58.9 b	63.3 c	
Interaction		ns				++			ns		
CV %		7.2				7.5			7.6		

[a]Average of three replications
[b]Three seasons in 19888/89: F = First season (April-July, 1988); S = Second season (August-November, 1988; and T = Third season (December, 1988 - March, 1989)
*Only means followed by different letter(s) within a column for each factor differ significantly at P ≤ 0.05 (DMRT).
+Significant at 5% level.
ns = Not significant.

Appendix 21. Mean squares for the effect of cropping pattern and variety on the incidence of brown blotch disease on cowpea pods during three growing seasons[a] in 1988/89.

Sources of variation	Degrees of freedom	Sum of squares		
		1988F	1988S	1988T
Cropping pattern	4	176.9++	1892.9++	864.9++
Variety	2	832.3++	893.4++	453.8++
Interaction	8	105.3++	19.8 ns	13.9 ns
Error	28	38.5	25.3	40.3

[a]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November, 1988); and T = Third season (December, 1988 - March, 1989).

++Significant at 1% level of probability
+Significant at 5% level of probability.
ns = Not significant.

Appendix 22. Analyses of variance for the effect of cropping pattern and variety on anthracnose disease on cowpea seed weight during three growing seasons[a] in 1988/89.

Sources of variation	Degrees of freedom	Sum of squares		
		1988F	1988S	1988T
Cropping pattern	4	3.3+	1.1 ns	0.8 ns
Variety	2	50.0++	18.6++	40.5++
Interaction	8	10.1++	1.9ns	0.4 ns
Error	28	7.3	7.4	4.8

[a]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November, 1988); and T = Third season (December, 1988 - March, 1989).

++Significant at 1% level of probability

+Significant at 5% level of probability.

ns = Not significant.

Appendix 23. Analyses of variance for the effect of cropping pattern and variety on cowpea seed weight following brown blotch infection during three growing seasons[a] in 1988/89.

Sources of variation	Degrees of freedom	Sum of squares		
		1988F	1988S	1988T
Cropping pattern	4	0.9 ns	1.1 ns	1.4 ns
Variety	2	94.3++	27.4++	24.7++
Interaction	8	1.5 ns	1.6 ns	2.5 ns
Error	28	6.4	4.5	5.6

[a]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November, 1988); and T = Third season (December, 1988 - March, 1989).

++Significant at 1% level of probability
+Significant at 5% level of probability.
ns = Not significant.

Appendix 24. Mean squares[a] showing the effect of cropping pattern and variety on the yield of cowpea infected with *Colletotrichum lindemuthianum* during three growing seasons[b] in 1988/89.

Sources of variation	Degrees of Freedom	1988F	1988S	1988T
Cropping pattern	4	42326.2++	33105.6++	36750.2++
Variety	2	21822.3+	16026.3++	38089.0++
Interaction	8	3133.1ns	2441.3++	4138.7++
Error	28	4190.1	507.2	787.6

[a]Average of three replications.
[b]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November, 1988) and T = Third season (December 1988 - March 1989).
++Significant at 1% level
+Significant at 5% level
ns - Not significant.

Appendix 25. Mean squares[a] showing the effect of cropping pattern and variety on the yield of cowpea infected with *C. truncatum* during three growing seasons[b] in 1988/89.

Sources of variation	Degrees of Freedom	1988F	1988S	1988T
Cropping pattern	4	60490.8++	40905.1++	34594.3++
Variety	2	4475.3+	2888.8+	2408.4+
Interaction	8	5793.1++	692.6 ns	4668.2++
Error	28	943.6	805.0	533.0

[a]Average of three replications.

[b]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November, 1988) and T = Third season (December 1988-March 1989).

++Significant at 1% level
+Significant at 5% level
ns - Not significant.

Appendix 26. Means squares from the analyses of the effect of *Colletotrichum truncatum* on cowpea genotypes introduced at different times into maize in three growing seasons in 1988/89.

Sources of variation	Degrees of freedom	Sum of squares		
		40 DAP	54 DAP	68 DAP
1988F				
Variety	2	105.3+	287.8+	707.5++
Error A	4	21.4	65.5	12.5
Date of introduction	4	6035.5++	10331.4++	12550.8++
Interaction	8	146.1ns	176.1ns	117.5ns
Error B	24	428.3	377.5	376.7
1988S				
Variety	2	147.8ns	220.3+	1821.9++
Error A	4	68.9	26.4	191.4
Date of introduction	4	5568.6++	5709.2++	1818.6++
Interaction	8	173.0ns	540.8+	369.7ns
Error B	24	643.3	680.0	579.2
1988T				
Variety	2	175.3++	635.3+	772.5++
Error A	4	1.4	73.9	62.5
Date of introduction	4	1298.0++	4593.9++	7357.5++
Interaction	8	67.8ns	545.3ns	765.0ns
Error B	24	236.7	835.8	116.5

[a]Three seasons in 1988/89: F = First season (April-July, 1988); S = Second season (August-November, 1988); and T = Third season (December, 1988 - March, 1989).

[b]Days after planting

++Significant at 1% level
+Significant at 5% level
ns = Not significant.