

AGRONOMIC STUDIES OF SWEETPOTATO
(*IPOMOEA BATATAS* (L.) LAM) INTERCROPPED WITH BEAN
(*PHASEOLUS VULGARIS* L.)

BY

CHARLES NAPOLY OCITTI P'OBWOYA

B.Sc. Agric.(Njala, University of Sierra-Leone)

M.Sc. Agronomy (University of Ibadan, Nigeria)

A Thesis submitted in fulfilment of the requirement

for the Degree of

DOCTOR OF PHILOSOPHY

of Makerere University

Department of Crop Science

Faculty of Agriculture and Forestry

Makerere University

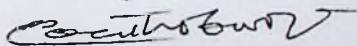
Kampala

NOVEMBER 1996

DECLARATION

I, the undersigned, declare that this Thesis is my original work which has not been submitted for any degree in any University.

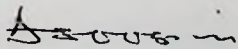
Signed



Date 12-11-96

This Thesis has been submitted for examination with my approval as the University supervisor.

Signed



Date 12-11-96

Professor D.S.O Osiru.
B.Sc (Agric); M.Sc; Ph.D.

TABLE OF CONTENTS

	Page
Title	1
Declaration	2
Dedication	3
Table of Contents	4
List of Tables	5
List of Figures	6
Chapter 1: Introduction	7
Chapter 2: Literature Review	10
Chapter 3: Methodology	15
Chapter 4: Results and Discussion	20
Chapter 5: Conclusion	25
References	28
Appendix	30

DEDICATION

To my dear sisters, Rose Mary Abwo- Akoborach and Samali Acaa-
Latete for their love and care.

CHAPTER 1: INTRODUCTION

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction and Background of the Study

2.1.1

2.2. Theoretical Framework and Conceptual Model

2.3. Research Objectives and Research Questions

2.4. Significance of the Study

2.5. Scope and Limitations of the Study

2.6. Summary of the Chapter

TABLE OF CONTENTS

	Page
Title	i
Declaration	ii
Dedication	iii
Table of contents	iv
List of Tables	ix
List of Figures	xxii
List of Appendices	xxv
Acknowledgement	xxix
Abstract	xxxi
 CHAPTER 1: Introduction	 1
 CHAPTER 2: Literature Review	 7
 2.1 Intercropping and its importance in subsistence farming	 7
2.2 Sweetpotato and bean in Tropical Agriculture	11
2.2.1 Sweetpotato and bean cultivation in Uganda	12
2.2.2 Sweetpotato and bean cropping calendar	17
2.2.3 Sweetpotato and bean production constraints	18
2.3 Sweetpotato genotypes for intercropping	19

2.4	Plant population and spatial arrangement in	
	intercrops	22
2.5	Competition for growth resources	27
2.5.1	Competition for light	29
2.5.2	Competition for nutrients	31
2.5.3	Symbiotic N ₂ Fixation in legume-non legume	
	crop association	33
2.5.4	Competition for water	35

CHAPTER 3: Materials and Methods

3.1	Description of the experimental site	38
3.2	Soil sampling and analysis	40
3.3	Leaf sampling and analysis	41
3.4	Experiment I, 1993/94 and 1994/95 seasons	42
3.4.1	Treatments and Experimental design	42
3.4.2	Land preparation	48
3.4.3	Sweetpotato measurements	51
3.4.4	Bean measurements	52
3.5	Experiment II, 1994/95 and 1995/96 seasons	53
3.5.1	Treatment and Experimental design	54
3.6	General measurements	59
3.6.1	Leaf area index	59
3.6.2	Light interception by crops	59

3.6.3 Crop growth rate (CGR)	60
3.7 Assessment of competition, Aggressivity and Yield	
Advantages in Sweetpotato/bean association	61
3.7.1 Competition ratio (CR)	61
3.7.2 Aggressivity coefficient (AC)	62
3.7.3 Land Equivalent Ratio (LER)	62
3.7.4 Area Time Equivalent ratio (ATER)	63
3.7.5 Economic Evaluation	64

CHAPTER 4: Results

4.1 Soil physical and chemical characteristics at the experimental sites	65
4.2 Experiment I. Compatibility of different sweetpotato and bean morphotypes grown in association, 1993/94 and 1994/95 seasons.....	65
4.2.1 Photosynthetically active radiation (PAR) interception	65
4.2.2 Sweetpotato growth	68
4.2.3 Sweetpotato yield and yield components	76
4.3 Bean growth	89
4.3.1 Common bean plant diseases	97
4.3.2 Bean yield and yield components	97
4.3.3 Sweetpotato/bean intercrop productivity	106

4.3.4 Competition between sweetpotato and bean	109
4.3.5 Aggressivity coefficient (AC)	115
4.4.0 Land use efficiency in sweetpotato/bean association	118
4.4.1 Monetary equivalent ratio (MER)	122
4.5.0 Experiment II. Effects of sweetpotato spatial arrangement and population density on the performance of sweetpotato in sweetpotato/bean association (1994/95 and 1995/96)	122
4.5.1 Photosynthetically active radiation interception	122
4.5.2 Sweetpotato growth	126
4.5.3 Sweetpotato yield and yield components	133
4.6.0 Bean growth	151
4.6.1 Common bean plant diseases	157
4.6.2 Bean yield and yield components	157
4.7.0 Sweetpotato/bean intercrop productivity	168
4.7.1 Competition between sweetpotato and bean	168
4.7.2 Aggressivity coefficients (AC)	178
4.7.3 Land use efficiency in sweetpotato/bean association	181
4.7.4 Monetary equivalent ratio (MER)	181
4.8.0 Foliar nutrient levels in sweetpotato and bean at 45 DAP	187

4.8.1 Soil nutrient uptake under sweetpotato/bean association	191
CHAPTER 5. Discussion	194
CHAPTER 6: Summary, Conclusion and Recommendation	220
REFERENCES	229
APPENDICES	257

LIST OF TABLES

Table		Page
1	Weather characteristics during experimentation periods for three seasons at Namulonge Agricultural and Animal Production Research Institute (NAARI), Kampala, Uganda.	39
2	Morphological characteristics of eight local sweetpotato genotypes evaluated	44
3	Storage root characteristics of eight local sweetpotato genotypes evaluated	45
4	Morphological characteristics of improved bean genotypes evaluated	46
5	A matrix of treatment combinations (intercrops) and control (sole crops), 1993/94 and 1994/95 cropping seasons [Experiment I]	47

6	The historical cropping patterns of the experimental sites at Namulonge Agricultural and Animal Production Research Institute	49
7	Spatial arrangement and population density for sweetpotato in association with beans	58
8	A matrix of treatment combinations (intercrops) and control (sole crop), 1994/95 and 1995/96 cropping seasons [Experiment II]	58
9	Physical and chemical characteristics of the soil at the experimental sites, Namulonge Agricultural and Animal Production Research Institute, Kampala, Uganda	66
10	Effects of intercropping different sweetpotato and bean genotypes on photosynthetically active radiation (PAR) interception (1993/94 and 1994/95)	67
11	Effects of sweetpotato morphotypes on sweetpotato vine length and growth rate (1993/94)	69

- 12 Effects of sweetpotato and bean morphotypes on
sweetpotato vine length and vine growth rate in
sweetpotato/bean association (1994/95) 70
- 13 Effects of sweetpotato plant types on sweetpotato dry
matter accumulation (DMA) in sweetpotato,
1993/94 and 1994/95 cropping seasons 73
- 14 Effects of intercropping on crop growth rate (CGR) in
sweetpotato, 1993/94 and 1994/95 cropping seasons . . . 74
- 15 Effects of intercropping on sweetpotato leaf area
index (LAI) (1993/94 and 1994/95) 75
- 16 Performance of eight sweetpotato genotypes when
intercropped with bean, 1993/94 cropping season 82
- 17 Performance of six sweetpotato genotypes when
intercropped with bean, 1994/95 cropping season 83
- 18 Effects of sweetpotato and bean morphotypes on the
performance of sweetpotato in sweetpotato/bean
association, 1993/94 cropping season 84

19	Effects of sweetpotato and bean morphotypes on the performance of sweetpotato in a sweetpotato/bean association, 1994/95 cropping season	85
20	Levels of significance from analysis of variance and contrasts in yield and yield components of eight sweetpotato and four bean genotypes (1993/94) [Experiment I]	86
21	Levels of significance from analysis of variance and contrasts in sweetpotato yield and yield components in mixtures of six sweetpotato and two bean genotypes (1994/95) [Experiment I]	87
22	Yield response of different sweetpotato genotypes to different bean genotypes in sweetpotato/bean association, 1993/94 and 1994/95 cropping seasons	88
23	Effects of intercropping on bean plant height in sweetpotato/bean association, 1993/94 and 1994/95 cropping seasons	91

24	Effects of intercropping on bean dry matter accumulation (DMA), 1993/94 and 1994/95 cropping seasons	92
25	Effects of intercropping on bean crop growth rate (CGR), 1993/94 and 1994/95 cropping seasons	93
26	Effects of intercropping on bean leaf area index (LAI) (1993/94)	95
27	Effects of intercropping on bean leaf area index (LAI) (1994/95)	96
28	Effects of intercropping on bean yield and yield components 1993/94 and 1994/95 cropping seasons . . .	101
29	Effects of intercropping different sweetpotato and bean morphotypes on the performance of bean 1993/94 cropping season	102
30	Effects of intercropping different sweetpotato and bean morphotypes on the performance of bean 1994/95 cropping season	103

31	Levels of significance from analysis of variance and contrasts in bean yield and yield components in mixtures of eight sweetpotato and four bean genotypes, 1993/94 cropping season	104
32	Yield response of different bean genotypes to different sweetpotato genotypes in sweetpotato/bean association, 1993/94 and 1994/95 cropping season	105
33	Sweetpotato/bean intercrop productivity 1993/94 cropping season	107
34	Sweetpotato/bean intercrop productivity 1994/95 cropping season	108
35	Competitive abilities of sweetpotato genotypes in sweetpotato/bean association 1993/94 cropping season	110
36	Competitive abilities of sweetpotato genotypes in sweetpotato/bean association, 1994/95 cropping season	111

37	Competitive abilities of bean genotypes in sweetpotato/bean association, 1993/94 and 1994/95 cropping seasons	112
38	Relative yields (RY) of bean and sweetpotato in sweetpotato/bean association, 1993/94 cropping season	113
39	Relative yields (RY) of bean and sweetpotato in sweetpotato/bean association, 1994/95 cropping season	114
40	Aggressivity coefficient (AC) in sweetpotato/bean association, 1993/94 cropping season	115
41	Aggressivity coefficient (AC) in sweetpotato/bean association, 1994/95 cropping season	117
42	Land equivalent ratio (LER) in sweetpotato/bean association, 1993/94 cropping season	119
43	Land equivalent ratio (LER) in sweetpotato/bean association, 1994/95 cropping season	120

44	Area time equivalent ratio (ATER) for sweetpotato/bean association, 1993/94 and 1994/95 cropping seasons . . .	121
45	Monetary equivalent ratio for sweetpotato and bean in a sweetpotato/bean association, 1993/94 and 1994/95	123
46	Monetary equivalent ratios (MERS) under various combinations of sweetpotato and bean genotypes in a sweetpotato/bean association, 1993/94 and 1994/95 cropping season	124
47	Effects of sweetpotato spatial arrangement and plant population density on photosynthetically active radiation (PAR) interception interception in sweetpotato/bean association 1995/96	125
48	Effects of sweetpotato spatial arrangement and population density on sweetpotato vine growth in sweetpotato/bean association, 1994/95	127

49	Effects of sweetpotato spatial arrangement and population density on sweetpotato vine growth in sweetpotato/bean association, 1995/96 cropping season	128
50	Effect of sweetpotato spatial arrangement and population density on the performance of sweetpotato in sweetpotato/bean association, 1994/95 cropping season	134
51	Effect of sweetpotato spatial arrangement and population density on the performance of sweetpotato in sweetpotato/bean association, 1995/96 cropping season	135
52	Levels of significance from analysis of variance and contrasts in yield and yield components of sweetpotato in mixtures with bean and three sweetpotato genotypes, two spatial arrangements and four sweetpotato population densities 1994/95 [Experiment II]	139

53	Levels of significance from analysis of variance and contrasts in yield and yield components of sweetpotato in mixtures with bean and three sweetpotato genotypes, two spatial arrangement and four sweetpotato population densities 1995/96 [Experiment II]	140
54	Effects of sweetpotato spatial arrangement and population density on bean plant height in sweetpotato/bean association, 1994/95 cropping season	152
55	Effects of sweetpotato spatial arrangement and population density on bean plant height in sweetpotato/bean association, 1995/96 cropping season	153
56	Effect of sweetpotato spatial arrangement and population density on the performance of bean in sweetpotato/bean association, 1994/95 cropping season	160

57	Effect of sweetpotato spatial arrangement and plant population density on the performance of bean in sweetpotato /bean association, 1995/96 cropping season	161
58	Levels of significance from analysis of variance and contrasts in bean yield and yield components in mixtures with three sweetpotato genotypes, two spatial arrangements and four sweetpotato population densities 1994/95 [Experiment II]	165
59	Levels of significance for analysis of variance and contrasts in bean yield and yield components in mixtures with three sweetpotato genotypes, two spatial arrangements and four sweetpotato population densities 1995/96 [Experiment II]	166
60	Sweetpotato/bean intercrop productivity, 1994/95 and 1995/96 cropping seasons	170
61	Effects of sweetpotato spatial arrangement and plant population density on competitive abilities of sweetpotato and bean, 1994/95 cropping season	171

- 62 Effects of sweetpotato spatial arrangement and plant population density on competitive abilities of sweetpotato and bean in sweetpotato/bean association, 1995/96 cropping season 172
- 63 Relative Yields (RY) and Land equivalent Ratios (LER) in sweetpotato/bean association, 1994/95 and 1995/96 cropping seasons 177
- 64 Aggressivity Coefficient (AC) in Sweetpotato/bean association, 1994/95 and 1995/96 seasons 180
- 65 Area Time Equivalent Ratio (ATER) in sweetpotato/bean association, 1994/95 and 1995/96 cropping seasons . . . 183
- 66 Effects of sweetpotato spatial arrangement and population density on relative monetary equivalent ratio (MER) in sweetpotato/bean association, 1994/95 cropping season 184
- 67 Effects of sweetpotato spatial arrangement and population density on relative monetary equivalent ratio (MER) in sweetpotato/bean association, 1995/96 cropping season 185

- 68 Effects of sweetpotato spatial arrangement and population density on monetary equivalent ratio (MER) in sweetpotato/bean association, 1994/95 and 1995/96 cropping seasons 186
- 69 Competition ratios, relative yields, and land use efficiency in sweetpotato/bean cropping systems during four cropping seasons under the Namulonge conditions . . 188
- 70 Effects of intercropping sweetpotato with beans on foliar nutrient concentration in sweetpotato and bean crops at 45 DAP (1995/96) 190
- 71 Effects of intercropping sweetpotato with beans on soil nutrient levels prior to planting, during growth and at bean and sweetpotato harvest (1995/96) 192

LIST OF FIGURES

Figure	Page
1	Spatial arrangement of sweetpotato and bean crop rows in intercropped and sole-cropped situations 50
2	Spatial arrangement of sweetpotato and bean crop rows in mixtures-single row of sweetpotato and double rows of bean 56
3	Spatial arrangement of sweetpotato and bean crop rows in mixtures-double rows of sweetpotato and bean 57
4	Effects of sweetpotato spatial arrangement and population density on sweetpotato dry matter weight . . . 131
5	Changes in sweetpotato LAI with sweetpotao population density 132
6	Effects of sweetpotato spatial arrangement and population density on sweetpotato storage root quality-number of marketable roots/plot 137

7	Effects of sweetpotato spatial arrangement and population density on sweetpotato storage root quality-number of unmarketable roots/plot	138
8	Effects of sweetpotato spatial arrangement and population density on storage root size distribution - average weight of marketable root (g/root)	144
9	Effects of sweetpotato spatial arrangement and population density on storage root size distribution -average weight of unmarketable root (g/root)	145
10	Effects of sweetpotato spatial arrangement and population density on total fresh root yield	147
11	Effects of sweetpotato spatial arrangement and population density on bean dry matter weight	154
12	Changes in bean LAI with sweetpotato population density	156
13	Effects of sweetpotato spatial arrangement and population density on number of seeds per plant	162

- 14 Effects of sweetpotato spatial arrangement and
population density on bean seed yield 167
- 15a Sweetpotato at low population density with CR of
2.12 against 0.61 for bean. Bean competed favourably
with sweetpotato 174
- 15b Sweetpotato at moderately low population density
with CR of 3.22 against 0.42 for bean. Bean competed
well with sweetpotato 174
- 16a Sweetpotato at its optimum population density in
mixtures with bean. Sweetpotato dominating with
CR of 5.38 against 0.24 for bean 175
- 16b Sweetpotato at high population density dominating
over bean with a CR of 5.3 against 0.24 for bean 175
- 17a Tororo 3, the most competitive sweetpotato genotype.
It mixes more intimately with bean 176
- 17b Sweetpotato genotype Bwanjule growing away from bean
in order to receive better interception of
photosynthetically active radiation 176

LIST OF APPENDICES

Appendix	Page
1 Sweetpotato and Bean World production trend	257
2 Map of Uganda showing the distribution of sweetpotato production by district	258
3 Map of Uganda showing the distribution of sweetpotato productivity by district	259
4 Map of Uganda showing the distribution of bean production by district	260
5 Map of Uganda showing the distribution of bean productivity by district	261
6 Percentage contribution of major Food crops to Total Food Crop Tonnage	262
7 Importance of Association of sweetpotato with other crops in seven districts in Uganda	263

8	An outline of analysis of variance table for sweetpotato and bean attributes (1993/94 cropping season) [Experiment I]	264
9	An outline of analysis of variance table for sweetpotato and bean attributes (1994/95 and 1995/96 cropping season) [Experiment II]	265
10	An outline of the combined analysis of variance table for sweetpotato and bean attributes over seasons (1993/94 and 1994/95) cropping seasons) [Experiment I]	266
11	An outline of the combined analysis of variance table for sweetpotato and bean attributes over seasons (1994/95 and 1995/96 cropping seasons [ExperimentII]	267
12	Levels of significance from combined analysis of variance and contrasts for sweetpotato yield and yield components in sweetpotato/bean association (1993/94 and 1994/95) [Experiment I]	268

13	Levels of significance from combined analysis of variance for bean yield and yield components in sweetpotato/bean association (1993/94 and (1994/95) [Experiment I]	269
14	Levels of significance from combined analysis of variance and contrasts for sweetpotato yield and yield components in sweetpotato/bean association (1994/95 and 1995/96) [Experiment II]	270
15	Levels of significance from combined analysis of variance and contrasts for bean yields and yield components in sweetpotato/bean association (1994/95 and 1995/96) [Experiment II]	271
16	Correlation coefficients (r) of foliar nutrient content in bean with soil available nutrients at 45 DAP	272
17	Correlation coefficients (r) of foliar nutrient content in sweetpotato with soil available nutrients at 45 DAP	273
18	Correlation coefficients (r) among soil nutrient levels and bean seed yield at bean harvest	274

19	Correlation coefficients (r) among available soil nutrient levels and sweetpotato root yield at sweetpotato harvest	275
----	--	-----

ACKNOWLEDGEMENTS

I wish to acknowledge a number of people without whose assistance and cooperation the task would not have been completed.

I am particularly indebted to Professor D.S.O. Osiru (major supervisor) and Professor J.C.M.Ddungu (second supervisor) of the Department of Crop Science, Makerere University, Kampala not only for their supervision, advice, constructive criticisms but also their active interest in the research.

I wish to thank Dr. Ted Carey, Regional Sweetpotato Breeder, International Potato Center(CIP) for his interest, advice, criticism and moral support. I am thankful to Professor James Oehmke of Michigan State University for his advice on statistics and Dr. C.S. Wortmann for his advice and technical support.

I am heavily indebted to Dr.S. Nganga, the former Regional Representative, CIP for his administrative support in soliciting funds to undertake this study; Dr.P.T.Ewell, the current CIP Regional Representative for his continued effort in soliciting funds to see this study completed. I wish to thank Professor J.K.Mukiibi, Director General, National Agricultural Research Organization.(NARO) and Dr.T. Sengooba, the Director of Research, Namulonge Agricultural and Livestock Research Institute (NAARI) and Mr.D.R.Akimanzi, National Coordinator, National Potato Research and Development Program for their administrative support.

I wish to thank all sweetpotato sub-program staff for their moral support. Finally, I am greatly indebted to my wife and children for their patience and encouragement. Above all, I thank Almighty God for his guidance throughout the study period.

ABSTRACT

Intercropping of sweetpotato with beans is common in highly populated medium and high altitude areas of Uganda. Both sweetpotato and bean are crops on which abundant research information is available. However, knowledge is still lacking on how the two crops interact when grown in the proximity of each other. This problem was addressed by conducting two sets of sweetpotato/bean intercropping experiments between 1993 and 1995 at Namulonge Agricultural and Animal Production Research Institute (NAARI), Kampala. The first experiment aimed at evaluating the compatibility of different sweetpotato morphotypes with bean of different growth types. It consisted of eight sweetpotato genotypes (Wagabolige, Entry 20, Entry 21, Bitambi, Tororo 3, New Kawogo and Tanzania) and four bean genotypes (White Haricot, MMS 224, A 197, and GLP 585) in the 1993/94 season with the objective to study the compatibility of the mixtures. In the 1994/95 season, six sweetpotato genotypes (Wagabolige, Bitambi, Tororo 3, New Kawogo and Tanzania) and two bean genotypes (White Haricot and GLP 585) were used. In both seasons double rows of bean were planted with double rows of sweetpotato at densities of about 440,000 and 33,333 plants/ha for bean and sweetpotato, respectively, in a split plot design in four replications. The second experiment aimed at determining the effects of spatial arrangements and plant population density of sweetpotato on the productivity of the components.

It consisted of one bean genotype (White Haricot); three sweetpotato genotypes (Wagabolige, Bwanjule and Tororo 3); two spatial arrangements (single and double rows) and four sweetpotato plant densities (16,666; 22,222; 33,333 and 66,666 plants/ha). Double rows of bean were planted with either single or double rows of sweetpotato in a split-split plot design in three replications. Growth and yield measurements were done at 4 WAP and continued at two weeks interval. Beans and sweetpotato were harvested at three and six MAP, respectively.

Light interception efficiency increased by an average of 8.1% of the sole crop. Sweetpotato vine growth rate was reduced by intercropping in all plant types except the spreading type. Bean plant height and leaf area indices of both species were also reduced by intercropping. Sweetpotato LAI increased with an increase in sweetpotato population while bean LAI increased with an increase in plant height and number of primary branches.

Storage root yield was increased by intercropping in the first experiment by an average of 23.1%, of the sole crop yield, but was reduced by an average of 22% in the second experiment. Bean yield was reduced by an average of 40.7% and 54% in the first and second experiments, respectively. The most compatible sweetpotato and bean morphotypes for intercropping relative to their respective sole crop yield was the erect and the determinate types, respectively.

In the first experiment the highest productivity of 30.1 t/ha and 28.4 t/ha were produced in mixtures with genotype Wagabolige in 1993/94 and 1994/95 season, respectively.

In 1994/95 and 1995/96 cropping seasons (experiment II), the highest productivity of 15.7 t/ha and 20.1 t/ha, respectively were achieved at 66,666 plants/ha. Bean yields were low accounting for only 2.4% and 1.5% of the productivity in 1994/95 and 1995/96, respectively. Generally bean yields were highest with a sweetpotato population of 22,222 plants/ha.

The competitive ability of bean was higher in single row than double rows but declined with increase in sweetpotato density. Sweetpotato had lower competitive ability in single row than double rows.

Mean land equivalent ratios (LER) were 1.60 and 1.32 and mean LER + ATER (area time equivalent ratio) were 1.33 and 1.53 for 1993/94 and 1994/95, respectively. In 1994/95 and 1995/96 the mean LER were 1.38 and 1.22 with average LER + ATER of 1.38 and 1.21, respectively. These values indicate that sweetpotato/bean association is biologically sound.

In monetary terms, sweetpotato/bean association is economically sound because mean monetary equivalent ratios (MER) were 1.60 and 1.15 for experiment one and two, respectively.

Mixtures of sweetpotato and bean have higher nutrient demand than when they were grown in pure stands, with sweetpotato demand exceeding that of bean.

CHAPTER 1

INTRODUCTION

In Uganda, sweetpotato (*Ipomoea batatas* (L.) Lam) and common bean (*Phaseolus vulgaris* L.) are important subsistence or food security crops for both rural and urban households. The crops are grown largely by small holder farmers particularly women for subsistence, rural employment and cash income. Also, sweetpotato vines are important source of animal feeds and in the wetter areas they are continuously fed to livestock.

Sweetpotato is the third most important starchy staple food after bananas (*Musa spp*) and cassava (*Manihot esculenta* Crantz). In areas where cassava yield has declined due to the epidemics of African Cassava Mosaic Virus Disease (ACMVD), sweetpotato has become an important substitute to cassava. Similarly, in areas where banana yields are low due to the effect of the Black Sigatoka disease (*Mycosphaerella musicola*) and banana weevils (*Cosmopolites sordidus* (Germar), sweetpotato production has increased significantly (Bashaasha *et al.* 1995).

Sweetpotato production is mainly concentrated in the densely populated, mid altitude regions between 1000-2000 meters above sea level where other agricultural activities are also concentrated, therefore, it occasionally competes with other crops for land resources necessitating intercropping or relay cropping.

Between 1986-1988, 1,699,000 t were produced and per capita production of sweetpotato was 95.4 kg/year (FAO, 1989).

Per capita production is higher in western Uganda. Average annual growth in sweetpotato production between 1970-72 and 1980-88 was 2% and production has continued to increase steadily (FAO, 1994).

Sweetpotato has a short-medium growth duration (4-6 months). It can be grown throughout the year in Central Uganda (particularly around the Lake Victoria Crescent) because of year round distribution of rainfall. Two crops of sweetpotato are possible in areas with bimodal rainfall regime. Optimum rainfall of between 750-1000 mm annually with about 500 mm falling during the growing period is required for good sweetpotato production. The crop thrives in well-drained sandy loam soils of pH 5.6-6.6 found in many areas of Uganda. Although sweetpotato can withstand drought conditions, yields are reduced if the drought occurs within the first six weeks after planting (Onwueme, 1978).

The common bean (*Phaseolus vulgaris* L) is the major source of plant protein in rural human diets especially for the middle and lower income people due to its low cost. It is grown by millions of small-scale farmers for home consumption and for market, particularly in the densely populated, intensively cultivated areas. Harvesting of fresh beans allows farmers to extend the period in which households can secure food from bean plantings. Purely commercial bean production is not common because of seed quality problems associated with excessive rainfall (Male-Kanyiwa, 1991). However, some farmers have specialized in bean production for export to Rwanda and Burundi. Both area and yield fluctuate depending on weather conditions but acreage of bean exceeds that of other grain legumes. It is exceeded only by bananas, sweetpotatoes, cassava and occasionally maize and millet (Rubaihayo *et al.*, 1973).

Bean production for 1992-1994 was estimated at 432,000 t and production was 17.7 kg/capita/year (Grisley and Mwesigwe, 1991). Average annual growth in the production of bean between 1970-72 and 1986-1988 was 1.6% and production has continued to increase steadily (FAO, 1994). Bean is grown during both rainy seasons while limited production occurs off-season in hydromorphic areas.

The maturity periods for bean vary with agro-ecological zones. In the short grass land of northern Uganda bean matures at 87 days after planting (DAP), and in eastern Uganda, at 96 DAP. In central and western regions dominated by the tall grasslands zone bean matures at 95 and 109 DAP, respectively (Mukasa, 1961). The variations in maturity period is particularly important with respect to timing the planting date in relation to moisture availability, harvesting time in relation to dry weather and also selection of suitable crop species for intercropping.

In densely populated areas intercropping of bean with other crops is important mainly because of land pressure but in areas where land pressure is not a constraint, beans are intercropped in order to have a diversity of crops and to improve labor use efficiency.

The most common intercrops used in sweetpotato-based cropping systems are legumes such as beans (*Phaseolus vulgaris*), groundnut (*Arachis hypogea*), green gram (*Vigna aureus*); cereals such as maize (*Zea mays*), sorghum (*Sorghum vulgare*) and root crops such as cassava (*Manihot esculenta* Crantz). Sweetpotato is also inter-planted with perennial crops such as coffee (*Coffea arabica* and *Coffea robusta*) and bananas (*Musa spp*).

Intercropping of sweetpotato and bean is common in traditional agricultural

systems in several African countries including Uganda, Ethiopia, Rwanda, Burundi, Zaire, western Kenya and North western Tanzania (Ewell and Kirkby, 1990). Sweetpotato has a short-medium growth cycle and is suited for intercropping with crops with shorter growing periods of 3-4 months such as bean, green gram, groundnut and early maturing maize varieties. These crops mature when sweetpotato crop is in the second phase of its growth which occurs from 9.5-16 WAP (Onwueme, 1978; Woolfe, 1992). The different growth patterns of sweetpotato and bean cause their time of peak demand on resources to differ. This complementarity can give better temporal use of resources (Willey, 1979a).

The advantages of intercropping long cycle crops with short cycle crops have been demonstrated (Willey and Osiru, 1972; Osiru and Willey, 1972; Fisher, 1977). Quirol *et al.* (1985) reported that intercropping sweetpotato with legumes was 3.5 times more profitable than sole cropping.

Various crop combinations are used by farmers. In most cases the yields of the component crops are low probably due to the use of unimproved crop varieties and inappropriate planting patterns and densities. These factors directly influence utilization of environmental resources (Leihner, 1983; Willey, 1979 a).

Sweetpotato and bean differ morphologically and architecturally which may influence their competitive abilities for growth resources. Within each crop, significant genotypic differences exist, which contribute to the differences in both above and below ground competition. The spatial arrangement and plant density of component crops also contribute to competition.

Sweetpotato requires much radiation while beans are relatively shade

tolerant (Wortmann *et al.*, 1991). Therefore, above ground competition may be important for light. In Taiwan, some soybean and sweetpotato genotypes were reported to be more suitable for intercropping than others (AVRDC, 1989). Information is scarce on temporal and spatial planting patterns and population density effects on root competition for moisture and nutrients in intercropping (Sanchez, 1976).

Three sweetpotato varieties responded differently to intercropping with cassava, bean and maize (UNRTCP, 1985) which led to the tentative conclusion that sweetpotato was more compatible with bean and maize than with cassava, and some sweetpotato varieties were more suited than others for intercropping.

Bashaasha *et al.* (1995) reported that associating sweetpotato with beans was the most popular sweetpotato-based intercropping system in Uganda, particularly in densely populated regions but the association has not been much studied by research.

However, intercropping increased sweetpotato storage root yields in one study (Ocitti p'Obwoya and Smit, 1995).

The traditional practice is predominantly mixed intercropping in which more than one genotype of bean and sweetpotato are planted in clusters with no definite pattern. Results of a Rapid Rural Appraisal (RRA) study in Mpigi district in central Uganda showed that 80% (n=100) of farmers intercrop sweetpotato with bean irrespective of their morphotypes. It is likely that the total population and planting arrangements used by farmers in this system are below the optimum, and the associated genotypes may be incompatible. Thus the simplest and more practical way to improve the productivity of sweetpotato/bean intercrop would be

the use of appropriate planting arrangement, suitable genotypes and optimum plant population density.

The main objectives of these studies were:

1. To evaluate the compatibility of selected sweetpotato morphotypes with selected bean morphotypes in sweetpotato/bean intercrops; and
2. To determine the effects of spatial arrangements and plant population density of sweetpotato on the productivity of the association.

CHAPTER 2

LITERATURE REVIEW

2.1 Intercropping and its importance in Subsistence Farming

Intercropping can be defined as the growing of two or more crops simultaneously on the same area of land. The crops are not necessarily sown at the same time and their harvest time may be quite different, but they are usually simultaneous for a significant part of their growing periods. There is intercrop competition during all or part of the crop growth and farmers manage more than one crop at a time in the same field (Willey, 1979 a).

Intercropping has been recognized as a very common practice throughout the developing tropics particularly in areas of high rainfall where temperature and moisture are favourable for year round crop production. In India its importance was highlighted almost 30 years ago in a comprehensive review by Alyer (1949). Historically, it was regarded as a primitive practice which would give way to sole cropping as a natural and inevitable consequences of agricultural development. However, now it has been realized that intercropping has some unique advantages due to which it would continue to be practised for a long time to come (Arnon, 1972; Dalrymple, 1971; Francis, 1975; Norman, 1974; Okigbo and Greenland, 1976).

Though the history of intercropping is old, it is only during the 1970s that the concept has received serious research attention.

Research from sole crops can not readily be applied in intercropping situations. It is also recognized that the existing intercropping systems are relatively cheap and thus more appropriate to resource poor farmers.

The merits and demerits of intercropping have been documented by several workers (Osiru and Willey, 1972; Willey and Osiru, 1972; Fisher, 1975; Okigbo and Greenland, 1975; Willey, 1979a; Willey and Rao, 1980). Recent evidence suggests that the advantages of intercropping can be substantial and important because they are achieved by simply growing crops together. The suggested advantages from intercropping are as follows:

- (i) Greater stability of yield over different seasons. This is of particular importance to small holder resource poor farmers because it can help to ensure food security if one crop fails or grows poorly, the other component crops can compensate. Such compensation is not possible if the crops are grown separately.
- (ii) Assures the farmer a regular and gradual supply of food as the season progresses and guarantees a regular supply of different crops to ensure balanced nutrition.
- (iii) As long as improved varieties of crops are used, the total yield from a

given area may well be higher than when a single crop is planted.

- (iv) More dry matter is produced per unit area of land than under sole cropping and
- (v) A mixture of several crops with different growth habits, root systems and demands on soil may enable the best use to be made of the soil nutrients, light and rainfall and thus provide the maximum return from land cultivated.

These advantages have resulted in more demand for reliable information on improved and more productive intercropping system. However, mixed cropping or intercropping has been considered incompatible with advanced and modern crop production technologies. While it is true that most modern technologies have been developed for sole cropping systems, possibilities exist for such technologies to be applied to mixed cropping systems, although modifications of the technology, the system or both may be necessary (FAO, 1991).

La-Anyae (1985) pointed out that African farmers choose a cropping pattern that could lead to the achievement of specific subsistence and financial goals. As long as agriculture is dominated by the resource poor small holder farmers with the hoe as the only farm tool, there is no technical reason for sole cropping and intercropping is likely to retain its importance, for the foreseeable future (Steiner, 1984). This is likely to be more so in tropical African agriculture which is characterized by small holder farmers and where intercropping or mixed cropping predominates (Okigbo, 1978).

Specific intercropping systems have developed over centuries in the

different regions and have adapted to the prevailing agro-climatic and soil conditions. However, the ratio between areas under sole and mixed crops depends on factors such as ecological zone, farm size and crop species (Okigbo, 1978).

The socio-cultural and eco-economic conditions have led to different cropping systems within the zone. The traditional farming systems take the forms of mixed intercropping which is the growing of two or more crops simultaneously with no distinct row arrangement. Row intercropping and alternate strip intercropping are not common except where animals or tractors are used in cultivation (Okigbo, 1978).

Jameson (1970) estimated the importance of intercropping in traditional agriculture in Uganda by the following proportion of crops grown in association with others; maize 80%, bean 81%, pigeon peas 76%, cow peas 61.8%, sesame 51%, coffee 62% and groundnut 56%. However, with the introduction of new, non-traditional cash crops such as soybean, sunflower, rice, solanum potato and the rapid increase in human population, intercropping has become more intensive as more

than two crops are grown together as arable land becomes fragmented and subjected to continuous cultivation.

Inevitably the original farming and cropping systems and patterns have changed. Small holder farmers have been practising intercropping basically to follow a normal traditional farm practice that has been in existence since time immemorial but due to the prevailing socio-economic circumstances farmers have recognized

that intercropping can maximize returns to the most limiting resources such as land and labour.

2.2 Sweetpotato and bean in Tropical Agriculture

Sweetpotato (*Ipomoea batatas* (L.) Lam.) is a polymorphic dicotyledonous species belonging to the family *Convolvaceae*. It is a plant native to tropical America (Hahn, 1977a; Yen, 1982). It is a perennial plant but is usually grown as an annual crop. It has a growing period of 3-7 months, depending on the environment and cultivar. It is grown over a wide range of environments between latitudes 40° N and 40° S of the equator, and between sea level and 2300 m above sea level. It is well adapted to several farm production systems and its production is world wide and widespread. About 80% of world production is from Asia (China), 15% from Africa and 5% from the rest of the world (Horton, 1988).

The crop grows in a wide range of soils and even on poor, acid soils it can give satisfactory yields. Although grown in areas with high rainfall, it cannot withstand water-logging conditions. It is relatively tolerant to drought.

The common dry or field bean (*Phaseolus vulgaris* L.) is a polymorphic species showing considerable variations in growth habit, vegetative characters, flower colour and size, shape and colour of both seeds and pods. Beans appear to be a relatively recent introduction to Africa from the Americas. Purseglove (1969) reported that they were brought by Spanish and Portuguese travellers to the East Africa coast. Common bean is adapted to both temperate and tropical

climates. In Africa production is concentrated in the cool highlands of central and tropical Eastern Africa lying between 800-2300 m above sea level where beans are the most important pulse crop. The crop can grow well in fertile volcanic soils but does not lend itself to acidic soils with pH 4.2 or below. Mean temperatures in principal areas of bean production ranges from 16 to 24°C. Annual precipitation is in the range of 500-2000 mm with a bimodal distribution in eastern Africa. However, a minimum of 400-800 mm is required for the drier bean growing areas. Sweetpotato and bean production has been increasing steadily (Appendix I).

2.2.1 Sweetpotato and bean cultivation in Uganda

Sweetpotato was well established as an important crop of Uganda at the time of the establishment of the British administration. The crop entered Uganda from both east and western parts of the African continent (Greenway, 1944). Winter (1955) pointed out that the crop was traditionally grown in appreciable quantities by the isolated Aruba tribe and Konjo of the Rwenzori slopes. Sweetpotato cultivation spread to northern Uganda during the early part of this century (Drisberg, 1923).

Today sweetpotato is an important crop that fits well in the farming and food systems of Uganda. It ranks third among starchy staple crops after cassava and banana.

Uganda leads Africa in production and is the fourth in the world producing 1.7 million metric tons annually on over 500,000 hectares. Sweetpotatoes are the

most widely cultivated and evenly spread of all the major Ugandan food crops (Appendices 2 & 3) because they store well in the soil, withstand extreme weather conditions and yield well in marginal soils. Most farmers plant more than five varieties with varied maturity periods enabling harvest all year round. Small plots are utilized, mainly on upland areas during growing season, and on valley bottoms for the off season crop (Bashaasha *et al.*, 1995).

Sweetpotatoes are more concentrated in the south-east of the interior plateau and in the south western highlands than in the highly populated Lake Victoria and mount Elgon regions. The crop has been introduced to some areas in Karamoja. Areas planted in Kabale is high, and the district leads in production but yields are reported to be declining due to deteriorating soil fertility (Bashaasha *et al.*, 1995). This is partly due to high population pressure, poor crop and land resource management systems and heavy reliance on low yielding, disease and pest susceptible land races. The contribution of sweetpotato to the total food crop tonnage was about 11.4% on average (MAAIF, 1994) (Appendix 6).

The crop is propagated from vine cuttings which are planted either on mounds, the most common type of seed bed, except in the highland areas of Kabale, Kabarole and Arua, where both mounds and ridges are used. Ridges are commonly used on hill slopes and are extensively used in the highland areas where ridging reduces soil erosion, and improves moisture conservation. Use of ridges is also becoming important in low land areas because of low labour demand and easy to make (Ocitti p'Obwoya, 1990). Plant density per mound varies from one location to another and sometimes from farmer to another depending on availability of planting materials and the traditional practices in

place. However, 3-4 vine cuttings per mound is the common practice (Bashaasha *et al.*, 1995).

The average mound is 30-45 cm in radius, and 50-60 cm in height, and is placed 90-120 cm apart, depending on the soil type. Vine cuttings may be planted either together in a cluster in the centre of the mound or separately in a triangular or rectangular form. In areas where sweetpotato is planted on ridges measuring 30-45 cm high and 90-120 cm apart, vine cuttings are planted 25-30 cm between plants in single or double rows.

The type of land allocated for sweetpotato cultivation varies among farmers. On average 51.3% use fertile land while 20.4% use infertile, poor land and 15% use newly opened fallow land ($n=344$).

Use of fertile soil may occasionally result in good yield but the risk of getting low yield is high as too much vegetative growth may occur at the expense of storage root development and enlargement (Bashaasha *et al.*, 1995).

The common bean is an important source of protein and calories in human diets in the tropical and sub tropical developing countries, particularly in the Americas accounting for 47%, and Eastern and Southern Africa accounting for 47% and 6%, respectively of world bean production. The immature pod is also one of the most widely eaten green vegetables in the world (Laing *et al.*, 1984).

Common beans are one of the crops grown widely in Uganda. It plays a very significant role as source of protein in the diets of both urban and rural households.

It is not known exactly when bean arrived in Uganda, but it has been estimated

that it arrived in the 18th century. Snowden (1913) reported the cultivation of bean in Uganda and serious bean production began in the 1920's with most of the introductions of new lines made then (Mukasa, 1970). Since 1916 the bean acreage has consistently exceeded that of other leguminous crops grown in the country (Rubaihayo *et al.*, 1981). The common bean is widely grown since farmers plant beans on any type of soil and the crop does well except on highly acid soils (Mukasa, 1970) (Appendices 4-5). Uganda ranks second after Kenya in bean production in Eastern Africa (Londono *et al.*, 1981). In areas where rainfall is high or distributed throughout the year, farmers plant beans whenever they feel there will be sufficient moisture for the crop. Yields as high as 272.7-318.2 kg/ha are obtainable in wetter parts of Buganda, Busoga, Western region and Lango. In drier areas yields are rather low ranging between 181.8-227.3 kg/ha. The crop contributes about 2.5% on average to total food crop tonnage (MAAIF, 1994) (Appendix 6).

In the western highlands of Uganda sweetpotato is the third most important crop after finger millet or sorghum and cassava. In these areas sweetpotato is planted as the major crop occasionally in pure stands but in most cases intercropped with beans and sometimes sparsely intercropped with maize and cassava (Appendix. 7).

In the southern and western tall grassland zone sweetpotato is second after bananas. Other important crops in this zone are cassava, maize and finger millet. In the highland areas of south western region sweetpotato follows a fallow period or is next to last or last in the rotation system. In the east the crop is grown after millet while in the north and some parts of the east it is the third after cassava,

a generally poor and un acceptable cropping pattern which may culminate in poor yield and soil degradation. In southern and western regions sweetpotato is used to open up fallow land and then put back as a last crop, or is the second after maize and bean. In the drier or semi arid rangelands sweetpotato is the third in the rotation after cassava or millet. Cropping systems may vary from one farmer to another and across locations. Each farm household formulates its own cropping system based on its resource endowments, experiences and priorities (Bashaasha *et al.*, 1995). Beans are one of the crops within the subsistence farming systems practised throughout Uganda.

In Uganda, an estimated 75 to 90 percent of beans are grown in association on small farms (Osiru, 1982). The most common intercrop with beans is maize. Bean/banana or bean/coffee associations predominate in some areas. Other companion crops include sweetpotato, peas, cassava, yam, cocoyam, potato and groundnut.

Beans are normally planted in fields which have been previously used for other crops and it is only when beans are intercropped with other crops that they get a chance to grow on newly opened land (Rubaihayo *et al.*, 1981). The spacing used in intercropping varies with the crop genotypes. Bean cultivars with a bush type architecture are generally preferred for intercropping because they do not intertwine with associated crops (Kisakye, 1991).

In bean/sweetpotato association, the bean seeds may just be broadcasted or planted on mounds or in the interspace between mounds. In western Uganda especially in Kabale district beans are haphazardly planted in between the sweetpotato rows on ridges (Bashaasha *et al.*, 1995; Rubaihayo *et al.*, 1981).

When beans are intercropped with maize, cassava, coffee or banana, they are primarily planted as cover crops in the inter spaces (Kisakye, 1991).

2.2.2 Sweetpotato and bean cropping calendar

The planting and harvesting times of sweetpotatoes are flexible. The peak season for planting is usually around March/April in most areas of Uganda. Peak harvesting occurs from June to September. Two crops of sweetpotato are possible in the south western Uganda because of the bimodal rainfall regime, while in northern, eastern, some parts of southern, central, north western and western Uganda only one crop of sweetpotato is possible due to a single rainfall pattern. In most parts of Uganda sweetpotato and beans are planted at the same time (*Bashaasha et al.*, 1995).

Two crops of beans a year are possible in areas with bimodal rainfall regime. The first rain bean crop is normally planted between March and April and harvested between June and July, while the second rain crop is planted between August and September and harvested between November and December.

Many farmers stagger the planting of bean because they want to avoid the heavy rains which can reduce yields. The staggered planting may also be related to household labour availability.

Since beans are rarely planted in pure stands, planting time seems to be under the influence of the main crop in the intercrop (Kisakye, 1991).

2.2.3 Sweetpotato and bean production constraints

Sweetpotato production is constrained by the shortage of clean and healthy planting materials, poor crop management practices such as poor seed bed preparation, low plant density, lack of appropriate intercropping system, untimely planting, weeding and harvesting. Weevils (*Cylas spp*), butter fly (*Acraea acerata*.) larvae and sweetpotato mosaic virus disease complex, root rot and erinose also reduce sweetpotato yield.

The socio-economic constraints include poor marketing organization, low produce price, shortage of labour, poor infrastructure and total lack of storage and packaging facilities, lack of knowledge on processing techniques and lower profitability (Bashaasha *et al.*, 1995)

As observed by Allen *et al.* (1989), wide variability of production conditions results in a wealth of diversity in cropping systems as well as agronomic constraints to bean production.

There are a number of constraints which limit bean yields throughout Africa, although the order of their severity varies significantly over short distances (Kirkby, 1990). These include soil fertility problems which are increasing in importance with increasing pressure on land resources. Seasonal labour shortages also limit bean yields on mixed farms, as farmers can not find time to weed thoroughly and perform other key operations in a timely manner. About 20 bean diseases have so far been identified (Rubaihayo *et al.*, 1981), important among

them are; common bacterial blight (CBB) caused by *Xanthomonas campestris, var.*, bean common mosaic virus (bean virus), *Anthracnose* and *Angular leaf spot* disease (ALS). These cause widespread damage.

Igram *et al.*, (1970) listed important bean pests in Uganda. These include the bean aphids (*Apis fabae*), bean fly (*Melanogromyza spp*), pod borers (*Muruca spp* and *Heliothis spp*), bean weevils (*Bruchids* and *Acanthoscelides*).

Within the household, a major problem is that bean takes a long time to cook. Fuel wood is a scarce resource in densely populated regions and in urban areas. However, research effort is being put by CIAT and the Uganda National Bean Program to develop faster cooking varieties and improved cooking methods (Desert, 1987).

2.3 Sweetpotato genotypes for intercropping

A number of sweetpotato genotypes with varied plant types, growth habits, vigour, vine length, leaf outline, lobes, leaf number, shape, size and petiole length are available. These morphotypes may influence the performance of intercrops in terms of the efficiency in resource utilization.

The sweetpotato varieties with erect growth habit, depending on the morphotypes may cause more or less shade to a low growing intercrop like common bean than those with spreading or semi-compact growth habit. Other factors such as leaf shape, size, petiole length and orientation, also participate in determining competition for light.

Willey (1979 a,b) has summarized data from multiple sources which showed that

substantial yield increases were associated with difference in the maturity periods of components of intercrop system. Components which differ in leaf arrangements and rooting systems may experience less shoot and root competitions for light and soil factors, respectively. Based on this, it is therefore imperative to identify sweetpotato and bean morphotypes for mixed cropping since the behaviour of these components in mixtures can not easily be predicted from that of the sole crops.

Several studies have been conducted in an attempt to identify suitable component genotypes for intercropping. Semu and Jana (1975) intercropped 12 varieties of soybean with maize to study the effects on growth and yields of both crops in pure stand and when intercropped. The results showed that soybean yield was decreased by 63% while maize yield decreased by only 8%. May and Misangu (1982) evaluated 20 genotypes of green gram, 20 genotypes of sesame and 9 genotypes of sunflower in four cropping systems. Yield differences existed among genotypes of each crop evaluated. However, genotype x cropping system interaction was not significant.

Makena and Doto (1982) evaluated 20 soybean varieties under four cropping systems involving maize, sorghum, millet and sole soybean. Intercropping hastened flowering and maturity, decreased number of productive pods/plant, seed weight and grain yield. They concluded that different varieties may have to be recommended for different cropping systems. Osiru (1982) found that early maturing bean varieties produced better yields in mixture with maize than medium or late maturing varieties.

AVRDC (1989) in a study to evaluate different leguminous crops and

examine their planting time relative to that of sweetpotato-based intercropping systems showed that there were significant effects of legume genotypes on sweetpotato yield and concluded that suitable genotypes and appropriate relative planting time should be identified to maximize the yield advantage of the intercrop.

Hoang *et al.* (1991) identified 10 sweetpotato varieties which were suitable for intercropping with maize at different planting densities. Villareal (1982) in a study to determine if genetic criteria could be used for selecting sweetpotato genotypes for relay cropping reported significant differences in root and top yield, number and average size of marketable roots due to cropping system. They concluded that some genotypes appeared better adapted to relay cropping and exhibited little yield loss, minimum reduction in root number and least gain in vine weight over root weight.

Cruz *et al.* (1992) in a study to determine the agronomic and economic advantages of intercropping sweetpotato and potato reported that yields of both crops were enhanced, while the land equivalent ratio (LER) and the profitability were increased, an indication that potato and sweetpotato are compatible as intercrops. All sweetpotato varieties tested were equally suitable for intercropping with potato.

Information on the effects of sweetpotato and bean plant types or genotypes on each others seem to be scanty. However, it is assumed that common bean might perform well under certain sweetpotato genotypes because of the different growth habits and morphotypes of sweetpotato and the shade tolerance characteristic in bean genotypes (Wortmann *et al.*, 1991).

2.4 Plant population and spatial arrangement in intercrops

The main reason often advanced for yield advantages of intercropping is greater utilization of environmental resources; light, nutrients and moisture, due to marked differences in height, root depths and growth cycles of component crops (Willey, 1979 a). Both plant density and spatial arrangements seem important in intercropping.

Willey (1979 b) defined plant population as the number of plants per unit area, which determines the size of the area available to the individual plant. Spatial arrangement defines the pattern of distribution of plants over the ground, which determines the shape of the area available to the individual plant. For crops arranged in rows, spatial arrangements can be concisely defined by the rectangularity (ratio of the inter-row spacing to the intra-row spacing) (Holliday, 1963).

When different crop species are grown in mixtures, they compete for growth resources. This competition may be reduced either by lowering the plant population and/or adjusting the spatial arrangement.

Willey (1979 b) observed that where intercropping resulted in yield advantage, the total population (all components) optimum may be higher than that of either sole crop. Advantages from population increases are most likely where component crops have large temporal differences in growth patterns. Studies with 80-90 day cereals and 150-180 day pigeon pea suggest that both components should be at their full sole crop optimum to ensure efficient use of early resources

(Freyman and Venkateswarlu, 1977). The component population (each component) mainly determine how much of the final yield is contributed by each component.

It has often been suggested that to get maximum benefit from any complementary effects, crops should be as intimately associated as possible (Andrews, 1972). But there have also been reports of no effects where increasing intimacy has decreased yield (Evan, 1960). For example Osiru (1974) found that in alternate row arrangements of sorghum genotypes of different heights, the shorter genotypes grew very poorly and overall yield decreased. In less intimate arrangements the shorter genotypes yielded better and yield advantages occurred.

Willey and Osiru (1972) and Osiru and Willey (1972), Fisher (1977) and Spitter (1983) reported that mixtures of maize/bean, sorghum/bean, and maize/groundnut, respectively, all required higher total populations than sole crops to produce maximum yields. In northern Tanzania Evans (1960) found that over a wide range of plant populations intercropping maize or sorghum with groundnut generally led to greater overall production per unit area than sole crops.

Herbert *et al.* (1984) intercropped maize and soybean in various planting patterns and found that dry matter yields per row of intercropped soybean were 6-32 % lower than the yields per row of soybean in pure stands. However, the dry matter yield per row of intercropped maize was increased by 21-53% compared to yield per row of pure stand of maize and compensated for the reduced dry matter of soybeans.

In Egypt Galal *et al.* (1980) found that maize and soybeans planted on

alternating ridges increased the percentage of harvested maize plants, number of ears/plant and grain weight/ear. Grain yields of intercropped maize were 25-30% higher than those grown in pure stands. Numbers of pod and seed /plant were 30-50% higher in soybean grown in pure stand than in mixtures. Seed yields were also more than 50% greater in sole soybean than in mixtures.

Crookston and Hill (1979) concluded that in Minnesota, land use efficiency was not improved by intercropping maize and soybean at various patterns.

They observed that although maize yields were significantly increased in some combinations, accompanying yields of soybean were always reduced to the extent that more of the combinations made significant different use of the land than sole cropping. In Zimbabwe, Beets (1978) also found that the grain yields of both maize and soybean in different spatial arrangements were reduced, although the LER values (1.02-1.23) were higher than those of sole crops.

Leihner (1983) noted that with an increment in cassava population, the yield of intercropped bean was reduced, and recommended a plant density of 6900-9300 plants/ha for acceptable yields of intercropped bean.

Thung and Cock (1979) showed that for cassava/bean systems optimum densities for sole cropping was also suited for intercropping and changing the plant arrangements did not have any effect. Samui *et al.* (1984) found that dry weight, leaf area index, crop growth rate and net assimilation of intercropped groundnut and sunflowers were better than sole crops when one row of groundnut alternated with one row of sunflower. From the available information there are indications that varying plant population and spatial arrangements of intercrops

generally, either causes a positive or a negative effect on the yields of the component crops.

FAO (1991) summarized data from many sources on different spatial arrangements, planting configuration, plant density and population pressure and concluded that intercropping produces higher yields provided soil moisture conditions are kept at an adequate level, particularly in semi-arid areas. This may be attributed to better utilization of soil resources from combined exploitation of different areas of the soil as a result of differences in rooting depths of component crops. Also, different growth cycles of the component crops produced a greater overall utilization of resources although as pointed out by Andrews (1972), this factor is likely to be of more importance under longer growing season. Cruz *et al.* (1992) reported that when sweetpotato intercropped in alternate single row beds of potato with 75 cm between rows, the two are compatible as intercrops. However, when planted too close, sweetpotato competed for nutrients with potato. The large canopy and long vines produced by sweetpotato covered potato during the tuber bulking stage and reduced potato growth and yield.

Carandang and Curayang (1989) reported that legume intercrops planted in single and double rows between rows of sweetpotato generally did not vary for plant height, dry matter yield and grain yield.

Vine lengths and number of marketable and un marketable roots of sweetpotato under different cropping systems also did not vary significantly. Information on yield was not indicated. In a similar study in which two sweetpotato genotypes were intercropped with three grain legumes, mungbean (Var MI-4), black grain (Var MI-I) and cowpea Var (TYX 1850 OE), the highest significant sweetpotato

yield reduction of 30-45% was recorded in crop combination with cowpea, irrespective of sweetpotato genotypes and season of cultivation.

Mungbean reduced sweetpotato yield by only 7-25% (Premaratne and Premachandra, 1990). The significant reduction in sweetpotato yield when grown in association with cowpea might be attributable to the fact that the sweetpotato genotypes used were not suitable and therefore not compatible with cowpea. The cowpea seemed to be a more competitive legume crop than mungbean and the black grain. The effects of legumes on sweetpotato performance was not discussed.

Sitompul *et al.* (1984) reported that alternation in sweetpotato plant density on the same ridge with cassava did not significantly affect the yield of cassava. Ndibaza (1987) reported that the plant arrangement of sweetpotato grown in association with cassava on the same ridge affected both the growth and yield of cassava and sweetpotato. Cassava intercropped with double rows of sweetpotato performed better than that grown with only single row. Fisher (1977) compared the productivity of maize/bean and maize/sweetpotato mixtures in alternate rows and found that both mixtures yielded higher than sole crops. Dai *et al.* (1991) reported a decrease in the sweetpotato fresh root yield and yield components with increased maize population. Davis *et al.* (1984) reported that in general, there is some yield loss of sweetpotato in sweetpotato/bean association.

Most of the literature seem to indicate that the yield of sweetpotato was reduced by intercropping with taller crops, which intercept light, although it is known that some cultivars are more tolerant to shade (Moreno, 1982; Zara *et al.*, 1982).

Information on the effects of spatial arrangements and plant population of sweetpotato on the performance of both sweetpotato and beans grown in association seems to be scanty and imprecise.

Sweetpotato and beans differ in their rooting system, in maturity period and growth habits.

2.5 Competition for growth resources

Competition between plants or species is the response of individual plants or species to their environment as modified by the presence of another plant or species (Hall, 1974 a, b; Trenbath, 1974).

Differences in morphology and physiology between the components in intercrop, and agronomic practices affect the nature of interactions among species and their use of resources (Trenbath, 1976; Martin and Snaydon, 1982). Competition normally occurs when one or more growth factors are limiting. Trenbath (1974) suggested a type of competition which he referred to as 'competitive interference' which occurs when one or more growth factors are limiting.

In such cases the plant or species which is better equipped to utilize a growth factor (the dominant species) increases its yield at the expense of the other plant which suffers a yield decrease (the dominated species). As a result of uneven sharing of the resources, plants of one species will be more vigorous when in association than in pure stand situations, while plants of the other species will be correspondingly less vigorous. The higher yielding species is termed the "aggressor" or dominant and the other the "subordinate", suppressed or

dominated (Donald, 1963; Huxley and Misangu, 1978; Willey, 1979 a). In this kind of association the per plant relative yield (RY) of the dominant species is greater than unity and that of the dominated species is less than unity. This behaviour is referred to as 'compensation' and is the commonest in mixtures. In intercropping, component species compete for light (above ground resources), water and nutrients (below ground resources).

Research on intercropping systems principally focuses on how best these resources can be utilized to produce higher component crop yields. Willey (1975) observed that there could be situations where a given crop will actually grow better in the presence of another crop than as a sole crop.

Usually yield advantage occurs because component crops differ in their use of growth resources in such a way that when they are grown in combination they are able to complement each other and so make better overall use of resources than when grown separately.

In terms of competition this means that in some way the component crops are not competing for the same overall resources and thus inter-crop competition is less than intra-crop competition (Trenbath, 1974; Willey, 1979 a).

Maximizing intercropping advantages is therefore a matter of maximizing the degree of complementarity between the components and minimizing inter-crop competition. On this basis, intercropping advantages are more likely to occur where the component crops are very different in some way. It is often argued that the main way that complementarity can occur is when the growth patterns of the component crops differ in time so that the crops make their major demands on resources at different times. This type of complementarity is said to give better

temporal use of resources. Its importance is indicated by substantial yield advantages that have occurred when there have been marked differences in the maturity periods of component crops (Willey, 1979 a).

For example yield increase of 55% in 85-day bean/120 day sorghum (Osiru and Willey, 1972), 38% in 85-day bean/120-day maize (Willey and Osiru, 1972), 30-40% in 90-day maize/160-day rice; 80% in 85-day pearl millet/150-day sorghum (Andrews, 1972). Information on complementarity that occurs in sweetpotato/bean association is scanty or not available.

Osiru and Willey (1976) reported yield increase of 25% in a maize/bean association while Osiru and Kabira (1979) reported yield increase in sorghum/pigeon pea and finger millet/groundnut mixtures and attributed the yield increases to the differences in maturity periods of the component crops.

2.5.1 Competition for light

Light is an indispensable growth resource in crop production. It differs from the other resources in that there is no reserve or other means from which demands could be met as required. Competition for light occurs in all crops whether in intercrop or sole crop situation. It occurs when one plant casts its shadow on another, or can occur within the same plant when one leaf shades another. The taller component will dominate the short one and intercept greater amount of light (Stern and Donald, 1962). Willey and Roberts (1976) stressed that sole crops are themselves usually capable of achieving a peak value of light interception which leaves little scope for greater spatial interception by intercrops.

Pendleton and Seif (1962) examined this effect by mixing maize genotypes of different heights but no effect on yield was observed.

Osiru (1974) on the other hand, found 9% increase in sorghum yield from intercropping genotypes of different heights. Evidence for useful improvement in spatial use of light may be lacking because component crops studied have been similar; where crop differences result in greater canopy differences, greater improvement may be possible.

Through changes in leaf size, shape and angle, it is possible to alter canopy characteristics. For example it is possible to have a sparse canopy, say an erect sweetpotato plant type, for the high light intensities at the top of the canopy and a more dense canopy, say compact legume for the lower intensities at the bottom. There is also the possibility of combining crops which have different inherent responses to light. Thus the top of the canopy could consist of a component with high light requirements and the bottom a component with a low light requirements, e.g. a tall C_4 crop combined with a short C_3 crop (Crookston and Kent 1976).

Wiley and Roberts (1976) noted that in pigeon pea mixtures with either sorghum or groundnut, there was a good early interception of light. However, with millet/groundnut system there was no greater interception of light than would be achieved by growing the crops separately. Light was better utilized in the former systems because of difference in maturity periods of the component crops. Cock (1983) observed that in order to optimize light interception in crop mixtures the choice of crops can be on the basis of morphology, relative growth duration, plant pattern or geometry and plant density. Even within species canopy

architecture such as erect, spreading, semi-compact growth habits may influence light interception.

Sweetpotato and bean are C_3 plants which have relatively low light energy requirements. However, sweetpotato requires more light than bean. Sweetpotato and bean mixtures might have a better light interception efficiency than would be achieved by growing the crops separately because of the growth habits of the two crop species.

2.5.2 Competition for Nutrients

Greater uptake of nutrients by intercrops have been reported by several workers (Dalal, 1974; Kassam and Stockinger, 1975; Hall, 1974 a, b; Wahua, 1983). It is often claimed as the basic cause of yield increase.

However, Willey (1979 a) cautioned that it was impossible to determine the cause or effect. Trenbath (1974) attributed yield advantages in some mixtures of oat varieties to the possibility that component crops may exploit different soil layers, thus in combination they may exploit greater total volume of soil.

Such differences in rooting patterns could occur because of the "mutual avoidance" of different root systems. This is simply the tendency for a crop to avoid areas that have already been depleted of resources by an associated crop. But such avoidance presumably also occurs between roots of the same species, so it is doubtful if this can be regarded as a general advantage of intercropping. Thus there is evidence from a number of studies that a deeper rooting component may be forced even deeper by the presence of a shallow rooting component,

Whittington and O'Brien (1968). However, roots of at least some crops intermingle freely (Lai and Lawton, 1962).

Hall (1974 b) showed that by calculating the relative yield totals (RYT) which is essentially the same as land equivalent ratio (LER) of Trenbath (1974) and crowding coefficients which is synonymous to competition ratio (CR) (Willey and Rao, 1980) for individual nutrients and comparing these with comparable values for total dry matter, nutrient use efficiency in intercropping can be determined.

If a RYT for a nutrient is less than that for the total dry matter, this probably indicates that the nutrient is being exploited less well than other resources by intercropping, and it may well be limiting the intercropping response. A higher value probably indicates that the nutrient is being better exploited by intercropping and is not limiting. This analysis assumes however, that differences in competition for different nutrients will be reflected in the differences in nutrient contents in the crop.

Hall (1974 a) used this analysis to show that there was some complementary use of nitrogen in two grass-legume mixtures.

Another possibility for yield advantage of intercropping is that even where growing periods are similar, component crops may have their peak demands for nutrients at different stages of growth, a temporal effect which may help to ensure that demand does not exceed the rate at which nutrients can be supplied. Another temporal effect could occur where nutrients released from one crop as a result of senescence of plant parts are made available to another crop, (Willey, 1979 a). Component crops may also differ in the type of nutrients they require and in their

ability to extract them from the soil.

Sweetpotato and bean mixtures might benefit because the adventitious roots of sweetpotato may grow as deep as 2 meters (Woolfe, 1992) and only 12-15 cm for bean (Laing *et al.*, 1984), thus the rooting depth and pattern in sweetpotato and bean differ greatly. The demands for growth resources at different stages of sweetpotato and bean crop species are also likely to be different.

2.5.3 Symbiotic N₂ fixation in legume/non legume crop association.

One of the reasons for intercropping legumes with non-legumes is that the legumes may obtain much of their nitrogen requirements by fixing atmospheric nitrogen, thus conserve soil N for the subsequent crop or the intercrop. Legumes can supply N to associated non-legumes by excretion of soluble amino acids from living roots or from decaying roots and herbage, Vallis (1979). Wilson and Wyss (1937), Walker *et al* (1954) have suggested that N excretion could be enhanced by shading but this may only be important after good growth has already been made under high light condition. Where legumes are continuously shaded their overall capacity for nitrogen fixation is likely to be impaired.

However, Wahua and Miller (1978) showed that when soybeans were intercropped with tall sorghum, nitrogen fixation was reduced by more than 98% due to shading. In mixture with short sorghum, soybean fixed more nitrogen than in sole crop.

It was concluded that possibly sorghum produced some chemical substances which

stimulated soybean to fix more nitrogen.

Agboola and Fayemi (1972), Misra and Misra (1975) concluded that legumes could not benefit associated non-legumes over the same growing period but rather during subsequent plantings. Their investigations showed that cowpea intercropped with maize did not benefit the early maize crop, but as green gram matures they were important source of nitrogen for maize in the late cropping season. The residual effects were the opposite, cowpea had greater effect on the yield of the subsequent maize crop.

In India, under rain-fed conditions, sorghum inter-planted with five different legumes consistently out-yielded sole sorghum, Singh (1977). The yield advantages ranged from 8% with soybean to 34% with cowpeas for fodder. Nitrogen contribution to intercropped maize has been estimated to be 40 kg/ha for groundnut and 25 kg/ha from mungbean.

In Zaire, Breth (1978) found that *Crotalaria* in rotation with maize raised yields from about 5.0 to 9.0 t/ha, a yield that in the absence of the legume would need 180 kg N and 120 kg P/ha. In Nigeria, Jones (1974) reported that maize following groundnut significantly out-yielded maize following sorghum or cowpea.

In other experiments, maize/groundnut in northern Nigeria, Kassam (1972), maize/soybean in East Africa, Finlay (1975), maize/bean in Colombia, CIAT (1974), and maize/cowpea in Nigeria, Wien and Nangju (1976), less pronounced yield advantages have been observed.

With regard to the efficiency of the fixation process, Thomson (1977) reported an apparent increase in nodule number and weight on soybean grown with maize,

although results were not statistically significant. His explanation for this was that the cereals depleted soil nitrogen, thus stimulating nitrogen fixation. If this is a real effect, it would seem to be a genuine advantage of intercropping.

Willey (1979 b) stressed that the only situation in which conclusions can really be drawn is where the presence of the legume produces a greater yield of non-legume than achieved in sole cropping.

Information on N contribution to intercropped sweetpotato by bean crop is scanty. An assumption can be made that symbiotic relationship exists between the two crops. Sweetpotato might benefit from N fixed by a bean crop and the nutrients that might be re-cycled from the decomposing bean crop residues because bean matures in about 90 days and is harvested leaving sweetpotato in the field for another 80-90 days. On the other hand, bean might also benefit from N fixed by associated nitrogen-fixing bacteria of the *Azospirillum* genus, supposed to be found in association with the roots of sweetpotato (Hill *et al.*, 1983).

2.5.4 Competition for water

Water is the most limiting factor in the semi-arid zones. Baker and Norman (1975) suggested that better water use was probably a common cause of yield advantages of intercropping in semi-arid tropical areas.

Kassam (1973) in Nigeria showed that in the early stages of growth of a maize crop there was water surplus to requirement. He suggested that an early intercrop such as millet would help to utilize this and so improve water use efficiency (WUE). In sweetpotato/bean association evidence for better WUE is

scanty. However, it is reasonable to assumed that sweetpotato/bean association would have greater WUE because bean is an early intercrop while sweetpotato is a late intercrop. Another possible reason for the better WUE with intercropping is the mat layer effect when low growing plants such as legumes are intercropped with spreading or semi-compact and erect sweetpotato or pumpkins or water melons. There is tendency for the old leaves to fall under the crop and form a mat layer which helps to reduce evaporation from the soil surface and preserves soil moisture for use by the crops.

At ICRISAT (1977) in sorghum/pigeon pea studies, intercropping produced greater yields of dry matter during the period of sorghum growth, but total water use was unchanged; thus water appeared to be used more efficiently. Willey and Reddy (1981) have, however, suggested that the main determinant of yield advantage was above ground interaction, where as root interaction were important in determining competition balance of the crops.

Information available indicate that generally, a genotype within a crop species responded differently when grown in mixtures with a genotype from another crop species. Planting arrangements and plant population densities are crucial factors in facilitating growth resource utilization and efficiency.

Therefore the performance of crops grown in association depend on the interactions that may occur during crop growth. A considerable research effort has been put in understanding the performance of sweetpotato and leguminous crops when grown in association. However, research gap still exists in the knowledge of as to what sweetpotato and bean morphotypes are compatible and are therefore suitable for intercropping, and if so, what would be the most

appropriate planting arrangement and population density which would minimize inter-intra specific competition for growth resources and enhance efficient utilization of the resources. The present study therefore aims at identifying compatible sweetpotato and bean morphotypes for intercropping and to establish the appropriate planting arrangement and population density for sweetpotato/bean cropping system.

CHAPTER 3

MATERIALS AND METHODS

3.1 Description of the experimental sites.

The field research was conducted between September 1993 and December 1995 at Namulonge Agricultural and Animal Production Research Institute (NAARI). Namulonge is situated in the south central part of Uganda about 23 km north of Kampala (altitude, 1150 m above sea level; 0° 32'N; 32° 35'E). The low undulating land scape has predominantly ferrallitic sandy loam, sandy clay loam and clay loam soils of the Namulonge Deep Red series derived from parent materials consisting of solid rock of mixed igneous and metamorphic material. The soils are formed in residuum from quartzite and gneiss on side slopes, laterite on small hill tops, and alluvium in valleys. The soils are classified as fine, kaolinitic, isohyperthermic Rhodic kandiudalf with pH 5.6-6.0, well drained with moderately rapid permeability, and with no measurable erosion hazards (David and Eswaran, 1990). The Udic moisture regime (1270 mm) is bimodal with peak periods in April/May and September/October or October/November. The weather conditions during the study period are summarized (Table 1).

Table 1. Weather characteristics during experimentation periods for three seasons at Namulonge Agricultural and Livestock Research Institute, Kampala, Uganda.

Month	Rainfall (mm)		Weather conditions				Temperature (°C)	
	Period		Period				Period	
	1993/94	1994/95	1995/96	1993/94	1994/95	1995/96	1993/94	1995/96
Jan	72.0	21.4	8.9	28.4	16.1	28.7	16.2	30.7
February	32.8	77.8	24.1	30.1	15.2	29.4	16.0	29.4
March	151.6	95.0	131.7	30.2	15.9	28.7	16.3	28.6
April	115.5	128.0	139.7	28.1	16.2	29.7	17.8	28.2
May	174.5	212.6	126.6	27.7	15.9	26.9	16.8	27.3
June	122.9	50.7	54.5	29.3	16.0	27.2	16.5	28.1
July	5.0	5.0	70.2	29.3	15.7	27.4	16.1	27.0
August	42.2	70.5	30.7	28.9	16.1	26.0	15.4	28.5
September	117.9	84.3	10.4	28.8	16.4	27.9	16.0	27.7
October	82.0	177.5	151.6	27.9	15.7	27.9	16.0	27.7
November	105.4	177.0	76.8	28.8	16.4	27.6	16.3	28.4
December	59.9	140.5	43.9	27.5	15.6	27.8	16.1	29.1
Total	1081.7	1240.3	869.1					
Mean	90.1	103.3	72.4	28.6	15.9	27.8	16.3	26.0

Source: Agrometeorological Unit, Namulonge Agricultural and Animal Production Research Institute, Kampala, Uganda.

There was no marked variability in the onset and secession of rain during 1993 and 1994 cropping seasons. The deviation from the annual mean (1270 mm) was 14.8% and 24.4% less during 1993 and 1995 cropping seasons, respectively, while 1994 received 15.3% more rain. During 1995/96 cropping season the normal dry month of July shifted to September, thus the first rain was longer than usual. Temperatures did not vary much across years.

3.2 Soil sampling and analysis

The soil was sampled prior to ploughing, and again from each experimental plot at 2 MAP, and at bean and sweetpotato harvests (3 and 6 MAP, respectively). At each sampling the techniques described by Tisdale *et al.* (1985) were adopted.

Samples taken prior to ploughing consisted of 40 cores from each experimental field using the auger at a depth of 0-25 cm. The samples were sun dried separately before mixing them to form a composite sample.

Ten sample cores were taken from each experimental plot and were treated the same way. All the soil analysis were done at the Department of Soil Science Laboratory, Makerere University.

The analysis for the particle size was done by the hydrometer method using calgon (sodium hexametephosphate) solution 10% as a dispersion agent, and drops of amyl alcohol to remove the froth.

The soil pH measurements were made using the electro- conductivity method,

Sulphuric acid and aqueous potassium dichromate ($K_2Cr_2O_7$) mixture was used. Total N and P were determined by a Kjeldahl digestive procedure (Okalebo *et al.*, 1993). N content was estimated by the calorimetric methods. Exchangeable potassium (K) and sodium (Na) were determined photometrically by comparing the intensities of radiation emitted K and Na atoms with respect to a series of standard solutions. Calcium (Ca) and magnesium (Mg) were determined by atomic absorption spectroscopy by comparing the absorbencies of Ca and Mg atoms with respect to a series of standard solution. Lanthanum was added as a releasing agent to prevent formation of refractory compounds, which may interfere with the results.

3.3 Leaf sampling and analysis

Bean and sweetpotato leaves were sampled at 45 DAP, from randomly selected plants in each experimental plot. For both bean and sweetpotato 50 well-expanded leaves were picked per plot from below the third leaf from the shoot. The samples were oven-dried to constant weight at 70 °C and stored in a cool dry place and were analyzed at Makerere University, Soil Science Department Laboratory for foliar N, P, K, Na, Ca, and Mg.

3.4 Experiment 1. Compatibility of different sweetpotato and bean morphotypes when grown in association (1993/94 and 1994/95 seasons)

This experiment was conducted during the second rains of 1993 to evaluate the compatibility of the selected sweetpotato and bean morphotypes in association.

3.4.1 Treatments and experimental design

Eight sweetpotato genotypes, namely Wagabolige, Bwanjule, Entry 20, Entry 21, Tanzania, Bitambi, New Kawogo and Tororo 3 were used. These are land races selected from 450 germplasm accessions maintained at NAARI. The eight genotypes had been verified through multi-location and on-farm trials as high yielding and pest and disease tolerant with high dry matter content, a characteristic highly correlated to high storage root quality acceptable to consumers. The genotypes can be classified into three main plant types; erect, semi-compact and spreading (Huaman, 1992) (Tables 2 and 3). The four bean genotypes used were, White Haricot, MMS 224, A 197 and GLP 585. The four genotypes included released varieties and breeding lines from CIAT, Bean Program based at Kawanda Agricultural Research Institute (KARI). They were chosen based on their morphotypes, yield potentials and acceptability in terms of taste and quality.

The four fall into two plant types (**Type 1** and **11**) (Table 4).

A split-plot design of four replicates was used, where bean varieties were the

main plot treatments. The design was used in order to estimate both main and interaction effects and also to achieve greater precision on interaction than on main effects. The sub-plot (7 m x 7 m) treatments were the eight sweetpotato genotypes. Sole crops of both components were planted separately in a complete randomized design (CRD) in three replications adjacent to the main trial. The same experiment was repeated in 1994/95 season to validate the results of the 1993/94 trial but with six sweetpotato genotypes; Wagabolige, Bwanjule, Tanzania, Bitambi, New kawogo and Tororo 3. Entry 20 and Entry 21 were dropped because of their poor performance in three agro-ecological zones where the same experiment was also conducted during 1993/94 cropping season. Also only two bean genotypes, White Haricot and GLP 585, were used. Genotypes MMS 224 and A 197 were left out because of lack of sufficient seeds.

All together there were three cropping systems consisting of mixtures of each sweetpotato genotype with each genotype of bean, sole sweetpotato stands of each genotype and sole bean stands of each genotype. All possible treatment combinations were used in this study giving a total of 32 and 12 treatment combinations for experiments I and II, respectively (Table 5).

Table 2. Morphological characteristics of eight local sweetpotato genotypes evaluated.

Genotype	plant type	vine length (cm)	Leaf outline (mature)	Leaf lobes	Number lobes	Shape central leaf	Mature leaf size	Petiole length (cm)
Wagabolige	spreading	151-250	tri- angular	slight	3	semi- elliptic	large	intermediate
Entry 21	spreading	151-250	hastate	very deep	5	linear	medium	short
Bitambi	semi-compact	75-150	lobed	moderate	5	semi- elliptic	medium	short
New Kawogo	semi-compact	75-150	lobed	deep	5	elliptic	large	intermediate
Tororo 3	semi-compact	75-150	hastate	deep	5	lanceolate elliptic	large	intermediate
Entry 20	erect	<75	hastate	deep	5	elliptic	large	intermediate
Bwanjule	erect	<75	almost	very	5	linear	large	intermediate
Tanzania	erect	<75	hastate	deep	3	elliptic	large	intermediate

source: Compiled by author based on description by Huaman (1992)

Table 3. Storage root characteristics of eight local sweetpotato genotypes evaluated

Genotype	% Root shape	Maturity Skin colour	Yielding Flesh colour	Cooked taste	Texture	Root system	Dry matter	period (days)	ability (t/ha)
Wagabo/ lige	round	brown/ orange	white	sweet	soft	very disperse	33.0	120-180	6-45
Entry 21	obovate	white/ yellow	white	moderate/ sweet	soft	open/ cluster	29.0	120-150	4-35
Bitambi	round/ elliptic	red	white	sweet	soft	open/ cluster	30.0	120-180	6-55
New Kawogo	obovate	red	white	sweet	soft	very/ disperse	32.0	120-180	6-45
Tororo 3	round	brown/ orange	white	sweet	soft	very/ disperse	31.0	120-180	5-52
Entry 20	round	white/ yellow	white	sweet	soft/ mealy	disperse	29.0	120-150	4-35
Bwanjule	obovate	purple/ red	white	sweet	soft	disperse	30.0	120-180	7-49
Tanzania	obovate	yellow/ whitish	pale/ yellow	sweet	soft	very/ disperse	32.0	90-135	5-58

Source: Compiled by author.

Plant data based on Huaman (1992).

Other data based on Sweetpotato Program Annual Reports, 1992-1994.

Table 4. Morphological characteristics of improved bean genotypes evaluated

Genotypes	Plant type	Growth habit	Attributes		
			Leaf size	Seed size	Seed colour
White Haricot	11	Indeterminate (bush)	large	small	white
MMS 224	11	Indeterminate (bush)	small	small	dark-brown
A 197	1	Determinate (bush)	large	large	cream
GLP 585	1	Determinate	small	large	light-brown

Source: Wortman, C.S. (1992).

Table 5. A matrix of treatment combinations (intercrops) and control (sole-crops), 1993/94 and 1994/95 cropping seasons

Intercrops								
Bean genotypes		Sweetpotato genotypes						
	Wagabolige	Entry-21**	Entry-20**	Bwan-jule	Tanzania	Bitambi	Tor 3	Nk
W. Haricot	WH	WH	WH	WH	WH	WH	WH	WH
MMS 224*	MMS 224	MMS 224	MMS 224	MMS 224	MMS 224	MMS 224	MMS 224	MMS 224
A 197*	A197	A197	A197	A197	A197	A197	A197	A197
GLP 585	GLP 585	GLP 585	GLP 585	GLP 585	GLP 585	GLP 585	GLP 585	GLP 585
Control (sole-crops)								

Bean genotypes

Sweetpotato genotypes

1. White Haricot (WH)
2. MMS 224
3. A 197
4. GLP 585

1. Wagabolige
2. Tanzania
3. Entry 21
4. Bwanjule
5. Entry 20
6. Bitambi
7. Newkawogo
8. Tororo 3

1993/94 = 32 intercrop combinations
 = 12 sole-crops
 1994/95 = 12 intercrop combinations
 = 8 sole crops

* , ** = Bean and sweetpotato genotypes, respectively excluded during 1994/95 cropping season.

3.4.2 Land preparation and crop management.

The first experiment was planted in a field which had been under fallow and then under grass pasture (Sirato) and the second experiment was planted after maize and groundnut, also after ley and grass pasture (Table 6). The bush was slashed and the field ploughed, disced after two weeks to allow thrash to decompose, and ridged. Ridges were 1 m apart.

Intercropped sweetpotato was spaced at 0.3 m within rows in double rows 0.6 m apart. Beans were planted in double rows 0.5 m apart at 0.1 m between plants within rows (Figure 1). Sole beans and sweetpotato were planted the same way as in the intercrop. Clean and healthy sweetpotato planting materials were obtained from the sweetpotato multiplication fields at Namulonge Agricultural and Animal Production Research Institute.

Table 6. The historical cropping patterns of the experimental sites at Namulonge Agricultural and Animal Production Research Institute

		Year and season													
		1989		1990		1991		1992		1993		1994		1995	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B
Field No.															
1	F	Pa	Pa	Pa	Pa	Pa	Pa	Pa	Pa	s/pot + bean (Exp.1)		-	-	-	-
2	L	L	L	Pa	Pa	Pa	Pa	Pa	Pa	M	G/nut	s/pot + bean (Exp.1 & 11)	-	-	-
3	So	So	So	M	So	M	Co	F	Co	R	Si	G/nut M	s/pot + bean (Exp.11)		

Key:

A = First rain
 B = Second rain
 L = Lay
 Pa = Pasture
 So = Soybean
 Co = Cotton
 R = Rice
 Si = Sinsim
 G/nut = Groundnut
 M = Maize
 S/pot = Sweetpotato
 F = Fallow

Source: Compiled by author from the Cropping Program for Namulonge Agricultural and Animal Production Research Institute, Kampala, Uganda.

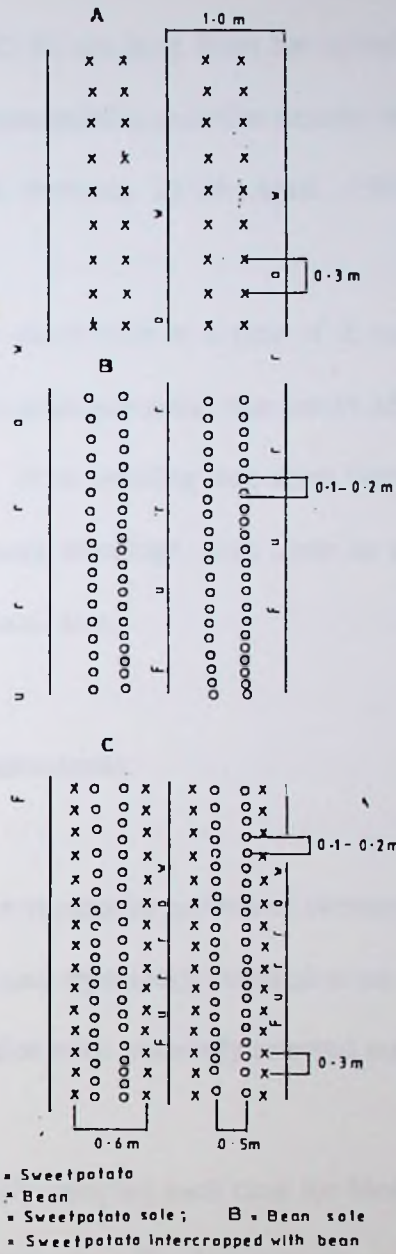


Fig.1 : Spatial arrangement of sweetpotato and bean crop rows in intercropped and sole cropped situations.

Vine cuttings measuring 25-30 cm long from the apical point were planted two days after cutting at a recommended population density of 33,333 plants/ha on the 20th September 1993 and between 21-24 April, 1994 for first and second experiment, respectively.

Beans were planted at the same time at a rate of 2 seeds per hole which was immediately thinned to one plant per stand two weeks after first weeding leaving about 440, 000 plants/ha. First weeding was done between two to three weeks after planting and subsequent weedings were done as required. Weeding was done manually using the hand hoe.

3.4.3 Sweetpotato measurements.

Treatment effects on vegetative growth of sweetpotato were assessed at 30 days after planting (DAP) and repeatedly assessed at an interval of 15 days until 75 DAP. Five plants per plot were randomly selected and tagged for vine growth determination.

Ten plants were destructively sampled each time for biomass determination from the ridges bordering the data area. The leaves were separated from the petioles and vines, and the fresh weight of each plant part was recorded. These were then oven-dried separately at 70 °C until constant dry weight.

The crop was harvested 6 months after planting (MAP) for each planting. At harvest, plants in the net data plot (16 m²) were counted. The four inner-most ridges were harvested, discarding three plants 1 m away from both ends of the ridges to avoid border effects.

Vines were first harvested and weighed. The storage roots were then carefully harvested using hand hoes, sorted into marketable and unmarketable sizes and the numbers recorded. There is no standard measurement for marketable and unmarketable sizes because marketable and unmarketable sizes vary from one location to another. For example, in India small sized storage roots are most preferred by consumers (Pers. comm. 1992), while large roots are preferred in Uganda.

In this study, all storage roots with diameter of 4.5 cm or more were considered marketable. Root yields were weighed. Harvest indices percent (HI%), defined as storage root yield/biological yield) x 100% and the shoot: root ratios were calculated. Average weights of individual marketable and unmarketable roots were also calculated. The dry matter content (DMC %) of the storage roots was determined by selecting mature, clean, weevil-free storage roots which were washed, sliced and weighed for fresh weight. These were oven-dried at 70 °C until constant dry weight.

3.4.4 Bean measurement

Treatment effects on vegetative growth and biomass production was assessed at the same time and at the same interval as in sweetpotato.

Five plants were randomly selected and tagged for plant height measurement. For destructive sampling, 10 plants were sampled and treated as with sweetpotato samples. The bean crop was harvested at 3 MAP for each planting.

Plants 1 m away from the end of the ridges in the net data plots as in sweetpotato

were discarded.

Disease incidence and severity, particularly common bacterial blight (CBB) and angular leaf spot (ALS) were scored using a scale of 1-9 (1= no visible symptom, 9= very severe symptom) at pod filling (R 8) and physiological maturity (R 9) stages. The crops were hand harvested by uprooting the whole stand. Harvesting was done in the morning to avoid shattering. The number of plants harvested was recorded. The number of pods and primary branches per plant were determined from the mean of a random sample of 10 plants. The number of seeds per pod was determined from the mean of a random sample of 10 pods. The number of seeds per plant was then calculated.

The harvested plants were sun dried separately, threshed, winnowed and seed yield per plot recorded.

The 100 dry seed weight (100 DSW) was determined from a random sample of 100 seeds from each plot. The yield per hectare was calculated using the relationship between number of plants harvested per plot, yield per plot, yield per plant and data area harvested.

3.5 Experiment II: Effects of sweetpotato spatial arrangements and population density on the performance of sweetpotato and bean in a sweetpotato/bean association (1994/95 and 1995/96 seasons)

This study was designed to determine the appropriate spatial arrangement and population density of sweetpotato for optimum storage root and bean seed yields when grown in association and to further examine the compatibility of

some sweetpotato and bean genotypes for sweetpotato/bean intercropping system.

3.5.1 Treatments and experimental design.

Three out of the original eight sweetpotato genotypes namely; Wagabolige, Bwanjule and Tororo 3 were used. The three genotypes were selected based on their performance in mixtures with bean. They also represent the three common morphotypes, erect, semi-compact and spreading. Only one bean genotype, White Haricot was used. It was also selected based on its good performance in mixtures with sweetpotato and availability of sufficient seeds.

There were four sweetpotato population densities, three varieties and two spatial arrangements evaluated in a split-split plot in a randomised complete block (RCBD) design in three replications.

Sweetpotato genotypes, spatial arrangement, and population density were in the main plot, sub-plot and sub-sub-plot factors, respectively. The plot size was 6 m x 6 m and 7 m x 7 m in 1994/95 and 1995/96 seasons, respectively. The 1995/96 experimental site had been under continuous cultivation and the trial followed maize.

Sole crop plots for both bean and sweetpotato were planted in two replications, adjacent to the intercropped plots.

There were four planting patterns: intercropped sweetpotato in double rows, intercropped sweetpotato in single row, sole-cropped bean and sole-cropped sweetpotato in single and double rows. Single row sweetpotato crops were planted in the middle of the ridges at 15, 30, 45, and 60 cm spacings between

plants (Figure 2). The double-row treatment were planted at 0.6 m between rows, and 30, 60, 90, and 120 cm spacings between plants within rows.

Beans were planted in double rows at 0.5 m between rows between the double rows of sweetpotato with 0.1 m between plants within rows. In the single row arrangement, double rows of bean were planted sandwiching the sweetpotato (Figures 3). The spatial arrangement and treatment combinations are presented (Tables 7 and 8).

The 1994/95 experiment was planted between 27 April-4th May. Bean was harvested 25-27th July, while sweetpotato was harvested between 28-30th November. The 1995/96 experiment was planted between 17-20th April, 1995 and harvested between 17-20th July and 17-20th

October for bean and sweetpotato, respectively. At harvest, plants in the data plot (20 m²) were counted. Observations were made as in experiment I and data was analyzed using MSTATC for ANOVA (Appendices 8 and 9), correlation and regression statistics.

Combined analysis over seasons was also performed to determine whether treatment main effects differ and season x treatment interactions effects exist (Appendices 10 and 11).

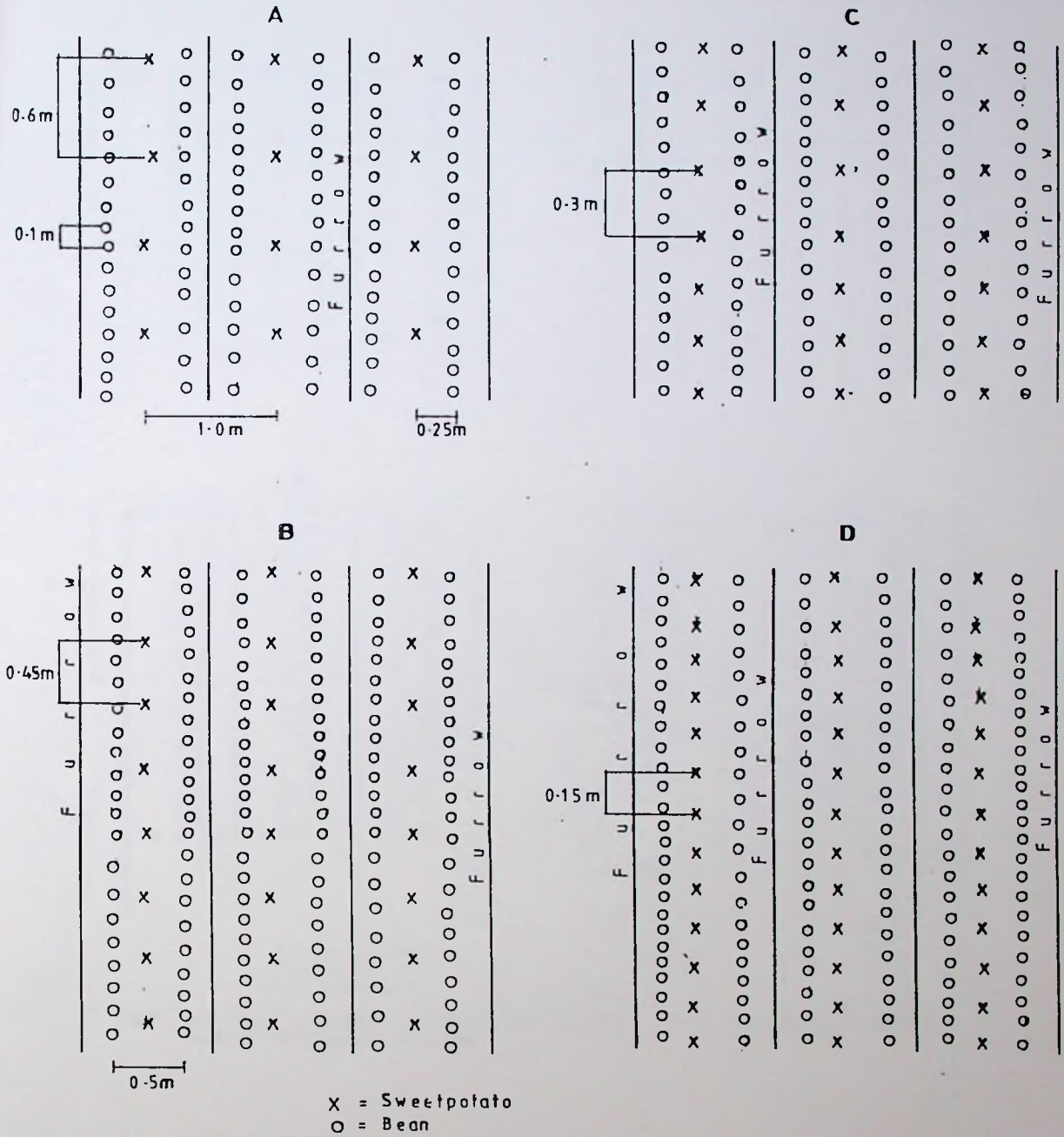


Fig. 2: Spatial arrangement of sweetpotato and bean crop rows in mixtures - single row of sweetpotato and double rows of bean.

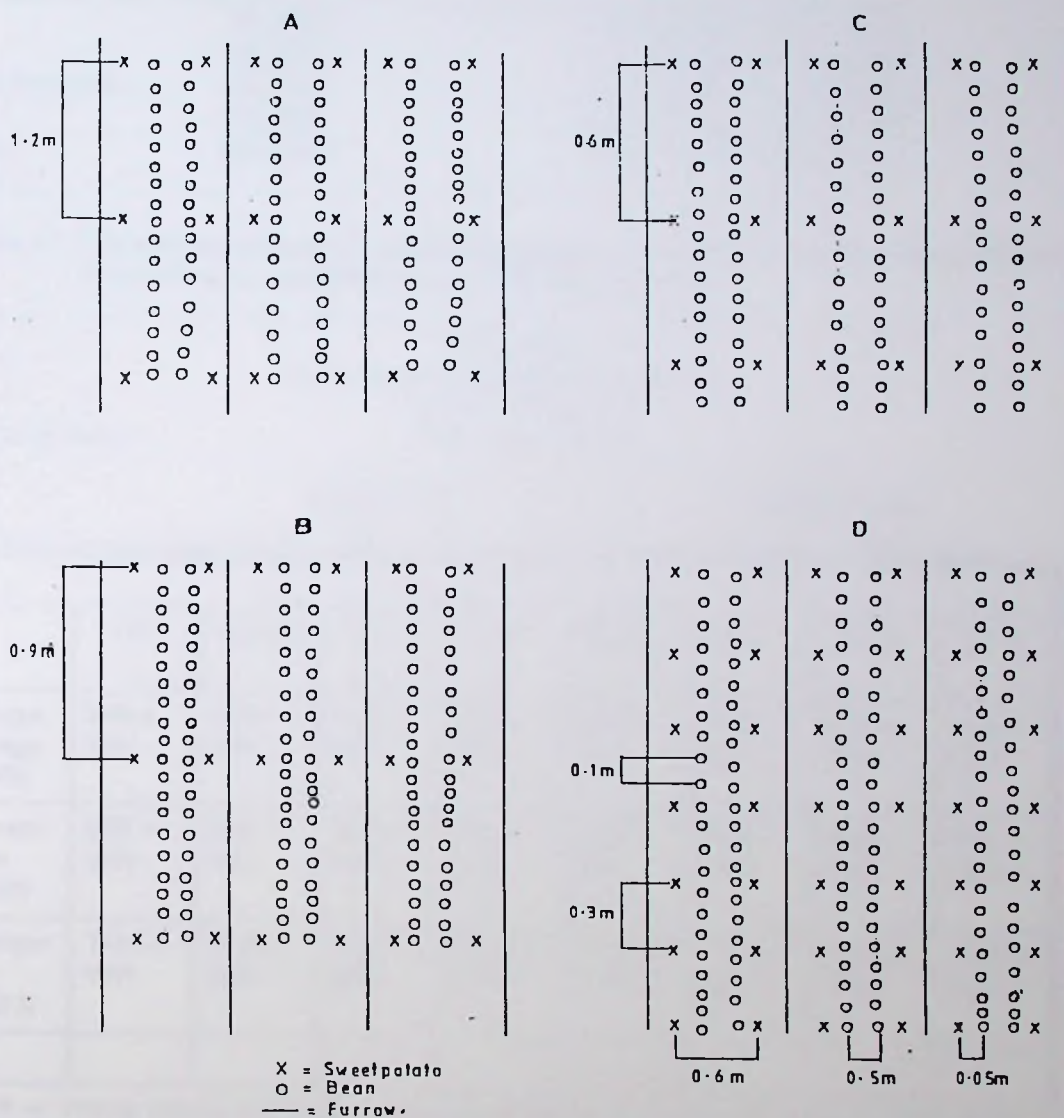


Fig. 3: Spatial arrangement of sweetpotato and bean crop rows in mixtures—double rows of sweetpotato and bean.

58

Crop	Plant density (plants/ha)	Planting pattern	
		Single row spacing (m)	Double rows
Sweetpotato	16,666	1.0 x 0.60	1.0 x 1.20
	22,222	1.0 x 0.45	1.0 x 0.90
	33,333	1.0 x 0.30	1.0 x 0.60
	66,666	1.0 x 0.15	1.0 x 0.30
Bean	440,000	0.5 x 0.10	0.5 x 0.10

Table 8. A matrix of treatment combinations (intercrops) and control (sole-crops), 1994/95 and 1995/96 seasons [Experiment II]

Sweetpotato	Intercrops Sweetpotato population density (‘000’ plants/ha) Planting pattern							
	Single row				Double rows			
	16.7	22.22	33.3	66.7	16.7	22.2	33.3	66.7
Wagabolige (WB)	WB + WH	WB + WH	WB + WH	WB + WH	WB + WH	WB + WH	WB + WH	WB + WH
Bwanjule (BW)	BW + WH	BW + WH	WB + WH	WB + WH	WB + WH	WB + WH	WB + WH	WB + WH
Tororo 3 (TO3)	TO3 + WH	TO3 + WH	TO3 + WH	TO3 + WH	TO3 + WH	TO3 + WH	TO3 + WH	TO3 + WH
WH = White Haricot (bean) at constant population density of 440,000 plt/ha WB, BW and TO3 = Wagabolige, Bwanjule and Tororo 3, respectively.								
Intercrops = 24 combinations: control = 24 sole-crops (sweetpotato) and 1 (bean)								

3.6 General measurements.

3.6.1 Leaf Area Index

Leaf area index (LAI) defined as the area of green leaf surface per unit area of land surface (Watson, 1947 a), was estimated using the punch disc method (Watson, 1958). Expanded, green and healthy leaf lobes were selected from the samples collected for growth analysis. The leaves were arranged in piles of 50 for easy punching using the cork bore of known diameter and discs produced. The number of discs per sample per plot and fresh weights of discs and leaves were recorded.

These were oven-dried at 70 °C until constant dry weight. The LAI was estimated as follows:

$$LAI = A \times L / (X \times G),$$

Where A = area of discs which is the product of number of discs
and area of 1 disc.

L = total dry weight of leaves

X = dry weight of discs

G = area occupied by the leaves of sampled plants

3.6.2 Light interception by crops.

Light interception by crops was measured using a Sunflect Ceptometre Model Sf-80 with 80 light sensors. The photosynthetically active radiation (PAR)

intercepted by crops in the different crop combinations and sole crops was determined by measuring the radiation falling on the crops (I) and radiation penetrating the crops (A). PAR reading from an up-facing Ceptometer above the canopy was measured by levelling the ceptometer with the internal bubble. Five readings were taken per plot from different positions and the mean radiation was calculated.

PAR below the canopy was estimated by positioning an up-facing Ceptometer below the crop canopy. The probe was placed under the canopy below all the leaves and readings taken from different positions in each experimental plot. Readings were taken at 30 DAP and then at intervals of 15 days until 75 DAP. This was done between 9.00 am and 11.00 am. Fractional total cropping system light interception was estimated using the formula:

$$F = I-A/I \times 100\%,$$

where I = Radiation falling on sweetpotato and bean crop canopies.

A = Radiation penetrating sweetpotato and bean canopies.

Radiation reflected from the canopy and soil surface were estimated by a down-facing Ceptometer, but was very little and negligible.

3.6.3 Crop growth rate (CGR)

In order to determine the dry matter accumulation in sweetpotato and bean mixtures, CGR was calculated. CGR is the rate at which the dry weight of the whole plant increases per unit area of land.

(g m⁻² day⁻¹). Hunt (1982) estimated CGR using the theoretical formula:

$$\text{CGR} = (W_2 - W_1) / P (T_2 - T_1),$$

Where W_1 and W_2 are dry weights of crop harvested at times T_1 and T_2 , and P is the land area.

3.7 Assessment of Competition, Aggressivity and Yield Advantages in Sweetpotato/bean association

3.7.1 Competition Ratio (CR)

In order to assess the degree of competition between sweetpotato and bean in the mixtures, CR was calculated according to Willey and Rao (1980) as :

$$\text{CRX} = \frac{\text{AX}}{\text{MX}}$$

$$\frac{\text{AY/MY} \times \text{sy/sx}}$$

Where AX and AY are the yields of crops X and Y in association; MX and MY are the respective sole crop yields; sy is the relative space occupied by crop Y and sx by crop X .

The competition ratio for sweetpotato/bean association was estimated by using the formula:-

$$\text{CR}_x = \frac{Y^a_{sp} / Y^a_B}{Y^s_{sp} / Y^s_B \times S_B / S_{Sp}}$$

Where Y_{sp}^a = Yield of sweetpotato in association

Y_{sp}^s = Yield of sweetpotato in sole stand

Y_B^a = Yield of bean in association

Y_B^s = Yield of bean in sole stand

S_{sp} = Relative space occupied by sweetpotato

S_B = Relative space occupied by bean

3.7.2 Aggressivity Coefficient (AC)

Aggressivity coefficient is an index of the relative crowding coefficient (McGilchrist, 1965 and Trenbath, 1971). It is defined essentially as $LA-LB$, where LA = relative yield (RY) of A (Sweetpotato) and LB = RY of B (Bean).

3.7.3 Land Equivalent Ratio (LER)

Yield advantages were analyzed in terms of Land Equivalent Ratio (LER) reviewed by Willey (1979a), Huxley and Maingu (1978), Mead and Willey (1980).

LER is essentially the same as the Relative Yield Total (RYT) of Trenbath (1974) and the Equivalent Areas or Ratio of Fisher (1977).

All the three are meant to express the relative land area under sole cropping that is required to produce the yields achieved in mixtures. LER is the ratio of the area needed under sole cropping at the same management level to give an equal amount of yield. It is the sum of the fractions of the intercrops relative to their

sole crop yields. LER values were estimated for intercrop combinations in the sweetpotato/bean association using the formula:-

$$\text{LER} = (Y_{sp}^a / Y_{sp}^s) + (Y_B^a / Y_B^s)$$

where,

Y_{sp}^a = yield of sweetpotato grown in association

Y_{sp}^s = yield of sole sweetpotato

Y_B^a = yield of bean grown in association

Y_B^s = yield of sole bean

Sweetpotato and bean differ in growth durations. Therefore to accommodate the time factor, further assessment was made using a formula referred to as ATER after (Hiesbsch and McCollum, 1978).

3.7.4 Area Time Equivalent Ratio (ATER)

ATER is defined as area time equivalent ratio.

ATER for sweetpotato/bean association was estimated by the formula:-

$$\text{ATER} = (Y_{sp}^a / Y_{sp}^s) + (Y_B^a / Y_B^s) (t_{mix} / t_{sp})$$

where $t_{mixture}$ = growth duration of the crop mixture

t_{sp} = growth duration of sweetpotato in sole cropping.

3.7.5 Economic Evaluation

The economic evaluation of intercropping is an assessment of the productivity of the system using the farmer's criteria, which depends on the farmer's objectives for producing the crops. For the purpose of this study the economic assessment for sweetpotato/bean association was based on the fact that the majority of subsistence farmers in Uganda produce sweetpotato and bean mainly for home consumption and cash income. Monetary equivalent ratio (MER) also called income equivalent ratio (IER) (Adetiloye, 1989) was used to evaluate the economic benefits from intercropping sweetpotato and bean if they were grown for sale.

MER is the ratio of the area needed under sole cropping to produce the same gross income as unit area of intercropping at the same management level.

MER is the conversion of LER into monetary terms. MER was estimated using the formula:-

$$\text{MER} = (P_1 \times y_1 + P_2 \times y_2) / P_1 Y_1$$

where y_1 = intercrop fresh marketable root yield of sweetpotato

y_2 = intercrop dry seed yield of bean

Y_1 = sole crop fresh marketable root yield of sweetpotato

P_1 = market price per kilogram of marketable roots of sweetpotato.

P_2 = market price per kilogram of dry bean seed.

CHAPTER 4

RESULTS

4.1. Soil physical and chemical characteristics at the experimental sites

The soils at the experimental sites are predominantly sandy clay loam with pH ranging between 6.0-6.3 (Table 9). The soil is generally low in soil N, P and Na, and high in K, Mg and Ca. The organic matter contents are variable ranging between 4.43 %-8.0%.

4.2 Experiment 1. Compatibility of different sweetpotato and bean morphotypes when grown in association, 1993/94 and 1994/95 seasons

4.2.1 Photosynthetically active radiation (PAR) interception

Light interception was not significantly affected by intercrop combinations at all sampling periods in each year (Table 10). PAR interception increased with time until 8 WAP and declined there after. The deviation from the mean decreased with time.

Table 9. Physical and chemical characteristics of the soil at the experimental sites, Namulonge Agricultural and Animal Production Research Institute, Kampala, Uganda

Soil characteristics	Sites and cropping season		
	A 1993/94	B 1994/94	C 1995/96
Textural class	Sandy clay loam	Sandy clay loam	Sandy clay loam
Particle size			
sand(%)	46.2	48.2	49.6
silt(%)	20.1	19.1	19.6
clay(%)	33.7	32.7	33.8
Chemical properties			
pH	6.3	6.0	6.2
Total N%	0.2	0.2	0.3
Organic matter(%)	8.0	7.0	4.4
Available cation (me/100 g)			
calcium	4.0	6.0	6.0
magnesium	1.4	1.1	1.3
sodium	0.1	0.3	0.3
potassium	0.6	1.2	0.6

Sampling depth: 0-25 cm.

Table 10. Effects of intercropping different sweetpotato and bean genotypes on photosynthetically active radiation (PAR) interception (1993/94 and 1994/95)

Cropping system	1993/94					1994/95				
	Percent PAR interception					Growth period (WAP)				
	4	6	8	10		4	6	8	10	
Sweetpotato + bean (Wagabolige-spreading)	79.6	91.8	94.2	89.0		81.0	95.4	95.6	92.0	
Sweetpotato + bean (Entry 21-spreading)	81.2	91.3	93.6	88.6		NA	NA	NA	NA	
Sweetpotato + bean (Bitambi-semi-compact)	84.6	92.8	95.0	88.6		87.4	95.3	96.1	91.0	
Sweetpotato + bean (Tororo 3-semi-compact)	82.9	91.3	94.9	89.0		86.1	95.5	96.0	91.4	
Sweetpotato + bean (New Kawogo-semi-compact)	85.5	90.3	93.1	88.1		89.3	92.9	94.4	89.7	
Sweetpotato + bean (Bwanjule-erect)	83.3	91.9	93.8	88.6		85.1	95.3	95.7	90.7	
Sweetpotato + bean (Entry 20-erect)	83.6	91.9	93.6	88.4		NA	NA	NA	NA	
Sweetpotato + bean (Tanzania-erect)	82.8	92.1	93.7	89.3		87.0	95.1	96.1	91.4	
Intercropped mean	82.9	91.7	94.0	88.7		85.9	94.9	95.6	91.0	
Sole-cropped mean	78.1	85.7	89.2	80.6		78.5	85.9	88.4	83.6	
SD +/-	1.85	0.73	0.67	0.38		2.82	1.00	0.65	0.79	
SD of the difference between the means		0.73**	0.23**	0.21**		1.43**	0.19**	0.22**		

** = Significant at LSD(0.01) probability level. NA = Not applicable.

Intercropping insignificantly increased PAR interception by 6.6% and 8.4% in 1993/94 and 1994/95 season, respectively compared to sole crop. The improved PAR interception may be attributed to increase in canopy density provided by the mixtures. The decline in PAR interception after 8 WAP may be attributed to leaf senescence particularly in bean crop and to a lesser extent in sweetpotato crop.

4.2.2 Sweetpotato growth

Vine length (VL) and growth

Intercropping had no significant effect on vine length and growth rate. Length and growth rate were similar among the sweetpotato genotypes during both cropping seasons. Vine growth rate increased with time until after 6 weeks after planting (WAP) and declined there after suggesting that assimilates were being shared for root initiation and enlargement (Tables 11 & 12).

Intercropping reduced vine growth by 10.6%, 9.5% and 6.4% of the sole crop for genotypes Bwanjule, Bitambi and Entry 20, respectively in 1993/94 season. In 1994/95 season, vine growth was reduced by 7.3% and 10.9% of the sole crop vine growth mean in genotypes Bwanjule and Tanzania, suggesting that vine growth were affected differently among genotypes.

Table 11. Effects of sweetpotato and bean morphotypes on sweetpotato vine length and growth rate (1993/94)

Morphotypes s/potato bean	Vine length (cm)				Vine growth rate (cm/day)			
					Growth period (WAP)			
	4	6	8	10	4	6	8	10
Spreading + indeterminate	48.1	77.8	79.4	81.2	1.6	2.0	0.1	0.2
determinate	38.2	74.7	77.5	79.4	1.3	2.4	0.2	0.2
Sole s/potato	40.9	68.8	81.2	82.3	1.4	1.8	0.8	0.1
Semi-compact + indeterminate	35.2	63.2	69.2	70.4	1.2	1.8	0.4	0.1
determinate	40.8	70.8	78.2	80.5	1.4	2.0	0.5	0.2
Sole s/potato	38.3	66.9	70.2	72.2	1.3	1.8	0.2	0.2
Erect + indeterminate	34.0	66.3	73.2	76.1	1.1	2.2	0.5	0.3
determinate	36.5	64.3	74.1	76.6	1.2	1.9	0.7	0.3
Sole s/potato	38.6	81.7	84.1	85.2	1.3	2.0	0.2	0.4
Intercropped mean	38.8	69.5	75.3	77.4	1.3	2.0	0.4	0.2
Sole-cropped mean	39.3	72.5	78.3	79.9	1.3	1.9	0.4	0.2
CV.	28.4%	16.0%	15.6%	15.4%				
SE.								
-bean	1.6	2.2	1.93	1.82				
-s/potato	3.62	3.69	3.87	3.85				

Table 12. Effects of sweetpotato and bean morphotypes on sweetpotato vine length and vine growth rate in sweetpotato/bean association (1994/95)

S/pot	bean	Vine length(cm)				Vine growth rate(cm/day)			
		4	6	8	10	4	6	8	10
Spreading + bean	-indeterminate	36.5	75.5	82.5	84.2	1.2	2.6	0.5	0.2
	-indeterminate	49.5	77.5	78.5	80.3	1.7	1.7	1.9	0.2
	-sole	50.1	79.8	82.2	83.6	1.7	2.0	0.2	0.2
Semi-compact + bean	-indeterminate	41.6	66.1	75.6	77.2	1.4	1.6	0.6	0.2
	-determinate	44.0	75.2	75.6	77.2	1.4	1.6	0.6	0.2
	-sole	37.4	64.5	72.9	73.5	1.2	1.8	0.6	0.1
Erect + bean	-indeterminate	40.3	70.3	77.3	79.4	1.3	2.0	0.4	0.2
	-determinate	35.5	66.3	71.8	77.8	1.2	2.0	0.4	0.6
	-Sole	40.1	80.8	83.1	85.2	1.3	2.7	0.1	0.2
Intercropped mean		41.2	72.0	77.1	79.7	1.4	2.0	0.3	0.2
Sole mean		42.5	75.0	79.4	80.9	1.4	2.2	0.3	0.1
CV.		23.8%	15.7%	15.9%	16.0%				
SE.-bean		0.76	1.58	2.67					
-s/potato		3.30	3.83	4.09	4.29				

Sweetpotato and bean plant types had no significant effect on vine growth. However, intercropping reduced vine growth rate by 13.5% and 10.2% of the sole crop in genotypes with erect growth habit in 1993/94 and 1994/95 seasons, respectively. Genotypes with semi-compact growth habit grown with indeterminate bean had their vine growth reduced by 3.9% of the sole crop. However, vine growth was increased by 4.6% in genotypes with spreading growth habit grown with indeterminate bean.

Dry matter accumulation (DMA) and crop growth rate (CGR)

During 1993/94 cropping season, sweetpotato genotypes differed in DMA and the bean crop had significant effect at 4 WAP. Sweetpotato x bean genotypes interaction effects were significant. In 1994/95 season, there were no significant differences in DMA.

Intercropping reduced DMA of sweetpotato by 6.4, 5.7, 8.4 and 11.9% of the sole crop at 4, 6, 8 and 10 WAP, respectively during 1993/94. In 1994/95 season, intercropping reduced sweetpotato DMA by an average of 18.5, 16.7 and 14.7% at 4, 8 and 10 WAP, respectively. The effects of sweetpotato morphotypes on DMA were not significant (Table 13).

CGR ($\text{g/m}^2/\text{day}$) was reduced by 7.3 and 27.8% of the sole crop in the spreading and semi-compact plant types, but increased by 9.3% in the erect plant type in 1993/94 season.

In 1994, CGR was reduced by 9.0, 6.5 and 5.4% of the sole crop for the spreading, semi-compact and erect plant types, respectively. Generally, CGR

increased with time, but mean CGR was 3.6% higher in 1994/95 than 1993/94 cropping season (Table 14). Overall, intercropping reduced CGR by 2.8% and 12.7% of the sole crop in 1993/94 and 1994/95 cropping seasons, respectively.

Leaf area index

During 1993/94 cropping season, leaf area index (LAI) was not significantly influenced either by sweetpotato or bean genotypes. In 1994/95 season, LAI differed with sweetpotato genotypes at 6, 8 and 10 WAP (Table 15). Sweetpotato genotype x bean genotype interaction effects were significant at 6 WAP. Intercropping reduced LAI by 18.2 and 19.0 % in 1993/94 and 1994/95 seasons, respectively. Mean LAI was 9.4% higher in 1994/95 than in 1993/94 season. LAI was positively correlated with CGR ($r = 0.565^*$, $n = 54$) at 10 WAP. In 1993/94 season, LAI did not vary much among sweetpotato plant types but LAI were 13.8% and 6.9% lower in spreading and erect plant types than in semi-compact plant types, respectively.

In 1994/95 season, LAI were 14.9% and 19.2% lower in spreading and erect plant types than in the semi-compact plant types. LAI increased with time until 8 WAP and declined there after.

Table 13: Effects of sweetpotato plant types on dry matter accumulation (DMA) in sweetpotato, 1993/94 and 1994/95 cropping seasons

Cropping system Plant types		1993/4				1994/95			
		Dry matter accumulation (g/m ²)				Growth period (WAP)			
		4	6	8	10	4	6	8	10
Sweetpotato	Bean								
Spreading	+ Indeterminate	4.1	10.0	19.7	90.8	5.3	10.6	17.6	69.4
Spreading	+ Determinate	5.0	9.7	13.7	104.1	5.6	11.0	17.4	112.1
Spreading	Sole-cropped	7.8	12.8	21.9	99.6	8.0	12.9	22.4	102.8
Semi-compact	+ Indeterminate	5.7	10.1	15.9	93.0	6.3	11.5	17.0	103.7
Semi-compact	+ Determinate	5.4	13.0	19.3	115.2	6.9	12.8	17.1	106.0
Semi-compact	Sole-cropped	5.7	12.4	19.3	130.2	7.0	13.2	20.0	166.5
Erect	+ Indeterminate	4.5	13.1	18.3	76.0	6.1	14.5	20.8	93.0
Erect	+ Determinate	4.9	10.6	16.0	89.9	5.3	9.8	14.2	78.4
Erect	Sole-cropped	5.6	5.6?	18.9	98.3	7.2	12.3	18.5	101.2
CV.		22.9% 28.2% 28.2% 34.0%				21.6% 32.6% 30.3% 32.2%			
SE. (bean)		0.27 0.60 0.74 16.1				0.16 0.62 1.07 14.6			
(sweetpotato)		0.43 1.11 1.66 11.6				0.44 1.33 1.83 11.27			
LSD (0.05)		NS NS NS NS				NS NS NS NS			

Table 14. Effects of intercropping on crop growth rate (CGR) in sweetpotato, 1993/94 and 1994/95 cropping seasons

Sweetpotato genotypes	Crop growth rate (g/m ² /day)									
	1993/94					1994/95				
	4	6	8	10	Growth period (WAP)	4	6	8	10	
Wagabolige + bean	0.25	0.16	0.16	1.41	0.28	0.41	0.41	0.78	1.75	
Bitambi + bean	0.31	0.15	0.20	1.72	0.33	0.43	0.43	0.57	1.56	
Tororo 3 + bean	0.22	0.19	0.14	1.70	0.24	0.51	0.51	0.61	1.62	
Bwanjule + bean	0.23	0.19	0.11	0.29	0.24	0.53	0.53	0.61	1.61	
New kawogo + bean	0.25	0.19	0.13	1.56	0.27	0.50	0.50	0.53	1.45	
Tanzania + bean	0.24	0.19	0.10	1.25	0.26	0.49	0.49	0.52	1.42	
Entry No.20 + bean	0.22	0.15	0.11	1.35	NA*	NA	NA	NA	NA	
Entry No.21 + bean	0.23	0.17	0.12	1.46	NA	NA	NA	NA	NA	
Intercropped mean	0.24	0.16	0.15	1.69	0.27	0.48	0.48	0.60	1.57	
Sole-cropped mean	0.25	0.15	0.13	1.51	0.27	0.45	0.45	0.72	1.62	
CV.	22.9%	28.2%	28.2%	34.0%	21.6%	32.6%	32.6%	30.3%	32.2%	
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	
SE. (bean)	0.27	0.60	0.74	16.07	0.16	0.62	0.62	1.07	14.55	
(sweetpotato)	0.43	1.11	1.66	11.58	0.44	1.33	1.33	1.83	11.27	

* NA = Not applicable because the genotypes were excluded during 1994/95 cropping season.

Table 15. Effects of intercropping on sweetpotato leaf area index (LAI)(1993/94 and 1994/95)

Sweetpotato variety and plant type	1993/94										1994/95									
	Growth periods (WAP)																			
	4	6	8	10	4	6	8	10	4	6	8	10	4	6	8	10	4	6	8	10
Sweetpotato-spreading + bean (Wagaboli-large leaves)	1.2	2.3	4.0	3.2	1.3	2.1	4.3	3.4	1.3	2.1	4.3	3.4	1.3	2.1	4.3	3.4	1.3	2.1	4.3	3.4
Sweetpotato-spreading + bean (Entry 21-medium leaves)	1.1	2.0	3.3	3.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sweetpotato-semi-compact + bean (Bitambi-medium-leaves)	1.3	2.7	4.6	3.6	1.4	2.7	4.9	3.7	1.4	2.7	4.9	3.7	1.4	2.7	4.9	3.7	1.4	2.7	4.9	3.7
Sweetpotato-semi-compact + bean (Tororo 3-large leaves)	1.3	3.3	4.6	4.1	1.4	2.1	3.6	3.0	1.4	2.1	3.6	3.0	1.4	2.1	3.6	3.0	1.4	2.1	3.6	3.0
Sweetpotato-semi-compact + bean (New Kawogo-large leaves)	1.1	2.1	3.3	3.0	1.1	1.9	3.6	2.9	1.1	1.9	3.6	2.9	1.1	1.9	3.6	2.9	1.1	1.9	3.6	2.9
Sweetpotato-erect + bean (Bwanjule-small leaves)	1.0	2.0	3.4	2.9	1.6	2.6	4.0	3.5	1.6	2.6	4.0	3.5	1.6	2.6	4.0	3.5	1.6	2.6	4.0	3.5
Sweetpotato-erect + bean (Entry 20-medium leaves)	1.1	2.1	3.1	3.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sweetpotato-erect + bean (Tanzania-small/medium leaves)	1.1	2.4	3.7	3.3	1.6	2.6	4.0	3.5	1.6	2.6	4.0	3.5	1.6	2.6	4.0	3.5	1.6	2.6	4.0	3.5
Intercropped mean	1.5	2.4	3.7	3.2	1.4	2.6	4.4	3.6	1.4	2.6	4.4	3.6	1.4	2.6	4.4	3.6	1.4	2.6	4.4	3.6
Sole cropped mean	1.6	3.1	4.6	3.9	1.8	3.3	5.3	4.3	1.8	3.3	5.3	4.3	1.8	3.3	5.3	4.3	1.8	3.3	5.3	4.3
CV%	47.3	51.0	33.2	35.3	42.4	51.1	32.3	33.9	42.4	51.1	32.3	33.9	42.4	51.1	32.3	33.9	42.4	51.1	32.3	33.9
SE. bean	0.24	0.55	0.56	0.52	0.26	0.61	0.58	0.53	0.26	0.61	0.58	0.53	0.26	0.61	0.58	0.53	0.26	0.61	0.58	0.53
s/potato	0.18	0.42	0.44	0.40	0.18	0.44	0.47	0.41	0.18	0.44	0.47	0.41	0.18	0.44	0.47	0.41	0.18	0.44	0.47	0.41
LSD (0.05)	NS	NS	NS	NS	NS	1.28	1.36	1.18	NS	1.28	1.36	1.18	NS	1.28	1.36	1.18	NS	1.28	1.36	1.18

4.2.3 Sweetpotato yield and yield components

Vine yield

Yield and yield components of sweetpotato during 1993/94 and 1994/95 cropping seasons were varied. During 1993/94 cropping season, vine yield varied significantly among sweetpotato genotypes. Sweetpotato genotype Entry No.20 produced the highest vine yield which was 44.5% higher than the sole crop yield (Table 16).

Vine yield was negatively and positively correlated with shoot/root ratio ($r=-0.472^{**}$, $r=0.327^{**}$, $n=120$) in 1993/94 and 1994/95 seasons, respectively. During 1994/95 cropping season Tororo 3 produced the highest vine yield which was 14.3% higher than the sole yield (Table 17). As in 1993/94 season, genotypes with erect growth habit produced the highest vine yield, which was, 8.1% lower than the sole yield (Table 18 and 19). By contrast, sweetpotato morphotypes differed significantly in vine yield (Tables 20 and 21). The genotypes with semi-compact growth habit produced the highest vine yield in mixtures with determinate bean genotype, which was 43.2% higher than the vine yield from sole crop. Vine yield varied significantly across seasons (Appendix 12).

Overall, intercropping reduced vine yield by an average of 9.7% of the sole yield. There was a linear negative correlation ($r=-0.727^{**}$ $n=48$) between vine yield and harvest index (HI) and a positive correlation ($r=0.687^{**}$, $n=48$) between vine yield and shoot/root ratio.

Storage root size distribution

In both seasons sweetpotato genotypes differed in the number of marketable (>4.5 cm diameter) and unmarketable roots. In both seasons, genotype Tanzania produced 52.4% and 22% higher marketable roots than the sole crop in 1993/94 and 1994/95, respectively. It also produced 63.6% and 29.5% higher percentage unmarketable storage roots than the sole crop in 1993/94 and 1994/95, respectively (Tables 16 and 17). Genotypes with erect growth habit grown with determinate bean genotype produced the highest percent of marketable and unmarketable roots in 1993/94 season (Table 18).

In 1994/95 season, genotypes with spreading growth habit grown with indeterminate bean produced the highest percentage of marketable roots which was 20% higher than the sole crop. The erect plant types grown with indeterminate bean produced the highest percentage of unmarketable roots which was 20.9% more than the sole yield (Table 19). By comparison, plant morphotypes differed in root size distribution (Tables 20 and 21).

Generally, percent marketable and unmarketable storage roots were higher in intercrop in 1993/94 season, but in 1994/95 season, percentages of unmarketable roots were reduced while percent marketable roots increased with intercropping. Percent marketable roots was linearly correlated with percent unmarketable roots and yield per plant ($r=0.513^{**}$, $r=0.726^{**}$, $n=72$), respectively. Both percentages of marketable and unmarketable storage roots varied across season. Genotypes performed differently across season and season x sweetpotato genotype interaction effects were significant for storage root size distribution.

Storage root weight distribution

Intercropping increased individual marketable root weights by 22.5% and 0.8% of the sole crop weight in 1993/94 and 1994/95 seasons, respectively. New Kawogo produced the heaviest root which was 39.3% higher than sole weight in 1993/94 cropping season (Table 16).

In 1994/95 season, Wagabolige produced the heaviest root which weighed 7.2% more than the sole crop weight (Table 17). There were no differences in the intercrop and sole crop yields in 1993/94 and 1994/95, respectively. New Kawogo produced the heaviest individual unmarketable roots both in 1993/94 and 1994/95 cropping seasons.

Genotypes with spreading growth habit grown with determinate bean produced the heaviest marketable roots which was 27.6% higher than the sole crop weight in 1993/94 season (Table 18). In 1994/95 season, the semi-compact genotype grown with indeterminate bean produced the heaviest marketable roots, which weighed similar to the sole crop roots (Table 19). Spreading genotypes grown with determinate bean produced the heaviest unmarketable roots in both seasons, which were 23.8% and 35.9% higher than the sole crop roots.

Weights of marketable roots varied across seasons and by contrast, plant morphotypes differed in individual marketable root weight (Tables 20 and 21). There were significant sweetpotato genotype x season, season x bean genotype and season x bean genotype x sweetpotato genotype interaction effects on root size distribution in sweetpotato.

Storage root yield

Marketable and total storage root yields were significantly influenced by intercropping. Sweetpotato genotypes differed in storage root yield with Wagabolige producing the highest total yield which was 60.3% and 17.7% higher than the sole crop mean yield in 1993/94 and 1994/95, respectively. Marketable yields were 87.4% and 86.7% of the total yield in 1993/94 and 1994/95 seasons (Tables 16 and 17).

Erect genotypes produced the highest yield, which was 58.2% higher than the sole crop yield of the same plant type in 1993/94 season. In 1994/95 season, spreading genotypes produced the highest yield which was 9.4% of the sole crop yield of the same plant type. In 1993/94 season, yield per plant was correlated with total root yield ($r=0.999^{**}$) and HI ($r=0.847^{**}$, $n=96$) but negatively with shoot/root ratio ($r=-0.677^{**}$, $n=96$). Total storage root yields were correlated with yield per plant ($r=0.782^{**}$) and weight of individual marketable roots ($r=0.429^{**}$, $n=96$). Sweetpotato genotypes responded differently in the various intercrop combinations as indicated by the ranks of various genotypes (Table 22).

Comparing the varietal intercropped and sole-cropped yield means, there is an indication that the genotypes that yielded high in pure stand also yielded very well in mixtures. This relationship has been confirmed by the correlation coefficient ($r = 0.812^*$, $n=6$) between the intercropped and sole-cropped yield. There were no significant differences in total yield across seasons. Intercropping increased total yield, with greater increase in 1993/94 season. Overall, the most compatible sweetpotato morphotypes with bean was the erect type followed by the semi-compact type.

Harvest index (HI)

Harvest index ranged from 8.4% to 44.6% in 1993/94 season and from 38.5% to 53.9% in 1994/95 cropping season (Tables 16 and 17). Wagabolige had the highest HI which was 38.8% and 21.7% higher than the sole crop HI in 1993/94 and 1994/95 seasons, respectively. Harvest index was negatively correlated with vine yield ($r = -0.727^{**}$, $n=96$) and shoot/root ratio ($r = -0.868^{**}$) but positively correlated with yield per plant ($r = 0.644^{**}$), marketable yield ($r = 0.524^{**}$), total root yield ($r = 0.581^{**}$, $n=96$), number of marketable roots per plot ($r = 0.517^{**}$). HI was influenced by season and sweetpotato genotypes. Intercropping increased HI by 6.5% and 4.7% of the sole crop HI in the 1993/94 and 1994/95 seasons, respectively.

Dry matter content percent (DMC%)

Dry matter content percent (DMC%) ranged from 31% to 34.1% in 1993/94 season and from 31.4% to 34.1% in 1994/95 season (Tables 16 and 17). Intercropping had no significant effect on DMC%.

Table 16: Performance of eight sweetpotato genotypes when intercropped with bean, 1993/94 cropping season

Sweetpotato genotypes	Yield and Yield Components								
	Fresh vine yield (g/plant)	% marketable roots/plot	% unmarketable roots/plot	Average weight of marketable roots (g)	Average weight of unmarketable roots (g)	Marketable yield (t/ha)	Total yield (t/ha)	Harvest Index (%)	DMC (%)
Wagabolige	395	50.4	40.6	281.2	76.5	24.2	27.7	44.6	34.1
Entry 21	610	60.0	40.0	285.7	71.6	3.9	4.6	8.4	32.0
Bwanjule	585	58.3	41.7	255.5	60.4	18.1	20.8	31.2	31.0
Entry 20	640	46.2	53.8	289.2	56.4	4.9	6.5	10.7	31.3
Tanzania	480	48.8	51.2	269.9	58.2	21.3	26.3	36.5	33.1
Bitambi	445	58.8	41.2	214.2	75.4	19.2	22.5	35.6	32.1
Tororo 3	625	61.5	38.5	289.6	60.6	23.0	26.3	32.3	31.2
New Kawogo	535	63.6	36.4	358.2	91.0	24.5	27.0	34.7	33.0
Intercropped mean	540	56.0	44.0	280.4	68.8	17.4	20.2	29.2	32.2
Sole cropped	355	56	44.4	217.3	65.5	9.0	11.0	27.3	32.3
CV	24.8%	29.8%	54.7%	40.3%	46.9%	40.6%	37.4%	27.5%	8.1%
SE	0.76	1.13	1.29	29.16	8.74	1.55	1.70	2.01	0.69
S/potato bean	0.58	1.48	1.38	25.24	7.10	1.78	1.96	2.98	0.60
LSD (0.05) S/potato	1.77	2.84	3.96	NS	NS	4.39	4.76	5.84	NS

Table 17: Performance of six sweetpotato genotypes when intercropped with beans, 1994/95 cropping season.

Sweetpotato genotypes	Yield and yield components									
	Fresh vine		%		Average weight		Average weight		Total	
	yield	(g/plant)	marketable	roots/plot	unmarketable	roots/plot	of marketable	unmarketable	yield	DMC
			roots/plot	roots/plot	roots (g)	roots (g)	roots (g)	roots (g)	(t/ha)	(%)
Wagabolige	500.0		60.0	40.0	395.7	88.4	25.5	29.4	53.9	34.1
Bwanjule	672.5		45.7	54.3	326.0	85.6	15.8	22.4	39.8	31.4
Tanzania	467.5		47.0	53.0	298.1	77.4	19.5	25.5	53.2	33.4
Bitambi	607.5		56.5	43.5	374.6	75.9	20.3	21.0	41.0	32.3
Tororo 3	750.0		54.4	45.6	340.6	83.2	19.9	25.3	39.3	31.7
New Kawogo	660		60.0	40.0	450.3	91.2	19.7	21.2	38.5	33.2
Mean	580		55.0	45.0	364.2	83.6	20.1	24.4	44.3	32.7
Sole mean	642.5		49.5	50.6	367.2	80.9	19.5	24.2	42.2	32.9
CV	33.0%		23.0%	36.2%	17.8%	22.3%	26.4%	23.2%	16.6%	8.3%
SE	71.2		3.0	4.15	18.73	5.38	1.53	1.63	2.12	0.79
S/potato bean	1.69		2.63	3.97	16.36	3.97	1.43	1.29	1.93	0.70
LSD (0.05)	NS		8.80	7.24	53.37	NS	4.36	4.64	6.05	NS

Table 18: Effects of sweetpotato and bean morphotypes on the performance of sweetpotato/bean association, 1993/94 cropping season.

Sweetpotato yield attributes									
Morphotypes	Fresh vine yield (g/plant)	Percent marketable roots/plot	Percent unmarketable roots/plot	Average weight of marketable root g/root	Average weight of unmarketable root g/root	Marketable yield (t/ha)	Total yield (t/ha)	Harvest Index (%)	DMC (%)
Sweetpotato + Bean									
Spreading + indeterminate	500.0	61.1	38.9	177.8	64.1	13.8	15.5	22.2	33.0
+ Determinate	505.0	55.6	44.4	340.6	91.2	14.8	16.9	29.1	33.0
Sole	400.0	56.2	43.8	246.5	69.5	7.8	9.6	24.0	33.0
Semi - compact									
+ Indeterminate	500.0	60.9	39.1	302.0	79.2	18.2	20.7	36.8	32.0
+ determinate	625.0	56.0	44.0	314.9	84.1	17.6	20.5	37.5	32.1
Sole	355.0	76.5	23.5	202.9	72.3	10.6	13.0	31.5	33.4
Erect + indeterminate	525.0	50.0	50.0	322.6	59.5	19.2	23.3	24.7	31.7
+ Determinate	540.0	51.4	48.6	251.0	58.2	19.7	23.7	27.5	31.0
Sole	350.0	55.6	44.4	212.4	56.3	8.1	9.9	25.4	31.8
Mean	535.0	55.0	45.0	284.8	72.2	17.2	20.1	29.6	32.1
Sole Mean	370.0	62.9	37.1	270.6	66.0	8.8	10.8	27.0	32.4
CV	24.8%	29.8%	54.6%	40.3%	46.9%	40.6%	37.4%	27.5%	6.13%
S.E.	0.63	1.01	1.40	9.55	8.34	1.55	1.69		

Table 19 : Effects of sweetpotato and bean morphotypes on the performance of sweetpotato in a sweetpotato / bean association, 1994/95 cropping season.

Sweetpotato Yield attributes									
Plant types	Fresh vine yield (g/plant)	Percent marketable roots/plot	Percent unmarketable roots/plot	Average weight of marketable g/root	Average weight of unmarketable g/root	Marketable yield (t/ha)	Total yield (t/ha)	Harvest index (%)	Dmc (%)
Sweetpotato									
Bean									
Spreading + indeterminate	522.5	60.4	39.6	381.1	82.0	27.6	31.2	55	33
+ Determinate	480.0	61.7	38.3	386.7	111.7	27.7	29.7	54	33.2
Sole	550.0	59.5	40.5	413.4	71.5	25.0	27.6	51	33.0
Semi-compact									
+ Indeterminate	677.5	55.0	45.0	398.4	89.2	18.5	25.1	42	32
+ Determinate	667.5	61.8	38.2	351.7	61.5	18.5	21.2	39	31.8
Sole	737.5	53.6	46.4	398.4	89.9	20.2	24.0	36	33.2
Erect +									
Indeterminate	550.0	48.5	51.5	334.1	81.9	20.7	25.6	48	31.0
+ Determinate	590.0	47.9	52.1	305.9	80.1	16.8	21.6	45	32.8
Sole	637.5	43.2	56.8	297.1	82.5	15.6	21.2	45	31.5
Mean - int.	580.0	55.7	44.3	359.7	84.4	21.6	25.7	47.2	32.2
Sole.	642.5	50.6	49.4	369.6	79.0	20.3	24.3	44	32.6
CV	33.0%	23.0%	36.2%	17.8%	22.3%	26.3%	23.2%	16.6%	8.34%
S.E.	2.84	2.97	4.15	18.73	5.38	1.53	1.63	2.12	0.78
LSD (0.05)	NS	29.12	11.83	197.5	NS	11.21	12.10	24.24	NS

Table 20. Levels of significance from analysis of variance and contrasts in yield and yield components of eight sweetpotato and four bean genotypes (1993/94)[Experiment I]

Source of variation	Degrees of freedom	Vine yield (g/plant)	Yield attributes					Harvest index percent	Total yield (t/ha)
			Percent mark. (root/plot)	Percent unmark. (root/plot)	Aver. weight mark. (g)	Aver. weight mark. (g)			
Replication	2	ns	ns	ns	ns	ns	ns	*	
Bean genotype	4	ns	ns	ns	ns	ns	ns	**	
Error (a)									
Sweetpotato genotype	7	**	**	**	ns	ns	**	**	
Bean x Sweetpotato	28	ns	ns	*a	ns	ns	ns		
ns									
Error(b)	70								
Contrast									
Determinate vs indeterminate	2	ns	ns	ns	ns	ns	ns	ns	
Semi-compact vs erect		**a	**qc	**a	ns	ns	**a	**a	
Semi-compact vs spreading		**a	**qc	**a	ns	ns	**a	**a	
Erect vs spreading		**a	**qc	**a	ns	ns	**a		
**a									
CV.		24.8%	29.8%	54.6%	40.3%	46.9%	27.5%	37.4%	

^a ^{ac}, quadratic, both quadratic and cubic coefficients, respectively.
ns, **, non-significant or significant at 1% probability level, respectively.

Table 21. Levels of significance from analysis of variance and contrasts in sweetpotato yield and yield components in mixtures of six sweetpotato and two bean genotypes (1994/95) [Experiment 1].

Source of variation	Degrees of freedom	Vine yield (kg/plant)	Percent market. (roots/plot)	percent unmark. (roots/plot)	Aver. wt. market. root(g)	Aver. wt. unmark. root(g)	Harvest index percent	Shoot/ root ratio	Total yield (t/ha)
Replication	3	ns	ns	*	ns	ns	ns	ns	ns
Bean genotype (BG)	2	ns	ns	ns	ns	ns	ns	ns	ns
Error(a)									
Sweetpotato genotypes (SPG)	5	**	**	**	**	ns	*	**	**
BG x SPG	10	ns	ns	ns	ns	ns	ns	ns	ns
Error (b)									
Contrast									
Semi-compact vs erect		** ^a	ns	ns	** ^c	ns	* ^c	** ^q	* ^q
Semi-compact vs spreading		** ^a	ns	ns	* ^c	ns	* ^c	** ^q	* ^q
erect vs spreading		** ^a	ns	ns	* ^c	ns	* ^c	** ^q	* ^q
CV.			23.0%	36.2%	17.9%	22.3%	23.2%	16.6%	32.9%

^{c,q} = Cubic and quadratic coefficients, respectively.

ns, *, ** = Non-significant or significant at 5% and 1% probability levels, respectively.

Table 22: Yield response of different sweetpotato genotypes to different bean genotypes in sweetpotato/bean association, 1993/94 and 1994/95 cropping season.

Sweetpotato genotypes	Mean fresh storage root yield (t/ha)									
	1993/94					1994/95				
	White Haricot	MMS 224	A 197	GLP 585	Varietal mean	Sole mean	White Haricot	GLP 585	Varietal Mean	Sole Mean
Wagabolige	18.9(4)*	24.9(1)	26.4(1)	26.2(1)	24.1(1)	14.0	31.2(1)*	27.7(2)	29.4(1)	29.7(1)
Entry 21	2.4(8)	4.9(7)	5.0(8)	4.7(7)	4.2(8)	1.7	NA	NA	NA	NA
Bwanjule	19.4(3)	19.6(4)	19.2(5)	15.1(6)	18.3(5)	13.0	22.0(5)	20.0(6)	21.0(6)	25.2(4)
Entry 20	3.1(7)	3.2(8)	6.9(7)	4.7(7)	4.5(7)	2.4	NA	NA	NA	NA
Tanzania	16.6(5)	17.1(6)	21.8(4)	18.3(4)	18.4(6)	8.7	29.2(2)	29.2(2)	25.1(2)	27.1(2)
Bitambi	16.3(6)	17.8(5)	16.7(6)	21.2(2)	18.0(3)	9.3	24.4(4)	21.8(3)	23.0(4)	17.1(6)
Tororo 3	24.1(1)	21.1(2)	25.4(2)	17.7(5)	21.3(2)	11.7	28.6(3)	20.7(5)	24.6(3)	26.6(3)
New Kawogo	22.1(2)	21.0(3)	23.2(3)	19.8(3)	21.5	11.0	22.0(5)	21.4(4)	21.7(5)	20.1(5)
Mean	15.0	16.2	18.1	16.0	16.3	9.0	26.2	23.8	24.1	24.3
C.V.	37.4%						23.2%			
S.E.	1.69						1.69			
LSD. (0.05) (S/potato)	4.76						4.64			(S/potato)
(bean)	3.31						NS			(bean)

* Numbers in parentheses are ranks within a column

4.3.0 Bean growth

Plant height

There were significant differences in plant heights among the bean genotypes at 8 WAP during 1993/94 season. Sweetpotato genotypes had no significant effects on bean growth (Table 23). The indeterminate beans were 19.3% and 17.7% taller under the erect than in the semi-compact and spreading genotypes, respectively. The determinate bean were 20.2% and 9.4% taller under the semi-compact than the spreading and erect types, respectively. In the 1993/94 season, intercropping reduced plant height by 17.2, 7.4 and 3.7% of the sole crop at 4, 6 and 8 WAP, respectively for the indeterminate bean genotypes.

The determinate bean had their heights reduced by 22.3% and 10.5% of the sole crop at 4 and 8 WAP, respectively. In 1994/95 season, plant heights were reduced by 3.0, 6.2, and 13.9 % at 4, 6 and 8 WAP, respectively for the indeterminate bean genotypes. There were increases of 21.2, 8.3, and 9.4 % at 4, 6 and 8 WAP, respectively for the determinate bean genotypes.

Plant height at first branching was 11.4% greater in determinate than indeterminate bean genotypes. However, plant height at first branching was reduced by 3.3% in the indeterminate and increased by 7.2% in the determinate bean genotypes.

Dry matter accumulation and crop growth rate

Dry matter accumulation (DMA) in bean was not significantly different at each sampling period in 1993/94 and 1994/95 seasons (Table 24). Sweetpotato genotypes had no significant influence on DMA. Crop growth rate (CGR) (Table 25) in indeterminate bean were 10.6% and 6.9% lower than in the determinate bean in 1993/94 and 1994/95 cropping seasons, respectively.

Table 23. Effects of intercropping on bean plant height in sweetpotato/bean association, 1993/94 and 1994/95 cropping seasons

Cropping system	1993/94					1994/95				
	Growth period (WAP)					Growth period (WAP)				
	height at first branching	4	6	8	height at first branching	4	6	8	height at first branching	4
Bean-indeterminate (large leaves) + sweetpotato	7.2	18.7	46.5	47.2	7.5	21.5	48.8	49.4		
Bean-determinate (small leaves) + sweetpotato	8.1	24.6	56.1	58.2	8.5	26.9	58.1	59.3		
Bean-indeterminate (large leaves) sole	7.5	22.6	50.2	49.0	7.7	24.7	52.5	57.4		
Bean-determinate (small leaves) sole	7.8	19.1	57.1	52.1	7.6	21.2	53.3	53.7		
Mean: intercropped	7.7	20.9	53.7	50.6	8.0	24.2	53.4	54.4		
Mean: sole-cropped	7.7	21.7	51.3	52.7	7.7	23.0	52.7	55.6		
CV.	10.1%	14.2%	17.2%	16.9%	9.02%	15.3%	16.7%	16.5%		
SE.	0.20	1.24	3.02	0.74	0.30	1.58	3.02	0.89		
LSD (0.05)	NS	NS	NS	4.51	NS	NS	NS	NS		

Table 24. Effects of intercropping on bean dry matter accumulation (DMA), 1993/94 and 1994/95 cropping seasons

		Dry matter accumulation (DMA) (g/m ²)							
		1993/94				1994/95			
Cropping system	Plant types	4	6	8	4	6	8	4	8
Sweetpotato	Bean								
Spreading + Indeterminate		1.60	7.51	13.5	1.79	7.72	13.73		
Spreading + Determinate		2.17	6.42	10.97	2.29	6.62	11.10		
Semi-compact + Indeterminate		1.77	7.20	11.60	1.80	7.14	12.00		
Semi-compact + Determinate		1.65	6.79	11.71	1.73	6.98	11.88		
Erect + Indeterminate		1.02	5.31	9.00	1.65	5.47	9.22		
Erect + Determinate		1.50	7.34	13.64	1.42	7.78	13.80		
Indeterminate- sole-cropped		1.50	8.92	9.13	1.61	9.15	12.57		
Determinate - sole-cropped		1.53	6.71	11.30	1.55	6.86	11.50		
CV.		37.2%	27.5%	28.0%	34.0%	27.0%	25.7%		
SE. (bean)		0.11	0.28	0.55	0.11	0.23	0.31		
(sweetpotato)		0.26	0.78	1.31	0.24	0.79	1.25		
LSD (0.05)		NS	NS	NS	NS	NS	NS		

Table 25. Effects of intercropping on crop growth rate (CGR) in bean, 1993/94 and 1994/95 cropping seasons

Cropping system	1993/94				1994/95			
	Crop growth rate (CGR) (g/m ² /day)				Crop growth rate (CGR) (g/m ² /day)			
	4	6	8		4	6	8	
Indeterminate + sweetpotato	0.2	1.25	0.85		0.2	1.26	0.98	
Indeterminate - sole-cropped	0.2	1.56	0.22		0.2	1.71	0.76	
Determinate + sweetpotato	0.2	1.22	1.16		0.2	1.28	1.14	
Determinate - sole-cropped	0.2	1.68	0.58		0.2	1.25	1.03	
Intercropped mean	0.2	1.23	1.00		0.2	1.27	1.06	
Sole-cropped mean	0.2	1.62	0.40		0.2	1.48	0.89	
CV.	37.2%	27.5%	28.0%		34.0%	27.0%	25.7%	
LSD (0.05)	NS	NS	NS		NS	NS	NS	
SE. (bean)	0.11	0.28	0.55		0.11	0.23	0.31	
(sweetpotato)	0.25	0.78	1.31		0.24	0.79	1.25	

Intercropping increased CGR by 14.3% and 4.7% of the sole crop for the indeterminate and determinate beans, respectively during 1993/94 season. In 1994/95 season, CGR was reduced by 11.0% for the indeterminate but was increased by 4.6% for the determinate bean. Crop growth rate was at maximum at 6 WAP both in sole and intercropped bean. At 8 WAP, CGR declined as bean crop shed off old leaves.

Leaf area index

LAI was significantly influenced by sweetpotato genotypes at each sampling period in 1993/94 season (Tables 26) and at 6 and 8 WAP in 1994/95 season (Table 27).

In 1993/94 season, there were significant differences in LAI between the bean genotypes at 4 and 6 WAP. The spreading sweetpotato reduced LAI by 32.0% and 25.6% for White Haricot and GLP 585, respectively. The semi-compact plant reduced LAI by 15.0 % and 9.3 % for White Haricot and GLP 585, respectively. The erect plant types reduced LAI by 16.2% for both bean genotypes.

In 1994/95 season, LAI for White Haricot was reduced by 34.5, 8.7 and 12.4% in spreading, erect and semi compact plant types, respectively.

Intercropping reduced LAI at various growth stages. In 1993/94 season, LAI were reduced by an average of 30.4, 5.3, and 23.7 % of the sole crop at 4, 8 and 10 WAP, respectively.

Overall, intercropping reduced LAI by an average of 23.1 % and 13.5 % in 1993/94 and 1994/95 seasons, respectively.

Table 26. Effects of intercropping on bean leaf area index (LAI) (1993/94)

Sweetpotato morphotypes	Bean morphotypes									
	Indeterminate (Type 11)					Growth periods (WAP)				
	4	6	8	10		4	6	8	10	
Sweetpotato-spreading (Wagaboli)	1.2	1.6	1.9	1.5		1.6	1.8	2.1		1.8
Sweetpotato-spreading (Entry 21)	1.4	2.0	2.1	1.9		1.5	1.9	2.0		1.7
Sweetpotato-semi-compact (Bitambi)	2.2	2.5	2.7	2.3		2.3	2.5	2.7		2.4
Sweetpotato-semi-compact (Tororo 3)	1.8	2.1	2.4	2.0		1.6	1.9	2.2		1.8
Sweetpotato-semi-compact (New Kawogo)	1.7	1.9	2.0	1.8		1.9	2.2	2.4		2.0
Sweetpotato-erect (Bwanjule)	1.8	2.0	2.3	2.0		1.7	1.9	2.2		1.8
Sweetpotato-erect (Entry 20)	1.6	2.0	2.2	2.7		1.5	1.8	2.2		1.8
Sweetpotato-erect (Tanzania)	2.2	2.5	2.7	2.1		2.6	2.3	2.4		2.3
Intercropped mean	1.7	2.0	2.3	1.9		1.8	1.8	2.3		2.0
Sole-cropped mean	2.8	3.2	3.4	2.7		2.6	2.9	3.1		2.7
CV.	33.1	28.0	25.6	24.5		33.1	28.0	25.6		24.5
SE.indet/deter bean	0.03	0.03	0.02	0.04						
s/potato	0.26	0.26	0.26	0.21						
LSD (0.05) (s/potato effect)	0.77	0.74	0.75	0.68						

Table 27. Effects of intercropping on bean leaf area index (LAI)(1994/95)

sweetpotato morphotypes	Bean morphotypes									
	indeterminate White Haricot			Growth periods (WAP)			determinate GLP 585			
	4	6	8	10	4	6	8	10		
Sweetpotato-spreading (Wagabolige)	1.2	1.7	1.9	1.6	1.7	2.0	2.2	2.0	2.2	2.0
Sweetpotato-semi-compact (Bitambi)	2.3	2.6	2.8	2.4	2.4	2.6	2.8	2.4	2.8	2.4
Sweetpotato-semi-compact (Tororo 3)	1.9	2.1	2.4	2.1	1.7	2.0	2.2	2.0	2.2	1.8
Sweetpotato-semi-compact (New Kawogo)	1.9	2.0	2.4	2.0	2.0	2.3	2.4	2.0	2.4	2.0
Sweetpotato -erect (Bwanjule)	1.9	2.1	2.4	2.1	1.7	2.0	2.2	2.0	2.2	1.8
Sweetpotato-erect (Tanzania)	2.4	2.6	2.8	2.3	2.0	2.5	2.7	2.0	2.7	2.3
Intercropped mean	1.9	2.2	2.4	2.1	1.9	2.2	2.4	2.1	2.4	2.0
Sole-cropped mean	2.9	3.3	3.4	2.8	2.7	3.1	3.3	2.7	3.3	2.7
CV.	33%	26.8%	24.5%	25.2%						
SE. indeterminate/ determinate bean	0.03	0.04	0.02	0.03						
sweetpotato	0.27	0.26	0.25	0.72						
LSD(0.05) NS.										

4.3.1 Common bean plant diseases.

The occurrence of common bean bacterial blight (CBB) caused by *Xanthomonas campestris*, var. at pod filling (R 8) and physiological maturity (R 9) stages were not significantly different between the two bean genotypes and sweetpotato had no significant effect on them (Table 28). Intercropping reduced CBB severity by 3.1% and 2.0% at R8 and R9, respectively; and reduced ALS by 3.7% and 2.1% at R8 and R9, respectively, when sweetpotato and bean were grown at their optimum population density. The highest reduction of 21.9% in CBB severity occurred in determinate bean grown with erect sweetpotato genotypes. Similarly, the highest reduction of 27.5% in severity of ALS occurred in the same bean genotype grown with the same sweetpotato genotypes. All in all, intercropping reduced CBB and ALS severity by an average of 12.9% and 18.9% of the sole crop mean severity, respectively, when sweetpotato and bean are grown at their optimum population densities.

4.3.2 Bean yield and yield components

Number of pods per plant

Yield and yield components were varied among the treatment combinations. In 1993/94 cropping season, bean genotypes differed, and pod production was influenced by sweetpotato genotypes (Table 28). Genotype MMS 224 produced 27.3% more pods per plant than the sole crop.

The lowest number of pods per plant in both intercrop and sole crop was produced by genotype A 197. The indeterminate bean plants produced 29.2% more pods than the sole crop. Number of pods per plant was positively correlated with yield per plant ($r = 0.613^{**}$), number of seed per pod ($r = 0.340^{**}$), number of seed per plant ($r = 0.872^{**}$) and yield per hectare ($r = 0.532^{**}$, $n = 108$).

Number of seeds per plant

Number of seeds per plant varied significantly with bean and sweetpotato genotypes. Genotype MMS 224 produced the most seed per plant which was 19.6% more than the sole mean in 1993/94 season. Season had no significant effect on number of pods and seeds per plant.

Indeterminate genotypes grown with erect sweetpotato genotypes produced the most seed per plant in 1993/94 season, which was 40.3% more than in sole crop (Table 29). In 1994/95 season, determinate bean genotypes grown with erect sweetpotato produced the most seed per plant which was 11.7% less than the sole crop yield (Table 30). The differences in number of seeds/plant from season to season may be ascribable to variability in moisture regimes between the seasons (Appendix 13). The erect sweetpotato morphotypes are relatively compatible with any bean plant morphotype.

The number of seeds per plant was not independent of bean plant morphotypes and bean morphotypes differed significantly in number of seeds per plant.

The 100 seed dry weight (100 DSW)

Seed weight varied significantly with bean and sweetpotato genotypes in 1993/94/season. In 1994/95 season, sweetpotato genotypes did not significantly affect seed weight but GLP 585 produced heavier seed than White Haricot. Bean genotype A 197 produced the highest 100 DSW which was 33.6% higher than the mean of the sole crop seed weight in 1993/94 season. In 1994/95 season bean genotype GLP 585 produced the highest 100 DSW which was 17.6% more than the sole crop seed weight (Table 28). Indeterminate bean genotypes produced the lowest 100 DSW which was 36.4% less than the 100 DSW from the determinate bean genotype in 1993/94 season (Table 29). In 1994/95 season, DSW of the determinate bean was 19.6% more than that of the indeterminate bean but not significantly different (Table 30). Seed weight varied with season.

Dry bean seed yield

The determinate bean genotypes grown with the erect sweetpotato genotypes produced the highest yield which was, however, 52.7% and 15.6% less than the sole yield in 1993/94 and 1994/95 seasons, respectively (Tables 29 and 30). Yield responses of bean genotypes varied with different sweetpotato morphotypes. By contrast, the effects of sweetpotato morphotypes on number of pods and seeds/plant, yield/plant and bean seed yield (t/ha) were significantly different. Bean morphotypes differed significantly in number of seeds/plant (Table 31). Higher yields were obtained in mixtures which were relatively compatible, while

yields were significantly reduced in relatively incompatible mixtures. Sweetpotato genotype effects on bean yield differed in 1993/94 season. However, yield was similar for all bean genotypes in 1994/95 season (Table 32). GLP 585 produced the highest yield which was approximately 68% and 66% of the sole crop mean in 1993/94 and 1994/95 season, respectively. Overall, intercropping reduced total yield by 39.2% and 42.2% of the sole crop yield in 1993/94 and 1994/95, respectively.

Table 28. Effect of intercropping on bean yield and yield components.

Cropping System	Number of pods/plant	Number of seed/pods	Number of seeds/plant	100 seed (g)	Yield/plant (g)	Yield (Kg/ha)	Cbb (r8)	Cbb (r9)	Als (r8)	Als (r9)
1993/94										
White haricot + Sweetpotato	10	5	52	18.1	6.2	695.7	NS			
MMS 224 + Sweetpotato	11	5	56	23.3	7.7	820.1				
A 197 + Sweetpotato	8	3	28	39.9	7.9	866.1				
GLP 585 + sweetpotato	9	4	43	24.8	7.9	915.9				
Mean	9.5	4	45	26.5	7.4	824.5				
Sole	8	5		28.5	6.3	1355.45				
CV %	21.7	8.8	25.0	6.0	22.0	25.0				
SE	3.53	0.10	1.417	0.55	0.62	44.06				
LSD (0.05)	1.24	NS	4.90	1.92	NS	NS				
S/potato	1.68	NS	9.21	2.23	1.33	168.4				
1994/95										
White haricot + Sweetpotato	10	4	41	22.6	5.4	732.2	6.3	7.3	3.3	4.0
White haricot + sole	12	4	58	25.3	10.1	1447.8	6.3	7.2	4.1	4.9
GLP 585 + Sweetpotato	10	4	42	28.4	5.6	885.6	6.1	7.1	4.5	5.5
GLP 585 Sole	13	4	59	23.4	9.3	1352.4	6.5	7.5	4.0	4.7
CV	31.7 %	7.67 %	36.7 %	13.3 %	39.9 %	39.5 %	9.47 %	7.89 %	20.0 %	11.7 %
SE	1.32	0.14	6.32	1.80	0.93	90.30	0.15	0.15	0.28	0.45
Bean	1.30	0.08	3.90	0.81	0.56	154.9	0.28	0.43	0.15	0.15
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 29: Effects of intercropping different sweetpotato and bean morphotypes on the performance of bean, 1993/ 94 cropping season.

Cropping Systems Bean + Sweetpotatoes	Mean bean yield attributes				
	No. of pods / plant	Number of seeds/pod	Number of seed/plant	Yield / plant (g)	100 seed weight (g)
Indeterminate + Spreading 'S/potatoes	10(3)	5(1)	40(3)	6.4(5)	19.9(5)
+ Indeterminate + Erect	11(2)	5(1)	62(1)	6.2(6)	19.8(6)
Indeterminate + S/compact.	13(1)	5(1)	54(2)	7.0(4)	20.2(4)
Indeterminate sole	8	5	37	5.7	22.0
Determinate + spreading	8(5)	4(4)	34(5)	7.3(3)	32.6(1)
Determinate + Semi- compact	9(4)	3(3)	30(6)	8.1(2)	32.1(2)
Determinate + Erect	7(6)	4(2)	39(4)	8.5(1)	31.6(3)
Determinate sole	8	4	32	7.0	34.6
CV	21.7%	8.8%	25.0%	22.0%	6.0%
S.E. bean)	3.52	0.10	1.42	0.63	0.55
					44.06

* Numbers in parentheses are ranks within a column excluding sole crop mean

Table 30. Effects of intercropping different sweetpotato and bean morphotypes on the performance of bean, 1994/95 cropping season.

Sweetpotato and bean plant types	Mean yield Attributes					Disease severity (sroce)					
	Number of pods/plant	Number of seeds/ pods	Number of seeds/ plant	100 seed weight (g)	Yield (kg/ha)	Cbb				Als	
						r8	r9	r8	r9	r8	r9
Spreading + indeterminate	9(3)	5(2)	41(3)	21.4 (6)	668.1(5)	6.7	7.0	3.0	3.6		
Semi-compact + indeterminate.	12(1)	4(3)	44(2)	23.2 (4)	828.0(2)	6.3	7.3	3.3	4.0		
Erect + indeterminate.	8(5)	4(3)	38(4)	22.4 (5)	620.6(6)	6.7	7.5	3.9	4.1		
Sole - indeterminate	13	4	58	25.3	1444.8	7.0	8	4	5		
Spreading + determinate.	9(4)	4(3)	37(5)	24.4 (3)	784.9(3)	5.7	7.7	4.0	5.3		
Semi-compact + determinate.	12(1)	6(1)	37(5)	28.2 (2)	748.3(4)	5.7	7.4	4.0	5.1		
Erect + determinate.	11(2)	4(3)	53(1)	30.6 (1)	1141.8(1)	5.8	6.3	3.5	5.2		
Sole - determinate	13	4	60	23.9	1352.4	7.5	8	5.0	7.0		
CV.	31.7%	7.6%	37.7%	13.4%	39.6%	9.5%	7.9%	20.0%	8.7		
SE. (bean)	1.30		3.90	0.81	154.9	0.15	0.15	0.28	0.15		
(S/potato)	1.32	0.14	6.32	1.80	90.3	0.15	0.15	0.28	0.45		

Numbers in parentheses are ranks within a column.

Table 31. Levels of significance for analysis of variance and contrasts in bean yield and yield components in mixtures of eight sweetpotato and four bean genotypes (1993/94)[Experiment 1].

Source of variation	Degrees of freedom	Num.of pods/plant	Num.of seeds/plant	100 seed weight (g)	yield/plant (g)	yield (kg/ha)
Replication	2	*	**	*	ns	ns
Bean genotype (EG)	3	*	**	**	ns	ns
Error(a)	6					
Sweetpotato genotypes (SPG)	8	**	**	ns	**	**
BG x SPG	24	ns	ns	**	ns	ns
Contrast						
Determinate vs indeterminate		* ¹	* ¹	ns	ns	ns
Semi-compact vs erect		* ^q	ns	ns	* ^q	* ^q
Semi-compact vs spreading		* ^q	ns	ns	* ^q	* ^q
Erect vs spreading		* ^q	ns	ns	* ^q	* ^q
CV.		21.7%	25.5%	6.0%	22.0%	25.0%

¹ ^q, Linear and quadratic coefficients, respectively.

ns, *, **, Non significant or significant at 5% and 1% probability levels, respectively.

Table 32: Yield response of different bean genotypes to different sweetpotato genotypes in sweetpotato/bean associations, 1993/94 and 1994/95 season.

Bean genotypes	Mean dry bean seed yield (kg/ha)									
	Sweetpotato genotypes									
	Wegabolige	Entry 21	Bwanjule	Entry 20	Tanzania	Bitambi	Tororo 3	New Kawogo	Varietal Mean	Sole Mean
1993/94										
White haricot +	628.4(3)	451.0(2)	558.4(4)	536.9(4)	540.4(4)	470.0 (4)	549.4(4)	558.1(3)	707.1(4)	1234.0
MMS 224 +	592.4(4)	428.6(4)	751.5(1)	780.8(1)	680.9(3)	595.3(1)	828.7(1)	549.9(4)	820.4(3)	1350.0
A 197 +	726.2(1)	434.6(3)	720.0(2)	710.2(3)	755.2(1)	635.0 (2)	697.2(2)	701.8(2)	866.3(2)	1314.0
GLP 585 +	711.0(2)	536.7(1)	708.6(3)	763.1(2)	595.9(2)	595.9(3)	582.2(2)	847.1(1)	915.8(1)	1684.0
Mean	664.4	462.7	684.6	697.7	643.1	570.6	730.5	581.7		
S.E. (bean)	44.06									
C.V.	25.05%									
LSD (0.05) (S/potato)	168.4									
1994/95										
White haricot +	668.1(2)	NA	665.6(2)	NA	575.6(2)	934.5(1)	754.8(1)	794.6(1)	732.2(2)	1444.8
GLP 585 +	784.9(1)	NA	1458.4(1)	NA	825.3(1)	799.1(2)	718.7(2)	727.1(2)	885.5(1)	885.6
Mean	726.5	NA	106.2	NA	700.4	866.8	736.75	760.85		1352.4
S.E. (Bean x S/potato)	141.59									
C.V.	39.58%									
LSD (0.05)	NS									

* Numbers in parentheses are ranks within a column
NA = Not applicable

4.3.3 Sweetpotato/bean intercrop productivity

The highest productivity of both storage root and bean seed was produced by Wagabolige intercropped with bean, and was 26.5% higher than the sole crop productivity. In 1993/94 season, Wagabolige produced the highest yield (Table 33). In 1994/95 season, the highest bean yield was obtained in mixtures with Bwanjule (Table 34). It was 23.6% higher than the sole crop yield. The highest total productivity of 28.36 t/ha and 30.1 t/ha were obtained in 1993/94 and 1994/95 season, respectively. Productivity of the cropping system was dependent on the relative performance of the individual crop component in association, being influenced by degrees of compatibility and their yield potentials. Productivity was 5.6% higher in 1994/95 than in 1993/94 cropping season.

Table 33: Sweetpotato/bean intercrop system productivity - 1993/94 cropping season

Cropping systems	Absolute yields (t/ha) and LER		
	Sweetpotato	Bean	LER
Wagaboligze + bean	27.7	0.66	1.60
Entry 21 + bean	4.6	0.46	0.70
Bwanjule + bean	20.8	0.68	1.45
Entry 20 + bean	6.5	0.70	0.8
Tanzania + bean	26.3	0.64	1.50
Bitambi + bean	22.5	0.57	1.38
Tororo 3 + bean	26.3	0.73	1.62
New Kawogo + bean	27.0	0.58	1.51
Intercrop mean	20.2	0.63	1.32
Sole - crop	10.8	1.40	1.0
CV% 37.39	37.4%	25.0%	24.7%
S.E.	1.69	0.44	0.19
LSD (0.05)	4.76	0.17	0.27

Table 34: Sweetpotato/bean intercrop system productivity - 1994/95 cropping season

Cropping systems	Absolute yields (t/ha) and LER		
	Sweetpotato	Bean	Total productivity
Wagabolige + bean	29.4(1)*	0.73(5)	30.1
Bwanjule + bean	21.0(6)	1.06(1)	22.1
Tanzania + bean	26.2(3)	0.70(6)	26.9
Bitambi + bean	22.0(5)	0.87(2)	23.0
Tororo 3 + bean	24.6(4)	0.74(4)	25.3
New Kawogo + bean	27.7(2)	0.76(3)	28.5
Intercropped mean	24.3	0.81	25.0
Sole - cropped mean	24.2	1.40	25.6
CV	23.2%	39.6%	
S.E.	1.63	0.13	
LSD (0.05)	4.64	NS	
			NS

* Numbers in parentheses are ranks within a column.

4.3.4 Competition between sweetpotato and bean

Competitive abilities varied with sweetpotato genotypes in both 1993/94 and 1994/95 seasons. Tororo 3 was the most competitive, with CR of 30.5% more than the mean of all genotypes. Entries 20 and 21 were the least competitive in mixtures. Sweetpotato crops in double rows grew away from bean crops in order to receive better light interception. However, CR for sweetpotato was generally higher in 1994/95 season than in 1993/94 season.

Competitive abilities of bean varied with bean genotypes. Genotypes grown with the least competitive sweetpotato genotypes (Entries 20 and 21) had high CR. The least and the most competitive bean genotype was A 197 and White Haricot, respectively (Tables 35 and 36). In 1994/95 season the CR for bean was generally low. White Haricot was 75.8% less competitive in 1994/95 than in 1993/94 season. Similarly GLP 585 was 64.6% less competitive in 1994/95 than in 1993/94 (Table 37).

Relative yields of bean and sweetpotato varied with intercrop combinations during both seasons. Relative yields less than unity showed that intercropping reduced yields of the component crops.

Where RY was greater than unity implies that sweetpotato crop was more competitive. The RY of sweetpotato were generally higher in 1994/95 than in 1993/94 season. Both Entries 20 and 21 had the lowest RY. The RY of beans were lower in 1994/95 season than in 1993/94 season, but was the reverse for RY for sweetpotato (Tables 38 and 39).

Table 35: Competitive abilities of sweetpotato genotypes in sweetpotato/bean association, 1993/94 cropping season.

Sweetpotato genotypes	Competition Ratio (CR) for Sweetpotato					Mean
	White Haricot	MMS 224	A 197	GLP 585		
Wagabolige	3.19	3.89	4.98	3.13		3.80
Entry 21	0.28	0.96	0.99	0.80		0.76
Bwanjule	3.27	0.90	0.87	0.74		1.45
Entry 20	0.61	0.63	1.28	0.75		0.82
Tanzania	3.20	2.83	3.73	2.98		3.18
Bitambi	3.22	3.38	2.77	3.61		3.24
Tororo 3	3.87	3.06	4.16	2.18		3.32
New Kawogo	3.47	3.53	1.46	2.38		2.71
Mean	2.64	2.40	2.53	2.07		
C.V.	43.3%					
S.E.	0.32					
LSD. (0.05)	0.91					

Table 36:: Competitive abilities of sweetpotato genotypes
in sweetpotato/bean association, 1994/95 cropping season.

Sweetpotato genotypes	Competition ratio (CR) for Sweetpotato) Bean Genotypes			Mean
	White Haricot	GIP 585		
Wagabolige	6.6	5.1		5.9
Bwanjule	3.0	2.6		2.8
Tanzania	5.3	5.5		5.4
Bilambi	3.5	5.9		4.7
Tororo 3	4.6	6.6		5.6
New Kawogo	4.7	4.6		4.6
Mean	4.6	5.0		
C.V.	54.9%			
S.E.	0.93			
LSD. (0.05)	NS			

Table 37: Competitive abilities of bean genotypes in sweetpotato/bean association, 1993/94 and 1994/95 cropping seasons.

Sweetpotato genotypes	Competition ratio (CR) for bean					
	1993/94			1994/95		
	White Haricot	MMS 224	A 197	GLP 585	Mean	White Haricot
Wagabollige	0.32	0.30	0.20	0.62	0.36	0.81
Entry 21	2.61	1.84	1.14	1.28	1.40	NA
Bwanjule	0.31	0.35	0.36	0.43	0.36	0.34
Entry 20	2.28	2.60	0.85	1.45	1.80	NA
Tanzania	0.38	0.65	0.27	0.37	0.42	0.20
Bitambi	0.32	0.36	0.36	0.28	0.33	0.32
Tororo 3	0.28	0.40	0.25	0.47	0.35	0.22
New Kawogo	0.45	0.26	0.32	0.29	0.33	0.23
Mean	0.87	0.84	0.47	0.65	0.67	0.21
CV.	46%					46.62
S.E.	0.17					0.05
LSD. (0.05) S/potato	0.56					NS

Table 38: Relative Yields (RY) of bean and sweetpotato in sweetpotato/bean association, 1993/94 cropping season.

Sweetpotato genotypes	Relative Yield of bean				Relative Yield of sweetpotato				Varietal Mean
	White Haricot	MMS 224	A 197	GLP 585	White Haricot	MMS 224	A 197	GLP 585	
Wagabollige	0.57	0.57	0.52	0.61	0.89	1.0	1.26	0.91	1.35
Entry 21	0.50	0.49	0.49	0.53	0.10	0.23	0.24	0.22	0.20
Bwanjule	0.54	0.63	0.61	0.61	0.89	0.90	0.87	0.74	0.85
Entry 20	0.53	0.64	0.63	0.63	0.16	0.20	0.39	0.24	0.25
Tanzania	0.43	0.60	0.63	0.56	0.89	0.82	1.0	0.87	0.90
Bitambi	0.50	0.56	0.58	0.55	0.80	0.87	0.79	0.99	0.86
Tororo 3	0.54	0.66	0.60	0.67	0.03	0.99	1.22	0.76	0.75
New Kawogo	0.53	0.54	0.61	0.53	0.98	0.95	1.00	0.90	0.96
Mean	0.52	0.59	0.58	0.59	0.59	0.74	0.85	0.70	
C.V.	11.64%				40.21%				
S.E.	0.02				0.09				
LSD (0.05)	0.05				0.25				

Table 39: Relative Yields (RY) of bean and sweetpotato in sweetpotato/bean association, 1994/95
Cropping season

Sweetpotato genotypes	Relative Yield (Beans)			Relative Yield (sweetpotato)		
	White Haricot	GLP 585	Varietal Mean	White Haricot	GLP 585	Varietal Mean
Wagabolige	0.43	0.46	0.44	1.29	1.14	1.21
Bwanjule	0.63	0.69	0.66	0.91	0.82	0.86
Tanzania	0.47	0.52	0.50	1.21	0.96	1.08
Bitambi	0.62	0.39	0.50	1.01	0.87	0.94
Tororo 3	0.51	0.73	0.62	1.18	0.86	1.02
New Kawogo	0.43	0.46	0.44	0.91	0.88	0.89
Mean	0.52	0.54	0.53	1.08	0.92	0.91
C.V.	45.80%			23.40%		
S.E.	0.09			0.08		
LSD. (0.05)	0.31			0.07		

4.3.5 Aggressivity Coefficient (AC)

Aggressivity coefficient (AC) varied among crop combinations in both seasons (Table 40). The most and the least aggressive genotypes were Wagabolige, Entry 20 and Entry 21 in 1993/94 season, respectively. The aggressivity coefficient was negatively correlated with CR and RY for bean ($r = -0.893^{**}$, and $r = -0.696^{**}$, $n = 96$), respectively but positively correlated with CR for sweetpotato ($r = 0.646^{**}$, $n = 96$). The AC varied over seasons. The most aggressive bean genotypes were A 197 and White Haricot in 1993/94 and 1994/95 seasons, respectively. A 197 was 50% and 23.1% more aggressive than GLP 585 and White Haricot in 1993/94 season, respectively. GLP 585 was 32.1% less aggressive than White Haricot in 1994/95 season (Table 41).

Table 40: Aggressivity coefficient (AC) in sweetpotato/bean association, 1993/94 cropping season.

Sweetpotato genotypes	Aggressivity coefficient Bean genotypes				Mean
	White Haricot	MMS-224	A 197	GLP 585	
Wagabolige	0.32	0.52	0.75	0.30	0.47
Entry 21	-0.27	-0.25	-0.25	-0.32	-0.27
Bwanjule	0.34	0.27	0.13	0.25	0.25
Entry 20	-0.37	-0.44	-0.24	-0.39	-0.36
Tanzania	0.33	0.22	0.47	0.31	0.33
Bitambi	0.30	0.31	0.21	0.44	0.31
Tororo 3	0.49	0.33	0.62	0.09	0.38
New Kawogo	0.44	0.41	0.39	0.37	0.40
Mean	0.20	0.17	0.26	0.13	0.19
S.E.	0.11				
LSD (0.05)	0.24				

Table 41. Aggressivity coefficient (AC) in sweetpotato/bean association, 1994/95 cropping season

Aggressivity coefficient (AC)			
Sweetpotato genotypes	Bean genotypes		
	White	GLP 585	Mean
Wagabolige	0.86	0.68	0.77
Bwanjule	0.27	0.13	0.20
Tanzania	0.74	0.45	0.60
Bitambi	0.34	0.48	0.41
Tororo 3	0.67	0.13	0.40
New Kawogo	0.47	0.42	0.44
Mean	0.56	0.38	
CV.	66.0%		
SE.	0.16		
LSD (0.05)	0.32		

4.4.0 Land use efficiency in sweetpotato/bean association

Intercropping sweetpotato with bean was beneficial because the LER were greater than unity except in two cases where LER were less than unity in 1993/94 season. In 1993/94 season, the highest LER were obtained in mixtures of Tororo 3 and A 197 (Table 42). In 1994/95 season, all mixtures had LER greater than unity (Table 43).

In both seasons, Land use efficiencies (LUE) were higher in mixtures than in sole cropping. In 1993/94 and 1994/95 seasons, the results indicated that between 38-62% and 40-70% more land would be required to plant sole crops of sweetpotato and bean to produce the same quantities of sweetpotato and bean that were produced in mixtures, respectively. The area time equivalent ratios (ATER) were less than unity and were significantly different among intercrop combinations (Table 44). The mean ATER values of 0.67 and 0.77 for 1993/94 and 1994/95 seasons, respectively showed that the sweetpotato/bean systems favoured sweetpotato. Compared to LER values (Tables 42 and 43), ATER underestimated LUE because the components differ in their growth durations. LER overestimated LUE because the difference in growth durations of the components were not considered. Therefore, to have a realistic estimate of LUE, LER values should be adjusted by 50%. The adjusted value added to ATER would give LUE value ranging from 44-69% in 1993/94 season and 42-68% in 1994/95 season for the individual mixtures.

LER was positively correlated with CR for sweetpotato ($r=0.902^{**}$, $n=96$) but negatively correlated with CR for bean ($r=-0.660^{**}$, $n=72$).

Table 42: Land Equivalent Ratio (LER) in Sweetpotato/bean association, 1993/94 cropping season

Sweetpotato plant genotypes	Bean genotype				Mean
	White Haricot Type II	MMS 224 Type II	A 197 Type I	GLP 523 Type I	
Wagabolige - Spreading	1.46(3)	1.66(1)	1.78(4)	1.43(2)	1.60(2)
Entry 21 - Spreading	0.66(8)	0.72(8)	0.73(8)	0.75(7)	0.70(8)
Bwanjule - Erect	1.43(4)	1.53(3)	1.51(5)	1.34(5)	1.45(5)
Entry 20 - Erect	0.70(7)	0.84(7)	1.02(7)	0.87(6)	0.80(7)
Tanzania - Erect	1.42(5)	1.42(6)	1.73(3)	1.43(4)	1.50(7)
Bitambi - Semi compact	1.29(6)	1.43(5)	1.37(6)	1.55(1)	1.38(6)
Tororo 3 - Semi compact	1.57(1)	1.65(2)	1.82(1)	1.44(3)	1.62(1)
New Kawogo - Semi compact	1.51(2)	1.49(4)	1.61(4)	1.43(4)	1.51(3)
Mean	1.26	1.34	1.45	1.29	1.32
C.V.	24.7%				
S.E. (S/potato)	0.09				
(Bean)	0.05				
LSD (0.05) (S/potato)	0.27				

* Numbers in parentheses are ranks within a column.

Table 43: Land Equivalent Ratio (LER) in Sweetpotato/bean association, 1994/95 cropping season

Sweetpotato Morphotypes	Bean genotypes			Mean LER.
	White Haricot Type II	GLP 585 Type I		
Wagabolige - Spreading	1.72(1)*	1.60(1)		1.7(1)
Bwanjule - Erect	1.52(4)	1.52(2)		1.5(3)
Tanzania - Erect	1.67(7)	1.47(3)		1.6(2)
Bitambi- Semi compact	1.62(2)	1.27(5)		1.4(4)
Tororo 3 - Semi compact	1.67(2)	1.60(1)		1.6(2)
New Kawogo - Semi compact	1.67(2)	1.35(4)		1.5(3)
Mean	1.64	1.46		
C.V.	23.3%			
LSD (0.05)	NS			
S.E. (S/potato)	0.13			
(Bean)	0.08			

* Numbers in parentheses are ranks within a column

Tabel 44: Area Time Equivalent Ratio (ATER) for sweetpotato/bean association, 1993/94 1994/95 cropping seasons.

Sweetpotato genotypes	1993/94 season					Area Time Equivalent Ratio (ATER)			
	1993/94 season					1994/95 season			
	White Haricot	MMS-224	A 197	GLP 585	Mean	White Haricot	GLP 585	Mean	
Wagabolige	0.73	0.83	0.89	0.74	0.80	0.86	0.80	0.83	
Entry 21	0.30	0.34	0.36	0.37	0.34	NA	NA	NA	
Bwanjule	0.71	0.76	0.75	0.67	0.72	0.76	0.76	0.76	
Entry 20	0.35	0.42	0.50	0.43	0.42	NA	NA	NA	
Tanzania	0.71	0.69	0.86	0.71	0.74	0.84	0.74	0.79	
Bitambi	0.64	0.71	0.68	1.10	0.78	0.81	0.64	0.72	
Tororo 3	0.84	0.82	0.91	0.72	0.82	0.84	0.80	0.82	
New Kawogo	0.75	0.74	0.80	0.64	0.73	0.67	0.67	0.67	
Mean	0.63	0.66	0.72	0.62	0.67	0.80	0.73	0.77	
C.V.	27.7%					23.3%			
S.E.	S/potato Bean	0.05 0.03				0.06 0.04			
LSD. (0.05)	S/potato	0.15				0.23			

NA = Not applicable.

4.4.1 Monetary equivalent ratio (MER)

Intercropping sweetpotato with bean is economically sound because the monetary equivalent ratio (MER) obtained were generally greater than unity. The highest MER which was 26.1% more than the cropping system mean MER was from mixtures of Wagabolige with bean (Table 45). Mean MER for various mixtures ranged from 0.62 to 2.11 (Table 46). On the average 56%, more land would be required to plant sole crop of sweetpotato and bean in order to realize the same yields of sweetpotato and beans to generate the same amount of cash income obtained from the mixtures of sweetpotato and beans.

4.5.0 Experiment II: Effects of sweetpotato spatial arrangement and population density on the performance of sweetpotato in sweetpotato/bean association (1994/95 and 1995/96 seasons)

4.5.1 Photosynthetically active radiation (PAR) interception.

PAR interception was not significantly influenced by spatial arrangement and population density (Table 47). PAR interception increased with time until 8 WAP and declined there after.

Intercropping increased PAR interception by 8.1% and 9.4% of the sole crop in the single and double rows arrangement, respectively.

Confidence limits at LSD (0.05) indicated that there were significant differences between means at different growth stages.

Table 45. Monetary equivalent ratio for sweetpotato and bean in a sweetpotato/bean association 1993/94 and 1994/95.

Cropping system	1993/94			1994/95		
	Sweetpotato	Bean	Total	Sweetpotato	Bean	Total
Sweetpotato + bean (Wagabolige)	1.62(1)*	0.50(3)	2.12(1)	1.31(1)	0.45(5)	1.76(1)
Sweetpotato + bean (Entry 21)	0.16(8)	0.34(7)	0.50(8)	NA	NA	NA
Sweetpotato + bean (Bwanjule)	1.23(5)	0.51(2)	1.74(4)	0.85(6)	0.66(1)	1.51(5)
Sweetpotato + bean (Entry 20)	0.21(7)	0.51(2)	0.72(4)	NA	NA	NA
Sweetpotato + bean (Tanzania)	1.24(4)	0.48(4)	1.72(5)	1.07(2)	0.49(4)	1.56(3)
Sweetpotato + bean (Bitambi)	1.09(6)	0.42(5)	1.51(6)	1.03(4)	0.50(3)	1.53(4)
Sweetpotato + bean (Tororo 3)	1.44(3)	0.53(1)	1.97(2)	1.05(3)	0.62(2)	1.67(2)
Sweetpotato + bean (New Kawogo)	1.45(2)	0.43(6)	1.88(3)	0.97(5)	0.45(5)	1.42(6)
Mean	1.05	0.46	1.51	1.05	0.53	1.58
CV.	40.1%	23.0%	30.0%	27.1%	45.6%	25.2%
SE.	0.13	0.04	0.14	0.10	0.09	0.19
LSD(0.05)	0.36	0.08	0.38	0.17	0.09	0.19

* - Numbers in parentheses are ranks within a column.
NA - Not applicable

Table 46. Monetary equivalent ratios (MERS) under various combinations of sweetpotato and bean genotypes in a sweetpotato/bean association, (1993/94 and 1994/95)

Sweetpotato genotypes	Bean genotypes					
	1993/94			1994/95		
	White Haricot	MMS 224	A 197	GLP 585	Mean	White Haricot
Wagabolige	1.73(3)*	2.13(1)	2.30(1)	2.30(1)	2.11(1)	1.85(1)
Entry 21	0.49(8)	0.62(8)	0.67(8)	0.72(8)	0.62(8)	NA
Bwanjule	1.72(4)	1.87(3)	1.82(5)	1.54(6)	1.74(4)	1.54(5)
Entry 20	0.60(7)	0.84(7)	0.99(7)	0.88(7)	0.83(7)	NA
Tanzania	1.52(5)	1.65(5)	2.07(4)	1.67(5)	1.73(5)	1.68(4)
Bitambi	1.43(6)	1.64(6)	1.59(6)	1.83(2)	1.62(6)	1.70(3)
Tororo 3	1.83(2)	2.02(2)	2.20(2)	1.82(3)	1.97(2)	1.71(2)
New Kawogo	1.99(1)	1.81(4)	2.08(3)	1.72(4)	1.90(3)	1.4(6)
Mean	1.41	1.57	1.71	1.56	1.56	1.65
CV.		30.0%				25.2%
SE.		0.05				0.14
LSD(0.05)		0.38				NS

* - Numbers in parentheses are ranks within a column.

NA = Not applicable

Table 47. Effects of sweetpotato spatial arrangement and plant population density on photosynthetically active radiation (PAR) interception in sweetpotato/bean association (1995/96)

Cropping system	Percent PAR intercepted									
	Spatial arrangement					Double rows of sweetpotato				
	Single row of sweetpotato					Growth periods (WAP)				
	4	6	8	10	10	4	6	8	10	
Bean + sweetpotato (16,666 plt/ha)	92.9	95.4	93.9	83.1		91.8	94.2	92.8	81.2	
Bean + sweetpotato (22,222 plt/ha)	91.3	94.4	92.5	80.7		93.3	95.6	93.9	82.9	
Bean + sweetpotato (33,333 plt/ha)	93.2	95.5	94.0	83.6		91.2	94.0	92.7	81.3	
Bean + sweetpotato (66,666 plt/ha)	90.4	94.2	92.7	81.1		89.5	93.3	91.4	80.1	
Intercropped mean	92.0	94.9	93.3	82.1		91.4	94.3	92.7	81.4	
Sole-cropped mean	84.5	86.4	85.8	76.1		82.5	85.4	83.9	74.3	
SD +/-	1.33	0.67	0.78	1.44		1.57	0.96	1.02	1.15	
SD of the difference between the means	0.34	0.01	0.33			0.12	0.14	0.02		

4.5.2 Sweetpotato growth

Sweetpotato vine length

In 1994/95 and 1995/96 cropping season, vine length varied with sweetpotato genotypes at 4 WAP. In 1995/96 season, vine length varied between the single and double rows arrangement of sweetpotato at 10 WAP (Table 48). There were significant sweetpotato genotypes x spatial arrangement interaction effects at 8 WAP and 10 WAP on vine length. In 1994/95 season, there were significant sweetpotato genotype x population density interaction effects at 10 WAP (Table 49).

Generally, vine growth was faster in double rows than in single row and growth rate was 7.4% higher in double rows than in single row due to shade effect from bean crop. Growth rate was 17.8% higher in Wagabolige (spreading type) than Bwanjule (erect type) and Tororo 3 (semi-compact type). Intercropping reduced vine growth rate by 13% and 9 % of the sole crop growth rate in 1994/95 and 1995/96 season, respectively. On the whole, intercropping reduced vine growth rate by 11 % of the sole crop growth rate.

Table 48. Effects of sweetpotato spatial arrangement and population density on sweetpotato vine growth in sweetpotato/bean association (1994/95)

Cropping system	Sweetpotato vine length (cm)									
	Spatial arrangements					Growth period (WAP)				
	Single row of sweetpotato					Double rows of sweetpotato				
	4	6	8	10	4	6	8	10	4	10
Bean + sweetpotato (16,666 plt/ha)	26.9	41.0	55.7	67.4	27.1	42.2	60.0	71.6		
Bean + sweetpotato (22,222 plt/ha)	25.7	39.5	57.0	64.8	26.2	43.2	58.5	67.4		
Bean + sweetpotato (33,333 plt/ha)	26.1	39.0	53.3	62.2	25.6	39.8	54.9	66.7		
Bean + sweetpotato (66,666 plt/ha)	27.0	40.5	54.1	62.4	26.7	42.0	52.0	68.4		
Mean	26.4	40.0	55.0	64.2	26.4	41.8	56.3	68.4		
CV	9.73%	9.42%	10.68%	9.570%	9.73%	9.42%	10.68%	9.570%		
SE:										
-s/potato	1.12	1.95	2.38	3.28						
-pattern	0.91	1.60	1.94	2.67						
-population	0.60	0.91	1.42	1.49						
LSD(0.05)	3.21	NS	NS	NS	3.21	NS	NS	NS		

NS = Not significant

Table 49. Effects of sweetpotato spatial arrangement and population density on sweetpotato vine growth in sweetpotato/bean association (1995/96)

Cropping system	Sweetpotato vine length (cm) spatial arrangement									
	Single row of sweetpotato					Double rows of sweetpotato				
	Growth periods (WAP)									
	4	6	8	10	4	6	8	10		
Bean + sweetpotato (16,666 plt/ha)	24.6	38.6	53.6	65.4	24.1	40.8	58.0	69.6		
Bean + sweetpotato (22,222 plt/ha)	23.6	37.2	54.9	62.4	24.4	40.9	56.1	64.9		
Bean + Sweetpotato (33,333 plt/ha)	24.0	37.0	50.9	60.1	23.4	37.7	53.2	64.6		
Bean + Sweetpotato (66,666 plt/ha)	24.7	38.2	52.1	60.3	24.4	40.0	54.8	66.5		
Mean	24.2	37.8	52.9	62.0	24.1	39.9	55.5	66.4		
CV.	12.0%	14.1%	13.3%	13.9%						
SE:										
-s/potato	1.16	1.56	2.37	2.73						
-pattern	0.48	0.91	1.19	1.49						
-cropping sys.	1.68	3.17	4.15	5.16						
LSD(0.05)(s/potato)	4.58	ns	ns (patt)	4.25	4.58	ns	ns	4.25		4.25

Dry matter accumulation and crop growth rate

In 1994/95 and 1995/96 season, DMA varied significantly among the genotypes at 8 WAP. The spatial arrangements differed in their effects at 4 and 6 WAP. Genotype x spatial arrangement interaction effects were significant at 8 WAP during 1995/96 season. Crop growth rate (CGR) increased with time and was negatively correlated with population density ($r=-0.356^{**}$, $n=72$) in 1995 (Figure 4).

Leaf area index

LAI varied among sweetpotato genotypes from 6 to 10 WAP and population densities but were not significantly different between the spatial arrangements. In 1995/96 season, there were significant sweetpotato genotype x population density interaction effects at 10 WAP. Spatial arrangement x population density interaction effects were significant at 8 WAP. LAI increased with increase in population density (Figure 5) and was positively correlated with population density ($r=0.627^{**}$ and $r=0.520^{**}$, $n=72$) in 1994/95 and 1995/96, respectively.

LAI was 14.5% and 7.2% higher in the double rows than single row arrangement in 1994/95 and 1995/96, respectively. In 1994/95 season, intercropping reduced LAI by 9.4% of the sole crop LAI of Bwanjule, but increased it by 31% and 10.2% in Wagabolige and Tororo 3, respectively.

In 1995/96 season, intercropping reduced LAI by 1.6, 8.7 and 5.9% in Bwanjule, Wagabolige and Tororo 3, respectively. On the whole, intercropping reduced LAI by an average of 5.3% in 1995/96 season, but increased LAI by 10.3% in 1994/95 cropping season.

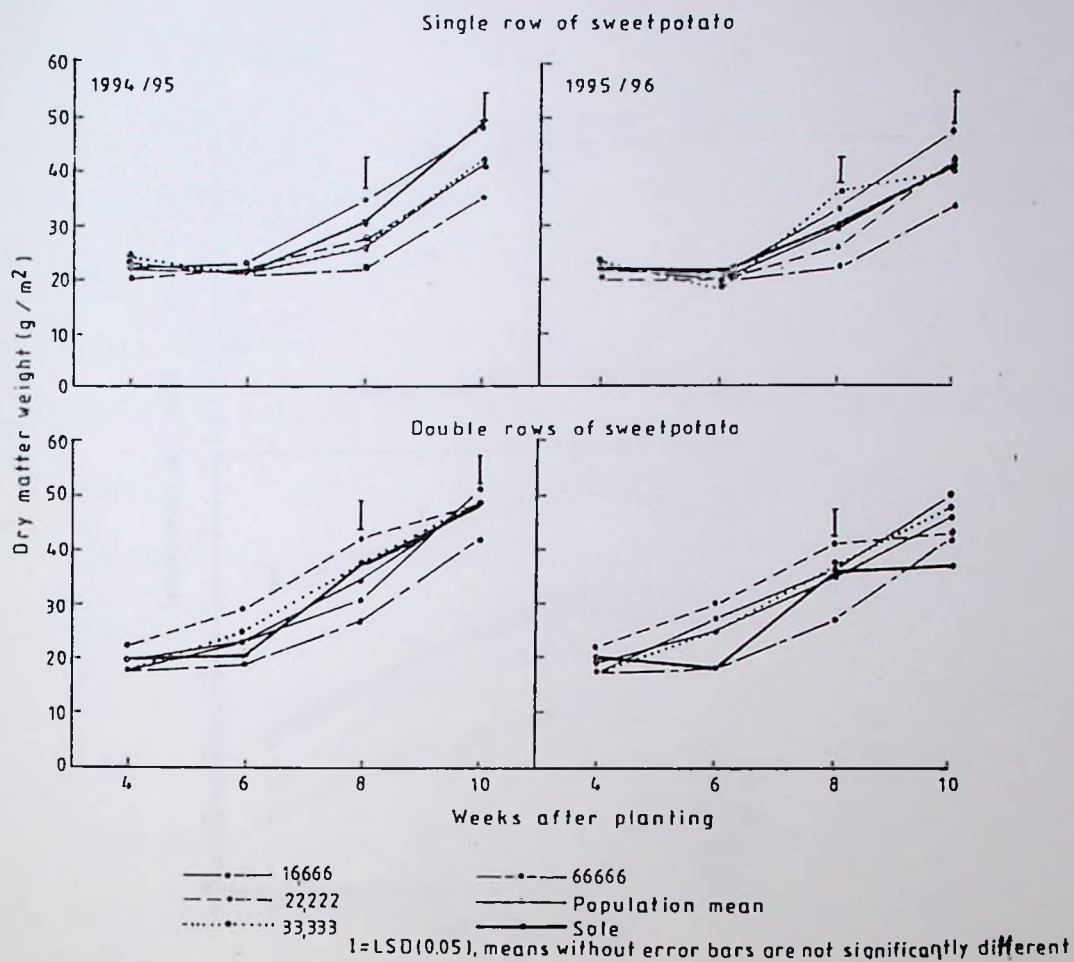


Figure 4. Effects of sweetpotato spatial arrangement and population density on sweetpotato dry matter weight

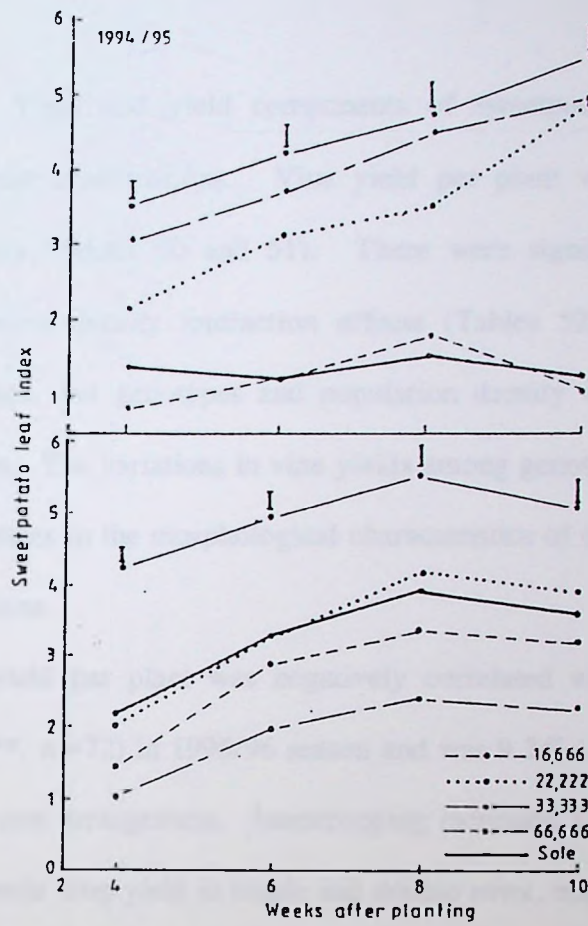


Figure 5. Changes in sweetpotato LAI with sweetpotato population density.

4.5.3 Sweetpotato yield and yield components

Vine yield.

Yield and yield components of sweetpotato were varied among the treatment combinations. Vine yield per plant varied among the population densities (Tables 50 and 51). There were significant spatial arrangement x population density interaction effects (Tables 52 and 53). Season had no influence, but genotypes and population density varied in their effects across seasons. The variations in vine yields among genotypes may be attributed to the differences in the morphological characteristics of the genotypes and the growth conditions.

Vine yield per plant was negatively correlated with population density ($r = -0.657^{**}$, $n = 72$) in 1995/96 season and was 9.3% higher in double rows than in single row arrangement. Intercropping increased vine yield by 7.4% and 8.6% of the sole crop yield in single and double rows, respectively in 1995/96 season. In 1994/95 season, intercropping increased vine yield by 2.8% of the sole crop yield in single row of sweetpotato. There was a decrease of 5.8% in vine yield in the double rows arrangement of sweetpotato.

Table 50: Effect of sweetpotato spatial arrangement and plant population density on the performance of sweetpotato in sweetpotato/ bean association, 1994/95 cropping season.

Cropping Systems	Sweetpotato yield attributes													
	Single row of sweetpotato							Double rows of sweetpotato						
	Vine Yield Kg/Plant	% mark root / plot	% unmark roots / plot	Total Yield (t/ha)	Harvest Index(%)	Shoot Root ratio	DMC (%)	Fresh vine yield Kg/plot	% mark roots / plot	% unmark roots / plot	Total Yield (t/ha)	Harvest Index (%)	Shoot Root ratio	DMC (%)
Bean + Sweetpotato (16,666) plants/ha	2.77	64.3	35.7	15.8	55.4	1.0	32.7	2.97	66.4	33.6	15.9	50.3	1.0	31.9
Bean + sweetpotato (22,222, plants/ha)	31.0	65.9	34.1	16.8	62.11	1.2	31.4	2.67	66.4	33.6	18.1	56.3	1.0	29.9
Bean + sweetpotato (33,333 plants/ha)	2.99	60.9	39.1	18.0	59.8	1.0	31.1	2.66	64.7	35.3	20.6	58.1	0.9	30.1
Bean + Sweetpotato (66,666 plants/ha)	3.24	49.3	50.7	19.5	64.8	1.0	31.6	3.15	54.4	45.6	19.8	55.1	0.9	30.3
Mean	3.02	58.9	41.1	17.5	60.5	1.05	31.7	2.86	62.0	38.0	18.6	55.0	1.0	30.6
Sole Mean	2.94	58.9	41.1	29.82	65.7	1.1	31.1	2.94	58.6	41.1	28.15	57.5	1.2	29.7
C.V.	19.2%	18.1%	36.8%	16.9%	13.6%	29.5%	5.0%	19.2%	18.1%	35.8%	16.7%	13.6%	29.5%	5.0%
S.E. (Pop)	3.78	4.14	5.47	0.71	2.49	0.10	0.37	3.28	4.14	5.47	0.71	2.49	0.10	
LSD (0.05) (Pop)	NS	11.90	15.69	2.03	1.06	NS	NS	NS	11.9	15.6	2.03	1.06	NS	

Table 51: Effect of sweetpotato spatial arrangement and population density on the performance of sweetpotato in sweetpotato/bean association, 1995/96 cropping season.

Cropping Systems	Sweetpotato yield attributes										Double rows			
	Single row													
	Vine Yield (Kg/plant)	% mark roots / plot	% unmark roots / plot	Total Yield (t/ha)	Harvest Index %	Shoot / root ratio	DMC (%)	Fresh vine yield kg/ plants	% mark roots / plot	% unmark roots / plot	Total Yield (t/ha)	Harvest Index (%)	Shoot / Root	DMC (%)
Bean + Sweetpotato (16,666) plants/ha	2.86	65.2	34.8	14.6	38.8	1.6	32.5	2.76	40	30	11.4	36.6	1.8	32.8
Bean + sweetpotato (22,222, plants/ha)	2.51	61.5	38.5	14.5	46.0	1.2	31.7	3.16	51	31	15.2	37.3	1.7	32.7
Bean + sweetpotato (33,333 plants/ha)	2.56	56.5	43.5	15.2	45.1	1.2	34.3	2.94	57	45	13.5	39.3	1.6	33.1
Bean + Sweetpotato (66,666 plants/ha)	2.98	41.0	59.0	16.6	44.7	1.3	30.4	3.23	60	85	14.3	37.9	1.7	32.1
Intercrop mean	2.73	52.8	47.2	15.2	43.7	1.3	32.2	3.02	52	48	13.6	37.8	1.7	32.7
Sole - crop mean	2.40	53.0	47.0	16.9	50.95	1.0	34.8	2.22	66	39	16.60	44.9	1.4	33.7
C.V.	24.9%	24.1%	27.3%	22.0%	11.1%	19.6%	11.0%	24.9%	24.1%	27.3%	22.0%	11.1%	19.6%	11.0%
S.E. (Pattern)	0.06	4.56	3.76	0.98	1.50	0.09	0.45	0.06	4.56	3.76	0.98	1.50	0.09	0.45
(Pop)	0.06	3.14	3.21	0.72	1.06	0.07	0.83	0.06	3.14	3.21	0.72	1.06	0.07	0.83
LSD. (0.05) (Pop)	0.18	9.02	9.21	2.08	3.04	0.20	NS	0.18	9.02	9.21	2.09	3.04	0.20	NS
(Pattern)	NS	NS	NS	NS	5.40	0.30	NS	NS	NS	NS	NS	5.40	0.30	NS
(S/potato genotype)	NS	11.52	NS	NS	NS	NS	NS	NS	11.52	NS	NS	NS	NS	NS

Storage root size distribution.

Numbers of both marketable and unmarketable roots varied among sweetpotato genotypes and population densities. There was a significant genotype x population density interaction effects in 1994/95 season. Season had a significant influence on root numbers. Spatial arrangements had significant effects on number of marketable roots across seasons but all genotypes behaved alike (Figures 6 and 7). Number of unmarketable roots varied across seasons among genotypes and population densities. There was a significant season x population density interaction effects on number of marketable roots (Tables 52 and 53)

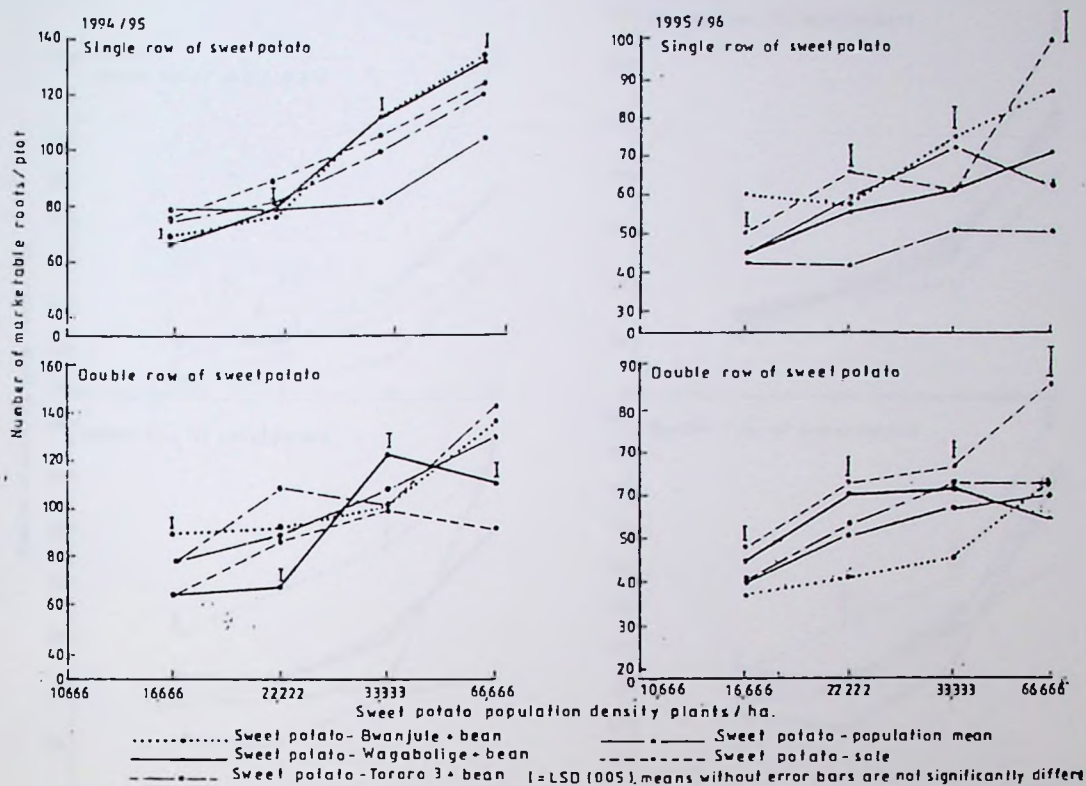


Figure 6. Effects of sweet potato spatial arrangement and population density on sweet potato storage root-quality number of marketable roots/plot.

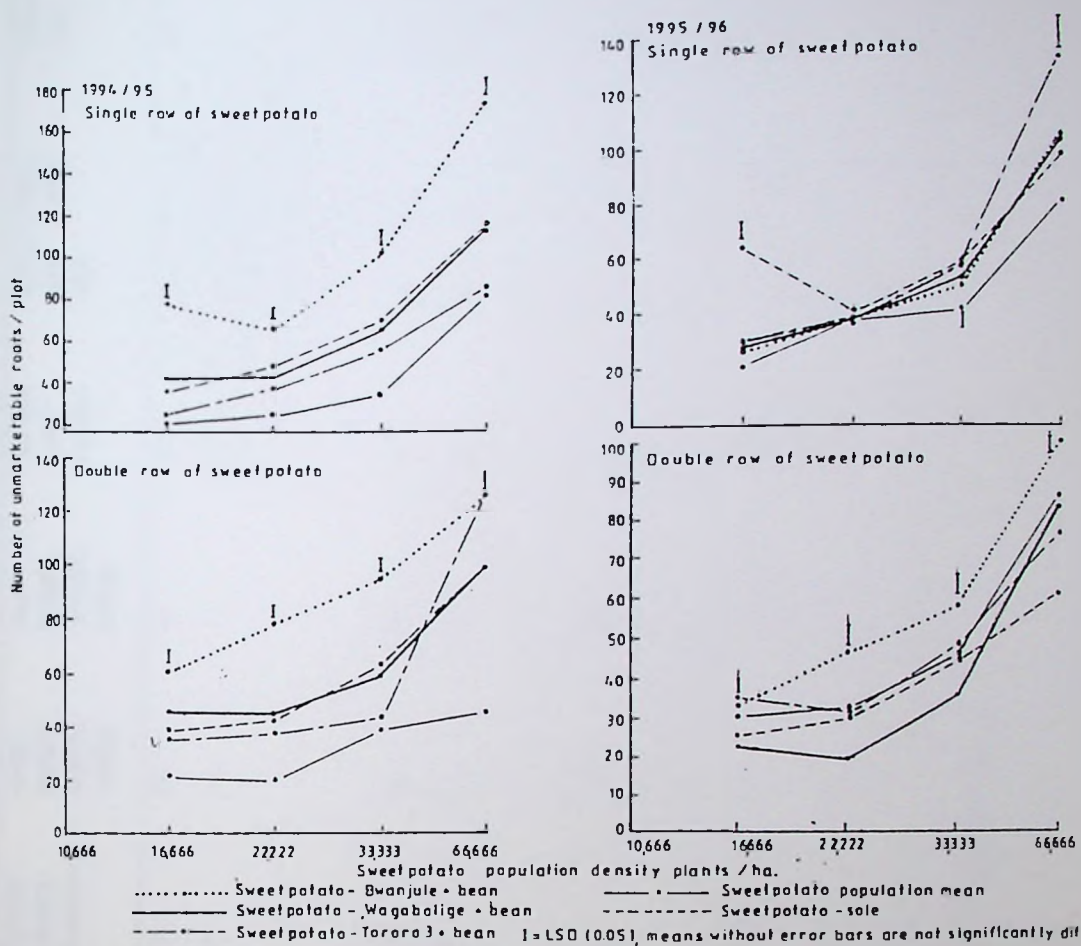


Figure 7. Effects of sweet potato spatial arrangement and population density on sweet potato storage root quality - number of unmarketable roots/plot.

Table 52. Levels of significance from analysis of variance and contrasts in yield and yield components of sweetpotato in mixtures with bean and three sweetpotato genotypes, two spatial arrangements and four sweetpotato population densities (1994/95)[Experiment II].

Source of variation	Degrees of freedom	Vine yield (kg/plant)	Percent market. (root/plot)	Percent unmark. (root/plot)	Aver. weight market. root(g)	Aver. weight unmark. root(g)	Harvest index percent	shoot/ root ratio	Yield (t/ha)	Percent dmc
Replication	2	ns	ns	ns	ns	ns	ns	ns	ns	ns
Sweetpotato genotype (SPG)	2	ns	**	**	**	**	ns	ns	ns	**
Error(a)	4									
Spatial arrangement	1	ns	ns	ns	ns	ns	ns	ns	ns	ns
SPG x SA	2	ns	ns	ns	ns	ns	ns	ns	ns	ns
Error (b)	6									
Sweetpotato population	3	**	**	**	**	ns	ns	ns	**	**
(PD)	6	*	ns	ns	ns	ns	ns	*	**	
SPG x PD	3	**	ns	ns	ns	ns	ns	ns	ns	ns
SA x PD	6	ns	ns	ns	ns	ns	ns	ns	ns	ns
SPG x SA x PD	36									
Error (c)			18.1%	36.9%	14.7%	19.8%	13.6%	29.5%	16.8%	5.0%
CV										
Contrast										
Among population		**	**	**	ns	ns	**	ns		

* = Linear coefficient

ns, *, ** = Non significant or significant at 5% and 1% probability level, respectively.

Table 53. Levels of significance from analysis of variance and contrasts in yield and yield components of sweetpotato in association with bean involving three sweetpotato genotypes, two spatial arrangements and four sweetpotato population densities (1995/1996)[Experiment II].

Source of variation	Degrees of freedom	Vine yield (kg/plant)	percent market. (roots/plot)	percent unmarket. roots per plot	Average weight market. (g)	Average weight unmarket. (g)	Yield (t/ha)	Harvest index percent	Shoot/root ratio	Percent dmc.
Replication (R)	2	ns	ns	ns	ns	ns	*	ns	ns	ns
Sweetpotato genotypes (SPG)	2	ns	*	ns	ns	ns	ns	ns	ns	ns
Error (a)	4									
Spatial arrangement (SA)	1	ns	ns	ns	ns	ns	ns	*	*	ns
SPG x SA	2	ns	ns	ns	ns	ns	ns	ns	ns	ns
Error (b)	6									
Sweetpotato population density (PD)	3	**	**	**	**	ns	*	*	*	ns
SPG x PD	6	ns	*	ns	ns	ns	*	ns	ns	ns
SA x PD	3	**	ns	ns	ns	ns	ns	ns	ns	ns
SPG x SA x PD	6	ns	ns	*	ns	ns	ns	ns	ns	ns
Error (c)	36									
Contrast										
Among population densities		*†	*†	*†	ns	ns	ns	ns	ns	ns
CV.		24.9%	24.1%	38.1%	23.0%	22.0%	11.1%	19.6%	11.0%	

† - Linear

ns, *, ** - Non significant or significant at 5% and 1% probability level, respectively.

There were also significant season x genotype, season x spatial arrangements x population density and genotype x spatial arrangement x population density interaction effects on the number of unmarketable roots (Appendix 14). Number of marketable storage roots was significantly correlated with population density ($r=0.605^{**}$, $r=0.383^{**}$, $n=72$) in 1994/95 and 1995/96 seasons, respectively. Number of unmarketable roots was also positively correlated with population density ($r=0.522^{**}$ and $r=0.766^{**}$) in 1994/95 and 1995/96 seasons, respectively. There were 5.1% more marketable roots in double rows than in single row in 1994/95 season. While in 1995/96 season there were 10.3% more marketable roots in single row than in double rows.

Number of marketable roots was 42.4% higher in 1994/95 season than in 1995/96 season. In both 1994/95 and 1995/96 seasons, there was 7.7% more unmarketable roots in the single row than in the double rows. Number of unmarketable roots was 20% more in 1994/95 season than in 1995/96 season. Intercropping reduced number of marketable roots by 3.1% of the sole crop in single row but increased it by 13.3% in the double rows arrangement in 1994/95 season.

In 1995/96 season, intercropping reduced number of marketable roots by 16.9% and 21.2% of the sole crop in the single and double rows, respectively. On the whole, intercropping increased number of marketable roots by 5.2% of the sole crop in 1994/95 season, but reduced it by an average of 16.7% in 1995/96 season.

In 1994/95 season, intercropping reduced the number of unmarketable roots by 3% in the single row but there was no difference between the sole-

cropped and the intercropped sweetpotato in double rows arrangement.

In 1995/96 season, intercropping reduced the number of unmarketable roots by 16.1% in the single row but increased it by 18.8% in the double rows. On the whole intercropping reduced the number of unmarketable roots by 1.6% and 2.8% in 1994/95 and 1995/96 seasons, respectively.

Storage root weight distribution

During 1994/95 cropping season, weights of individual marketable roots varied among genotypes and population densities. In 1995/96 season, weight of individual marketable root varied with population density only. Season had no significant effect but spatial arrangement and population density had significant effects on weights of individual marketable root (Appendix 14).

Average weight of marketable root decreased with increase in plant population density (Figure 8) due to increase in intra-specific competition for nutrients and space. It negatively correlated with population density ($r = -0.507^{**}$ and $r = -0.622^{**}$) in 1994/95 and 1995/96 seasons, respectively. In 1995/96 season, it was 4.2% higher in single row than double rows. Average weights of individual unmarketable root varied among genotypes in 1994/95 season but not in 1995/96 season (Figure 9). Season had significant influence on individual unmarketable root size. The average weight of unmarketable roots had no trend with population density. The average weight of marketable roots was 4.6% higher in the double rows than single row in 1994/95 cropping season.

The average weight of unmarketable roots was 6.7% higher in the single row than

the double rows in 1994/95 season. Intercropping increased average weight of marketable roots by 8.9% and 1.5% in single row and double rows arrangement, respectively in 1994/95 season.

In 1995/96 season, intercropping increased the weight by 13.5% of the sole crop weight in the single row but reduced it by 4% in the double rows arrangement. The average weight of unmarketable roots was increased by 9.8% of the sole crop weight in the single row but reduced it by 8% in the double rows arrangement in 1994/95 season. There was no consistency among genotypes in the average weight of unmarketable roots. In 1995/96 season, the average weight of unmarketable roots was 39.5% higher than in 1994/95 season in single and double rows arrangement, respectively.

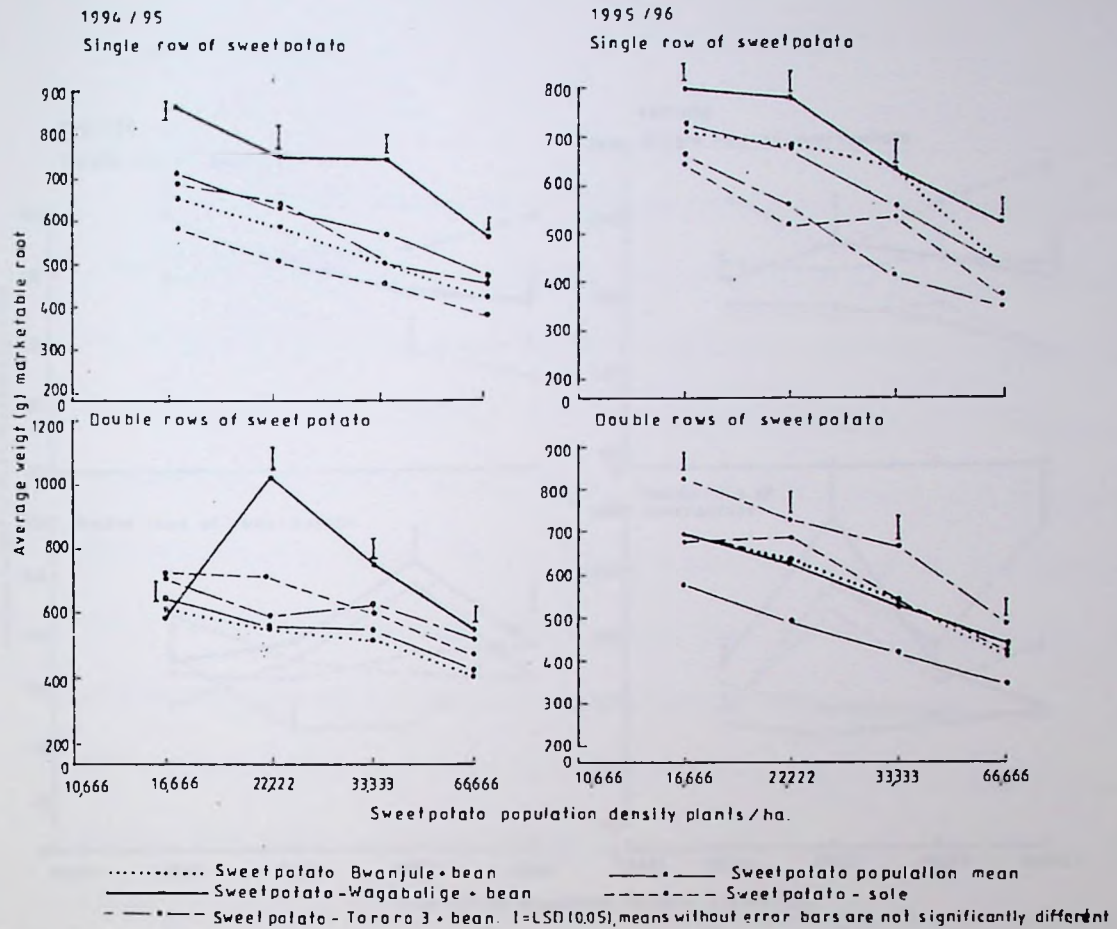


Figure 8. Effects of sweetpotato spatial arrangement and population density on storage root size distribution-average weight of marketable roots (g/root)

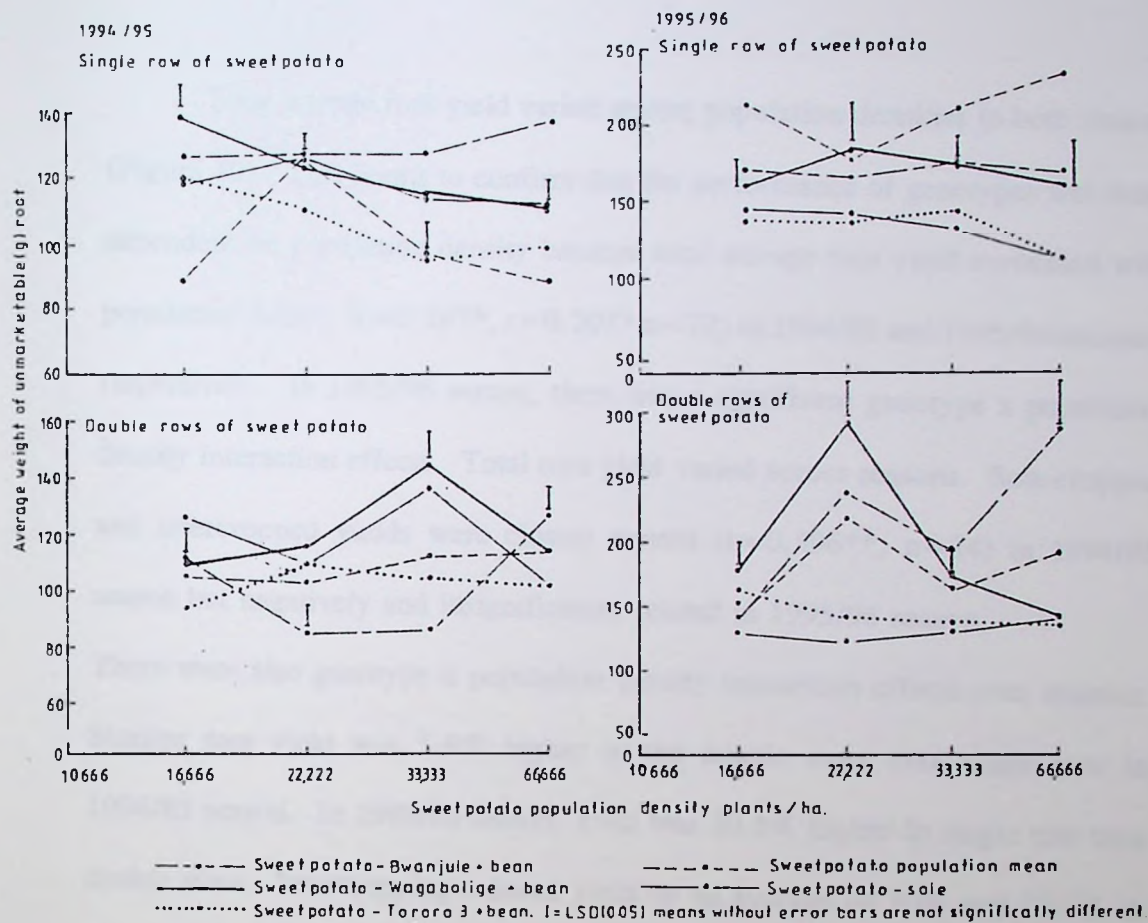


Figure 9. Effects of sweetpotato spatial arrangement and population density on storage root size distribution – average weight of unmarketable roots (g/root).

Intercropping increased the weight by 21.8% and 20.1% of the sole crop weight in the single and double rows arrangement, respectively.

Storage root yield

Total storage root yield varied among population densities in both seasons (Figure 10). This seems to confirm that the performance of genotypes was more dependent on population density because total storage root yield correlated with population density ($r=0.297^*$, $r=0.207^*$ $n=72$) in 1994/95 and 1995/96 seasons, respectively. In 1995/96 season, there was a significant genotype x population density interaction effects. Total root yield varied across seasons. Sole-cropped and intercropped yields were closely related ($r=0.596^{**}$, $n=24$) in 1994/95 season but negatively and insignificantly related in 1995/96 season.

There were also genotype x population density interaction effects over seasons. Storage root yield was 5.9% higher in the double rows than single row in 1994/95 season. In 1995/96 season, yield was 10.5% higher in single row than double rows. Intercropping reduced yield by an average of 10% and 18.1% in the single and double rows, respectively in 1994/95 season.

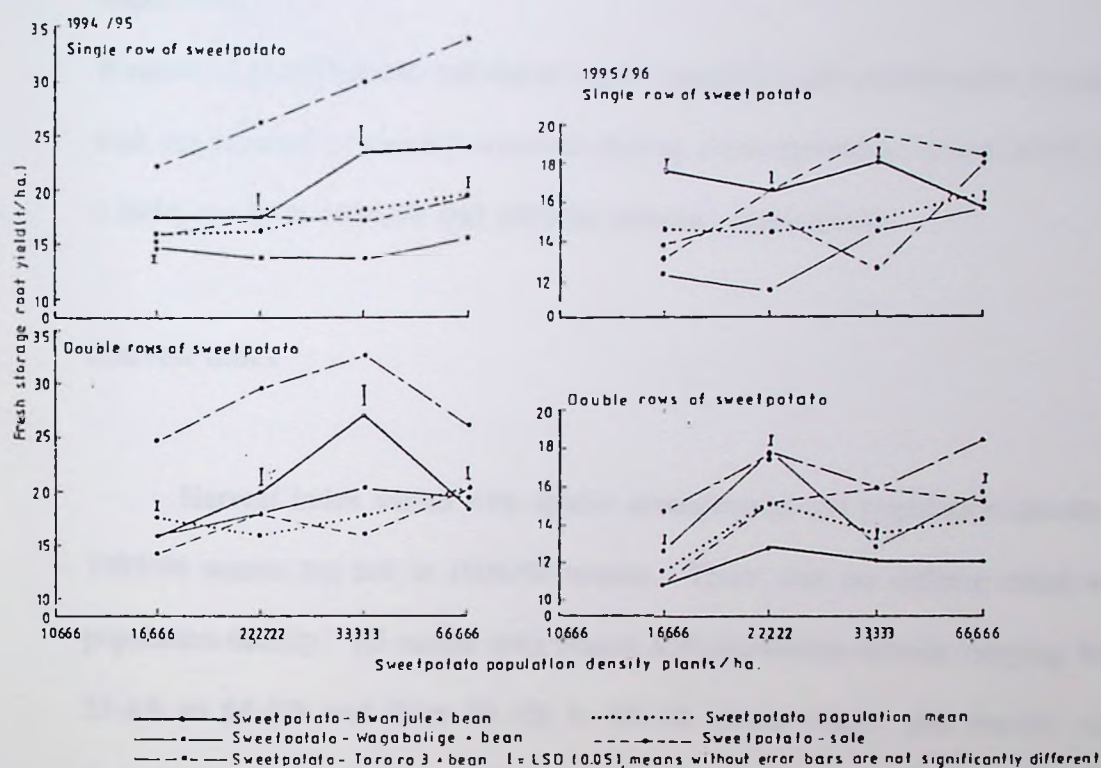


Figure 10. Effects of sweetpotato spatial arrangement and population density on total fresh root yield.

Thus although yield was higher in the double rows, yield reduction was equally high in the double rows. In 1995/96 season, intercropping reduced yield by an average of 41.3% and 33.9% in single and double rows arrangement, respectively. On the whole, intercropping reduced storage root yield by an average of 37.7% and 14.1% in 1994/95 and 1995/96 cropping season, respectively.

Weights of unmarketable individual roots negatively and significantly correlated with the amount of rainfall received during experimentation ($r=-0.819^*$, $r=-0.895^*$, $n=6$) in 1994/95 and 1995/96 seasons, respectively.

Harvest index

Harvest index varied with spatial arrangement and population density in 1995/96 season but not in 1994/95 season. There was no definite trend with population density. HI varied with season and population density ranging from 55.4% to 64.8% and from 50.3% to 58.1% in the single and double rows arrangement, respectively in 1994/95 season (Table 50). In 1995/96 season, HI ranged from 38.8% to 46% and from 36.6% to 39.3%, in the single and double rows arrangement, respectively (Table 51). The highest HI of 64.8% and 58.1% were produced at population densities of 66, 666 and 33, 333 plants/ha in single and double rows, respectively in 1994/95 season. In 1995/96 cropping season the highest HI of 46.0% and 39.3% were produced at population densities of 22, 222 and 33, 333 plants/ha in the single and double rows arrangement, respectively.

Intercropping reduced HI by 7.9% and 4.3% in single and double rows arrangement, respectively in 1994/95 season, and by 14.2% and 15.8% in single and double rows arrangement, respectively in 1995/96 season.

Shoot/root ratio (S/R)

Shoot:root ratio varied significantly among population densities and spatial arrangements only during 1995/96 cropping season. In 1994/95 season S/R ratio was 8.3% lower in single row than double rows (Table 50). In 1995/96 season S/R ratio was 23.5% lower in single row than double rows (Table 51). Intercropping reduced S/R ratio by an average of 4.5% and 16.7% in the single row and double rows, respectively in 1994/95 season. In 1995/96 season intercropping increased S/R ratio by an average of 23.1 and 17.6% in single and double rows, respectively. Shoot/root ratio was 23.3% lower in 1994/95 than in 1995/96 season. Season and population density had significant influence on S/R. High S/R is highly associated with low storage root yield.

Dry matter content percent (DMC %)

Dry matter content percent varied significantly among genotypes and population densities in 1994/95 season but not in 1995/96 season. There were significant spatial arrangement x genotype and genotype x population density interaction effects on DMC %. DMC % was not correlated with population density and yield per plant but was influenced by season and the effects of

genotypes spread over seasons as well. Generally, intercropping had no significant effect on dry matter accumulation in storage roots. However, intercropping increased DMC% by an average of 2.4% in 1994/95 season but reduced it by an average of 5.3% in 1995/96 season. In 1994/95, season DMC % was 3.5% higher in single row than in double rows, but was 1.5% higher in double rows than in single row in 1995/96 season. Generally DMC % was 6.3% higher in 1995/96 season than in 1994/95 season.

4.6.0 Bean growth

Plant height

The effects of sweetpotato genotypes, spatial arrangements and population densities on plant height were not significant (Tables 54 and 55). Plant heights were 3.9% and 2.3% lower in the double rows than single row in 1994/95 and 1995/96 seasons, respectively. Heights decreased with increase in population density. Intercropping reduced plant height by 3.2% and 4.2% of the sole crop in 1994/95 and 1995/96 seasons, respectively.

Dry matter accumulation

Dry matter accumulation (DMA) did not vary significantly with population density in both seasons. It was 5.7% higher in single row than in double rows and it decreased with increase in population density. This was reflected by the negative correlation with population density ($r=-0.298^*$, $r=-0.304^*$, $r=-0.309^*$, $n=72$) at 6, 8 and 10 WAP, respectively.

In 1995/96 season, DMA was 8.3 % higher in single row than in double rows. DMA increased with time but decreased with increase in population density. Intercropping increased DMA in bean by 17.9% and 26.2% in 1994/95 and 1995/96 seasons, respectively (Figure 11).

Table 54. Effects of sweetpotato spatial arrangement and population density on bean plant height in sweetpotato/bean association, 1994/95 cropping season

	Bean plant height (cm)					
	Spatial arrangement					
	Single row of sweetpotato			Double rows of sweetpotato		
	Growth period (WAP)					
Cropping system	4	6	8	4	6	8
Bean + sweetpotato (16,666 plt/ha)	16.8	36.1	42.3	16.3	31.7	42.5
Bean + sweetpotato (22,222 plt/ha)	16.8	35.5	44.2	14.8	31.6	42.4
Bean + sweetpotato (33,333 plt/ha)	16.3	28.9	40.4	17.1	34.1	45.6
Bean + sweetpotato	16.7	31.2	44.1	15.0	28.3	35.5
Mean-intercropped	16.7	32.9	42.8	15.8	31.4	41.5
Mean-sole-cropped	15.9	34.7	45.7	15.4	34.7	45.7
CV.	8.5%	15.6%	20.3%	8.5%	15.6%	20.3%
SE.	0.56	2.05	3.50	0.56	2.05	3.50
LSD (0.05)	NS	NS	NS	NS	NS	NS

Table 55: Effects of sweetpotato spatial arrangement and population density on bean plant height in sweetpotato/bean association, 1995/96 cropping season

Cropping system	Bean plant height (cm)							
	Spatial arrangement				Double rows of sweetpotato			
	Single row of sweetpotato		Growth period (WAP)		Growth period (WAP)		Double rows of sweetpotato	
	4	6	8	4	6	8	4	8
Bean + sweetpotato (16,666 plt/ha)	15.4	37.7	44.0	14.3	34.0	44.0		
Bean + sweetpotato (22,222 plt/ha)	14.7	34.2	41.8	13.9	33.7	40.7		
Bean + sweetpotato (33,333 plt/ha)	14.7	31.4	41.6	14.7	34.1	44.4		
Bean + sweetpotato (66,666 plt/ha)	15.5	34.3	44.6	13.9	32.8	40.3		
Mean-intercropped	15.1	34.4	43.0	14.2	33.7	42.3		
Mean-sole	12.6	37.2	45.5	12.6	37.2	45.5		
CV.	13.4%	29.6%	28.4%	13.4%	29.6%	28.4%		
SE.	0.65	3.12	4.04	0.65	3.12	4.04		
LSD (0.05)	NS	NS	NS	NS	NS	NS		

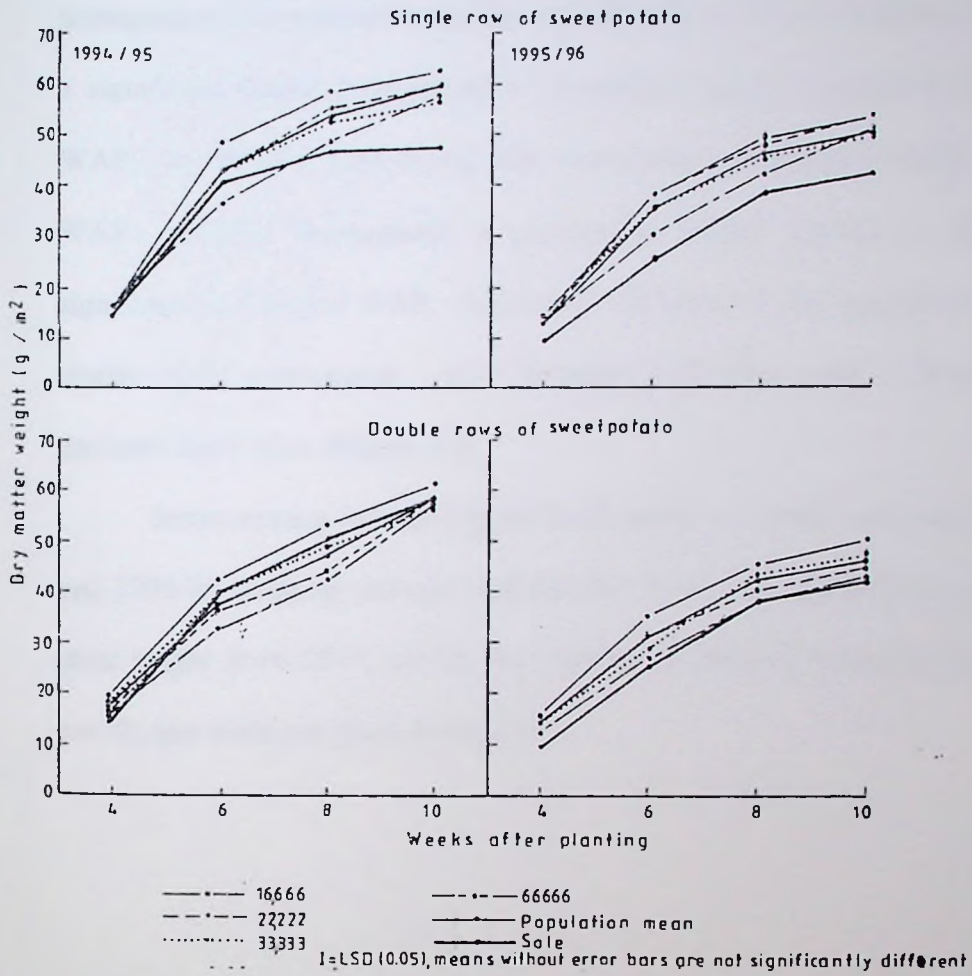


Figure 11. Effects of sweetpotato spatial arrangement and population density on bean dry matter weight

Leaf area index

In 1994/95 cropping season, the effects of sweetpotato genotypes, spatial arrangement and population density on bean LAI were not significant. There was a significant spatial arrangement x population density interaction effects at 10 WAP. In 1995/96, LAI varied with sweetpotato population density at 8 and 10 WAP. Spatial arrangement x population density interaction effects were significant at 8 and 10 WAP. LAI was 2.5% lower in the single row than in the double rows arrangement. LAI increased with time until 6 WAP and then declined there after (Figure 12).

Intercropping reduced LAI by 5.1% and 8.1% of the sole crop in 1994/95 and 1995/96 cropping seasons, respectively. LAI was positively correlated with plant height ($r=0.257^*$, $n=72$) and number of primary branches ($r=0.488^{**}$, $n=72$) and yield per plant ($r=0.273^*$).

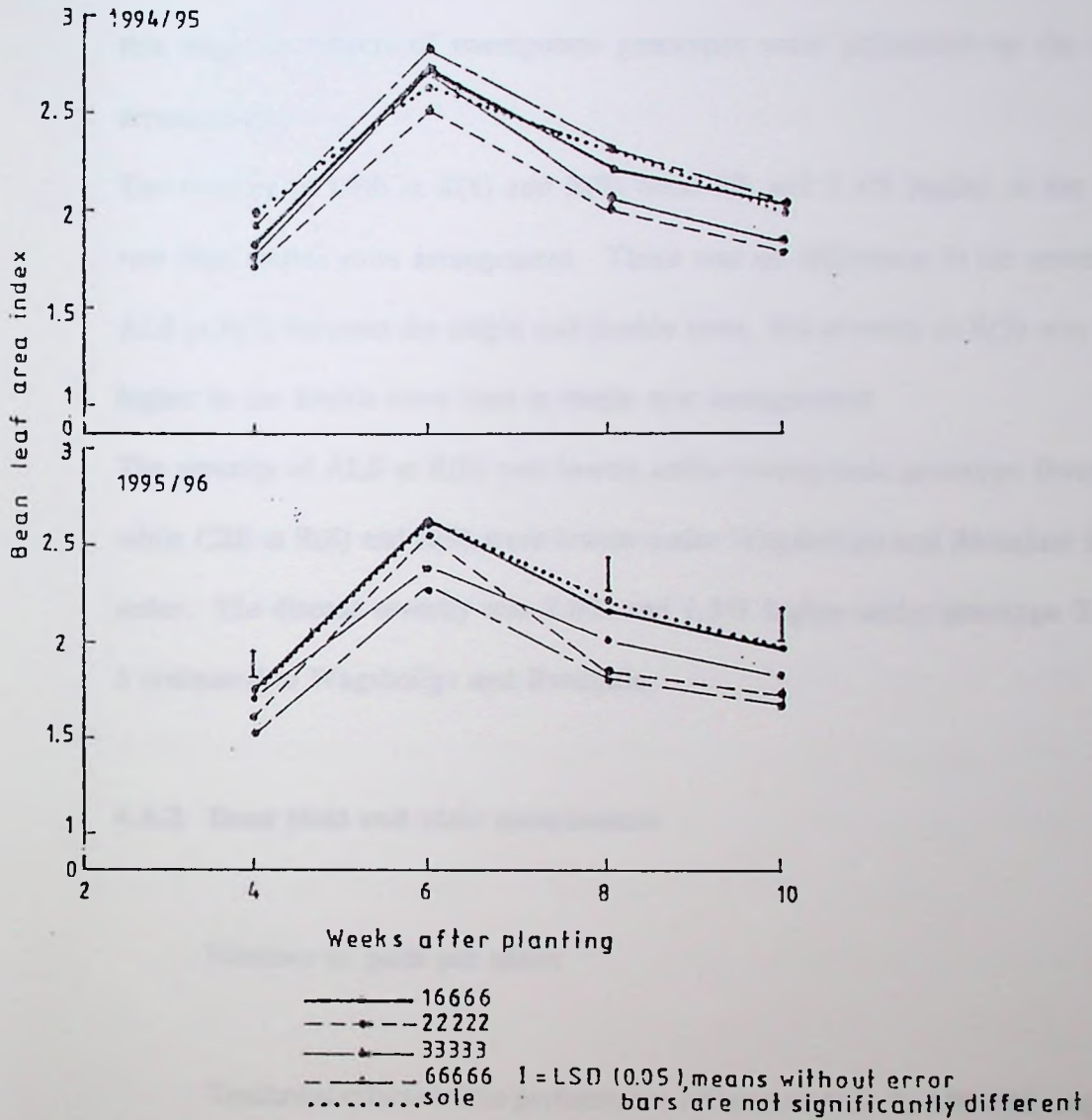


Figure 12 Changes in bean LAI with sweet-potato population density.

4.6.1 Common bean plant diseases

The severity of CBB and ALS were not significantly influenced by spatial arrangement, sweetpotato genotype and plant population density. Spatial arrangement x genotype interaction effects on CBB at R(9) was significant. At this stage the effects of sweetpotato genotypes were influenced by the spatial arrangement.

The severity of CBB at R(8) and R(9) were 4% and 5.4% higher in the single row than double rows arrangement. There was no difference in the severity of ALS at R(8) between the single and double rows, but severity at R(9) was 3.2% higher in the double rows than in single row arrangement.

The severity of ALS at R(8) was lowest under sweetpotato genotype Bwanjule, while CBB at R(8) and R(9) were lowest under Wagabolige and Bwanjule in that order. The disease severity was 2.6% and 1.5% higher under genotype Tororo 3 compared to Wagabolige and Bwanjule.

4.6.2 Bean yield and yield components

Number of pods per plant

Treatment effects on the performance of bean varied. In 1994/95 cropping season, spatial arrangements and sweetpotato genotypes did not significantly affect pod production but it varied with sweetpotato plant density (Table 56). Season had no significant influence on pod production (Appendix 15) but there were

significant spatial arrangement x population density interaction effects suggesting that the effects of population density on pod production was dependent on sweetpotato spatial arrangements.

In 1994/95 season, pod production was reduced by 23.1% and 30.8% of the sole crop in the single and double rows, respectively. In 1995/96 cropping season intercropping increased number of pods per plant by 11.1% of the sole crop only in the double rows arrangement. Number of pods per plant decreased with increase in sweetpotato plant density (Table 57).

Number of seeds per plant

In 1994/95 season, number of seeds per plant varied with sweetpotato plant density but spatial arrangements and sweetpotato genotypes had no significant effect. Number of seeds per plant was 6.2% more in single row than double rows in 1994/95 season. In 1995/96 season, there was 7.7% more seeds/plant in double rows than single row arrangement. Intercropping reduced number of seeds per plant by 18.6% and 23.7% of the sole crop in the single row and double rows of sweetpotato, respectively in 1994/95 season.

In 1995/96 season, intercropping reduced number of seeds per plant by 4.2% of the sole crop in single row but increased it by 11.5% of the sole crop in the double rows of sweetpotato. On the whole, intercropping reduced number of seeds per plant by an average of 8.1% of the mean sole crop number for the two cropping seasons. Number of seeds per plant was negatively correlated with sweetpotato population density ($r=-0.279^*$, $n=72$) in 1994/95 season.

The effects of sweetpotato spatial arrangement and population density on number of seeds per plant are illustrated in (Figure 13).

The 100 dry seed weight (100 DSW)

Sweetpotato genotypes, spatial arrangements and population density had no significant effect on DSW. There were significant differences in the effects of season on 100 DSW. Sweetpotato genotype x spatial arrangement, and season x genotype x spatial arrangement interaction effects on 100 DSW were significant.

Table 56: Effect of sweetpotato spatial arrangement and population density on the performance of bean in sweetpotato/bean association, 1994/95 cropping season.

Cropping Systems	Bean Yield Attribute									
	Single row of sweetpotato					Double rows of sweetpotato				
	No. of pods/plant	No. of seeds / plant	100 seeds weight (g)	Yield / Plant (g)	Yield (kg/ha)	No. of pods/plant	No. of seeds/plant	100 seeds weight (g)	Yield/ plant (g)	Yield (Kg/ha)
Bean + Sweetpotato (16,666) plants/ha	11	55	23.3	7.06	787.1	10	48	22.7	6.46	691.9
Bean + sweetpotato (22,222, plants/ha)	10	46	23.7	6.02	713.7	10	49	23.0	6.08	715.6
Bean + sweetpotato (33,333 plants/ha)	10	49	22.7	5.88	648.1	8	41	22.3	4.92	545.0
Bean + Sweetpotato (66,666 plants/ha)	8	40	22.7	4.89	481.5	9	43	23.3	5.69	480.8
Mean	10	48	23.1	5.96	657.6	9	45	22.8	5.79	608.3
Sole	13	59	24.6	9.7	1400	13	59	24.6	9.7	1400
C.V.	19.5%	22.2%	6.7%	24.5%	26.5%	19.5%	22.2%	6.7%	24.5%	26.5%
S.E. (Pop)	0.50	3.06	0.51	0.48	58.87	0.50	3.06	0.51	0.48	58.87
LSD. (0.05) (Pop)	1.27	7.00	NS	1.67	113.4	1.28	7.00	NS	1.67	113.4

Table 57: Effect of sweetpotato spatial arrangement and plant population density on the performance of bean in sweetpotato/bean association, 1995/96 cropping season

Cropping Systems	Bean Yield Attributes									
	Single row of sweetpotato					Double rows of sweetpotato				
	No. of pods/ plant	No. of seeds / plant	100 seeds weight (g)	Yield / Plant (g)	Yield (kg/ha)	No. of pods/ plant	No. of seeds/ plant	100 seeds weight (g)	Yield/ plant (g)	Yield (t/ha)
Bean + Sweetpotato (16,666) plants/ha	9	53	26.3	2.8	369.1	8	54	27.0	3.4	399.1
Bean + sweetpotato (22,222, plants/ha)	8	45	26.5	3.1	334.2	10	57	27.5	3.1	410.6
Bean + sweetpotato (33,333 plants/ha)	7	43	26.0	2.5	233.5	9	53	27.0	3.2	347.1
Bean + Sweetpotato (66,666 plants/ha)	8	44	27.1	2.0	221.3	8	43	25.4	2.23	223.2
Mean	10	48	23.1	5.96	289.5	9	45	22.8	5.79	345.0
SE										
CV	25.4%		6.5%	32.8%	32.1%	25.4%		6.5%	32.8%	25.4%
LSD (0.05)	NS	NS	0.62	0.62	67.9	NS	NS	NS	0.62	67.9

NS = Not significant

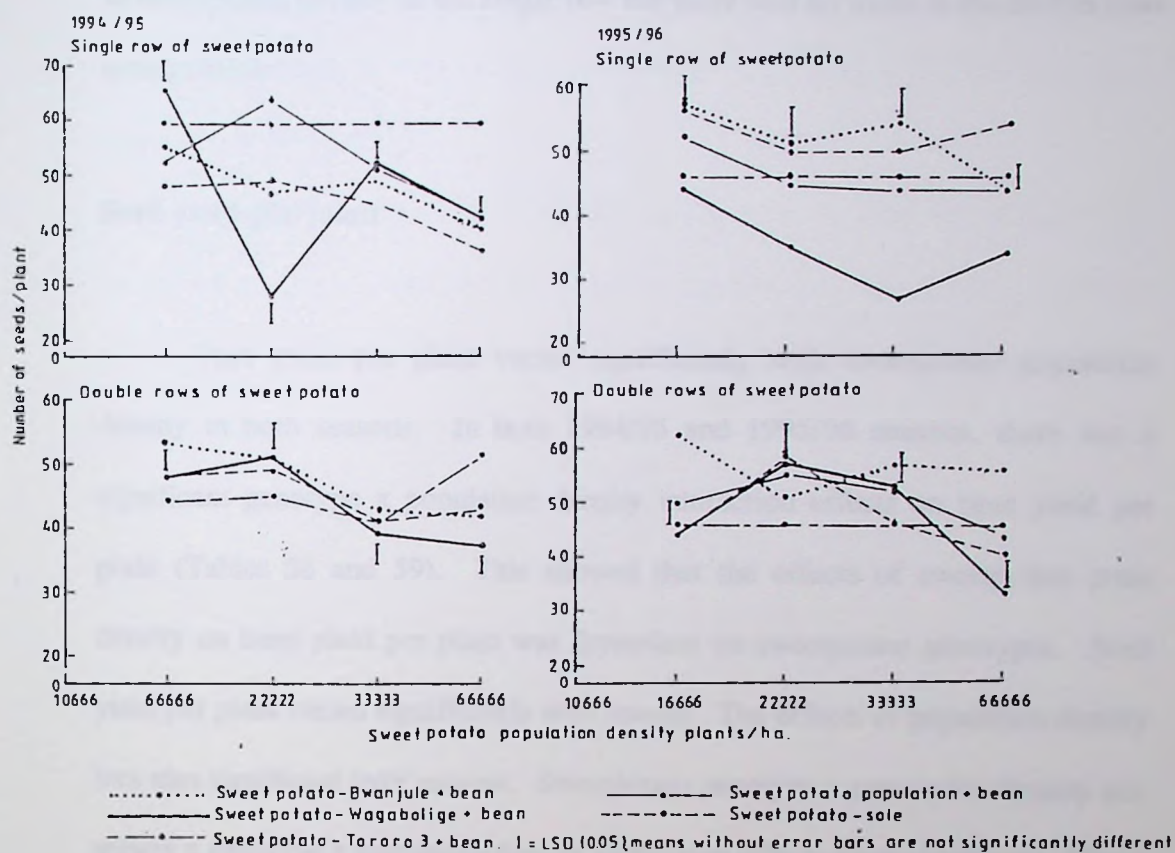


Figure 13. Effects of sweetpotato spatial arrangement and population density on number of seeds per plant.

In 1994/95 season, intercropping reduced 100 DSW by 6.1% and 7.3% in single row and double rows arrangement, respectively. In 1995/96 season, intercropping reduced 100 DSW by 7.3% and 6.6% in single row and double rows, respectively. In 1994/95 season, 100 DSW slightly decreased with increase in sweetpotato density in the single row but there was no trend in the double rows arrangement.

Seed yield per plant

Seed yield per plant varied significantly with sweetpotato population density in both seasons. In both 1994/95 and 1995/96 seasons, there was a significant genotype x population density interaction effects on bean yield per plant (Tables 58 and 59). This showed that the effects of sweetpotato plant density on bean yield per plant was dependent on sweetpotato genotypes. Seed yield per plant varied significantly with season. The effects of population density was also significant over seasons. Sweetpotato genotype x population density and season x genotype x population density interaction effects were significant. These interactions indicate that the effects of sweetpotato genotypes was influenced by population density and that the combined effects of sweetpotato genotypes and population densities on bean yield per plant was influenced by season.

Yield per plant decreased with increase in sweetpotato plant density and was reduced by 38.6% and 40.3% of the sole crop yield in single row and double rows in 1994/95 season. In 1995/96 season, yield per plant was increased by 7.7% and 20% of the sole crop yield in single and double rows, respectively.

Dry bean seed yield

Total dry seed yield (TDSY) was affected only by sweetpotato plant density in both seasons. TDSY also varied over seasons. The effects of sweetpotato population density on TDSY were reflected by its negative correlations ($r=-0.377^{**}$, $r=-0.338^{**}$, $n=72$) in 1994/95 and 1995/96 seasons, respectively (Figure 14).

TDSY was 49.9% higher in 1994/95 season than in 1995/96 season. The variations in yield across seasons could be attributed to variabilities in weather conditions during experimentation. Treatment means varied among the various cropping systems across seasons.

Table 58. Levels of significance from analysis of variance and contrasts in bean yield and yield components in mixtures with three sweetpotato genotypes, two spatial arrangements and four sweetpotato population densities (1994/95)[Experiment II].

Source of variation	Degrees of freedom	Number of pods per plant	Number of seeds per pod	100 seed weight (g)	Yield per plant (g)	Yield per plot (g)	Yield kg per hectare
Replication (F)	2	ns	ns	ns	ns	**	**
Sweetpotato genotypes (SPG)	2	ns	ns	ns	ns	ns	ns
Error(a)							
Spatial arrangement (SA)	1	ns	ns	ns	ns	ns	ns
SPG x SA	2	ns	ns	ns	ns	ns	ns
Error(b)	6						
Sweetpotato population (PD)	3	*	*	ns	*	**	**
SPG x PD	6	ns	ns	ns	*	ns	ns
SA x PD	3	ns	ns	ns	ns	ns	ns
SPG x SA x PD	6	ns	ns	ns	ns	ns	ns
Error(c)	36						
Contrast							
Among population densities		ns	ns	ns	ns	+	+
CV		25.3%	8.0%	6.5%	32.9%	32.8	32.1%

1 = Linear

ns, * = Non significant or significant at 5% probability level, respectively.

Table 59. Levels of significance for analysis of variance and contrasts in bean yield and yield components in mixtures with three sweetpotato genotypes, two spatial arrangements and four sweetpotato population densities (1995/96)[Experiment 11].

Source of variation	Degrees of freedom	Number of pod plant	Number of seed plant	100 seed weight (g)	Yield per plant (g)	Yield kg per hectare	CBB (R8)	CBB (R9)	ALS (R8)	ALS (R9)
Replication	2	ns	ns	ns	ns	ns	**	ns	ns	ns
Sweetpotato genotype (SPG)	2	ns	ns	ns	ns	ns	ns	ns	ns	ns
Error(a)										
Spatial arrangement	1	ns	ns	ns	ns	ns	ns	ns	ns	ns
(SA)										
SPG x SA	2	ns	*	ns	ns	ns	ns	ns	ns	ns
Error(b)										
Sweetpotato population	3	*	ns	ns	*	**	ns	ns	ns	ns
(PD)										
SPG x PD	6	ns	ns	ns	*	ns	ns	ns	ns	ns
SA x PD	3	ns	ns	ns	ns	ns	ns	*	ns	ns
SPG x SA x PD	6	ns	ns	ns	ns	ns	ns	ns	ns	ns
Error (c)	36									
Contrast										
Among population densities		ns	ns	ns	ns	ns	ns	ns	ns	ns
CV.		19.9%	9.86%	6.6%	24.5%	26.5%	10.9%	7.4%	8.6%	10.1%

ns, *, ** - Not significant or significant at 5% and 1% probability levels, respectively.

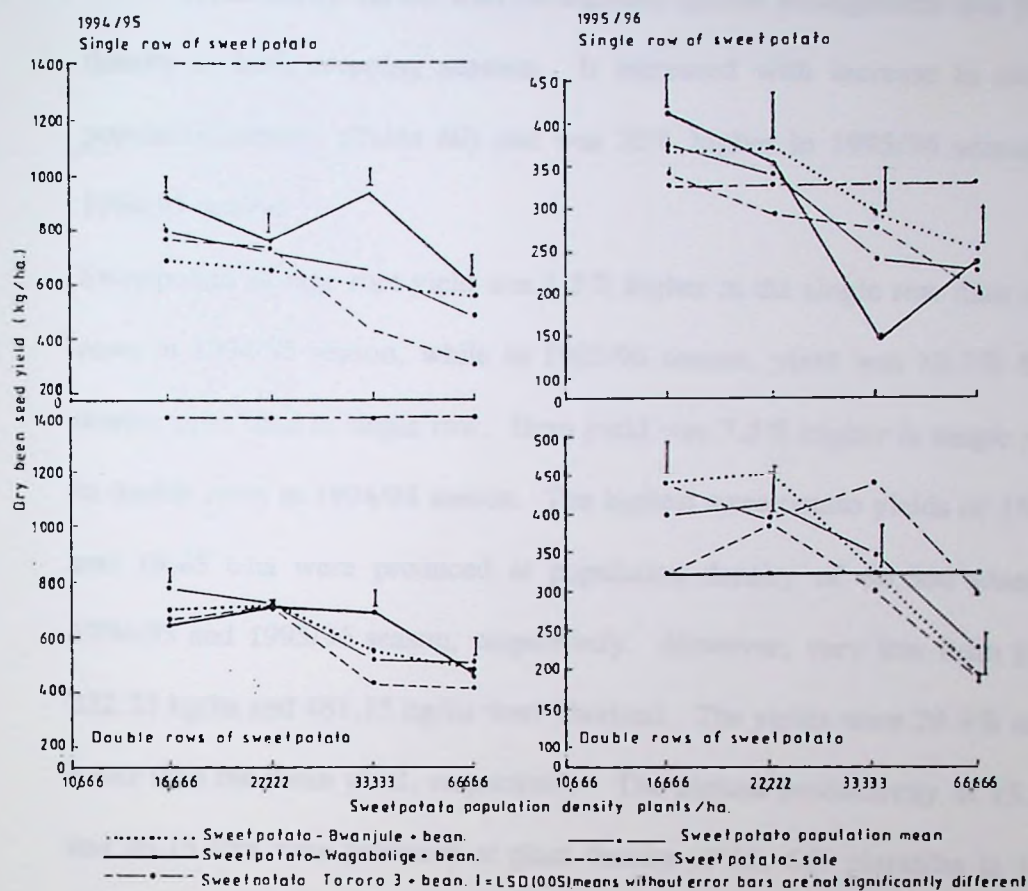


Figure 14. Effects of sweetpotato spatial arrangement and population density on bean seed yield.

4.7.0 Sweetpotato/bean intercrop productivity.

Productivity varied with sweetpotato spatial arrangement and population density in both cropping seasons. It increased with increase in sweetpotato population density (Table 60) and was 22% higher in 1995/96 season than in 1994/95 season.

Sweetpotato storage root yield was 1.5% higher in the single row than in double rows in 1994/95 season, while in 1995/96 season, yield was 10.5% higher in double rows than in single row. Bean yield was 7.5% higher in single row than in double rows in 1994/95 season. The highest sweetpotato yields of 15.45 t/ha and 19.65 t/ha were produced at population density of 66,666 plants/ha in 1994/95 and 1995/96 season, respectively. However, very low bean yields of 222.25 kg/ha and 481.15 kg/ha were obtained. The yields were 29.9% and 24% lower than the mean yield, respectively. The highest productivity of 15.73 t/ha and 20.13 t/ha were produced at plant density of 66, 666 plants/ha in 1994/95 and 1995/96 season, respectively. However, the contribution of bean yield to the productivity was only 2.4% and 1.4% in 1994/95 and 1995/96 cropping season, respectively.

4.7.1 Competition between sweetpotato and bean

The competition ratio (CR) of bean was 61.7% and 50% higher in the single row than in double rows in 1994/95 (Table 61) and 1995/96 (Table 62) season, respectively. In 1995/96 season, CR for bean was significantly

influenced by sweetpotato spatial arrangement and population density. There was also a significant spatial arrangement x population density interaction. This implies that the effects of sweetpotato population density was influenced by the sweetpotato spatial arrangement.

Table 60: Sweetpotato/bean intercrop productivity, 1994/95 and 1995/96 cropping season.

Cropping systems	Sweetpotato (t/ha)			Bean (Kg/ha)		
	Single Rows	Double rows	Mean	With single row of sweetpotato	With double rows of sweetpotato	Mean
1994/95						
Bean + sweetpotato (16,666) plts/ha)	14.6	11.4	13.0	369.0	399.1	384.05
Bean + sweetpotato (22,222 plts/ha)	14.5	15.2	14.85	334.2	410.6	372.4
Bean + sweetpotato (33,333 plts/ha)	15.2	13.5	14.35	233.5	346.8	290.15
Bean + sweetpotato (66,666 plts/ha)	16.6	14.3	15.45	221.3	223.2	222.25
Mean	15.2	13.6	14.4	289.5	344.9	317.2
1995/96						
Bean + sweetpotato (16,666 plts/ha)	15.8	15.9	15.85	787.1	691.9	739.5
Bean + sweetpotato (22,222 plts/ha)	16.8	18.1	17.45	713.7	715.6	714.65
Bean + sweetpotato (33,333 plts/ha)	18.0	20.6	19.3	648.1	545.0	596.5
Bean + sweetpotato (66,666 plts/ha)	19.5	19.8	19.65	481.5	480.8	481.15
Mean	17.5	18.6	18	657.6	608.3	632.95
						18.69

Table 61: Effects of sweetpotato spatial arrangement and plant population density on competitive abilities of sweetpotato and bean, 1994/95 cropping season.

Cropping System	Competition Ratio (bean)		Competition ratio (sweetpotato)	
	With single row of sweetpotato	With double rows of sweetpotato	With single row	With double rows
Bean + Sweetpotato (16,666 plants/ha)	0.51	0.22	2.11	4.66
Bean + sweetpotato (22,222, plants/ha)	0.48	0.21	2.52	5.35
Bean + sweetpotato (33,333 plants/ha)	0.48	0.15	2.80	6.92
Bean + Sweetpotato (66,666 plants/ha)	0.41	0.14	3.45	7.41
Mean	0.47	0.18	2.72	6.08
C.V.	44.8%			33.5%
S.E. (Pattern) (Population density)	0.04 0.03			0.30 0.30
LSD. (0.05) (Population density) (Pattern)	0.14 0.01			1.0 1.05

Table 62: Effects of sweetpotato spatial arrangement and plant population density on competitive abilities of sweetpotato and bean in sweetpotato/bean association, 1995/96 cropping season.

Cropping System	Competition ratio (bean)		Competition ratio (sweetpotato)	
	With single row of sweetpotato	With double rows of sweetpotato	With single row	With double rows
Bean + Sweetpotato (16,666 plants/ha)	0.61	0.24	2.12	3.93
Bean + sweetpotato (22,222, plants/ha)	0.42	0.18	3.22	6.67
Bean + sweetpotato (33,333 plants/ha)	0.24	0.20	5.38	5.60
Bean + Sweetpotato (66,666 plants/ha)	0.24	0.14	5.39	7.85
Mean	0.38	0.19	4.03	6.01
C.V.	47.5%		57.5%	
S.E. (Population density) (Pattern)	0.04 0.03		0.83 0.59	
LSD (0.05) (Pattern) (Population density)	0.17 0.12		0.16 0.12	

In 1995/96 season, CR negatively correlated with sweetpotato plant density ($r = -0.422^{**}$, $n=72$). CR for bean decreased with increase in sweetpotato population, thus sweetpotato dominated the cropping system (Figures 15a, b and 16a, b). The most competitive sweetpotato genotype was Tororo 3 (Figure 17a), while Bwanjule grew away from bean to avoid competition (Figure 17b).

The CR for sweetpotato varied significantly with both spatial arrangement and population density in 1994/95 season, but only with population density in 1995/96 cropping season. The CR was 50.0% higher in single row than double rows arrangement in 1994/95 season, and 32.9% lower in single row than double rows in 1995/96 season.

CR increased with increasing population density and was correlated ($r = 0.314^{**}$, $r = 0.375^{**}$, $n=72$) in 1994/95 and 1995/96 season, respectively.

It is likely that bean competed favourably with sweetpotato in the single row arrangement of sweetpotato when bean crop closed over sweetpotato crop. This may partly explain the higher CR in single row than in double rows arrangement of sweetpotato.

The CR for sweetpotato and beans were negatively correlated ($r = -0.799^{**}$, $r = -0.682^{**}$, $n=72$) in 1994/95 and 1995/96 season, respectively. However, the competitive abilities of both crop species are reflected in their relative yields (RY) (Table 63). The RY of bean varied significantly with sweetpotato plant density in both seasons while that of sweetpotato did not vary significantly.



Fig.15 a. Sweetpotato at low population density with CR of 2.12 against 0.61 for bean. Bean competed favourably with sweetpotato.



Fig.15 b. Sweetpotato at moderately low population density with a CR of 3.22 against 0.42 for bean. Bean competed fairly well with sweetpotato.



Fig.16 a. Sweetpotato at its optimum population density in mixtures with bean. Sweetpotato dominating with CR of 5.38 against 0.24 for bean.



Fig.16 b. Sweetpotato at high population density dominating over bean with a CR of 5.3 against 0.24 for bean.



Fig. 17 a. Tororo 3, the most competitive sweetpotato genotype. It mixes more intimately with beans.



Fig.17 b. Sweetpotato genotype Bwanjule growing away from bean in order to receive better interception of photosynthetically active radiation.

Table 63: Relative Yields (RY) and Land Equivalent Ratio (LER) in sweetpotato/bean association, 1994/95 and 1995/96 cropping seasons.

Cropping Systems	Relative Yields				Land Equivalent Ratio		Total LER Mean
	Sweetpotato		Bean		With single row of sweetpotato	With double rows of sweetpotato	
	single row	Double rows	With single row of Sweetpotato	With double rows of sweetpotato			
1994/95							
Bean + Sweetpotato (16,666) plants/ha	0.70	0.65	0.76	0.69	1.46	1.34	1.40
Bean + sweetpotato (22,222, plants/ha)	0.71	0.71	0.69	0.71	1.39	1.42	1.41
Bean + sweetpotato (33,333 plants/ha)	0.75	0.81	0.66	0.59	1.37	1.40	1.39
Bean + Sweetpotato (66,666 plants/ha)	0.77	0.77	0.57	0.54	1.36	1.30	1.33
Mean	0.73	0.73	0.65	0.63	1.39	1.36	1.38
C.V.	17.8%			18.6%		13.1%	
SE	0.03			0.02		0.04	
LSD (0.05)	NS			0.08		NS	
1995/96							
Bean + Sweetpotato (16,666) plants/ha	0.60	0.56	0.62	0.66	1.23	1.22	1.22
Bean + sweetpotato (22,222, plants/ha)	0.72	0.74	0.38	0.65	1.30	1.39	1.34
Bean + sweetpotato (33,333 plants/ha)	0.75	0.68	0.37	0.62	1.12	1.30	1.21
Bean + Sweetpotato (66,666 plants/ha)	0.82	0.62	0.40	0.42	1.22	1.04	1.13
Mean	0.72	0.65	0.49	0.59	1.22	1.24	
C.V.	20.6%			31.0%		20.9%	
SE	0.07			0.06		0.59	
LSD (0.05)	NS			0.14		0.16	

There was no significant difference between single and double rows arrangement but, in 1995/96 season RY was 9.7% higher in double rows than single row. The RY of sweetpotato slightly increased with increase in sweetpotato plant density in both seasons.

The RY of bean decreased with increase in sweetpotato plant density ($r = -0.397^{**}$, $n=48$ and $r = -0.349^{**}$, $n=72$) in 1994/95 and 1995/96 season, respectively. The RY of bean dependent on the competitive abilities of the bean plant and were highly correlated ($r = 0.592^{**}$ $n=72$). In 1994/95 season, RY of bean was only 3.1% higher in single row than in double rows but in 1995/96 season, the RY was 16.9% higher in double rows than in single row.

The RY of bean and sweetpotato are the determinants of LER, hence they are highly correlated with LER ($r = 0.669^{**}$ and $r = 0.631$, $n=72$), respectively in 1994/95 season.

4.7.2 Aggressivity Coefficient (AC)

The magnitudes of aggressiveness of sweetpotato and bean grown in association varied with sweetpotato plant density and genotypes in 1994/95 season. Aggressivity coefficients (AC) increased with increase in sweetpotato plant density in both seasons (Table 64) and was 9.3% and 72.7% higher in single row than double rows of sweetpotato in 1994/95 and 1995/96 season, respectively.

AC linearly correlated with sweetpotato population density ($r = 0.361^{**}$, $n=72$, and $r = 0.371^{**}$, $n=48$) in 1994/95 and 1995/96 seasons, respectively.

In 1994/95 season, AC was positively correlated with sweetpotato CR ($r=0.586$, $n=72$) but negatively with bean CR ($r=-0.575^{**}$, $n=72$). In 1995/96 season, AC was positively correlated with sweetpotato CR ($r=0.621^{**}$, $n=72$) but negatively with bean CR ($r=-0.613^{**}$, $n=72$). This relationship indicated that the AC were dependent more on the competitive abilities of sweetpotato and bean crops. It also shows that sweetpotato crop generally dominated over bean crop in the mixtures.

Table 64: Aggressivity Coefficient (AC) in sweetpotato/bean association

	1994/95		1995/96	
	0.01	-0.01	-0.02	-0.09
Bean + Sweetpotato (66,666) plants/ha				
Bean + sweetpotato (22,222, plants/ha)	-0.04	-0.003	0.15	0.08
Bean + sweetpotato (33,333 plants/ha)	0.10	0.16	0.38	0.05
Bean + Sweetpotato (66,666 plants/ha)	0.20	0.21	0.42	0.19
Mean	0.075	0.068	0.22	0.06
C.V.				
SE				
(Pattern)	0.08			0.01
(Population density)	0.05			0.05
LSD. (0.05) (Population density)	0.14			0.06

4.7.3 Land use efficiency in sweetpotato/bean association

Intercropping sweetpotato with bean was advantageous because the LER values were greater than unity in the various mixtures. In 1994/95 and 1995/96 seasons, the highest LER was 1.41 and 1.34, respectively. These were achieved in crop mixtures with sweetpotato plant density of 22, 222 plants/ha. The LER ranged from 1.33 to 1.41 and from 1.13 to 1.34 in 1994/95 and 1995/96 seasons, respectively, suggesting that more than 33-41% and 13-34% more land would be required to plant sole crops of sweetpotato and bean to produce the same yields of sweetpotato and bean that were produced in mixtures.

However, ATER values were generally below unity (Table 65). ATER under estimates while LER over estimates LUE. The average LER added to ATER resulted into values greater than unity, showing that intercropping sweetpotato with bean was advantageous because the LUE was increased.

4.7.4 Monetary equivalent ratio (MER)

Results showed that intercropping sweetpotato with bean is economically advantageous because the MER values were greater than unity. In 1994/95 season, MER ranged from 1.0 -1.14 and from 1.0-1.20 in the single and double rows, respectively (Table 66). In 1995/96 season, MER ranged from 1.05 -1.32 and from 1.04-1.39 in single and double rows, respectively (Tables 67 and 68). There was no significant difference in bean MER between spatial arrangements but it varied with sweetpotato plant density.

MER for sweetpotato were not significantly different among the sweetpotato population densities.

The results showed that on average about 15% more land would be required to plant sole crops of sweetpotato and bean in order to realize the same yields of sweetpotato and bean to generate the same amount of cash income obtained from the mixtures.

Bean MER were positively correlated with total MER ($r=0.678^{**}$, $n=72$, $r=0.741^{**}$, $n=48$) in 1994/95 and 1995/96, respectively. Sweetpotato MER were also positively correlated with total MER ($r=0.700^{**}$, $n=72$, $r=0.643$, $n=48$) in 1994/95 and 1995/96 cropping seasons, respectively.

Table 65: Area Time Equivalent Ratio (ATER) and Aggressivity coefficient (AC) in Sweetpotato/bean association

Cropping Systems	1994/95		1995/96	
	With single row of sweetpotato	With double rows of sweetpotato	With single row of Sweetpotato	With double rows of sweetpotato
Bean + Sweetpotato (16,666) plants/ha	0.72	0.67	0.61	0.55
Bean + sweetpotato (22,222, plants/ha)	0.70	0.70	0.64	0.69
Bean + sweetpotato (33,333 plants/ha)	0.70	0.70	0.57	0.65
Bean + Sweetpotato (16,666 plants/ha)	0.67	0.65	0.62	0.52
Mean	0.70	0.68	0.61	0.60
C.V.		12.96%		22.15%
SE		0.04	0.07	
(Pattern)				
(Population density)		0.02		0.04
LSD. (0.05) (Population density)		NS		NS

Table 66. Effects of sweetpotato spatial arrangement and population density on relative monetary equivalent ratio (MER) in sweetpotato/bean association, (1994/95)

Cropping system	Monetary equivalent ratio			
	Sweetpotato		Bean	
	single row	double rows	single row	double rows
Bean + sweetpotato (16,666 plt/ha)	0.57	0.58	0.56	0.49
Bean + sweetpotato (22,222 plt/ha)	0.60	0.66	0.58	0.51
Bean + sweetpotato (33,333 plt/ha)	0.63	0.73	0.46	0.39
Bean + sweetpotato (66,666 plt/ha)	0.61	0.65	0.37	0.34
Mean	0.60	0.66	0.49	0.43
CV.	22.1%			26.1%
SE.	0.07			0.04
LSD(0.05)	NS			0.08

NS = Not significant.

Table 67. Effects of sweetpotato spatial arrangement and population density on relative monetary equivalent ratio (MER) in sweetpotato/bean association, (1995/96)

Cropping system	Monetary equivalent ratio (MER)				
	Sweetpotato			Bean	
	single row	double row	single row of sweetpotato	double rows of sweetpotato	
Bean + sweetpotato (16,666 plt/ha)	0.66	0.42	0.63	0.66	
Bean + sweetpotato (22,222 plt/ha)	0.72	0.74	0.58	0.65	
Bean + sweetpotato (33,333 plt/ha)	0.75	0.68	0.37	0.64	
Bean + sweetpotato (66,666 plt/ha)	0.63	0.62	0.40	0.42	
Mean	0.69	0.61	0.50	0.60	
CV.	20.26%			30.88%	
SE	0.07			0.06	
LSD (0.05)	NS			0.14	

NS = Not significant

Table 68. Effects of sweetpotato spatial arrangement and population density on monetary equivalent ratio (MER) in sweetpotato/bean association, (1994/95 and 1995/96)

Cropping system	Monetary equivalent ratio (MER) Season			
	1994/95		1995/96	
	single row of sweetpotato	double rows of sweetpotato	single row of sweetpotato	double rows of sweetpotato
Bean + sweetpotato (16,666 plt/ha)	1.14	1.10	1.32	1.08
Bean + sweetpotato (22,222 plt/ha)	1.10	1.20	1.30	1.39
Bean + sweetpotato (33,333 plt/ha)	1.10	1.12	1.12	1.32
Bean + sweetpotato (66,666 plt/ha)	1.00	1.00	1.05	1.04
Mean	1.10	1.10	1.20	1.21
CV.		17.4%		18.7%
SE.		0.08		0.14
LSD(0.05)		NS		NS

NS = Not significant

The correlation coefficients appear to indicate that bean crop contributed more than sweetpotato in terms of cash income. This may be true because the cost of one kilogram of bean is about 72.5% higher than the cost of one kilogram of fresh sweetpotato storage root. Monetary equivalent ratio is the conversion of land equivalent ratio into economic terms and are strongly associated ($r=0.954^{**}$, $n=72$ and $r=0.973^{**}$, $n=48$).

Results of this study show that intercropping of sweetpotato with bean is both biologically and economically advantageous (Table 69). LER, average LER + ATER and MER were 1.37, 1.36 and 1.35, respectively. These values are very close to each other although they were derived from different mathematical procedures.

4.8.0 Foliar nutrient levels in sweetpotato and bean at 45 DAP.

Foliar nutrient concentrations varied between bean and sweetpotato for N, P, K and Ca (Table 70). Foliar concentrations of N, P and K were higher by 10.0%, 28.5% and 56.7%, respectively in sweetpotato than in bean. However, foliar Ca concentration was 48.1% higher in bean than sweetpotato.

Table 69: Competition ratios, relative yields, and land use efficiency in sweetpotato/bean cropping systems under Namulonge conditions during four cropping seasons..

Attributes	Cropping season				
	Experiment 1		Experiment 2		
	1993/94	1994/95	1994/95	1995/96	Mean
Competition Ratio (CR)					
- Sweetpotato	2.69	4.8	4.4	5.0	4.2
- Bean	0.67	0.3	0.32	0.28	0.39
Relative Yields (RY)					
-Sweetpotato	0.83	1.0	0.73	0.68	0.81
-Bean	0.57	0.53	0.64	0.54	0.57
Land Equivalent Ratio (LER)	1.32	1.55	1.38	1.22	1.37
Area Time Equivalent Ratio (ATER)	0.67	0.76	0.69	0.60	0.70
1/2 LER + ATER	1.33	1.53	1.38	1.21	1.36
Monetary Equivalent Ratio (MER)	1.51	1.58	1.10	1.20	1.35

The differences in concentration show that plants differ in their requirements for nutrients and uptake may depend on the amount of nutrient available in the soil. Foliar P, K and Na concentrations increased with increase in sweetpotato population density. The nutrient levels were positively correlated among themselves except N which decreased with increase in Na concentration, an indication that the uptake of one nutrient may influence the uptake of the others. The concentration of Na also varied significantly with Ca concentration, but insignificantly with Mg. In sweetpotato Ca concentration was positively correlated with K concentration ($r=0.390^*$, $n=24$), while in bean foliar N, K and Ca concentrations were positively correlated with soil P ($r=0.463^*$, $r=0.411^*$, $r=0.441^*$, $n=24$) (Appendices 16 and 17).

In bean foliar N, P and K concentrations were also positively correlated with soil K concentration ($r=0.641^{**}$, $r=0.526^{**}$ and $r=0.519^{**}$) respectively, suggesting that P and K are interdependent and both may have influence on N but only P has significant influence on Ca which was highly correlated with soil Ca ($r=0.568^{**}$). Foliar K and Ca concentrations positively correlated with soil K and Ca ($r=0.519^{**}$, $r=0.568^{**}$), respectively.

Table 70. Effects of intercropping sweetpotato with beans on foliar nutrient concentration in sweetpotato and bean crops at 45 DAP (1995/96)

Cropping system	P (ppm)	N %	Nutrient concentration			
			K	Na	Ca me/100 g	Mg
Intercropped bean	0.40	3.86	1.67	0.002	1.29**	0.31
Sole-cropped	0.41	3.91	1.75	0.003	1.33	0.31
Intercropped sweetpotato	0.56**	4.29*	3.86**	0.002	0.67	0.29
Sole-cropped sweetpotato	0.58	4.31	3.89	0.003	0.72	0.32
Intercropped mean	0.49	4.07	2.77	0.002	0.98	0.30
Sole-cropped mean	0.50	4.10	2.82	0.003	1.02	0.32
SD of the difference between the means of intercropped s/potato and bean nutrient levels	0.02	0.18	0.20	NS	0.07	NS

ns, *, ** = Not significant or significant at 5% and 1% probability level, respectively.

4.8.1 Soil nutrient uptake under sweetpotato/bean association

Soil P and Ca concentrations were much lower before cropping than during crop growth (Table 71). At 45 days of crop establishment, soil OM, K, Na, Ca and Mg levels were higher while N and P levels were lower in intercropped than sole-cropped soil at 45 days of crop establishment. At bean harvest, OM, N, P, K, Ca and Mg levels were higher in sole-cropped than in intercropped soil.

At sweetpotato harvest, OM, P, K, Na, Ca and Mg levels were lower in intercropped than sole-cropped soil except N. Confidence limits at LSD (0.05) indicated that there were significant differences in the means at different sampling stages.

At 45 day of crop establishment, sweetpotato population density significantly influenced uptake of K which was reduced by 12.2% of the sole crop soil K level. This seemed to indicate that K requirement by crop mixtures was higher than the requirement by sole crop, and that the demand for K was higher than for other soil nutrients. Soil Mg was positively correlated with bean yield ($r=0.331^*$, $n=72$).

Table 71. Effects of intercropping sweetpotato with bean on soil nutrient levels prior to planting, during growth and at bean and sweetpotato harvest (1995/96)

Sampling period	Cropping system	pH	Soil nutrient levels					
			OM %	N %	P (ppm)	K	Na	Ca me/100 g
Before ploughing	Fallow	6.2	4.43	0.30	7.20	0.60	0.25	6.0
During growth (45 DAP)	inter.	5.8	3.27	0.19	11.18	0.69	0.27	12.0
	Sole.	5.8	3.23	0.21	13.24	0.65	0.23	12.0
At bean harvest	intercropped	5.9	3.90*	0.20*	14.81*	0.68	0.25	10.8
	sole s/potato	5.8	5.27	0.25	17.05	0.78	0.23	11.6
	sole bean	5.5	4.79	0.20	13.22	0.66	0.35	9.8
At sweetpotato harvest	intercropped	5.74	3.27	0.19	11.10	0.58	0.25	10.31
	sole s/potato	6.0	3.69	0.02	13.53	0.65	0.27	12.37

* = Significant at 5% probability level.

However, Mg was negatively correlated with sweetpotato yield ($r=0.280^*$, $n=72$). Soil pH, OM, P, N, K, and Ca were negatively correlated with clay ($r=-0.544^{**}$, $r=-0.366$, $r=-0.676^{**}$, $r=-0.122$, $r=-0.403$, $r=-0.740^{**}$), respectively. Namulonge soil is predominantly sandy clay loam dominated by 1:1 clays (Kaolinitic) which are known to retain P to greater extent and control K fixation in both quantity and nature (David and Eswaran, 1990; Tisdale *et al.*, 1985). The activities of the clay soils may be responsible for the negative correlation of soil nutrients with bean yield because they were available in un available form.

Silt has insignificant influence in the uptake of soil nutrients by crops.

At bean harvest, soil OM, N and P levels were 25.9%, 18.8% and 13.1% lower than the levels under sweetpotato sole crop, respectively. There was a decrease in the level of each nutrient. At sweetpotato harvest, P level in intercropped soil was significantly reduced by 9.9% of the sole-cropped P level. Soil Mg was positively correlated with population density ($r=0.336^*$, $n=48$). Sweetpotato yield was positively correlated with soil OM, K, Ca and Mg ($r=0.470^{**}$, $r=0.310^*$, $r=0.556^{**}$ and $r=0.480$), respectively at sweetpotato harvest (Appendices 18 & 19).

CHAPTER FIVE

DISCUSSION

Soil physical and chemical characteristics at the experimental sites

The variations in soil nutrient levels across experimental sites may be attributed to the different cropping patterns. In 1993/94 season sweetpotato/bean association was planted in a field which had been under pasture for three years. In 1994/95 and 1995/96 seasons the sweetpotato/bean association followed groundnuts.

Effects of intercropping on growth and yields of sweetpotato and bean

No significant differences in the interception of photosynthetic active radiation were observed among mixtures. This agrees with a report by Cock (1983) that optimum light interception in mixtures is dependent on morphology, relative growth duration, plant pattern and density. Intercropping increased photosynthetically active radiation intercepted, confirming reports by Crookston and Kent (1976); Stern and Donald (1962); Pendleton and Seif (1962); Harris (1990); Willey and Osiru (1972) that light resource is better utilized in mixtures than in the sole crop situation. The deviation from the mean decreased with time, indicating that at early growth stages canopy density varied among intercrop combinations.

Sweetpotato vine length and vine growth rate were either reduced or increased but not significantly by intercropping. The 4.6% increase in growth rate in spreading genotypes might have been due to the growth habit, trailing below bean to reach source of light. Also roots formed at the various nodes grow into the soil and greatly increase the effective feeding area, hence growth of the crop (Onwueme, 1978). Competition for light between the erect and the semi-compact genotypes with bean was critical because of their similar growth habits with bean.

Higher growth rate than in sole-cropped situation was expected especially among the erect genotypes but a reduction in both vine length and vine growth rate occurred. The semi-compact genotypes were genetically limited and could not therefore grow beyond their optimum. Further more bean crop suppressed growth in them through stiff competition for both light and nutrients. The erect genotypes could probably have grown much taller but it appears that competition for light and other growth resources was simultaneous. The high vine growth rate in double rows of sweetpotato may be attributed to low shade effect of bean crop, compared to high shade effect in the single row of sweetpotato.

It appears that in the single row arrangement both intra/inter-specific competitions were higher than in double rows of sweetpotato as evident by the lower vine growth in the single row than in the double rows. Vine growth rate was reduced in erect genotypes by bean as they possess similar growth characteristics. The significant sweetpotato genotype x spatial arrangement interaction at 8 and 10 WAP and sweetpotato genotype x population density interaction effects indicate that the effects of spatial arrangement and population density were

dependent and or influenced by the different sweetpotato genotypes. Both indeterminate and determinate bean genotypes attained highest heights under the erect sweetpotato genotypes. Bean grown with semi-compact sweetpotato had no significant difference in height as both crops have bushy growth habit. Bean grown with the spreading sweetpotato genotypes probably had minimum competition for light because the bean canopy was above that of sweetpotato. Plant height at first branching was higher in determinate than in indeterminate bean. This may be attributed to differences in genetic variability in maturity periods. Graham (1981) observed that the determinate beans generally mature earlier than indeterminate type.

This suggests that growth should be fast enough to attain a suitable height before branching. Bean plant height was higher in the single row than double rows of sweetpotato and it decreased with increase in sweetpotato population density. Under high sweetpotato population competition for both light and nutrients was critical. High sweetpotato population also shaded bean crop. The differences in the degree of competitive abilities and aggressivity coefficient of the various sweetpotato and bean genotypes in association might help to explain the differences in plant height. Bean genotypes with high competitive abilities and are aggressive competed favourably with sweetpotato.

Dry matter accumulation (top biomass) in sweetpotato varied among genotypes due to genetic variability among the genotypes.

The significant sweetpotato genotype x bean genotype interaction effects on DMA indicates that intercropping effects differed with bean genotypes. Bean crop reduced sweetpotato growth significantly during phase one of sweetpotato growth.

Phase one is characterized by slow growth of the vines with poor canopy coverage (Woolfe, 1992) and since bean crop grew faster, by 4 WAP it would have attained a good canopy which shaded sweetpotato crop. At 10 WAP, DMA decreased due to rapid growth of vines, increased leaf area, and root initiation and development taking place in phase two, with assimilates being partitioned to various parts of the plant. Generally, however, intercropping significantly reduced dry matter accumulation in sweetpotato due to competition for growth resources. DMA was lower at low population density (16,666 plants/ha) in double rows arrangement probably due to the low number of plants sampled/unit area.

Crop growth rate (CGR) in sweetpotato were generally smaller at first, increased to a maximum and then declined towards maturity. Early in the season CGR rate was lower because the crops have low photosynthetic capacity which increases until maximum and declines later in the season due to few actively photosynthetic leaves (Hahn and Hozzo, 1984).

In sweetpotato CGR negatively and significantly correlated with sweetpotato population density, suggesting that more dry matter was accumulated under low competition for growth resources. In bean CGR was higher in determinate (large-seeded) than in the indeterminate (small-seeded) genotypes under mixed crop situation. This is contrary to a report by CIAT (1980 b) that CGR decreased as seed size increased. Probably CIAT results were obtained from sole-cropped situation where only intra-specific competition for growth resources occurred. Intercropping affected the vegetative growth of both component crops in all mixtures although at different magnitudes.

This was reflected in the leaf area indices (LAI) of the component crops. LAI of sweetpotato and bean varied significantly among genotypes partly because of the variations in leaf number, leaf size, length, shape, branching abilities, degree of mutual shading, number of growing points, leaf longevity, nutrient uptake, water requirement and to some extent the growth habits of the component crops (Hahn and Hozyo, 1984). LAI were lower in genotypes with spreading and erect growth habit than the semi-compact types mainly due to morphological differences.

A Russian worker, Nichiporovic suggested that every crop has an optimum LAI which ranged between 2.5 and 5.0 (Black and Watson, 1960). Although Black and Watson's report may hold true for crops grown in pure stands, it may not be so for crops grown in mixtures. Further variations in LAI are expected in different crop genotypes with varied morphological characteristics. For example rate of leaf production and leaf longevity vary among genotypes hence optimum LAI. In this study LAI was reduced by intercropping due to competition.

The optimum LAI for sweetpotato and bean in mixtures obtained from this study range from 3.6 to 4.6 and 2.48 to 2.50, respectively, and that for sole sweetpotato and bean 4.6 to 5.3 and 2.4 to 2.6, respectively.

LAI increased with time until optimum and declined thereafter as expected. This occurred because leaf expansion takes place in the early phase of growth, and at maximum canopy LAI is fairly static and expansion of new leaves approximately balanced by senescence of old leaves in succession from the base of the stem upwards. At leaf senescence stage LAI falls off.

The variation in LAI with time is therefore ascribable to changes in leaf area per plant. High population density increased LAI in the early growth stages and usually has some influence on peak LAI. Formation of primary branches may not have significant effect on LAI since branching and therefore leaf production per plant are normally reduced at high population density.

The positive and significant correlation between sweetpotato LAI and population density suggests that the greater the number of plants per unit area the higher the LAI for sweetpotato. The significant sweetpotato genotype x population density interaction at 10 WAP; and spatial arrangement x population density interaction effects indicate that the effects of population density was dependent on the different sweetpotato genotypes and spatial arrangements. In bean, LAI increased with increase in number of primary branches which increased the number of leaves per plant that enhanced interception of PAR.

The relationships between vine yield and other yield components are clear evidence that each component was dependent on one another.

For example, the negative correlation between vine yield and harvest index (HI) suggests that a genotype with high vine yield is likely to have low HI and vice versa. Low HI may result because growth resources have been diverted to vegetative growth at the expense of storage root development and enlargement (Onwueme, 1978). The negative correlation between vine yield with numbers of marketable and unmarketable storage roots might help to confirm the diversion of growth resources to vegetative parts.

As shoot: root ratio increased with increase in vine yield, storage root yield decreased because the activities leading to storage root yield are impaired as more

growth resources are mobilized to vegetative growth. Thus storage root yield is inversely related to vine yield and shoot:root ratio. However, not all genotypes with high vine yields produce low storage root yields. Results showed that some of the genotypes do not have both potentials as reflected in their harvest indices. Vine yield was negatively correlated with sweetpotato population density suggesting that an optimum population density for optimum vine yield in sweetpotato/bean mixtures could be determined. The decrease in vine yield with increase in population density may be attributed mainly to intra-specific competition for growth resources. This could be useful in the production of vines as livestock feeds.

Vine yield per plant was higher in double rows than single row due to high competitive ability of bean which was 61.7% higher in single row than double rows. This has been shown by the significant interaction between spatial arrangement and population density. Vine yield was lower in 1993/94 season than 1994/95 season, suggesting that sweetpotato did not completely dominate over bean. In 1994/95 season, sweetpotato dominated over bean hence higher vine yield. Therefore, in the selection of suitable genotypes for sweetpotato/bean association vine yield and HI could be used as indicators of compatibility of sweetpotato with bean.

Storage root size distribution varied among genotypes, spatial arrangement, population density and season. The significant genotype x population density and season x population density interaction effects on the number of marketable roots; season x spatial arrangement x population density, genotype x spatial arrangement x population density and genotype x spatial

arrangement x population density interaction effects on the number of unmarketable roots indicate that the performance of genotypes were dependent on population density. The effect of population density on number of marketable roots were influenced by season and the performance of genotypes were dependent on season. The combined effects of spatial arrangements and population densities were dependent on both genotypes and season. Genotypes have varied genetic potentials, for example Tanzania produced the highest numbers of both marketable and unmarketable roots/plot, suggesting that Tanzania has the potential of apportioning growth resources between storage root development and enlargement so that both occur concurrently.

The positive and significant correlation between numbers of marketable and unmarketable roots confirms Tanzania's potential. It also suggests that rate of root development was possibly equal to rate of root enlargement. However, this situation may be reversed when growth resources become limiting. This also suggests that selection of genotypes for association could consider storage root size distribution as a criterion. Bean genotypes had significant influence on storage root size and the indeterminate bean was more compatible with the spreading sweetpotato genotype, while the determinate bean was more compatible with the erect sweetpotato genotypes.

This agrees with the report that legume genotypes had significant effects on sweetpotato yield (AVRDC, 1989). This compatibility may be associated with growth habits, competitive abilities and aggressivity of the crop species in mixtures.

The spatial arrangement of the mixtures was intended to enhance complementarity and reduce competition between the mixtures so that the physiological advantage from combining the two components is maximized (Willey, 1979a). There were variations in the performance of mixtures over seasons. For example in one season the storage root quality was 5.1% higher in the double rows than in the single row of sweetpotato and during the other season root quality was 10.3% higher in single row than double rows of sweetpotato. However, this variation may partly be attributed to variability in moisture distribution during root development and enlargement in the two seasons, and partly to availability of growth resources in the soil.

The number of marketable and unmarketable roots increased with increase in sweetpotato population density. This may be attributed to number of plants/unit area. This could also be due to higher moisture retention under high population density. Nevertheless, this was not expected since it is assumed that growth resources might become limiting under high population density.

Intercropping improved root size by increasing the weights of storage roots. Genotypes, New Kawogo and Wagabolige produced the highest individual root weights both for marketable and unmarketable sizes. These are the best yielder of all genotypes tested.

However, root size distribution varied with bean, sweetpotato genotypes and season. These factors had interaction effects on root size distribution. The positive correlation between weights of individual marketable root with vine yield may be explained in terms of source-sink relationship in sweetpotato crop. Kato and Hozyo (1974, 1978) have concluded that it is primarily the characteristics of

the sink (storage roots) and not those of the source (leaves) that determine the rate of photosynthesis and the total yield. Cultivars with inherently large sink capacity will respond to differences in source more than those with poor sink capacity. Hahn (1977 b) reported that sink characteristics more than source characteristics affect photosynthesis and translocation and that the sink thereby regulates dry matter production and yield.

There is an inverse relationship between the growth of leaf and storage roots because there was a significant negative correlation between vine yield and harvest index. As storage roots increase in size, branch and leaf production gradually ceases and the existing leaves senescence and the total leaf area declines.

This results in a decrease in the rate of photosynthesis and storage root growth. As this process continues, root growth eventually ceases. Some reinvestment in new leaf growth serves to prolong the duration of growth of the crop and contributes to increased yield.

However, too large an investment in new shoot growth is inefficient and can lead to poor yields (Tsuno and Fujise, 1963).

The variation in storage root size distribution between spatial arrangement was not significant but root size varied with population density and across seasons. It negatively correlated with sweetpotato population density. Selection for big storage roots should therefore be done at a lower population density. The effects of population were mainly due to intra-specific competition for both nutrients and space in the soil among storage roots because the number of marketable roots decreased while number of un marketable roots increased with

increase in sweetpotato population density. The variations over season may be explained in terms of moisture distribution during growth.

Yield per plant was positively correlated with average weight of individual marketable and total root yield, suggesting that selection for high total yield in sweetpotato/bean association could also be based on yield/plant. The negative and significant correlation between S/R and yield/plant further indicates that the higher the vegetative yield the lower the storage root yield. Total storage root yields were significantly influenced by bean crop. In some mixtures, bean out competed sweetpotato crop, reducing total yield significantly. Entries 20 and 21 were out-competed by bean and the competition ratios for bean were highest for all bean genotypes except genotype A 197.

Differences in storage root yield was significant in experiment I but not in experiment II. The observed increases may be explained in terms of complementarity that occurred resulting from better temporal use of resources, (Trenbath, 1976; Willey, 1979 a). The increase in storage root yields in 1994/95 season may be attributed to variations in moisture distribution during crop growth period. Phase I of sweetpotato growth and development is dominated by rapid growth of adventitious roots and phase II is dominated by rapid growth of the vines and hence large increase in leaf area accompanied by initiation of storage root development (Onuweme, 1978 and Woolfe, 1992). During these phases moisture requirement is critical. In 1994/95 season, there was a relatively low moisture during phase II of sweetpotato growth compared to 1993/94 season. Therefore the growth conditions during the moisture stress could have been worse in mixtures as both nutrient and moisture uptake by crops in

mixtures have been reported to be higher and competitive (Dalal, 1974; Kassam and Stockinger, 1975 and Hall, 1974 a, b).

Intercropping increased yield of sweetpotato probably due to additional nutrients released from the decomposing bean crop residues which was readily available to sweetpotato crop. In 1993/94 season, bean was harvested at the time when there was sufficient moisture in the soil which probably accelerated the decomposition of bean crop residues to release nutrients which were subsequently utilized by sweetpotato during the three extra months it remained in the field. In 1994/95 season, bean crop was harvested during a relatively dry spell and it is likely that the decomposition of the crop residues by micro-organisms was not as quick as in 1993/94 season to benefit sweetpotato. Bean's harvest could have increased the rate of moisture loss from the soil surface due to evaporation. At sweetpotato harvest, N level was higher in intercropped than sole-cropped soil, indicating N release from the decomposed bean crop residues to benefit sweetpotato. This agrees with report by Willey (1979 a) that nutrients released from one crop as a result of senescence of plant parts are made available to the subsequent crop.

Yield differences over seasons may also be explained by the growth conditions during the final phase of sweetpotato growth when further vine growth ceases and a rapid bulking of storage roots takes place (Woolfe, 1992). In 1994/95 season, there was so much moisture (monthly mean of 100 mm of rainfall) during the final phase. Vegetative growth thus continued at the expense of root enlargement.

Total root yield was positively and significantly correlated with weight of individual marketable root, suggesting that selection of genotypes for high yield in sweetpotato/bean association could be based on the weight of individual marketable roots obtained.

Sole-cropped and intercropped root yields were positively related, suggesting that sweetpotato genotypes that performed better in sole stands performed equally well in mixtures. Similar results were reported by Osiru *et al.* (1992) for cassava/groundnut and cassava/maize systems. Root yield increased with increase in sweetpotato population density.

The significant genotype x population density interaction effects on root yield over seasons indicate that different genotypes had different growth requirements and the effects of population density was influenced by genotype and season. Total storage root yields were positively correlated with HI, and genotypes with high HI have correspondingly low vine yield hence S/R ratios. Negative correlation of HI with vine yield suggests that assimilates were being directed more for vegetative growth at the expense of storage root development and enlargement. In experiment II, HI for various cropping systems varied and were higher than in experiment I because of varied sweetpotato spatial arrangements and population densities. Yield per plant, hence total yield are significant components of HI. According to Bradbury and Holloway (1988) the average dry matter is about 30% but varied widely depending on such factors as cultivars, location, climate, season, soil type, incidence of pests and diseases and cultivation practices.

In this study dry matter content ranged between 31% to 34.1% in experiment I and 30.4% to 34.3% in experiment II. The significant spatial arrangement x genotype and genotype x population density interaction effects indicate that DMA in roots was influenced by spatial arrangement and the influence of population density was dependent on the genotypes. DMA was negatively and insignificantly correlated with sweetpotato population density. Shar Fuddin and Voican (1984) reported a small increase in starch brought about by decreasing population density which they presumed provided the space required for better growth and increased efficiency in photosynthesis. The report agrees with the results of this study. The positive relationship between dry matter accumulation and yield per plant suggests that yield per plant could be used as dry matter yield indicator in genotype selection.

Bean yield and yield components varied significantly among genotypes and intercropping reduced bean yield significantly. This may be attributed to inter-specific competition between the component crops. Number of pods varied among genotypes. The significant spatial arrangement x population density interaction effects indicate that the effects of population density on pod production was dependent on sweetpotato spatial arrangement.

The significant relationship between number of pod per plant, number of seed per pod, seed per plant, yield per plant and total yield suggest that these variables could be used as yield indicators in selecting bean genotypes for high yielding abilities in mixtures with sweetpotato.

Sweetpotato population density significantly affected pod production. This agrees with the observation that number of pod per plant in leguminous crops is usually

the component most readily affected by competition (Willey and Osiru, 1974). More pods, seed and yield per plant and highest total yield were produced in single row than double rows of sweetpotato because the competition ratios for bean were higher in single row than in double rows, indicating that bean out-competed sweetpotato.

Number of seed/pod varied significantly among genotypes because of great variability in seed size. Genotypes with large seeds such as A 197 form fewer seeds/pod, while small seeded genotypes such as White Haricot form more seeds/pod. Seed formation stage is very sensitive to competition as reflected by the negative correlation with population density. Seed formation therefore does not tolerate competition in mixtures.

The 100 DSW varied significantly among bean and sweetpotato genotypes and season due to differences in seed size among genotypes. The significant sweetpotato genotype x spatial arrangement and season x sweetpotato genotype x spatial arrangement interaction effects on 100 DSW indicate that the effects of spatial arrangement were dependent on sweetpotato genotypes. Similarly, the combined effects of sweetpotato genotypes were dependent on season. The bean genotypes have different seed colour, size and shape, with seed size being the most important component in determining the seed weight. White Haricot and MMS 224 are small seeded with weights ranging from <25 g/100 seeds. GLP 585 has medium sized seed with weights within the range of >25 <35 g/100 seeds, while A 197 has large seed with weights within the range of >35 g/100 seeds, Laing *et al* (1984). Stocker (1974) points out that the major components of yield that are affected by drought are the number of pods/plant and to a lesser

extent the number of seeds/pod. Seed size is little changed. The significant effects of season on 100 DSW may be attributed to the effects of moisture stress at seed filling stage and harvest. The mean 100 DSW was 28.5 g in 1993/94, compared to 25.5 g in 1994/95 season. This is because in 1994/95 season, there was a dry spell that coincided with podding and seed filling stages. Similar seasonal effects on 100 DSW occurred in the second experiment in 1994/95 season. At harvest, bean seeds are physiologically matured and if they imbibe moisture, the process of germination begins and stored food is broken down into sugars and energy is released. The germination process probably reduced weight, hence the dry seed yield. In 1995/96 season, there was so much moisture at harvest that 100 DSW seed weight was reduced.

Laing *et al.* (1984) observed that probably the most important factor in determining cultivars' response to intercropping is competitive ability, which in simple terms defined as the effects of a variety on the yield of the associated crop. Competitive abilities of sweetpotato and bean varied significantly among the genotypes of each crop species in the mixtures. Sweetpotato genotype, Tororo 3 was the most competitive among all the genotypes in mixtures with bean. Entries 20 and 21 were the least competitive in mixtures probably because they are genetically poor competitors under the experimental conditions.

Competition between crop species in mixtures varies depending on the cropping systems and plant types employed. CIAT (1978) reported that **Type 1** materials were the least competitive and gave poor yields when intercropped with maize. In this study bean genotype GLP 585 (**Type I**) produced the highest seed yield compared to White Haricot and MMS 224 (**Type II**) materials when

intercropped with sweetpotato. The better performance of **Type I** with sweetpotato seems to indicate that it is more compatible with sweetpotato than **Type II**. Compared to maize, sweetpotato growth habits do not cause serious competition for light as maize does in maize/bean mixtures. In experiment II, White Haricot (**Type II**) produced the lowest seed yield under high sweetpotato population density. This indicates that **Type II** bean have low competitive ability and may perform well only in situation of low competition.

The negative and significant correlation between bean seed yield and sweetpotato population suggests that the overall performance of bean in mixtures was greatly influenced by sweetpotato plant density. This also suggests that selection of bean morphotypes for high yield in sweetpotato/bean association can be done at high sweetpotato plant density.

In the second experiment bean was more competitive in the single row than double rows of sweetpotato. Single row arrangement permits bean crop to cover sweetpotato more than in the double rows arrangement. Under this growth situation sweetpotato crop received minimum PAR. However, the competitive ability of bean decreased with increase in sweetpotato population density, suggesting that bean crop does not tolerate high competition in mixtures. Bean would therefore prefer a mixture with appropriate sweetpotato population in order to compete favourably. The dominance of sweetpotato over beans is reflected in the negatively and significant correlation between the competition ratio of bean with that of sweetpotato.

The competitive abilities of the various intercrop combinations were reflected in their relative yields (RY), which, if greater than unity, suggests that

intercropping increased yields of the component crops to a level greater than the sole crop yield of each component crop. Relative yield of sweetpotato increased with increase in population density. However, this increase was not statistically significant.

On the other hand, the RY of bean was negatively and significantly correlated with sweetpotato population density, suggesting that bean crop yield was reduced relative to bean yield in sole-cropped situation. However, the RY of bean was higher in single row than double rows of sweetpotato, indicating that bean yield in single row arrangement was higher than in the double rows arrangement. The intercrop combinations that gave higher values of RY of both sweetpotato and bean show compatibility of sweetpotato and bean in mixtures, while that which gave lower RY values show incompatibility, producing much lower yields than their sole crop yields. In a combination where values of RY were not significantly different, suggests equal effects of intercropping.

The aggressivity coefficient (AC) was negatively and significantly correlated with CR and RY for bean in experiment I. This relationship suggests that in the selection of suitable bean genotypes for intercropping with sweetpotato the RY and CR could be included as components of the selection criteria. On the other hand, AC was significantly and positively correlated with sweetpotato CR. This relationship suggests that sweetpotato crop generally dominated over bean in mixtures.

The competitive ability of sweetpotato increased with population density, but decreased as competitive ability of bean increased. Aggressivity coefficient was higher in single row than double rows arrangement. In single row

arrangement, the crop components were very close hence intensive inter-specific competition for growth resources.

Land use efficiency in sweetpotato/bean cropping systems

Willey and Osiru (1972) observed that advantages that may accrue from mixing two species must be partly dependent on the requirements of the farmer. If the farmer's requirements are simply for maximum yield, irrespective of how much comes from either species, then for a mixture to give a yield advantage it must exceed the maximum yield of the higher yielding species. If it does not do this, it would be more advantageous to grow only the higher yielding species. This argument could apply in a situation where two cereals are being grown and they are equally important. However, when two species such as sweetpotato and bean are being grown the situation is different since these two species produce very different types of yields.

In this situation, therefore, an advantage occurs if mixtures produce more yield from a given area of land than can be obtained by dividing that area of land into pure stand of the two species. On this basis, a yield advantage can occur without mixtures exceeding the yield of the higher yielding species. The results of the experiments reported here represent the situation where some yield was required from each crop species. Sweetpotato/bean mixture yield under the traditional system is 14.1 t/ha. (Ocitti p'Obwoya and Smit, 1995) which was 32.3% less than the yield obtained in this study in 1993/94 season.

In 1994/95 season, productivity per hectare was 17.7% higher than that of the sole crop. In the second experiment, productivity varied with sweetpotato spatial arrangement and population density. It increased with increase in sweetpotato population because sweetpotato yield increased with increase in population density, but bean yield decreased with increase in sweetpotato population density, suggesting that the productivity of the system was more dependent on sweetpotato yield level. Under this cropping system the productivity was 17.9% higher than that obtained in the traditional intercropping system. The low productivity under the traditional intercropping system indicates that land use efficiency was sub-optimal probably due to inappropriate planting patterns, plant population density and use of incompatible crop species. Results have shown that intercropping sweetpotato with bean is advantageous because LER values were greater than unity. Mean LER of 1.37 was achieved in four cropping seasons. LUE estimated by adding average of LER to ATER showed that intercropping increased productivity. The LUE obtained was 1.36. The LER positively correlated with CR for sweetpotato but negatively with CR for bean, indicating that sweetpotato dominated over bean and contributed more to LUE than bean. In monetary terms intercropping sweetpotato with bean was economically beneficial because the MER values were greater than unity. This agrees with Quirol *et al.* (1985) who reported that intercropping sweetpotato with legumes was 3.5 times more profitable than sole cropping. Mean MER was 1.35, indicating that an average of about 35% more land would be needed to plant sole-cropped sweetpotato and bean in order to realize the same yields of sweetpotato and bean to generate the same cash income obtained from mixtures.

This indicates that the components are compatible as intercrops as also reported by Cruz *et al.* (1992) for sweetpotato/potato association.

The positive and significant correlation between bean MER and sweetpotato MER with the total MER suggests that the cash return that would accrue from bean sale was not significantly different from that of sweetpotato despite the significant bean yield reduction by intercropping. This is ascribable to higher cost price of bean seed which was about 73% higher than the cost of fresh sweetpotato storage root at the time of experimentation.

The MER and the LER of this system were highly associated, hence either MER or LER could be used to evaluate the biological and economic advantages of the intercropping system. The average LER, LUE and MER values of 1.37, 1.36 and 1.35, respectively are not significantly different although they were derived from different mathematical procedures. This suggests that in reality sweetpotato/bean association under improved management practices have significant biological and economic advantages over sole cropping of sweetpotato and bean. Overall, intercropping sweetpotato with bean under improved management practices significantly increased productivity.

Effects of intercropping on the incidence of common bean diseases

Intercropping provides better disease control than those of sole cropping and rate of development of disease epidemic is reduced if a crop susceptible to a disease is intercropped with another that is resistant to it (Mukiibi, 1976).

Intercropping sweetpotato with bean, although not statistically significant reduced

the incidence of CBB and ALS by 21.9% and 27.5% of the sole crop situation. The reduction was higher in beans grown with erect sweetpotato probably because the two grew intimately in mixtures and therefore created a micro-climate for the bean component which was not conducive for the development and spread of the diseases. This agrees with the findings of Hasselbach and Ndegwa (1982) that CBB and ALS incidence were lower in beans intercropped with maize than in sole crop. However, Mukiibi (1982) reported no effect on the incidence or severity of ALS in beans in mixtures with groundnut because groundnut had little effect on the micro climate of the bean component in the intercrop. Thus, bean or other crop diseases seem to have certain specific environmental conditions that meet their requirements.

The incidence of CBB was higher in single row than double rows of sweetpotato because in the latter bean crop rows were sandwiching sweetpotato rows while in the former sweetpotato rows were sandwiching bean rows. In the latter situation bean rows neighboured one another, thus giving close contact with each other while in the former situation the bean crops were separated from crops in the neighbouring ridges by sweetpotato crop which probably acted as a barrier to disease spread.

The incidence of CBB at R(8) increased but not significantly with increase in sweetpotato population density. Sweetpotato plant types influenced disease severity but not significantly.

Effects of intercropping on soil nutrient uptake.

After 45 days of crop establishment, foliar nutrient concentrations in sweetpotato and bean were significantly different. Foliar nutrient concentrations were higher in intercropped than sole-cropped sweetpotato and bean. The observation shows that nutrient uptake in mixtures exceeded uptake in sole crops, and that uptake varied among crop species. This is in agreement with reports by Dalal (1979), Kassam and Stockinger (1975) and Hall (1974) of greater nutrient uptake in mixtures than in sole crops. The relatively high concentrations of foliar N, P, K and Ca in sweetpotato can also be explained by the increased demand for nutrients by sweetpotato at various population densities, suggesting that competition was high. Components may differ in the type of nutrients they require and in their ability to extract them from the soil. Demand for nutrients at different growth stages may also differ, Willey (1979 a).

The concentration of foliar K was much higher in sweetpotato than in bean while the concentrations of Ca and Mg in sweetpotato was much lower than in bean. Tisdale *et al.* (1985) observed that Ca and Mg compete with K for entry into plants, thus at low concentration of Ca and Mg, K uptake increases. Foliar concentration of Ca was high in bean probably because of low K concentration. This was also true for Mg, although not significant. Foliar N was significantly lower in beans than in sweetpotato. According to Tisdale *et al.* (1985), the fixation of nitrogen by legume is at maximum only when the levels of soil available nitrogen is at minimum or low. Soil P and Ca concentrations were much lower before cropping than during crop growth.

This agrees with earlier reports that organic P available in soils are lowered due to continuous cultivation. Also workers in Iowa and Japan observed that during cropping mineralization of organic P is accelerated with subsequent release of P for uptake by crops (Tisdale *et al.*, 1985)

However, the soil N level in the experimental field was low. Therefore, N fixation should have been at maximum. This indicates that the low N level in bean was probably due to low competition by bean crop for N. The suggestion agrees with the observation made by Enyi (1973), that leguminous crops will not usually compete with other crop species for nitrogen but will compete for other growth resources. Foliar N concentration in bean decreased with increase in Na concentration which in turn decreased significantly with increase in Ca. In bean, all foliar nutrient concentrations except Mg were negatively correlated to soil available nutrients. In sweetpotato, foliar Mg negatively and significantly correlated with storage root yields, suggesting that either Mg concentration had reached toxic level or there were interactions between Mg and other nutrients that did not favour sweetpotato crop hence yield reduction in sweetpotato.

According to Tisdale *et al.* (1985), Mg deficiencies are not common and can occur only in acid, sandy, highly leached soils with low cation exchange capacities. The Namulonge soils lack these characteristics (David and Eswaran, 1990). Soil pH, OM, P, N, K and Ca were negatively correlated with clay. Foliar Ca was significantly correlated with Ca in the soil. This is because the exchangeable and solution forms of Ca are in dynamic equilibrium, such that Ca removed by plants or leached is replaced from the adsorbed phase, therefore ensures Ca availability to plants (Tisdale *et al.*, 1985).

Levels of OM, K, Na, Ca, and Mg were higher while N and P were lower in intercropped than sole-cropped soil. The observation shows that the demand for N and P by mixtures was higher than the demand for other nutrients. Thus N and P may be exhausted faster in mixtures than in sole-cropped situation. At sweetpotato harvest, levels of all other nutrients except N were low in intercropped than in sole-cropped soil. The observation suggests that N was either replenished from nutrient re-cycling through the activities of the micro-organism on bean crop residues or that rate of N uptake was lowest. This agrees with Agboola and Fayemi (1972) and Misra and Misra (1975) who concluded in a study that legumes do not benefit associated non-legumes over the same period but rather during subsequent plantings. P, K, Ca and Mg levels were lower in intercropped than sole-cropped soil, indicating that sweetpotato/bean mixtures extracted more of the nutrients than sole crops of sweetpotato and bean. This is important because it indicates that intercropping sweetpotato with bean provides an opportunity for maximum utilization of soil nutrients in a given volume of soil. Tisdale *et al.* (1985) reported that higher plant population and closer spacing affects nutrient needs of a plant particularly K. He observed that in intercropping, total yield and removal of K per unit time are increased and this intensifies the demand for soil K, accelerating the rate of K draw down and expanding the amounts of K needed for maintenance program. This might help to explain the significant K uptake in the mixtures in this study, Tisdale *et al.* (1985). Soil OM, K, Ca and Mg significantly correlated with sweetpotato storage root yield. Similar result was reported for K at Kawanda and Rubare by Stephens (1968).

However, this was after the application of N, **P** and K fertilizers. The results of this study suggest that these nutrients were essential for sweetpotato growth and yield, and are yield indicators.

CHAPTER 6

SUMMARY, CONCLUSION AND RECOMMENDATION

Intercropping or mixed cropping of sweetpotato with beans is common in highly populated medium and high altitude areas of Uganda. Lack of information on important aspects such as suitable sweetpotato and bean morphotypes for association, appropriate sweetpotato spatial arrangement and plant population density and other important agronomic parameters in sweetpotato/bean association led to this study.

Two sweetpotato/bean intercropping experiments were conducted in the field at Namulonge Agricultural and Animal production Research Institute (NAARI), Kampala during 1993/94, 1994/95 and 1995/96 cropping seasons. Experiment I (1993/94 cropping season) evaluated eight sweetpotato genotypes (Wagabolige, Entry 20, Entry 21, Bitambi, Tororo 3, New Kawogo, Bwanjule and Tanzania) selected from Sweetpotato Program germplasm bank, and four bean genotypes (White Haricot, MMS 224, A 197 and GLP 585) obtained from CIAT Bean Program based at Kawanda Agricultural Research Institute (KARI) for their compatibility when grown in association. In experiment I (1994/95 cropping season) six sweetpotato and two bean genotypes were used. Experiment II (1994/95 and 1995/96 cropping seasons) investigated the effects of two sweetpotato spatial arrangements (single and double rows), four sweetpotato plant population densities (16,666; 22,222; 33,333 and 66,666 plants/ha) and three sweetpotato genotypes (Wagabolige, Bwanjule and Tororo) on sweetpotato and bean performances.

The results of the studies showed that:-

1. Intercropping improved interception of PAR by 8.1% of the sole crop. This was due to a greater increase in canopy density in mixtures than in sole-cropped situation, suggesting better utilization of light resources in mixtures than in sole crop of either species. Vine growth rate was generally reduced in all the sweetpotato plant types except the spreading type. Bean plant height was also reduced by intercropping.
2. Intercropping reduced leaf area indices of both sweetpotato and bean probably due to competition for growth resources such as light, nutrients and moisture. In sweetpotato LAI increased with increase in sweetpotato population density due to increase in number of plants/unit area. The increase in sweetpotato storage root yield with increase in population density may partially be attributed to increase in assimilation rate. In beans LAI increased with an increase in number of primary branches.
3. Intercropping increased storage root yield in the first experiment by 23.1% of the sole crop, but reduced it by 22% of the sole crop in the second experiment. Bean yield was reduced by about 40.7% of the sole crop yield in experiment one, while in experiment two bean seed yield was reduced by only 1.2% in 1994/95 season, and by 54.8% in 1995/96 season. Yield decreased with an increase in sweetpotato population density.

4. The most compatible sweetpotato and bean morphotypes for intercropping, relative to their respective sole crop yield was the erect (non-creeping) and the determinate (non-climbing/twining) types, respectively. This compatibility may be attributed mainly to the plant morphotypes of the component crops with low level of inter-specific competition. All in all, the most compatible sweetpotato plant morphotype which can be grown in association with any bean plant morphotype is the erect morphotype. Therefore, the intercropping of bean with erect sweetpotato plant morphotype should be encouraged.
5. The spatial arrangement had no significant effect on bean and sweetpotato yields and the three sweetpotato genotypes did not differ significantly in their compatibility with bean. Bean yields were highest under sweetpotato population density of 16,666 and 22,222 plants/ha. Therefore, to optimize bean yield, sweetpotato should be planted either in single or double rows at population density of 16,666 plants/ha or 22,222 plants/ha so that competition for growth resources would be reduced. However, this population may be relatively low for sweetpotato in sweetpotato/bean mixtures. A population density which falls between 22,222 and 33,333 plants/ha would probably give an optimum yields for both bean and sweetpotato grown in association.

6. The competitive abilities of bean crop was high in single row than double rows of sweetpotato but it decreased with an increase in sweetpotato population density. On the other hand, the competitive ability of sweetpotato was lower in single row than in double rows and it increased with an increase in population density. Bean crop therefore competed better with sweetpotato under single than double rows arrangement of sweetpotato. The results seemed to suggest that in sweetpotato/bean mixtures, double rows of bean should be planted with single row of sweetpotato in order to reduce sweetpotato dominance over bean.
7. The relationship between the aggressivity coefficient with competition ratios and relative yields for both sweetpotato and bean show that sweetpotato crop generally dominated over bean crop. The aggressivity coefficient increased with increase in sweetpotato population density and it positively correlated with sweetpotato competition ratio but negatively with that of bean. This seemed to suggest that aggressivity coefficient was more dependent on competitive abilities of sweetpotato and less on competitive ability of bean.
8. Intercropping improved on land productivity by an average of 28.8% more than the productivity from the traditional intercropping system. In 1993/94 and 1994/95 seasons, the highest productivity of 30.1 t/ha and 28.4 t/ha were respectively, produced in sweetpotato/bean mixtures involving sweetpotato genotype Wagabolige.

In some mixtures high productivity was not associated with high LER values because LER depended on the relative yields of the component crops, while productivity depended on the yields of the component crops in the mixtures. In 1995/96 season, productivity increased with an increase in sweetpotato population density. The highest productivity of 15.7 t/ha and 20.1 t/ha were achieved at sweetpotato population density of 66,666 plants/ha in 1994/95 and 1995/96, respectively. However, the bean yields were very low under high sweetpotato population density. Thus, in 1994/95 and 1995/96 season, bean yields were 222.22 kg/ha and 481.15 kg/ha, respectively, accounting for only 2.4% and 1.4% of the productivity, respectively.

9. Intercropping sweetpotato with beans increased the land use efficiency (LUE) by an average of 36%, indicating that mixtures made the best use of the available growth resources and is therefore biologically sound. Mean LER of 1.6 and 1.32 were achieved in 1993/94 and 1994/95 season, respectively. Thus about 60% and 32% more land would be required to plant sole crops of sweetpotato and bean to produce the same yields of sweetpotato and beans that were produced in mixtures, respectively. The average LER + ATER were 1.33 and 1.53 for 1993/94 and 1994/95 seasons, respectively.

In 1994/95 and 1995/96 season, mean LER were 1.38 and 1.22, respectively. The average LER + ATER were 1.38 and 1.21, for 1994/95 and 1995/96, respectively. These values seemed to indicate that

although there were both inter and intra-specific competitions in the crop mixtures, LUE was improved and that the crop mixtures appeared to have made the best use of the available growth resources.

10. In monetary terms, intercropping sweetpotato with bean is economically viable because the MER were greater than unity with an average of 1.35. MER varied with sweetpotato population density and was lowest under the highest (66,666 plants/ha) population density. The low MER under high population density may be ascribable to two factors, the significantly reduced bean yield due to high competition between bean and sweetpotato and the poor storage root size distribution under high population density. This suggests that bean genotypes adapted to high population pressure of sweetpotato crop should be developed so that reasonable bean yield would be achieved which can offset the poor root size distribution and improve on the MER. At high sweetpotato population, more unmarketable and less marketable roots were produced. Since only marketable yields were considered in the calculation of MER, this may explain the differences in MER. Similarly the relatively low MER at low population density (16,666 plant/ha) may be attributed to the low sweetpotato storage root yield.
11. Soil P level increased during crop growth due to accelerated mineralization of organic P with subsequent release for uptake by crop. Foliar NPK concentration was high in sweetpotato than in bean, while Ca concentration was higher in bean than in sweetpotato.

Foliar concentration of P, K and Na increased with increase in sweetpotato population density. Foliar N, K and Ca concentration in bean positively correlated with available soil P concentration. The uptake of K was significantly high in mixtures than in sole crop. Sweetpotato root yield was positively correlated with soil N, P, K, Ca and Na concentration available during crop growth. Soil OM, K, Na and Ca levels were higher, while N and P levels were lower in intercropped than sole-cropped soil. At bean harvest soil OM, N and P levels were lower in intercropped than sole-crop soil. At sweetpotato harvest soil P level was significantly reduced in mixtures than in sole crops and sweetpotato population density had significant influence on P uptake. Also soil N level was higher in intercropped than sole-cropped soil.

From these results it may be concluded that sweetpotato nutrient demands exceeds that of bean crop in mixtures and that mixtures of sweetpotato and bean have higher nutrient demand than when the crops were grown separately in pure stands, indicating that mixtures of sweetpotato with bean fully utilize available soil nutrients in a given volume of soil. Thus, suggesting that soil nutrient reserves will therefore be exhausted faster in sweetpotato/bean association than in pure stands of bean or sweetpotato. However, soil N level was either replenished by intercropping with bean or the rate of uptake was slow. The study also revealed that the critical growth stage at which optimum nutrients are required by either bean or sweetpotato appeared to be different and not known. The studies also showed that all nutrients are essential in sweetpotato/bean mixtures since there was no evidence of symbiotic co-existence during crop growth.

Based on the results of the study, the following areas are therefore recommended for further research:

1. Growth and yield results from sweetpotato/bean association appear to indicate that both intra and inter-specific competitions were higher in single row than in double rows arrangement of sweetpotato. There is no evidence to show which one of the two types of competition is crucial. Therefore, there is need to determine which of the two is a major factor. The results of such a study would help to determine the appropriate spatial arrangement and optimum population density of sweetpotato for optimum bean and sweetpotato yields in sweetpotato/bean association.
2. Generally, sweetpotato dominated over bean although bean crop also dominated over some of the sweetpotato genotypes with low competitive abilities. Bean crop does not appear to tolerate high competition in mixtures. Bean would therefore prefer a mixture with appropriate sweetpotato plant type and population density in order to compete favourably. In order to minimise yield losses of both crop components, sequential cropping system of bean with sweetpotato in relation to appropriate time of incorporating the bean crop residues into the soil before planting sweetpotato should be investigated.
3. The nutrient uptake of sweetpotato/bean mixtures was greater than that in their respective sole cropping, suggesting that soil nutrient reserves will

be depleted faster in intercropping than in sole sweetpotato or bean. A sound fertilization in sweetpotato and bean association should be put in place to ensure soil fertility maintenance under this cropping system for improved and sustainable productivity. Research into the efficient use of organic matter, crop residues, organic manure, crop rotation with leguminous plants which may be more attractive options to small holder farmers should be conducted.

4. Critical growth stages at which optimum nutrients are required by either bean or sweetpotato seem to be different and not known.

Variability in nutrient demand, uptake rate and efficiency seems to be high among sweetpotato genotypes.

Rooting characteristics of some common sweetpotato and bean genotypes in relation to nutrient uptake should be well understood before studies leading to the understanding of nutrient requirements, uptake rate, efficiency and the critical time for nutrient demand by individual component can be conducted.

REFERENCES

- Adetiloye, P.O. 1989. A Review of current competition indices and models for formulating component proportions in intercropping, P.72-90. In: Cassava-based cropping systems research II. Contributions from the second annual meeting of the collaborative group in cassava-based cropping system research. 7-10 November 1988. IITA, Ibadan, Nigeria.
- Agboola, A.A. and Fayemi, A.A. 1972. Fixation and excretion of nitrogen by tropical legumes. *Agronomy Journal* 64, 409-412.
- Allen, D.J. Desert, M. Trutmann, P. and Voss, J. 1989. Common beans in Africa and their constraints. In. H.F. Schwarts and M.A. Pastorcorrales Eds. *Bean Production problems in the Tropics* (second edition) Cali, CIAT, pp 9-32.
- Alyer, A.K.Y.N. 1949. Mixed cropping in India. *Indian Journal of Agricultural Science* 19, 439-543.
- Andrews, D.J. 1972. Intercropping with sorghum in Nigeria. *Experimental Agriculture* 8, 139-150.

Asian Vegetable Research and Development Centre (AVRDC) Annual Report 1989. Intercropping of sweetpotato and legumes. Shanhua (China, Republic of). Asian Vegetable Research and Development Report, 1990. pp. 240-243.

Arnon, I. 1972. Mixed Cropping. In: Intercropping-Its importance and research needs. Part 1. Competition and Yield Advantages. Willey, R.W. Ed. Field Crops Abstract 32: (1) pp. 1-10.

Baker, E.F.I. and Norman, D.W. 1975. Cropping systems in northern Nigeria. In Proceedings of the cropping systems workshop, p. 334-361. Los Banos, IRRI.

Bashaasha B., Mwanga R., Ocitti p'Obwoya C. and Ewell P.T. 1995. Sweetpotato in the Farming and Food Systems of Uganda: A Farm Survey Report, International Potato Centre (CIP), National Agricultural Research Organization (NARO). p 63.

Beets, W.C. 1978. Multiple cropping and tropical farming systems. Gower Great Britain, West view Press. USA, 156 p.

Black, J.N. and Watson, D.J. 1960. Photosynthesis and Theory of obtaining High Crop Yields by A.A Niciporavic: Field Crop Abstract 13 : 169-175.

Bradbury, J.H. and Halloway, W.D. 1988. Chemistry of tropical root crops: significance for nutrition and agriculture in the Pacific ACIAR Monograph Ser. No 6. Canberra.

Breth, S.A. 1978. Transforming maize farming in Zaire. CIMMYT TODA -Y No. 8, pp. 16, **Field Crops Abstract** 32 : 6778.

Carandang, J.A. and Curayag, L.Z. 1989. The influence of legume intercropping on the production of sweetpotato (*Ipomoea batatas* L. Poir). CMU Journal of Science- Central Mindanao University. (Philippines) ISSN 0116-7847, 1989 2 (3) 19-35.

Centro de la Tropical Agriculture (CIAT). 1974. Multiple Cropping. In : CIAT Annual Report for 1974, pp. 147- 149.

1978. Annual Report 1977. Bean Program. PP BI-B85 CIAT, Cali, Colombia. In the Physiology of Tropical Field Crops-eds P.R. Goldworthy and N.M. Fisher 1984. pp. 305-345.

1980 b. Descriptive Catalogue of Bean (*Phaseolus vulgaris* L.) Germplasm. CIAT, Cali, Colombia. In the Physiology of Tropical Field Crops-eds P.R. Goldworthy and N.M. Fisher 1984.

- Cock, J.H. 1983. Cassava. Potential productivity of field crops under different environments, IRRI, Los Banos pp. 341-359.
- Crookston, R.K. and Kent, R. 1976. Intercropping-a new version of an old idea. *Crops and Soils*. 28 (9) 7-9
- Crookston, K.S. and Hill, D.S. 1979. Grain yields and land equivalent ratios from intercropping corn and soybean in Miniesota. *Agronomy Journal*. 71, 41-43.
- Cruz, A.A. De la. Malab, B.S. Manuel, R.T. Sana, E.J.R asco Jr. and Aromin, F.B. 1992. Intercropping potato with sweetpotato. Manila (Philippines) SAPPRAD 1992 VOL 1 pp. 106-127.
- Dai, Q., Qiu, R., Xu, P., Xie, Y., Lin, C. and Zhang, L. 1991. Row ratio and planting density in sweetpotato intercropped with maize. Chujoy, E.(ed) Potato and sweetpotato research in China. Manila (Philippines) CIP; Chinese Academy of Agricultural Science. (AAS). 1991 pp.103-111.
- Dalal, R.C. 1974. Effects of intercropping maize with pigeon peas on grain yield and nutrient uptake. *Experimental Agriculture* 10, 219-224.

Dalrymple, D.G. 1971. Survey of multiple cropping in less developed nations-Foreign Economic Development Service, U.S Department of Agriculture. Cooperating with U.S Agency for International Development. Washington D.C. 20350, 108 p.

David, Y. and Eswaran, H. 1990. Major Land Resource Areas Of Uganda
Report submitted by : Soil Management Support Services, Agency for International Development Washington D.C, USA to USAID/Kampala.
p.217.

Davis, J.H.C., Van Beuningen, L., Ortiz, M.V. and Pino, C. 1984. Effect of growth habit of beans on tolerance to competition from maize when intercropped. **Crop Science 24 : 751-755.**

Desert, K.C. 1987. "Intra-house dynamics and farming systems research".
Paper presented at CIMMYT/ODA Workshop on Farming Systems Research, Lusaka, Zambia.

Donald, C.M. 1963. Competition among crops and pasture plants. **Advances in Agronomy 15. 1-118.**

Drisberg, J.H. 1923. The Lango : a Nilotic Tribe of Uganda. London, Unwin. In : A Subsistence Crop Geography of Uganda, David, N.McMaster. The World Land use Survey. Occasional papers No.5, L.Dudley Stamp, Ed. Geographical Publications Limited, 1962. p 111.

Enyi, B.A.C. 1973. Effects of intercropping maize or sorghum with cowpeas, pigeon peas or beans. **Experimental Agriculture**. 9 : 83-90.

Evans, A.C. 1960. Studies of intercropping 1. Maize or Sorghum with groundnut. **East African Agriculture and Forestry Journal** 26, 1-10.

Ewell, P.T. and Kirkby, R.A. 1990. Roots, Tubers and beans in the Food Systems of Eastern and Southern Africa. Paper presented at the conference on Dialogue and training for promotion of roots, tubers and legumes in Africa, Mombasa, Kenya, November, 26-30, 1990.

Food and Agricultural Organization of the United Nations (FAO). 1991. Review of Literature on Agro- Socio-economic Aspects of mixed cropping in sub-Sahara Africa. RAFR. Technical Series 91/01. pp 49.

_____. 1989. Year Book Production Volume 43.

_____. 1994. Year Book Production Volume 48.

Finlay, R.C. 1975. Intercropping soybean with cereals. Soybean production, protection and utilization. INTSOY Series 6, P.75-85. Univ. of Illinois, Urbana-Champaign.

_____ 1976 c. Selection criteria in intercrop breeding. In Monyo, J.H., Ker, A.D.R. and Cambel, M. Intercropping in semi-arid areas, p 33-36, Ottawa, IDRC.

Fisher, N.M. 1975. Investigation into the competition relations of maize and beans in mixed crops. Technical communication No. 15. Department of Crop Science, University of Nairobi, Kenya.

_____ 1977. Studies in mixed cropping 1. Seasonal differences in relative productivity of crop mixtures and pure stands in Kenya Highlands. **Experimental Agriculture**. 13. 177-184.

Francis, C.A. 1975. Adapting varieties for intercropped systems in the tropics. In : Multiple Cropping Symposium (proceedings). **American Society of Agronomy**. Annual Meeting, Knoxville, Tennessee 24-29th August.

_____ 1986. Distribution and Importance of Multiple Cropping. Multiple Cropping Systems. MacMillan Publication Company. 866 Third Avenue, New York N.Y-10022, pp 1-19.

Freyman, S. and Venkateswarlu, J. 1977. Intercropping on rain-fed red soils of the Deccan Plateau. India. **Canadian Journal of Plant Science**, **57**, 697-705.

Galal, S. Hindi, L. Abdalla, N.M.F. and Metwally, A.A. 1980. Soybean and corn yields under different intercropping patterns. In: World Soybean research Conference 11 : **Field Crops Abstract 34 : 10091 (F.T Corbin, Ed.)**

Graham, P.H. 1981. Some problems of nodulation and symbiotic nitrogen fixation in *phaseolus vulgaris* L., A review, **Field Crops Research**, **4**, 93-112.

Greenway, P.J. 1944. Origins of some East African Food Plants. *East African Agricultural Journal*, Vol. 10. pp. 34-9, 115-19, 117, 180, and vol 11 pp. 56-63.

Grisley, W. and Mwesigwa, R. 1991. A report on the socio-economics of bean Production and Marketing in Uganda : Information for research Planning. In proceedings of a Workshop on National Research Planning For Bean Production in Uganda.

Hahn, S.K. 1977 a. Sweetpotato. In *Ecophysiology of Tropical Crops*. (Eds R.T.Alvim and T.T.Kozlowski) pp. 237-248. Academic Press, New York.

_____ 1977 b. A quantitative approach to source potentials and sink capacities among reciprocal grafts of sweetpotato varieties; **Crop Science**; **17. 559-562.**

_____ and Hozyo, Y. 1984. Sweetpotato. In *Encophysiology of Tropical Crops*. (Eds R.T. Alvin and T.T. Kozlowski) pp. 237-248. Academic Press, New York.

Hall, R.L. 1974 a. Analysis of the nature of interference between plants of different species 1. Concepts and extension of the de Wit's analysis to examine effects. *Australia Journal of Agricultural Research* **25, 739-47.**

- Hall, R.L. 1974 b. Analysis of the nature of interference between plants of different species 11. Nutrient relations in a Nandi setaria and Greenleaf Desmodium association with particular reference to potassium. *Australia Journal of Agricultural Research*, 25, 749-57.
- Harris, P.M. 1990. Potato crop radiation use: A justification for intercropping. *Field Crops Research* 25(1990) 25-39.
- Hasselbach, O.E. and Ndegwa, A.M.H. 1982. Modifying the competitive relationship in maize/bean mixtures in Kenya-Summary. In Keswani, C.R and Ndunguru, B.J.-eds. *Intercropping : proceedings of the second symposium on intercropping in semi-arid areas*, p 68 Ottawa, IDRC.
- Herbert, S.J. Putnam, D.H. Poos-Floyd, M.I.Vargas, A.and Creighton, J.F. 1984. Forage yields of intercropped corn and soybean in various planting patterns. *Agronomy Journal*, 76, 507-510.
- Hiebsch, C.K. and R.F. McCollum. 1978. Area x time equivalent ratio: a method for evaluating the productivity of intercrops. *Agronomy Journal* 79: 15-22.

Hill, W.A. Bacon-Hill, P. Crossman, S.M. and Stephens, C. 1983. Characterization of N_2 -fixating bacteria associated with sweetpotato. In: Sweetpotato: an untapped Food Resources, Woolfe Jennifer, A. 1992. Camb. University Press. p 1-8 .

Hoang, K.Nguyen, T.T. Nguyen, T.B.Zaag, P.Vander. Chujoy, E. (CIP). 1991. Studies on intercropping sweetpotato with maize. CIP. The potato and sweetpotato in southeast Asia and the Pacific region. Manila (Philippines) CIP, SE. Asia and Pacific Regional Office 1991. pp. 154-164.

Holliday, R. 1963. The effect of row width on the yield of cereals. **Field Crops Abstract- 16 . 71-81.**

Horton, D.E. 1988. World patterns and trends in sweetpotato production and use. pp.17-25. In: Exploration, maintenance and utilization of sweetpotato genetic resources. Report of the first sweetpotato planning Conference 1987, CIP, Lima, Peru.

Huaman, Z. 1992. Morphologic Identification of duplicates in Collections of *Ipomoea batatas*. CIP, Research Guide 36. pp. 28.

Hunt, P. 1982. Plant growth curves. Edward Arnold Limited. London. pp 14-41

Huxley, P.A. and Misangu, R. 1978. Use of systematic spacing design as an aid to the study of intercropping. Some general considerations. **Experimental Agriculture** 14, 49-56.

Ingram, W.R. Davis, J.C. and McNutt, D.N. 1970. Agriculture Pest Handbook. Department of Agriculture, Uganda pp. 4-5.

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 1977. Report on the Cropping Systems research carried out during the Kharif (monsoon) and Rabi (post monsoon) season of 1976. Hyderabad. India. 44 pp.

Jameson, J.D. 1970. Agriculture in Uganda. Oxford University Press. Second Edition, 380 pp.

Jones, M.J. 1974. Effects of previous crop on yield and nitrogen response of maize at Samaru, Nigeria. **Experimental Agriculture**, 10, 273-279.

Kassam, A.H. 1972. Effects of plant population and inter-specific competition on yield of sorghum and groundnut under mixed cropping. Inst. of Agric. Research, Reports 1969-72, Samaru, Nigeria.

Kassam, A.H. 1973. In search for greater yields with mixed cropping in Northern Nigeria-a report on agronomic work-Report. Institute for Agricultural Research, Samaru, Nigeria.

Kassam, A.H. and Stockinger, K.R. 1975. Growth and nitrogen uptake of sorghum and millet in mixed cropping. Samaru Agricultural Newsletter, 15; 25-32.

Kato, S., and Hozyo, Y. 1974. Translocation of C14 photo-synthates at several growth stages of the grafts between improved cultivars and wild type plants in Ipomoea; Bull: Nat. Inst. Agric. Sci. Japan. Series D, 25, 31-58.

_____ 1978. The speed and coefficient of C14 photo-synthates translocation in stem of grafts between improved cultivars and wild type plants in Ipomoea, Bull., Nat., Inst., Agric. Sci. Japan Series D, 29, 113-131..

Kirkby, R.A. 1990. Production constraints and their diagnosis. Paper presented at 9th SUA/CRSP-Bean Research Workshop, Morogoro, Tanzania.

Kisakye, J. 1991. Bean Production and Constraints to production in the Highland Areas of Uganda. In : Proceedings of a Workshop on National Research Planning for Bean Production in Uganda. Jan. 28-Feb 1, 1991. CIAT African Workshop Series No.9.

La-Anyae, S. 1985. Economics of Agricultural development in tropical Africa. New York, John Wiley and Sons.

Lai, T.M.; and Lawton, K. 1962. Root competition for fertilizer phosphorus as affected by intercropping. Proceedings of the Soil Science Society of America, 26, 58-62.

Laing, D.R. Jones, P.G. and Davis, J.H.C. 1984. Common Bean (*Phaseolus vulgaris* L.) In: The Physiology of Tropical Field Crops. eds.P.R. Goldsworthy and N.M. Fisher, Wiley and Son Ltd. pp 305-349.

Leihner, D.E. 1983. Management and evaluation of intercropping systems with cassava. CIAT, Cali, Colombia. 70 p.

Londono, Nohra, R., Juliet, W. Gatheo and John, H. Sanders. 1981. Bean Production Trends in Africa, 1966-1979. Proceedings, Regional Workshop on Potential for Field Bean in Eastern Africa, Lilongwe, Malawi, 1980, Cali, Colombia, CIAT 1981, 226p. pp.19-29.

Ministry of Agriculture, Animal Industries and Fisheries (MAAIF). 1994.

Report on Uganda National Census of Agriculture and Livestock (1990-1992).

Makena, M.M. and Doto, A.L. 1982. Soybean/cereal intercropping and its implications in sorghum breeding. In : Keswani, C.L and Ndunguru, B.J. Eds. Intercropping, Proceedings of the second symposium on intercropping in semi-Arid areas. pp 84-90. Ottawa IDRC.

Male-Kanyiwa, B.S. 1991. Review of bean Production in Uganda outside the highlands and the Fertile crescent zone. In Proceedings of a Workshop on National Research Planning For Bean Production in Uganda. Uganda National Bean Program, Kawanda Agricultural Research Institute, Kampala, Uganda.

Martin, M.P.L.O and Snaydon, R.W. 1982. Intercropping barley and beans 1. Effects of planting pattern. *Experimental Agriculture*. 18, 139-148.

- May, K.W. and Misangu, R. 1982 a. Genotype evaluations and implications for adapting plant materials for intercropping. In : Keswani, C.L. and Ndunguru B.J.eds. Intercropping, proceedings of the second symposium on intercropping in Semi arid areas. pp 79-83. Ottawa, IDRC.
- McGilchrist, C.A. and Trenbath, B.R. 1971. A revised analysis of plant competition in Experiments. *Biometrics* 7 : 659-671.
- Mead, R. and Willey, R.W. 1980. The concept of land equivalent ratio and advantages in yields from intercropping. *Experimental Agriculture* 16 : 217-228.
- Misra, A. and Misra, H.C. 1975. Effect of legumes on associated and subsequent crop. *Indian Journal of Genetics and Plant Breeding*, 35, 230-241.
- Moreno, R.A. 1982. Intercropping with sweetpotato (*Ipomoea batatas* L.) in Central America. pp 243-254. In : Villareal, R.L. and Grigs, T.D. eds. Sweetpotato AVRDC, Shanhua, Tainan, Taiwan, China.
- Mukasa, S.K. 1961. The improvement of beans in Uganda. Contribution, 9th SCAB meeting (cyclostyled).

- Mukasa, S.K. 1970. Beans (*Phaseolus vulgaris* L.) In: Agriculture in Uganda. J.D. Jameson eds. Second Edition, pp. 240-242.
- Mukiibi, J. 1976. Possible relationship between intercropping and plant disease problems in Uganda. In Monyo, J.H., Ker, A.D.R and Cambell, M. eds. Intercropping in semi-arid areas p 45, Ottawa, IDRC.
- _____ 1982. Effects of intercropping on some diseases of bean and groundnut-Summary. In Keswani, C.L and Ndunguru, B.J., eds. Intercropping : proceedings of the second symposium on intercropping in semi-arid areas, p 116-117, Ottawa, IDRC.
- Ndibaza, R.E. 1987. Performance of sweetpotato (*Ipomoea batatas* L.) grown in mixtures with cassava (*Manihot esculenta* Crantz) M.Sc. Thesis. University of Ibadan, Ibadan, Nigeria. 83 p.
- Norman, D.W. 1974. Rationalizing mixed cropping under indigenous conditions. The example of Northern Nigeria. Journal of Development Studies 11 (1), 3-21. (Samaru Research Bulletin 232).
- Ocitti p'Obwoya, C.N. 1990. Effects of seed bed preparation on tuber yield and quality of sweetpotato and the economic implications. In Proc. 4th Eastern and southern Africa Regional Workshop on Root and Tuber Crops. Manza - Zambia October 22nd-29th November 1990.

Ocitti p'Obwoya, C.N. and Smit, N.E.J.M. 1995. The performance of sweet potato and common bean under the traditional intercropping system in the low land areas of Uganda. Paper presented at the 6th International Society for Tropical Rootcrops-Africa Branch (ISTRC-AB), Lilongwe, Malawi, October 21-29, 1995.

Okalebo, J.R., Gatuna, K.W. and Woomer, P.L. 1993. Laboratory methods of soil and plant analysis. A Working Manual. Soil Science Society of East Africa (SSSEA) Technical Publication No.1. Printed by Marvel EPZ (Kenya) Ltd, Nairobi, Kenya.

Okigbo, B.N. and Greenland, D.J. 1976. Intercropping systems in Tropical Africa. In : Multiple Cropping Symposium (Proceedings). American Society of Agronomy. Special publication 27 : 63-102.

_____ 1978. Cropping systems and related research in Africa. AAASA. Occasional Publications Series OT-1.

Onwueme, I.C. 1978. The Tropical Tuber Crops-Yams, cassava, sweetpotato and cocoyam. John Wiley and Sons Ltd, 1978.

Osiru, D.S.O. and Willey, R.W. 1972. Studies on mixtures of dwarf sorghum and beans (*Phaseolus vulgaris* L.) with particular reference to plant population. *Journal of Agricultural Science, Cambridge* 79 (3) 531-540.

_____ 1974. Physiological studies of some annual crop mixtures. Ph.D. Thesis. Makerere University Kampala, Uganda, 260 p.

_____ and Willey, R.W. 1976. Studies on mixtures of maize and bean with particular emphasis on the time of planting bean In : Symposium on intercropping in Semi Arid Areas (Proceedings). Morogoro, Tanzania 10-12 May, 1976, Ottawa, IDRC.

_____ and Kabira, G.R. 1979. Sorghum/pigeon pea and finger millet/groundnut mixtures with special reference to plant population and crop arrangement. [In] proceedings of the International Workshop on Intercropping p 78-85, Hyderabad, ICRISAT.

_____ 1982. Genotype Identification for Intercropping system Summary. In : Keswani, C.L. and Ndunguru, B.J.eds. Intercropping in Semi-arid areas. Proceedings of the second Symposium on intercropping in semi-arid areas, pp.91-92. Ottawa, IDRC.

- Pendleton, J.W. and Seif, R.D. 1962. Role of height in corn competition. *Crop Science* 2 (2), 154-156.
- Premaratne, K.P. and Premachandra, G.S. 1990. Study of intercropping sweetpotato with selected grain legumes grown in Sri-Lanka. Howeler, R.H.(ed) Proceedings of the 8th Symposium of ISTRC, Bangkok, Thailand.
- Purseglove, J.W. 1969. Tropical crops; Dicotyledons. Longman pp.304-310.
- Quirol, B.F., Escalada, R.G., Manated, F.A. 1985. Inter-cropping sweetpotato with legumes as a cultural management system. *Annals of Tropical Research* 6:20-32.
- Rubahaiyo, P.R. 1973. Status and potentials of beans (*Phaseolus vulgaris* L.) in Uganda. Proceedings. Inst. Symposium, Uganda Society of Agronomy. Kampala, pp 65-72.
- Rubahaiyo, P.R., Mulindwa, D., Sengooba, T and Kamugira, F. 1981. Bean Production in Uganda. In: Regional Workshop on Potential for Field Bean in Eastern Africa. Lilongwe, Malawi, 19980, proceedings, Cali Colombia, CIAT 1981. pp 155-186.

- Samui, R.C. Roy, A. and Bhattacharyya, P. 1984. Effect of inter-cropping on growth parameters of groundnut and sunflower. *Journal of Agronomy and Crop Science* 153, 161-166.
- Sanchez, P.A. 1976. Multiple Cropping-an Appraisal of Present knowledge and Future needs. In: Multiple Cropping, eds M. Stanly, David, M. Kral and Linda, C. Eisele. American Society of Agronomy-Special Publication. No. 27, Madison, Wis.
- Semu, E. and Jana, R.K. 1975. Intercropping soybean with maize. First World Soybean Research Conference. Urbana, Champaign. Univ. of Illinois.
- Sharfuddin, A.F.M. and Voican, V. 1984. Effect of plant density and N P K dose on chemical composition of fresh and stored tubers of sweetpotato. *Indian Journal of Agricultural Science*. 54(12) : 1094-6.
- Singh, S.P. 1977. Intercropping and double cropping studies in grain sorghum. In : International Sorghum Workshop, ICRISAT, Hyderabad, India, March 6-12th 1977.
- Slompul, S.M. Harliganto, P.H.S. and Bambang, G. 1984. The effect of sweetpotato population on the yield of cassava and sweetpotato in an intercropping system. *Agrivita (Indonesia)* 1984 7(1): 6-14.

- Snowden, J.D. 1913. Report on the government plantation. In: Department of Agriculture, Annual Report for the year ended March 1913.
- Spitter, C.J.T. 1983. An alternative approach to analysis of mixed cropping experiments. 1. Estimation of competition effects. **Netherlands Journal of Agricultural Science. 31, 1-11, 143-155.**
- Steiner, K.G. 1984. Intercropping in Tropical Smallholder Agriculture with Special Reference to West Africa, German Agency for Technical Cooperation (GTZ) D-6236 Eschborn, German. 304 pp.
- Stephens, D. 1968. The effects of fertilizers, manure and trace elements in continuous cropping rotations in southern and western Uganda. **East Africa Agriculture and Forestry Journal. 32 : 401-417.**
- Stern, W.K. and Donald, C.M. 1962. Light relationship in grass-clover swards. **Australia Journal of Agricultural Research. 13, 599-614.**
- Stocker, R. 1974. Effect of dwarf beans of water stress at different phases of growth, N.Z.J. **Experimental Agriculture. 2 : 13-15.**

- Thomson, D.R. 1977. The effect of cereal height on performance of stands intercropped with soybeans. M.Sc Thesis University of Dar-es-Salaam, Morogoro, Tanzania. In: Willey, R. W., 1979. *Field Crops Abstracts*. vol. 32. No.1.
- Tisdale, S.M, Werner, L.N and Beaton J.D. 1985. *Soil Fertility and Fertilizers*, 4th Edition, MacMillan Publishing Company. pp.754.
- Thung, M. and Cock, J.H. 1979. Multiple cropping cassava and field bean: status of present work at CIAT. In: Weber, E., Nestle, B. and Cambel, M.(Eds). *Intercropping with cassava: Proceedings, International Workshop, 27 Nov-1 to Dec, 1978, Trivandrum, India, IDRC, Ottawa*.
- Trenbath, B.R. 1974. Biomass productivity of mixtures. *Advances in Agronomy*, 26, 177-210.
- Trenbath, B.R. 1976. Plant interaction in mixed\crop communities. In Papendick, R., Sanchez, P.A. and Triplett, G.B. (eds). *Multiple Cropping*. ASA. special publication 27. American Society of Agronomy, Crop Science Society of America and Soil Science Society of America, Madison Wisconsin, USA pp.129-170.

- Tsuno, Y, and Fujisi, K. 1963. Studies on the dry matter production of sweetpotato. 11. Aspects of dry matter production in the field; **Crop Science Society, Japan**, 26, 285-288.
- Uganda National Rootcrops Program (UNRCP). 1985. Annual report 1985. Effects of intercropping sweetpotato with cassava, maize and beans on the performance of sweetpotato, cassava maize and bean crops in mixtures. In Uganda National Rootcrops Program Annual Report, 1985.
- Vallis, I. 1979. Nitrogen relationships in grass-legume mixtures. In : **Plant Relations in Pastures**.
- Villareal, R.L. Hsu, M. 1982. Varietal responses of sweetpotato to relay cropping. **Philippines Journal of Crop Science** 7(3), 134-136.
- Wahua, T.A.T. 1983. Nutrient uptake by intercropped maize and cowpea and a concept of nutrient supplementation index (NSI). **Experimental Agriculture**. 19 : 263-275.
- _____ 1985. Simplified Applied Statistics for Agricultural and Biological Sciences. p 312-349.

_____ and Miller, D.A. 1978. Effects of inter-cropping on soybean N₂-Fixation and plant composition on associated sorghum and soybeans. **Agronomy Journal** 70, 92-295.

Walker, T.W. Orchiston, H.D. and Adams, A.F.R. 1954. The nitrogen economy of grass legume associations. **Journal of British Grassland Society** 9, 249-274.

Watson, D.J. 1947 a. "Comparative Physiological Studies on the Growth of Field Crops.1. Variation in Net Assimilation Rate and Leaf Area between Species and Varieties, and within and between Years. In: Understanding Crop Production. Neal C. Stoskopf Reston Publishing Company. Inc. Reston Virginia, A prentice-Hall Company 1981 pp.91-110.

_____ 1958. The Physiological Basis of Variation in Yield. **Advances in Agronomy**. 4, 101-144.

Whittington, W.J. and O'Brien, T.A. 1968. A comparison of yields from plots sown with a single species or mixture of grass species. **Journal of Applied Ecology** 5, 209-213.

Willey, R.W and Osiru, D.S.O. 1972. Studies on mixtures of maize and beans (*Phaseolus vulgaris*) with particular reference to plant population. **Journal of Agricultural Science. Cambridge** 79, 519-529.

- _____ 1975. The use of shade in coffee, cocoa and tea. **Horticultural Abstracts** 45, 791-798.
- _____ and Roberts, E.H. 1976. Mixed Cropping. In: Solar energy in Agriculture. Joint Solar Energy Society Conference (proceedings), University of Readings, England.
- _____ and Lakhani, D.A. 1976. Some aspects of the productivity and resource use of mixtures of sunflower and fodder radish [In] Symposium on intercropping in Semi-Arid Areas (proceedings) Morogoro, Tanzania, 10-12th, May, 1976.
- _____ 1979 a. Intercropping-Importance and research needs, Part 1. Competition and yield advantages. **Field Crops Abstract.** 32(1), 1-10.
- _____ 1979 b. Intercropping-Importance and research needs, Part 2. Agronomy and Research Approach. **Field Crops Abstract.** 32 : 73-85.
- _____ and Rao, M.R. 1980. A competitive ratio for quantifying competition between intercrops. **Experimental Agriculture.** 16: 117-125.

_____ and Reddy, M.S. 1981. A field techniques for separating above and below ground interaction in intercropping : an experiment with pearl millet/groundnut. *Experimental Agriculture*. 17, 257-264.

Wilson, P.W. and Wyss, O. 1937. Mixed cropping and the excretion of nitrogen by leguminous plants. In: Soil Science Society of America (proceedings) 289-297.

Wien, H.C. and Nangju, D. 1976. The cowpea as an intercrop under cereals. In: Symposium on intercropping in Semi Arid Areas, proceedings, Morogoro, Tanzania 10-12, May.

Winter, E.H. 1955. Bwamba Economy: the development of a primitive subsistence Economy in Uganda, Kampala East African Institute of Social Resources. In: A Subsistence Crop Geography of Uganda, David N. MacMaster. The world land use Survey. Occasional Papers No.2. L. Dudley Stamp, Ed.

Woolfe, J.A. 1992. Sweetpotato an untapped Food Resources. Press Syndicate of the University of Cambridge, The Pitt building, Trumington street, Cambridge, CB 2, RP, Camb. Uni. Press, 1992. p. 643.

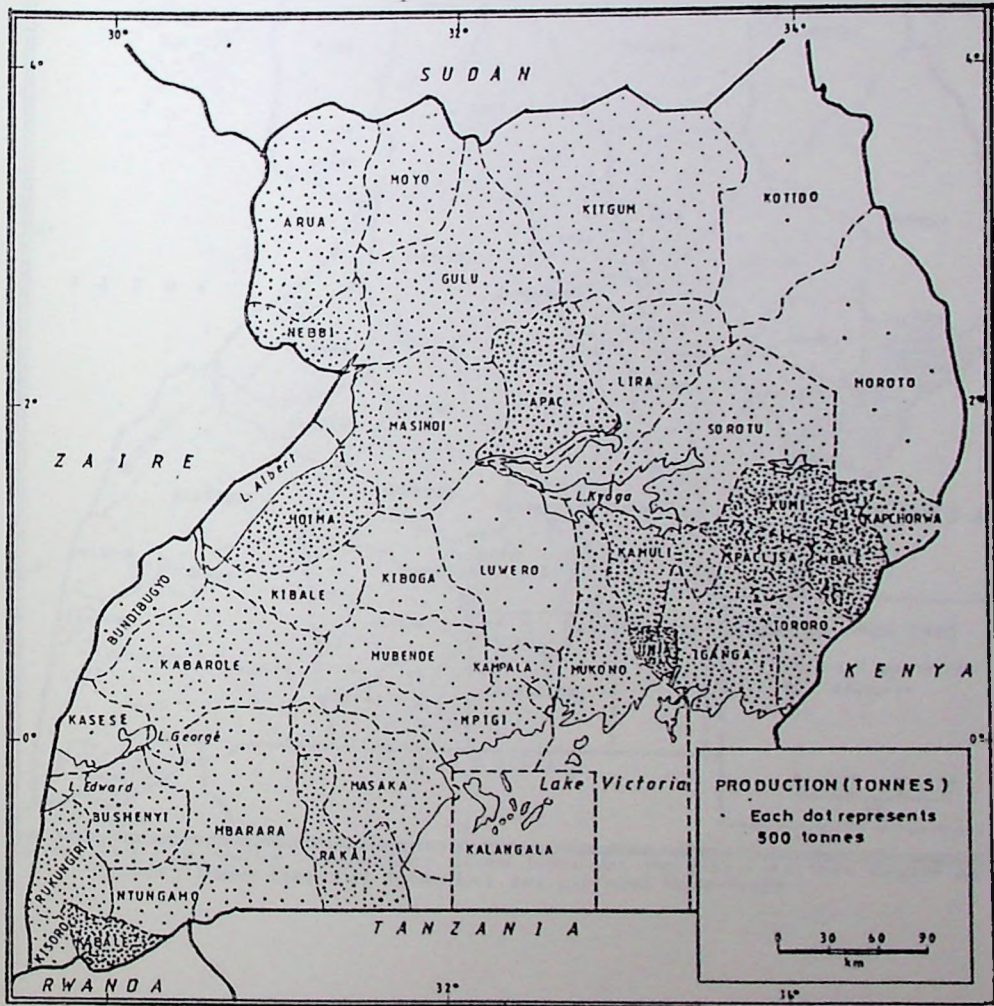
- Wortmann, C.S. Sengooba, T. and Kyamanywa. 1991. Banana and Bean intercropping : Factors affecting bean yield and land use efficiency. *Experimental Agriculture*. (1992) Vol 28. pp.287-294. (MS 2839).
- Yen, D.E. 1982. Sweetpotato in historical perspective. In : Woolfe Jennifer, A. 1992. Sweetpotato: an untapped food resource. Cambridge University Press 1992, p 643.
- Zara, D.L. Cuevas, S.E. and Carlos, J.T. 1982. Performance of sweetpotato varieties grown under coconuts. In Sweetpotato Proc. First Int. Symposium (R.I. Villareal and T.D. Grigs eds. AVRDC. Taiwan pp. 234-24

Appendix 1. Sweetpotato and bean production trends

	Year			
	1979-81	1992	1993	1994
Sweetpotato				
Area harvested	279,000	442,000	460,000	478,000
Production				
Yield (mt)	1,257,000	1,905,000	1,978,000	2,151,000
Bean				
Area harvested (ha)	250,000	536,000	552,000	574,000
Production (mt)	185,000	402,000	442,000	459,000

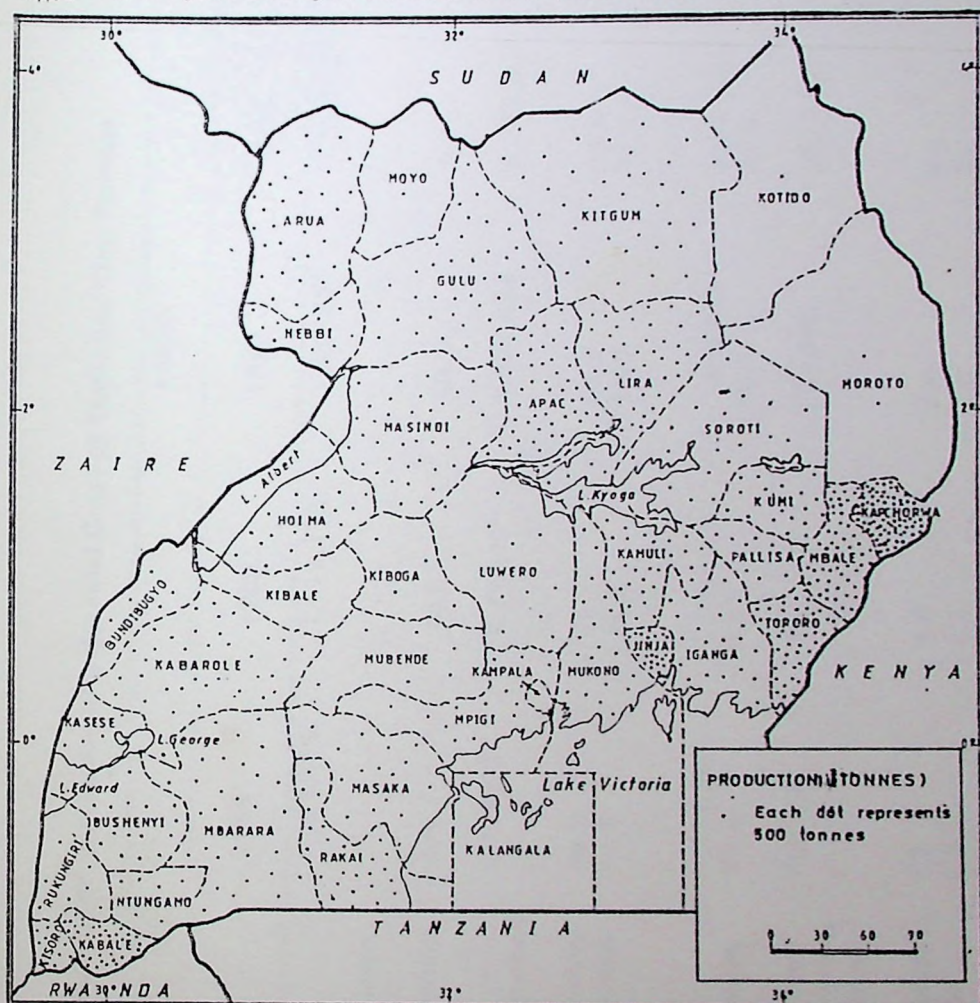
Source: FAO Year Book Production Vol 48, 1994.

App. 3: Map of Uganda showing the distribution of sweetpotato productivity by districts.



Source: Data from Ministry of Agriculture, Animal Industries and Fisheries, 1994 Report on Uganda National Census of Agriculture and Livestock (1990-1992).

App. 5: Map of Uganda showing the distribution of bean productivity by districts.



Source: Data from Ministry of Agriculture, Animal Industries and Fisheries, 1994 Report on Uganda National Census of Agriculture and Livestock (1990-1992).

Appendix 6. Percentage contribution of major Food Crops to Total Food Crop Tonnage.

Crops	YEARS				
	1988	1989	1990	1991	1992
Cereals (finger millet, sorghum, rice, maize wheat)	1,399,569	1,617,228	1,580,851	1,526,893	1,702,913
Percent contribution	9.6	10.6	10.1	9.7	11.2
Rootcrops (Cassava, sweetpotato, Irish potato)	5,176,547	5,474,171	5,336,536	5,269,954	5,027,157
Percent contribution	35.6	35.7	34.2	33.5	33.1
Sweetpotato contrib.	11.8	10.8	10.9	11.3	12.3
Plantains (bananas)	7,292,580	7,468,509	7,842,067	8,080,245	7,585,032
Percent contribution	50.2	48.7	50.3	51.4	50.0
Legumes and others (beans, g/huts, cowpea pigeon pea, sesame)	656,096	769,197	838,165	850,442	869,052
Percent contribution	4.5	5.0	5.4	5.4	5.7
Bean contribution	2.3	2.5	2.5	2.4	2.6
Total Tonnage	14,524,792	15,329,105	15,597,621	15,727,534	15,184,154

Source: Ministry of Agriculture, Animal Industries and Fisheries, 1994 Report on Uganda National Census of Agriculture and Livestock (1990-1992).

Appendix 7. Importance of association with sweetpotato in seven districts of Uganda.

District	Number of respondents	(n = 346)		Intercropping (%)		
		Sole- cropping		Beans	Cassava	Maize
		%				
Kabale	52	56	42	0	0	2
Gulu	53	60	38	0	0	2
Iganga	49	64	30	6	6	0
Mpigi	47	67	27	6	6	0
Luwero	50	96	2	2	2	0
Kabarole	46	63	2	2	2	7
Arua	49	61	35	0	0	4

Source: Bashaasha *et al.*, 1995. Sweetpotato in the Farming and Food Systems of Uganda: A Farm Survey Report.

2013.

Appendix 8.

An outline of analysis of variance table for
sweetpotato and bean attributes (1993/94
cropping season)[Experiment I]

Source of Mean variation	Degrees of freedom	
Replication (R)	$(r-1)$	$= 2$
Main factor:		
Bean genotype (BG)	$(bg-1)$	$= 4$
Error (a)	$(r-1)(bg-1)$	$= 8$
Sub-plot factor:		
Sweetpotato genotype (SPG)	$(spg-1)$	$= 7$
Main plot factor x Sub-plot factor		
BG x SPG	$(bg-1)(spg-1)$	$= 28$
Error (b)	$bg(r-1)(spg-1)$	$= 70$
Total		119

R = number of replications; bg and spg are levels of BG and SPG,
respectively.

Appendix 9. An outline of analysis of variance table sweetpotato and bean attributes (1994/95 and 1995/96 cropping season)
[Experiment II]

Source of variation	Degrees of freedom	
Replication (R)	$(r-1)$	$= 2$
Main factor: Sweetpotato genotype (SPG)	$(spg-1)$	$= 2$
Error (a)	$(r-1)(spg-1)$	$= 4$
Sub-plot factor: Spatial arrangement (SA) (sa-1)		$= 1$
Main factor x Sub-plot factor SPG x SA	$(spg-1)(sa-1)$	$= 2$
Error (b)	$spg(r-1)(sa-1)$	$= 6$
Sub-sub plot factor: Sweetpotato population density (PD)	$(pd-1)$	$= 3$
SPG x PD	$(spg-1)(pd-1)$	$= 6$
SA x PD	$(sa-1)(pd-1)$	$= 3$
SPG x SA x PD	$(spg-1)(sa-1)(pd-1)$	$= 6$
Error (c)	$(spg)(sa)(r-1)(pd-1)$	$= 36$
Total	$(spg.r.sa.pd)-1$	71

R = number of replications; spg, sa and pd are levels of SPG, SA and PD, respectively.

Appendix 10

An outline of a combined analysis of variance table for sweetpotato and bean attributes over seasons (1993/94 and 1994/95 cropping seasons) [Experiment I]

Source of variation	Degrees of freedom	
Replication (R)	$(r-1)$	= 2
Main factor: Season (S)	$(s-1)$	= 1
Sub-plot factor: Bean genotype (BG)	$(bg-1)$	= 1
Main plot factor x sub-plot factor S x BG	$(s-1)(bg-1)$	= 1
Error (a)		
Sub-sub-plot factor: Sweetpotato genotypes (SPG)	$(spg-1)$	= 5
Main plot factor x sub-sub plot factor. S x SPG	$(s-1)(spg-1)$	= 5
Sub-plot factor x sub-sub plot factor: BG X SPG	$(bg-1)(spg-1)$	= 5
Main plot factor x sub plot factor x sub-sub plot factor, S x BG x SPG	$(s-1)(bg-1)(spg-1)$	= 5
Error	$sbgr-1)(spg-1)$	= 40
Total		= 71

R = number of replications; s, bg and spg are levels of S, BG and SPG, respectively.

Appendix 11. An outline of a combined analysis of variance table for sweetpotato and bean attributes over seasons (1994/95 and 1995/96 cropping seasons) [Experiment II]

Source of variation	Degrees of freedom	
Replication (R)	(r-1)	= 2
Main plot factor:		
Season (S)	(s-1)	= 1
Sub-plot factor-		
Sweetpotato genotype (SPG)	(spg-1)	= 2
Main plot factor		
x subplot factor		
S x SPG	(s-1) (r-1)	= 2
Error (a)	(s spg-1) (r-1)	= 10
Sub-sub plot factor:		
Spatial arrangement(SA)	(sa-1)	= 1
Main plot factor x		
Sub-sub plot factor		
S x SA	(s-1) (sa-1)	= 1
Sub-plot factor x		
Sub-sub plot factor		
SPG x SA	(spg-1) (sa-1)	= 2
Main plot factor x		
Sub- plot factor		
x Sub-sub plot factor,		
S x SPG x SA	(s-1) (spg-1) (sa-1)	= 2
Error (b)	s spg(r-1) (sa-1)	= 12
Sub-sub-sub-plot factor:		
Sweetpotato plant density (PD)	(pd-1)	= 3
S x PD	(s-1)(pd-1)	= 3
SPG x PD	(spg-1)(pd-1)	= 6
S x SPG x PD	(s-1)(spg-1)(pd-1)	= 6
SA x PD	(sa-1)(pd-1)	= 3
S x SA x PD	(s-1)(sa-1)(pd-1)	= 3
SPG x SA x PD	(spg-1)(sa-1)(pd-1)	= 6
S x SPG x SA x PD	(s-1)(spg-1)(sa-1)(pd-1)	= 6
Error -by subtraction		72
Total		143

R = number of replications; s, spg, sa and pd are levels of S, SPG, SA and PD, respectively.

Appendix 12. Levels of significance from combined analysis of variance and contrast in sweetpotato yield and yield components in sweetpotato/bean association, (1993/94 and 1994/95)[Experiment I]

Source of variation	Degrees of freedom	Vine yield g/plant	Percent market root/plot	Percent unmark. root/plot	Aver. weight market.	Aver. weight unmarket.	Harvest index percent	Yield tone/hectare
Replication (R)	2	ns	ns	ns	ns	ns	ns	ns
Season (S)	1	**	**	**	**	ns	*	ns
Bean genotype (BG)	1	ns	ns	ns	ns	ns	ns	ns
S x BG	1	ns	ns	ns	*	ns	ns	ns
Error(a)	6							
Sweetpotato genotype (SPG)	5	ns	**	**	**	ns	*	ns
S x SPG	5	ns	ns	**	**	ns	ns	ns
BG x SPG	5	ns	ns	ns	ns	ns	ns	ns
S x BG x SPG	5	ns	ns	ns	ns	*	ns	ns
Error(b)	40							
Contrast								
Sweetpotato plant types		ns	ns	ns	*c	ns	*q	ns
S vs BG		ns	ns	ns	*c	ns	ns	ns
S vs SPG		ns	**	**	**	ns	ns	ns
CV.		40.9%	31.8%	37.5%	19.9%	21.3%	22.8%	31.5%

L.C.Q. = Linear, cubic and quadratic, respectively.

ns, *, ** = Non significant or significant at 5% and 1% probability level, respectively.

Appendix 13. Levels of significance from combined analysis of variance for bean yield and yield components in sweetpotato/bean association (1993/94 and 1994/95)[Experiment I].

Source of variation	Degrees of freedom	Number of pod per plant	Number of seed per pod	Number of seed per plant	100 seed weight (g)	Yield per plant (g)	Yield (kg/ha)
Replication (R)	2	ns	ns	ns	ns	ns	ns
Season (S)	1	ns	**	**	**	*	ns
Bean genotype (BG)	1	ns	ns	ns	**	ns	ns
S x BG	1	ns	ns	ns	ns	ns	ns
Error (a)	6						
Sweetpotato genotype (SPG)	5	ns	ns	ns	ns	ns	ns
S x SPG	5	ns	ns	ns	ns	ns	ns
S x BG x SPG	5	ns	ns	ns	ns	ns	ns
Error (b)	40						
CV.		24.9%	8.4%	27.2%	12.0%	27.8%	33.2%

ns, *, ** = Non significant or significant at 5% and 1% probability level, respectively.

Appendix 14. Levels of significance from combined analysis of variance and contrast for sweetpotato yield and yield components in sweetpotato/bean association (1994/95 and 1995/96)[Experiment II].

Source variation	Degrees freedom	Vine yield/plant	Percent mark. root/plot	Yield (kg/plant)	Aver. weight market. (g/root)	Aver. weight unmark. (g/root)	Yield (t/ha)	Harvest index percent	Dry matter
Replication	2	*	ns	ns	ns	ns	ns	ns	*
Season(S)	1	ns	**	**	ns	**	*	**	*
Sweetpotato genotype (SPG)	2	*	ns	**	**	ns	ns	ns	*
S x SPG	2	ns	ns	ns	ns	ns	ns	ns	*
Error (a)	10								
Spatial arrangement	1	ns	*	ns	**	ns	ns	ns	ns
(SA)SPG x SA	2	ns	ns	ns	ns	ns	ns	ns	ns
S x SPG x SA	2	ns	ns	ns	ns	ns	ns	ns	ns
Error(b)	12	ns	ns	ns	ns	ns	ns	ns	ns
ns Population density (PD)	3	*	**	**	**	ns	ns	*	ns
S x PD	3	ns	*	ns	ns	ns	ns	ns	ns
SPG x PD	6	ns	ns	ns	ns	ns	ns	ns	ns
S x SPG x PD	6	ns	ns	*	ns	ns	*	ns	ns
SA x PD	3	ns	ns	ns	ns	ns	ns	ns	ns
S x SA x PD	6	ns	ns	ns	ns	ns	ns	ns	ns
S x SPG x SA x PD	6	ns	ns	ns	ns	ns	ns	ns	ns
Error (c)	72								
Contrast									
Among population densities		ns	**	**	*	ns	ns	ns	ns
ns									
CV.		19.4%	22.5%	27.7%	16.0%	18.4%	20.0%	12.9%	10.3%

= Linear coefficients.

ns, *, ** = Non significant or significant at 5% and 1% probability level, respectively.

Appendix 15. Levels of significance from combined analysis of variance and contrast for bean yield and yield components in sweetpotato/bean association (1994/95 and 1995/96)[Experiment III].

Source of variation	Degrees of freedom	Number of pod per plant	Number of seed per pod	100 seed weight (g)	Yield per plant (g)	Yield per (kg/ha)
Replication	2	*	ns	ns	ns	**
Season	1	ns	**	**	**	**
Sweetpotato genotype	2	ns	ns	ns	ns	ns
S x SPG	2	ns	ns	ns	ns	ns
Error (a)	10					
Spatial arrangement	1	ns	ns	ns	ns	ns
(SA)						
S x SA	1	ns	ns	ns	ns	ns
SPG x SA	2	ns	ns	*	ns	ns
S x SPG x SA	2	ns	ns	*	ns	ns
Error (b)	12					
Population density (PD)	3	ns	ns	ns	**	**
S x PD	3	ns	ns	ns	ns	ns
SPG x PD	6	ns	ns	ns	**	ns
S x SPG x PD	6	ns	ns	ns	*	ns
SA x PD	3	*	ns	ns	ns	ns
S x SA x PD	3	ns	ns	ns	ns	ns
SPG x SA x PD	6	ns	ns	ns	ns	ns
S x SPG x SA x PD	6	ns	ns	ns	ns	ns
Error (c)	72					
Contrast						
S vs SA		ns	ns	**	ns	ns
Among population densities		ns	ns	ns	*	ns
CV.		22.3%	10.3%	16.9%	28.4%	32.2%

ns, *, ** = Linear and quadratic/cubic coefficient, respectively.

ns, *, ** = Non significant or significant at 5% and 1% probability level, respectively.

Appendix 16. Correlation coefficients (r) of foliar nutrient content in bean with soil available nutrients at 45 DAP

Foliar nutrients in bean (n = 24)

Soil available nutrient	P	N	K	Na	Ca	Mg
P	+ ns	+	+	+ ns	+	+ ns
N	- ns	+ ns	- ns	- ns	+ ns	- ns
K	+	+	+	+ ns	+ ns	+ ns
Na	- ns	- ns	- ns	+ ns	- ns	- ns
Ca	- ns	+ ns	- ns	- ns	+	+ ns
Mg	- ns	- ns	- ns	- ns	- ns	- ns

+, + ** = Positive and significant at 5% and 1% probability level, respectively.
- ns, + ns = Negative or positive but not significant.

Appendix 17. Correlation coefficients (r) of foliar nutrient contents in sweetpotato with soil available nutrients at 45 DAP.

Soil available nutrients	Foliar nutrients in sweetpotato (n = 24)					
	P	N	K	Na	Ca	Mg
P	+ ns	+ ns	+ ns	+ ns	+ ns	ns
N	+ ns	+ ns	+ ns	+ ns	+ ns	+ ns
K	+ ns	+ ns	+ ns	- ns	- ns	- ns
Na	+ ns	+ ns	- ns	+ ns	+ ns	+ ns
Ca	+ ns	+ ns	+	+ ns	+ ns	+ ns
Mg	- ns	+ ns	+ ns	+ ns	+ ns	+ ns

+ *, Significant at 5% probability level.

+ ns = Positive but not significant.

- ns = Negative but not significant

Appendix 18. Correlation coefficients (r) among soil nutrient levels and bean seed yield at bean harvest.

Nutrients (n = 24)												
	pH	OM	P	N	K	Na	Ca	Mg	Bean yield			
pH	-	+ns	+	**	+ns	+ns	-ns	+	**	+ns	+ns	
OM		-		+ns	+ns	+ns	+ns	+ns	+ns	+ns	+ns	
P			-		+ns	+	**	-ns	+	**	+ns	+ns
N				-		+ns	+ns	-ns	-ns	-ns	-ns	-ns
K					-		+ns	+ns	+ns	+ns	-ns	-ns
Na						-	-ns	-ns	-ns	-ns	+ns	+ns
Ca							-	+ns	+ns	+ns	+ns	+ns
Mg											-ns	-ns

+ ** = Positive and significant at 1% probability levels.

-ns = Negative and not significant.

+ns = Positive and not significant.

Appendix 19.

Correlation coefficients (*r*) among soil nutrient levels and sweetpotato root yield at sweetpotato harvest.

Nutrients	Population	pH	OM	P	Nutrients (n=48)					Ca	Mg	S/pot. yield
					N	K	Na					
Population	-	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	**
pH		-	**	**	ns	**	ns	ns	**	**	**	**
OM			-	ns	ns	ns	ns	ns	**	**	**	**
P				-	ns	**	ns	ns	**	ns	ns	ns
N					-	**	ns	ns	ns	ns	ns	ns
K						-	ns	ns	ns	**	**	**
Na							-	ns	ns	ns	ns	ns
Ca									-	**	**	**
Mg										-	**	**
Sweetpotato yield												-

*, **, Significant at 5% and 1%, respectively.