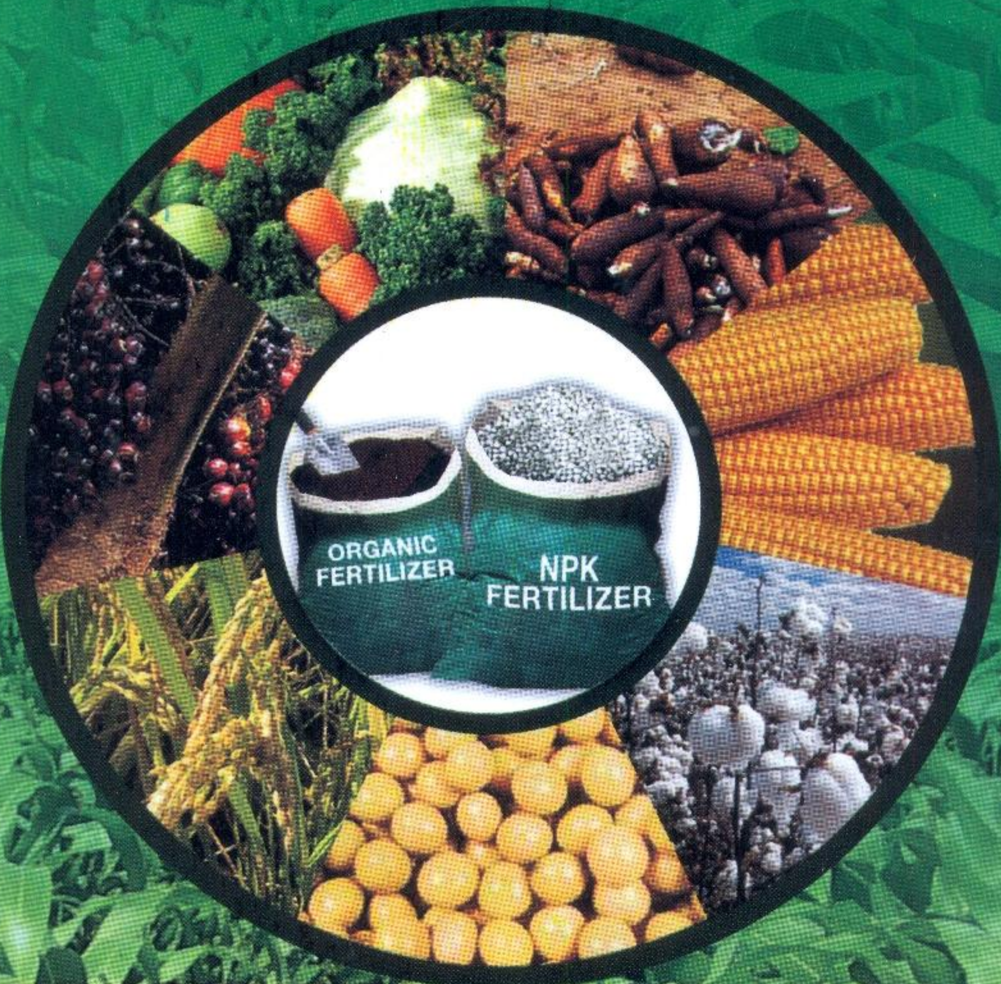
FERTILIZER USE AND MANAGEMENT PRACTICES FOR CROPS IN NIGERIA

4TH EDITION



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FEDERAL FERTILIZER DEPARTMENT
FEDERAL MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT, ABUJA.

2012

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TABLE OF CONTENTS

Membership of fertilizer use review committee ii
Table of contents iii
List of tables vii
List of figures x
Preface xi

CHAPTER ONE
1.0 Introduction 1
1.1 Historical account of fertilizer use 1
1.2 Natural Resources 1
1.3 Nigerian Agriculture 6
1.3.1 Fertilizer Demand Projection 7
1.3.2 Geographic Indication of Projected Fertilizer Demand 13
1.4 Major Nigerian soil groups and agriculture 15
1.4.1 Soil resources of the northern Nigerian savanna region 15
1.4.2 Soils of south-eastern Nigeria 18
1.4.3 Soils of south western Nigeria 22
1.5 Soil management and conservation for effective fertilizer use 25
1.6 Fertilizer - soil relationships 26
1.6.1 Determining fertilizer needs of crops 26
1.6.2 Factors affecting fertilizer use 27
1.6.3 Role of plant nutrients and their deficiency symptoms 28
1.6.3.1 Symptom Description 28
1.6.4 Fertilizer use and cation balance in soils 39
1.6.5 Fertilizer use under irrigation 40
1.6.6 Soil acidity and liming 41
1.6.7 Soil salinity and alkalinity 41
1.6.8 Soil fertility maps 42
1.6.8.1 Rating for Soil Fertility Classes 42
1.7 Supplements to chemical fertilizers 43
1.7.1 Crop residues 43
1.7.2 Animal manures and household refuse 51
1.7.3 Nitrogen fixation 51
1.7.4 Precaution on the use of organic and inorganic fertilizer 51
1.8 Fertilizer handling 52
1.8.1 Transport 52
1.8.2 Storage 52
1.8.3 Supplies and sales 52
1.9 Principles of fertilizer application 53
1.9.1 Fertilizer broadcasting 53
1.9.2 Fertilizer placement 53
1.9.3 Fertilizing tree crops/plants 53
1.9.4 Foliar application of fertilizer 54

1.9.5 Fertilizers and the environment 54
1.9.6 Socio-economic and policy aspects of fertilizer use 54
1.9.7 Fertilizer Extension: Issues and Options 58
1.9.8 Extension Strategies for Facilitating Increased Fertilizer Use 60
CHAPTER TWO
2.0 Fertilizer practices for sole cropping 62
2.1 General concept....62
2.2 Cereals 62
2.2.1 Maize *(Zea mays* L*)* 62
2.2.2 Guinea corn (Sorghum *bicolor*) 67
2.2.3 Millet (Pennisetum *typhoideum*)....69
2.2.4 Rice (O*ryza sativa* L) 71
2.2.5 Wheat (*Triticum aestivum*) 75
2.2.6 Barley (*Hrdeum vulgare*) 76
2.2.7 Sugarcane (*Saccharurn officinarum*) 77
2.2.8 Acha (*Digitaria exilis*) 79
2.3 Fat and oilseeds 80
2.3.1 Groundnut (*Arachis hypogaea*)....80
2.3.2 Benniseed (*Sesanum indicum*, L)....82
2.3.3 Sunflower (*helianthus annuus* L)....84
2.3.4. Miscellaneous fat and oilseeds 86
2.4 Grain Legumes....87
2.4.1 Cowpea (*Vigna unguiculata*) 87
2.4.2 Soyabean (*Glycine max*) 90
2.4.3 Miscellaneous grain legumes 91
2.5 Fibre crops 91
2.5.1 Cotton *(Gossypium hirsutum* and G. *barbadense)* 91
2.5.2 Kenaf (*Hibiscus cannabinus*) 94
2.5.3 Miscellaneous vegetable fibres 96
2.6 Root and tubers 96
2.6.1 Yams *(Dioscorea spp)* 96
2.6.2 Cultural practices for production of seed yam from minisetts. 100
2.6.3 Cassava (*Manihot esulenta*) 102
2.6.4 Irish potato (*Solanum tuberospin*)....104
2.6.5 Cocoyam (*Colocasia spp* and *xanthosoma spp*) 107
2.6.6 Sweet potato (*Ipomoea batatas*) 110
2.6.7 Ginger (*Zingiber officiale*)....111
2.6.8 Carrots (*Daucus carota*) 112
2.7 Vegetable crops....113
2.7.1 Tomato (*Lycopersicum esculentum*) 113
2.7.2 Onion (*Alliurn cepa*) 116
2.7.3 Okra (*Hibiscus esculentus*) 118
2.7.4 Peppers and chillies (*Capsicum spp*) 119
2.8 Tree crops 121
2.8.1 Cocoa (*Theobroma. cacao* L.) 121

2.8.2 Coffee (C*offee robusta* and C. *arabica*) 123
2.8.3 Kola (*Cola nitida* and c. *acuminata*) 123
2.8.4 Cashew (*Anacardium occidentale* l) 124
2.8.5 Tobacco (*Nicotiana tabacum*) 127
2.8.6 Oil palm (*Elaeis guineensis, jacq*) 128
2.8.7 Coconut palm (*Cocoa nucidera*)..139
2.8.8 Date palm (*Phoenix dactylifera*) 144
2.8.9 Raphia palms (*Raphia spp*) 144
2.8.9.1Rubber (*Hevea brasiliensis*) 147
2.9.0 Fruits, pastures, grasses and legumes..150
2.9.1 Citrus (*Citrus spp*) 150
2.9.2 Mango (*Mangifera indica*) 152
2.9.3 Pineapple (*Ananas commosus*.) 153
2.9.4 Plantain (*Musa paradisiaca, l.*) 155
2.9.5 Pastures grasses and legumes 156
2.9.6 General agronomy 156
2.9.7 Areas of production 156
2.9.8 Pasture establishment 156
2.9.9 Pasture management 157
2.9.9.1 Nutritive value of grasses and legumes 158
2.9.9.2 Forage species..158
2.9.9.3 Grasses 158
2.9.9.4 Legumes..163
2.9.9.5 Management of forage grasses..169
2.9.9.6 Gamba (Andropogon *gayanus*)..169
2.9.9.7 Signal grass (Brachiaria *decumbens*) 170
2.9.9.8 Buffel grass (*Cenchrus ciliaris*)..171
2.9.9.9 Rhodes grass (*Chloris gayana*)..172
2.9.9.9.1 Woolly finger grass (*Digitaria smutsii*)..172
2.9.9.9.2 Guinea grass (*Panicum maximum*) 173
2.9.9.9.3 Miscellaneous forage grasses..173
2.9.9.9.4 Management of forage legumes..174
2.9.9.9.5 Common stylo (*Stylosanthes guianensis*)..174
2.9.9.9.6 Lablab (*Lablab purpureus*)..175
2.9.9.9.7 Verano stylo (stylosanthes hamatan cy verano) 175
2.9.9.9.8 Miscellaneous forage legumes 176

CHAPTER THREE

3.0 Fertilizer practices for mixed cropping..177
3.1 General concept..177
3.2 Crop categories 177

CHAPTER FOUR

4.0 Areas for further research and suggestions 182
4.1 General concept..182

4.2 Fertilizer recommendations 182
4.3 Characterization of soil groups 182
4.4 Soil testing facilities 182
4.5 Fertilizer formulations 183
4.6 Fertilizer blending facilities 186
4.7 Specific nutritional problems 186
4.8 Nutrition in crop mixtures 186
4.9 Fertilizers in forest production 186
4.10 Source of nitrogen 186
4.11 General agronomy 187
4.12 Crop varieties and nutrient requirement 187
4.13 Agronomy of forage crops 187
4.14 Agricultural statistics 187
4.15 Missing extension linkage 188
4.16 Industries and agricultural research 188
4.17 Pesticide residues 188
4.18 Integrated plants nutrition 188
4.19 Research on rock-phosphate 189
4.20 Use of synthetic fertilizers and the concept of ecological or organic agriculture 189
4.21 Conducting A Fertilizer Demonstration 190
4.22 Demonstration of Plot Size 191
4.23 Calculation of Fertilizer Rates Per Plot 193
4.24 Broadcasting Fertilizer on small Plots 193
4.25 Evaluation of Fertilizer Demonstration 194
4.26 Conducting Meetings on Fertilizers 194

APPENDICS 166

Appendix I Acronyms 196
Appendix ii Nutrient content of some common fertilizer materials 197
Appendix iii Glossary of terms on fertilizers 198
Appendix iv Conversion table for liquid herbicide formulations 209
Appendix v Conversion table for wettable powders, soluble salts and granules 209
Appendix vi Fertilizer marketing companies in Nigeria, August 2000 210
Appendix vii Methods of qualitative identification of elements contained in fertilizer materials 211
Appendix viii Calculating fertilizer rates 213

LIST OF TABLES

Table No.

1.1	-	Ranking of AEZs by potential rainfed agriculture area expansion	4
1.2	-	Assumptions made to estimate future agricultural commodity demand	7
1.3	-	Commodity production projections, '000 tonne	9
1.4	-	Commodity production projections, '000 tonnes (2007 – 2016)	10
1.5	-	Area and Cropping Index	10
1.6	-	Sources of Production growth%	11
1.7	-	Area ('000 ha) yield (t/ha) and production ('000 tonnes) projections	12
1.8	-	Fertilizer Consumption Tonnes Nutrients	12
1.9	-	Demand Projection for Fertilizer 2007 – 2016 "000 Tonnes Nutrients	13
1.10	-	Projected Crop Production and Fertilizer Use for selected crops in Nigeria according to agro-ecological Zones (2030)	14
1.11	-	Soil Mapping Units: Jungerius and FDALR	20
1.12	-	Fertilizer Demand and Supply, 1992 – 2000	57
2.1	-	Recommended maize varieties for different agro-ecological zones	64
2.2	-	Fertilizer recommendations for maize (open pollinated) (Based on soil test/soil fertility map)	64
2.3	-	Generalized fertilizer recommendation for maize (Open pollinated) (Based on agro-ecological zones)	65
2.4	-	Fertilizer recommendations for guinea corn (Sorghum) (Based on soil test/soil fertility map)	67
2.5	-	Generalized fertilizer recommendations for guinea corn (Sorghum) (Based on agro-ecological zones)	68
2.6	-	Improved guinea corn varieties	68
2.7	-	Fertilizer recommendations for millet (Based on soil/test soil fertility map)	69
2.8	-	General fertilizer recommendations for millet (Based on agro-ecological zones)	70
2.9	-	Fertilizer recommendations for upland and lowland rice (Based on soil test/soil fertility map)	73
2.10	-	Recommended upland rice varieties for the different agro-ecological zones	74
2.11	-	Recommended lowland varieties for different agro-ecological zones	74
2.12	-	Fertilizer recommendations for wheat	75
2.13	-	Fertilizer recommendations for Barley	76
2.14	-	Generalized fertilizer recommendations for sugar cane (Based on soil test/soil fertility map)	78
2.15	-	Generalized fertilizer recommendations for sugarcane (Based on agro-ecological zones)	78
2.16	-	Recommended sugarcane varieties for agro-ecological zones	79
2.17	-	Fertilizer recommendations for groundnut in different agro-ecological zones	80
2.18	-	Groundnut varieties suitable for different agro-ecological zones	81
2.19	-	Fertilizer recommendations for cowpea and soyabean (Based on soil test/soil fertility map)	87
2.20	-	Generalized fertilizer recommendations for cowpea and soyabean (Based on agro-ecological zones)	88

2.21	-	Recommended cowpea varieties for different agro-ecological zones	88
2.22	-	Recommended soyabean varieties for different agro-ecological zones	90
2.23	-	Fertilizer recommendations for cotton	92
2.24	-	Fertilizer recommendations for kenaf	94
2.25	-	Improved Yam Varieties	96
2.26	-	Selected yam varieties	98
2.27	-	Fertilizer recommendations for yam	98
2.28	-	Other fertilizer recommendations for yam	99
2.29	-	Herbicide recommendations for yam	100
2.30	-	Fertilizer recommendations for yam mixtures	101
2.31	-	Improved Cassava varieties and their characteristics	102
2.32	-	Fertilizer recommendations for cassava	103
2.33	-	Other recommendations for cassava	103
2.34	-	Recommended cassava varieties for different zones of Nigeria	104
2.35	-	Herbicide recommendation for cassava	104
2.36	-	Fertilizer recommendation for Irish potato	105
2.37	-	Recommended varieties for Irish potato	106
2.38	-	Herbicide recommendations for Irish potato	107
2.39	-	Pesticide recommendations for Irish potato	107
2.40	-	Fertilizer recommendations for cocoyam	108
2.41	-	Fertilizer (Compound Fertilizer) requirement for Cocoyam	108
2.42	-	Herbicide recommendations for cocoyam	109
2.43	-	Fertilizer recommendations for sweet potato	110
2.44	-	Herbicide recommendations for sweet potato	111
2.45	-	Fertilizer recommendations for ginger	111
2.46	-	Herbicide recommendations for ginger	112
2.47	-	Fertilizer recommendations for carrots	112
2.48	-	Fertilizer recommendations for tomato	114
2.49	-	Recommended improved tomato varieties currently in use	115
2.50	-	Fertilizer recommendation for onion	116
2.51	-	Fertilizer recommendations for okra	118
2.52	-	Improved okra varieties	119
2.53	-	Fertilizer recommendations for pepper and chillies	120
2.54	-	Improved pepper varieties	120
2.55	-	Fertilizer recommendations for cocoa	122
2.56	-	Fertilizer recommendations for coffee	123
2.57	-	Fertilizer types and rates for mature cashew plant	125
2.58	-	Fertilizer recommendations for tobacco	128
2.59	-	Fertilizer recommendations for oil palm on the moderately wet acid sands of the forest zone (1,700 - 2,000mm/year rainfall)	130
2.60	-	Fertilizer recommendations for oil palm on the relatively wet acid sands of the forest zone (2,000 - 3,000mm/year rainfall)	131
2.61	-	Fertilizer recommendation for oil palm on the basement complex soils of South - Eastern Nigeria	132
2.62	-	Fertilizer recommendation for oil palm on the soils of the sub-recent terrace	

		(Sombreiro - Warri Deltaic Plain)	133
2.63	-	Fertilizer recommendation for oil palm on the marginal areas, of middle belt (1,200 - 1,500mm/year rainfall)	134
2.64	-	Fertilizer recommendation for oil palm/food crop mixture	135
2.65	-	Recommended rates for NPK, magnesium, compound fertilizer (12 - 12 - 17 + 2) for oil palm	135
2.66	-	Fertilizer recommendations for coconut palm	143
2.67	-	Fertilizer recommendation for rubber	149
2.68	-	Agronomic characteristics of grasses	159
2.69	-	Recommended forage species for Nigeria	160
2.70	-	Agronomic characteristics of legumes	164
3.1	-	Fertilizer recommendations for crop mixtures	179
3.2	-	Fertilizer recommendations for crop mixtures based on phosphorus requirement	179
4.1	-	Soil and crop specific fertilizer formulation based on Soil Fertility Maps of Nigeria	183
4.2	-	Demonstration design for calculation of fertilizer per plot	193

LIST OF FIGURES

Figure			Page No
1	-	Agro Ecological Zones Map of Nigeria	3
1.1	-	Major vegetation/agro-ecological zones of Nigeria	4
1.2	-	Soil resources of Northern Nigeria	16
1.3	-	Soils resources of South Eastern Nigeria	21
1.4	-	Soils resources of South Western Nigeria	23
1.5	-	Magnesium deficiency symptoms in Tomato	29
1.6	-	Magnesium deficiency symptoms in Maize leaves	29
1.7	-	Manganese deficiency symptoms in Tomato	30
1.8	-	Molybdenum deficiency symptoms in Tomato	31
1.9	-	Nitrogen deficiency symptoms in Tomato	32
1.10a	-	Phosphorus deficiency symptoms in Tomato	33
1.10b	-	Potassium deficiency symptoms in Maize	33
1.11	-	Sulfur deficiency symptoms in Tomato	34
1.12	-	Zinc deficiency symptoms in Tomato	34
1.13	-	Boron deficiency symptoms in Tomato	35
1.14	-	Calcium deficiency symptoms in Tomato	36
1.15	-	Chloride deficiency symptoms in Tomato	36
1.16	-	Copper deficiency symptoms in Tomato	37
1.17	-	Iron deficiency symptoms in Tomato	38
1.18a	-	Potassium deficiency symptoms in Tomato	39
1.18b	-	Potassium deficiency symptoms in Maize Plant	39
1.19	-	pH Water Fertility Map of Nigeria	44
1.20	-	Total Nitrogen Fertility Map of Nigeria	45
1.21	-	Phosphorus Fertility Map of Nigeria	46
1.22	-	Potassium Fertility Map of Nigeria	47
1.23	-	Organic Carbon Fertility Map of Nigeria	48
1.24	-	Zinc Fertility Map of Nigeria	49
1.25	-	Boron Fertility Map of Nigeria	50
1.26	-	Example of the lay-out of a simple demonstration with control plot and two different rate of N	192

PREFACE

This monograph, "Fertilizer Use and Management Practices for Crops in Nigeria", is a revised version of the third edition which was published in 2000. The revision was done by a committee of agricultural scientists, set up by the Federal Fertilizer Department (FFD). The membership of the Committee, covered various disciplines in Agriculture.

The fourth edition of the Monograph is a marked improvement on the previous three editions in layout and presentation. It contains agronomic and other cultural practices on arable, tree, pasture and vegetable crops, with strong emphasis on fertilizer rate, method and nutrient deficiency symptoms. An attempt has been made in this edition to provide graded fertilizer recommendations based on soil tests. Soil classification was also done using FAO or USDA systems in the revision, thus marking a beginning for extrapolation of results of fertilizer trials from one geographical area to another. Soil maps are now in colour and new chapters and information on crop varieties are included in this edition.

This new edition still recognizes geographical boundaries (Fig. 1.1) in its package of recommendations, for example, in crop varieties and fertilizer use. These zones which are linked to States have 6 Zonal Research Centres with Headquarters at six Institutions namely:

North East Zone	-	Maiduguri (Lake Chad Research Institute)
North West Zone	-	Zaria (Institute for Agricultural Research)
Middle Belt Zone	-	Badeggi (National Cereals Research Institute)
South East Zone	-	Umudike (National Root Crops Research Institute)
South West Zone	-	Ibadan (Institute of Agricultural Research and Training)
South South Zone	-	Benin (Nigerian Institute for Oil Palm Research)

Extension specialists, soil scientists agronomists, and other agricultural research scientists, the National Fertilizer Demonstration Centre (Coordinating fertilizer research on crops), students, as well as others who require information on fertilizer use, will find this monograph very useful as a good reference book. Agricultural agencies such as ADPs, River Basin Authorities and large scale farmers will also find the monograph very useful. Attempts to cover a wide range of crops notwithstanding, gaps in knowledge are also highlighted in this work. It is hoped that these will serve as good guides for Universities and Research Institutions in formulating research proposals.

The Committee gratefully acknowledges the approval and support of the Honourable Minister of Agriculture and Rural Development, Dr. Akin Adesina, Honourable Minister of State for Agriculture and Rural Development Dr. Bukar Tijani and the Permanent Secretary, Dr. Ezeikel Omowunmi. Also worthy of mention is the continuous encouragement given by the Ag. Director, Federal Fertilizer Department (FFD) Mr. A. Osho and to make the review a reality.

Finally, I thank colleagues and members of the team who worked tirelessly to make the project a resounding success.

Prof. Victor Okechukwu Chude
Chairman
Review Committee

CHAPTER ONE

1.0 INTRODUCTION

1.1 Historical Account of Fertilizer Use

As in most parts of tropical Africa, the traditional method of maintaining soil fertility and productivity in Nigeria has, hitherto, been the bush-fallow system whereby arable land is allowed to revert to fallow after 3 - 4 years of continuous cultivation. The system evolved out of natural exigencies and the degree of regeneration of soil fertility is generally dependent on the length of the fallow period, which, in turn, is related to the availability of land. In view of growing human population and other socio-economic pressures, attempts were made to shorten the fallow period from about 7 - 10 years to 2 - 3 years by planting leguminous and grass fallows. Although it was clearly demonstrated that soil fertility could be effectively maintained in this way, its acceptance by the peasant farmer was hampered by the tedium of land preparation with native hoes and the economics of the practice; it was not an easy task convincing a farmer to adopt a system that included unproductive fallows.

The next historical development was to replace the fallow system with the use of manures particularly where there were large numbers of animals. This brought into eminence the agricultural value of Farm Yard Manure (FYM), including poultry dropping, dung and house-hold refuse. By the late 1940s the benefits of FYM had been so established that penning of cattle on the farm and mixed farming were being actively encouraged by the Nigerian Government.

However, with agriculture becoming more and more intensive, coupled with the introduction of higher-yielding and more nutrient demanding crop varieties, it became obvious that FYM could not be obtained in sufficient quantities to meet the farmers' demand. Even where available, transportation problem and labour costs (unavoidably) limited its use on a routine basis. In the circumstance, attention was turned to mineral fertilizers as the alternative.

The first recorded indication of the potential values of inorganic fertilizers in Nigeria was in 1937 when it was shown that response of cereal crops to small applications of FYM was matched by the use of Single Super-phosphate (SSP) containing quantities of phosphate equivalent to that in the organic manure.

The need to apply mineral nutrient elements to depleted soils to resuscitate plant productivity heralded the birth of series of fertilizer experiments on the response of crops to elements such as nitrogen, phosphorus and potassium (NPK) by indigenous soil scientists pioneered between 1950 and 1970 by B. O. E. Amon, S. A. Adetunji, S. A. Ekwebelam, B. A. Enyi, S. A. A. Fayemi, W. O. Enwesor, D. M. Ekpete, A. A. Agboola, F. O. C. Ezedinma, Late O. E. Jaiyebo and a host of others in various parts of Nigeria. These contributions marked the beginning of fertilizer consumption in the country. Fertilizer consumption figures date back to the late 1930s while actual usage by farmers did not commence until the late 1940s when the West African Oil Seed Mission recommended the supply of phosphate fertilizers to boost groundnut production.

1.2 Natural Resources

As outlined in Ojanuga (2006), Nigeria spreads over some 92 million hectares of land stretching from its Atlantic coast near the equator to 14 degrees north. The country enjoys a high potential to produce agricultural commodities due to a combination of favourable climatic conditions, undulating topography, and soils amenable to cultivation. Some 72 million hectares (78 percent) of the total land area are considered suitable for crops.

Annual rainfall decreases Northwards from 4000 mm close to the equator to 500 mm in the Northeast. It is uni-modal close to the equator and in low rainfall areas above 9 degrees, and bi-modal in areas receiving 1250 to 1500mm between latitudes 4 and 9 degrees North (FAO 1984). The annual distribution is erratic in 6 out of 10 years, and a pronounced dry season ranging from 3 to 8 months occurs from the high rainfall areas in the South to the driest areas in the North. The benefit of high rainfall is attenuated by high evapotranspiration of the order of 1400 to 1500mm. High evapotranspiration, erratic rainfall and soils with relatively low moisture holding capacity (characteristic of many soils in Nigeria) combine to increase the likelihood of soil moisture deficits during cropping thereby raising production risks faced by farmers.

The country benefits from uniformly high temperatures throughout the year. Mean annual temperatures range from 25 to 33 degrees Celsius and never fall below 18 degrees in any month indicating the tropical nature of the climate. Vegetation varies from tropical forest in the Southeast through moist Guinea savannahs to dry Sahel savannah in the Northeast.

Nineteen Agro Ecological Zones (AEZs) have been described based on physiographic, agro climatic and soils (including soil moisture regimes) criteria (Ojanuga, 2006). These zones are shown in Figure 1 below.

In none of these nineteen AEZs has agricultural potential been met due to a number of sometimes interrelated reasons including:

- underutilization of arable land,
- decline in soil fertility and productivity resulting from ongoing soil nutrient mining and practices which reduce soil organic matter content leading to soil loss and degradation (e.g. erosion), and
- small land holdings farmed by aging, resource poor farmers who produce mainly for own consumption and are limited in their means to progress towards high input, market oriented agriculture.

It is estimated that approximately 38 million hectares are currently cultivated. This represents about 53 per cent of total land area suitable for cultivation under current level of crop production technology as estimated from the vegetation and land use map (FORMECU, 1995 in Ojanuga, 2006). Furthermore, levels of productivity are low and decreasing with farmers achieving approximately one third of attainable yields. There is thus considerable scope to increase production through area expansion of harvested land and through more intensive land use.

Possibilities for area expansion and cropping intensification under rainfed conditions were assessed in all AEZs using criteria including land availability and suitability (soils and climate), land use intensity, population density and economic considerations such as land preparation costs (Federal Ministry of Agriculture and Water Resources, Federal Fertilizer Department, 2006b). As shown in Table 2 this information was used to group AEZs into *high, medium and low* categories according to their propensity for area expansion and intensification.

Figure 1: Agro Ecological Zones map of Nigeria

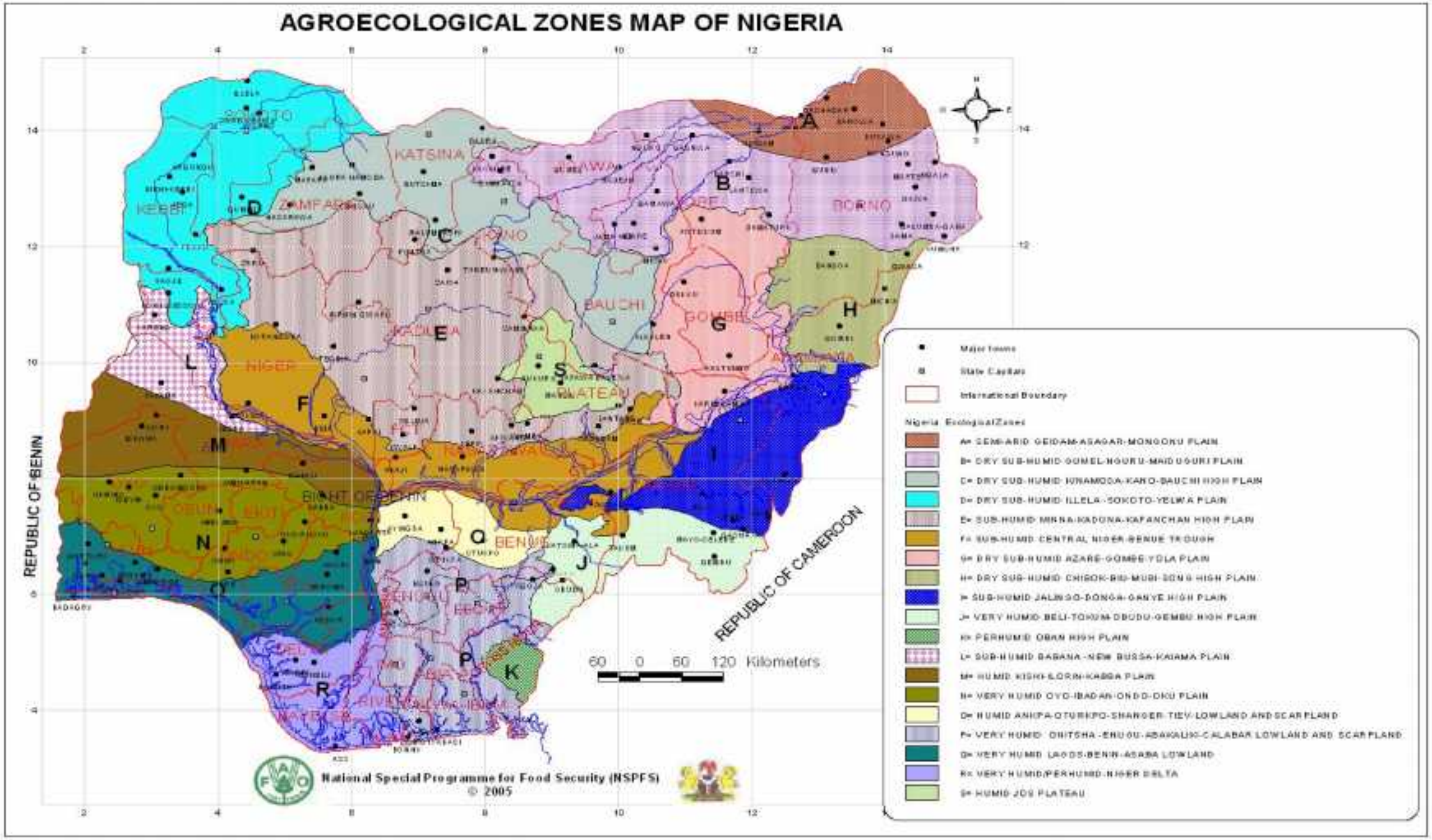

Fig. 1.1 Major Vegetation/Agro-ecological zones of Nigeria

A Semi-Arid Geidam-Asagar-Mongonu Plain
B Dry Sub-Humid Gumel-Nguru-Maiduguri Plain
C Dry Sub-Humid K/Namoda-Kano-Bauchi High Plain
D Dry Sub-Humid Illela-Sokoto-Yelwa Plain
E Sub-Humid Minna-Kaduna-Kafanchan High Plain
F Sub-Humid Central Niger-Benue Trough
G Dry Sub-Humid Azare-Gombe-Yola Plain
H Dry Sub-Humid Chibok-Biu-Mubi-Song High Plain
I Sub-Humid Jalingo-Donga-Ganye High Plain
J Very Humid Beli-Takum-Obudu-Gembu High Plain
K Peri- Humid Oban High Plain
L Sub-Humid Babana-New Bussa-Kaiama Plain
M Humid Kishi-Ilorin-Kabba Plain
N Very Humid Oyo-Ibadan-Ondo-Oka Plain
O Humid Ankpa-Otukpo-Shanger Tiev Lowland and Scarpland
P Very Humid Onitsha-Enugu-Abakaliki Calabar Lowland and Scarpland
Q Very Humid Lagos-Benin-Asaba Lowland
R Very Humid/Perhumid Niger Delta
S Humid Jos Plateau.

Table 1.1 Ranking of AEZs by potential rainfed agriculture area expansion

Ranking	AEZs	Limiting Factors
High	E, F, G, I, L, M, O, S	Nil
Medium	C, H, J, N, Q	High or low population density, land suitability
Low	A, B, D, K, P, R	Unfavourable agro-climate, land suitability, high population density

Area expansion is possible in all AEZs but is most favoured in AEZs E, F, G, I, L, M, O and S. These AEZs are located in Nigeria's "middle belt" where the grain crop economy of the north and the root economy of the south merge. This middle belt experiences favourable rainfall that sometimes allows two cropping seasons per annum. Relatively low population densities favour the expansion of cultivated land but could limit labour supply. Access to services and output markets may also be a constraint. The main factors limiting area expansion in AEZs ranked *medium* (C, H, J, N, and Q) and *low* (A, B, D, K, P, and R) are high population density, unsuitable land and unfavourable climate.

Production can be intensified in all AEZs. This is likely to occur first in localities within AEZs ranked medium and low where suitable soil and climatic conditions are juxtaposed with densely populated areas, as urbanisation strengthens demand and augments remittances to rural areas. AEZs ranked high hold the greatest natural potential for future agricultural production. However, these zones are sometimes far from big markets and fallow land tends to be found in areas with poor transport links. Strong price signals will be needed to overcome such obstacles and induce increased production. It has been suggested that farmers in highly ranked AEZs should be encouraged to gradually shift from subsistence to commercially oriented production. The first step would be to favour the expansion and consolidation of land holdings, thereby facilitating subsequent adoption of intensive, commercially orientated farming practices (including mechanisation), when future increased demand provides the incentive for this (Federal Ministry of Agriculture and Water Resources, 2006b).

In general, soils in Nigeria have formed from the residues of deeply weathered, complex base rocks and alluvial materials derived from these under humid to dry tropical conditions. A high proportion of soils are amenable to cultivation during the rainy season because of their adequate depth and permeability. The cultivation of some soils is limited by very low water holding capacity while in others, poor permeability and weak root penetration caused by impervious layers or excessive clay content, are a hindrance.

Most soils are highly leached resulting in medium to high acidity, moderate to low cation exchange capacity and base saturation, and low organic matter content. Soil nutrient replenishment from organic and mineral sources is a prerequisite for continuous cultivation of such soils particularly under intensive production.

In accordance with their physical and chemical characteristics described above, virgin soils in Nigeria are characterized by low cation exchange capacity, high acidity and low available levels of nitrogen, phosphorus and potassium. Many soils are susceptible to erosion due to their relatively low nutrient status and organic matter content, and fragile structure. Soil degradation and attendant depressed yields due to nutrient mining, and inadequate soil and moisture conservation practices, has already reached severe proportions in several parts of the country. By removing the protective cover of natural vegetation and surface litter, conventional tillage practices lead to soil structure deterioration, loss of nutrients and erosion.

As in most parts of tropical Africa, the traditional method of maintaining soil fertility and productivity in Nigeria is the bush-fallow system. However, growing population densities and associated factors have shortened the fallow period. Attempts to improve soil fertility by planting legumes and grass fallows, and adding farm yard manure, have been little applied and are inadequate for higher yielding and nutrient demanding crops and production systems. Overall, levels of mineral fertilizer use have been too low to compensate for soil nutrient removal.

Over the past 30 years, cultivated land in Africa has lost an average of 660 kg N/ha, 75 kg P/ha and 450 kg K/ha. This contrasts with average net positive nutrient balances for temperate zones of about 2 000 kg N/ha, 700 kg P/ha and 1 000 kg K/ha for the same period. Nutrient depletion is also the norm in Nigeria where fertilizer use is very low compared with crop requirements. In the savannah areas where soil organic matter is low, it is recommended that applications of 100 to 120kgN, 50 to 60 P2 O5 and 40 to 60 kg K2O are required for a good maize yield. This translates into an average of 190 to 240 kg of nutrients per hectare. However, the average application per hectare is less than 30kg compared to the world average of 85 kg/ha and about 80kg/ha in Kenya (FAO, 1996).

A rough comparison of the quantities of some essential elements (N, P) removed by commonly grown crops in Nigeria with actual fertilizer use in the country, show that applications meet only 5 to 10 percent of biological demand (Federal Ministry of Agriculture and Water Resources, 2006b). A similar exercise showed that in 2000 the amount of fertilizer applied to field crops represented only about 3 percent of the total agronomic requirements (FMARD, 2004 in World Bank, 2005). Rapid and sustainable agricultural growth will not be achieved without increased adoption of purchased inputs to help compensate for crop nutrient removal.

1.3 Nigerian Agriculture

About 90 percent of the total agricultural output is produced by smallholder farmers cultivating between 0.8 to 1.2 hectares in forest areas and 2 to 4 hectares in the savannah areas where land preparation is easier. A large variety of food crops are grown. Roots and tubers dominate in the forest and forest-savannah transitional areas in the South consisting mainly of cassava, yams, cocoyam, and sweet potatoes. Grain crops such as guinea corn, millet, maize, rice and wheat predominate in the Northern savannah areas. Other crops that are important in the diet of Nigerians such as groundnut, melon, beans, soybean, Benin seed, okra and peppers are widely dispersed in the different vegetation zones. Cassava is also grown widely due to its tolerance of a wide range of soils. Cereals account for the largest share of the cultivated area, while roots and tubers contribute the largest share of production due to their much higher yields per unit land area. Cereals dominate in terms of value because they command higher prices.

Agricultural production techniques have remained rudimentary. The use of inputs such as fertilizers and improved seeds is low. The current average application of nutrients per ha of arable land is estimated at 6 kg. The average yields of millet and sorghum, which together account for almost one third of the harvested area, remain virtually unchanged at about 1000 kg per ha. From a food-deficit situation during the late 1970s and early 1980s, Nigeria's agricultural production grew throughout the 1990s to attain self sufficiency in major staples such as maize, sorghum, millet as well as in cassava, yams and cocoyam. Rice production also increased. Over the past 20 years value added per capita in agriculture has risen by less than 1 percent per year. Food production gains have not kept pace with population growth, resulting in rising food imports and declining levels of national food self-sufficiency (World Bank, 2005).

Production gains have come mainly from increases in area planted and not from increases in yield. Yields were increased only for maize and cotton. The supply of unused crop land is unfortunately not inexhaustible. According to satellite data, in 1995 (the most recent year for which reliable data are available) crop land occupied over two-thirds of total land area in nearly one-half of the states (AIAE, 2005 in World Bank, 2005). Today, this must be the case in a higher proportion of states. In many parts of the South, further crop land expansion can only come at the expense of the last remaining dense forest areas. Throughout much of the North, crop production is in serious competition with livestock ranging. Crop land expansion is increasingly taking place on marginal land where yields are lower and crop failure higher. With the supply of unused crop land dwindling, the current agricultural growth strategy based on expanding area planted is clearly unsustainable over the longer term (World Bank, 2005).

Increased aggregate food production has not necessarily translated into improved household food security and nutrition. During the pilot phase of the Nigeria Programme for Food Security (NPFS), it was found that out of a total of 1,718 households in four Local Government Councils of Kano State, 80 percent were food insecure; almost half suffered from temporary food insecurity while 34 percent suffered from chronic food insecurity (FAO, 1996).

Even though it has long been recognised that water is a limiting factor to agriculture especially in the Northern parts of Nigeria, less than ten percent of the countries' irrigation potential, estimated at between 2 and 2.5 million ha, has been developed. Irrigation is practised in low rainfall areas (AEZs A, B, C, D, F, G, L) on vegetables, Irish potatoes, rice, maize and wheat in that order. Most irrigation takes place on poorly maintained large scale public schemes which are often only partially operational. Efforts to stimulate small scale irrigation mostly of the fadama type have been more successful. Irrigated production contributes little to overall output other than for wheat and vegetables for which it is anticipated that the contribution could reach approximately 24 per cent by 2030.

In recent years the farming population has aged, reflecting the migration of youth to the rapidly expanding urban economy where services are better than in rural areas. Smallholder or subsistence agriculture is unattractive for the youth. The steady out-migration of younger workers to urban centres has deprived the agricultural sector of labour, creating the paradox of rural labour shortages in a labour-surplus economy (World Bank,2005).

Fertilizer use declined drastically from 1993 to 1997 following the sudden disengagement by government from fertilizer importation under the liberalization policy. In 1999/2000, only 200,000 tonnes of fertilizer were used, as compared to the 506,000 tonnes in 1993/94 the highest annual consumption on record. This scenario lasted till 1999 when government restored a 25 percent fertilizer subsidy under the market stabilisation programme. Since then there has been a slow and erratic upward trend in fertilizer use. In spite of the growth in fertilizer consumption since independence, Nigeria still ranks among the lowest users of fertilizer in the world in terms of fertilizer nutrients per hectare. The need for Nigeria to intensify fertilizer use, improve agricultural production and productivity, and raise rural income in the face of a rapidly growing population and worsening poverty incidence is obvious.

1.3.1 Fertilizer demand projections

Fertilizer use derives from the demand for agricultural commodities; thus a high effective demand for agricultural commodities is the primary driving force for farmers fertilizer use. Therefore the sequence of steps involved in projecting fertilizer demand starts with future demand estimates for food and fibre followed by demand projection for fertilizer use. These steps are presented for the two alternative approaches to commodity projection outlined in the methodology.

Effective demand approach

The underlying assumption is that two exogenous driving forces for changes in future demand for agricultural commodities (food and fibre) are population growth and disposable income (ceteris paribus). Therefore UN population growth and World Bank per capita GDP projections are used to estimate future agricultural commodity demand (Table 3).

Table 1.2 Assumptions made to estimate future agricultural commodity demand

Nigeria	2000	2015	2030	2000-2015	2016-2030
GDP (million USD)	38 437	69 570	127 111	4.0%	4.1%
Population ('000)	114 750	161 726	206 696	2.3%	1.6%
Labour force ('000)	51 055	77 804	106 602	2.8%	2.1%
Agricultural labour force ('000)	15 150	13 972	12 010	-0.5%	-1.0%
Diet, per capita calorie per day	2 747	2 997	3 099	0.6%	0.2%

This approach leads to effective demand as predicated on consumers' ability to pay for new commodity output based on the income they earn in future. To arrive at final demand, a food supply utilization account for Nigeria made up of 24 commodities used for food, raw materials, feed and seed, and including estimated post harvest losses, was used. Final demand was then adjusted for respective commodity imports and exports. In this regard it was assumed that self sufficiency ratios for these commodities during the projected periods to 2015 and 2030 will be little different from the self sufficiency ratios computed for the base year 2000 (average 1999-2001)1. This means that specific policy measures that may influence commodity imports and exports are not taken into account. Such measures and their possible impact would be very difficult to forecast and are considered beyond the scope of this study. The final demand computed in this manner is taken as being equivalent to the total output which has to be provided through domestic production.

The production growth requirements show that over 90 per cent increase in demand is attributable to population growth and the remainder to dietary changes. The results obtained show that considerable effort will be required to meet future food demand through domestic production if Nigeria is to maintain its food self sufficiency at a level similar to that in the base year 2000.

Highest production growth will have to be realised for wheat and Irish potatoes. However, the total output for both these crops is low and could thus be imported particularly in the case of wheat. A far greater challenge, which also holds implications for food security in Nigeria, will be to sustain annual production growth rates (albeit at lower levels) of major cereals such as maize, millet, sorghum and rice. Implementing policy measures effectively will be difficult because of large volumes, large production areas mainly under extensive conditions, and the high number of producers involved.

Other important staples due to their large output are cassava and sweet potatoes. But, in both cases, lower production growth rates will be required to meet dietary intake requirements. Due to growing urbanisation and improving diets, relatively high rates of production growth will be required for fruits and vegetables both of which involve large outputs. Pulses and oils constitute an important part of the national diet, but represent lower though challenging, volumes of projected production and associated growth rates, (Table 4).

Table 1.3 Commodity production projections, '000 tonnes

Nigeria	Demand			SSR			Production			Growth %	
	2000	2015	2030	2000	2015	2030	2000	2015	2030	2000-2015	2016-2030
Wheat	2 086	3 425	4 784	0.04	0.04	0.05	75	137	235	4.1	3.7
Rice	4 793	7 130	10 001	0.65	0.58	0.55	3 109	4 118	5 484	1.9	1.9
Maize	4 742	6 627	8 338	1.00	0.97	0.97	4 734	6 404	8 108	2.0	1.6
Millet	5 853	8 668	11 343	1.00	1.00	1.01	5 865	8 708	11 443	2.7	1.8
Sorghum	7 442	10 685	13 401	1.00	0.99	0.99	7 437	10 628	13 332	2.4	1.5
Other cer.	97	135	162	0.78	0.69	0.69	76	93	112	1.4	1.2
Potato	591	1 093	1 801	1.00	1.00	1.00	590	1 089	1 795	4.2	3.4
S. potato	28 613	28 585	28 198	1.00	0.99	0.99	28 613	28 299	27 916	-0.1	-0.1
Cassava	32 432	43 041	53 347	1.00	0.99	0.99	32 431	42 669	52 914	1.8	1.4
Other roots	3 877	5 196	5 629	1.00	0.99	0.99	3 877	5 155	5 586	1.9	0.5
Plantain	1 957	2 665	3 156	1.00	1.00	1.00	1 957	2 664	3 156	2.1	1.1
Sugar	1 056	1 684	2 457	0.07	0.06	0.06	694	1 064	1 681	2.9	3.1
Pulses	2 194	3 331	4 657	1.00	1.00	1.00	2 193	3 331	4 657	2.8	2.3
Vegetables	7 924	12 514	17 425	0.99	0.99	0.99	7 855	12 443	17 325	3.1	2.2
Citrus	3 248	4 926	6 515	1.00	1.00	1.00	3 247	4 926	6 515	2.8	1.9
Fruit	13 780	23 367	31 730	0.99	1.00	1.00	12 538	23 303	31 614	4.2	2.1
veg. Oil	2 324	3 596	4 871	0.96	0.89	0.91	2 232	3 185	4 455	2.4	2.3
Cocoa	122	141	150	2.46	2.56	2.66	301	361	400	1.2	0.7
Coffee	5	11	16	0.75	0.43	0.31	4	5	5	0.8	0.7
Teas	7	10	12	0.00	0.00	0.00					
Tobacco	14	23	44	0.61	0.57	0.46	8	13	20	3.1	2.9
Cotton	146	250	350	1.01	1.00	1.00	147	250	350	3.6	2.3
Fibres	1	2	1	0.88	1.00	1.00	1	1	1	0.0	0.0
Rubber	73	100	150	1.47	2.00	2.00	107	200	300	4.2	2.7

Demand = food + industrial use + feed + seed + waste

SSR = self sufficiency ratio

Policy driven approach

The policy driven approach assumes that commodity demand is given within the period of projection; i.e. 2007-2016 and meets production targets established in compliance with the government adopted goal of doubling agricultural production within 10 years; i.e. an a compounded average annual output growth rate of 6%. The results are presented below.

Table 1.4 Commodity production projections '000 tonnes

	Maize	Rice	Sorghum	Wheat	Groundnut	Cassava	Yam
2007	5 028	3 479	8 192	78	3 007	36 160	27 872
2016	8 495	5 878	13 841	132	5 080	61 092	47 090

Fertilizer demand estimates

The methods followed for estimating fertilizer demand to support crop production projections carried out above are distinct as follows. The *effective demand* approach uses a sources-of-growth model in deriving fertilizer demand estimates to achieve concomitant yields. The *policy driven approach* employed an input-requirement model for yields that would lead to production levels based on the established growth target. Both methods are inherently different with respect to structural elements and underlying assumptions; consequently the ensuing estimates are different.

"Sources of growth" model

Three sources of production growth of crop commodities are considered; area expansion changes in cropping intensity and yield growth. Arable land expansion is projected to grow at less than one percent per year between 2000 and 2030; the total harvested land is projected to grow at a slightly higher pace as the result of irrigated land expansion and the further reduction of fallow land in cropping systems. The current cropping index (harvested land in relation to arable land) of 92 percent will thus increase to about 95 percent in 2030 reflecting the availability of potentially arable land (Table 6).

Table 1.5 Area and Cropping Index

Nigeria	2000	2015	2030	Annual growth	
				2000-2015	2016- 2030
Total harvested land ha	43 637	49 895	56 352	0.9%	0.8%
Arable land ha	47 742	53 265	59 545	0.7%	0.7%
Cropping Index	91	94	95	0.2%	0.1%

Yield growth has been analyzed using the agro-ecological zones in the country. Yield growth projections were made by respecting yield potentials for different crops in the different agro-ecological zones where they are grown and by considering realistic progress in adopting improved crop production technology. Highest yield growth (greater than 2 percent per annum till 2030) will have to be achieved for rubber pulses Irish potatoes and oil palm all relatively low total output crops (Table 3). A greater challenge will be to achieve medium yield growth (1 to 2 percent per annum till 2030) for high output food crops such as cereals cassava fruit and vegetables. Such yield growth is considered perfectly feasible from an agro-ecological point of view. Because of its extensive production system projected increased production of cassava could probably all come from area expansion if the envisaged yield growth cannot be realised.

A distinction is made between the respective contributions of rain fed and irrigated land to production growth between 2000 and 2030. Contributions to production growth under rain fed agriculture come from the following sources; area expansion 32 percent yield increases 62 percent and increased cropping index 6 percent. The relative contributions to production growth under irrigated farming are; area expansion 8 percent yields 61 percent and cropping index 31 percent (Table 7). This implies more intensive utilisation of irrigation facilities deemed possible given the current low efficiencies in this sub-sector. While the relative contribution of irrigated agriculture to total output is presently low it is projected to improve somewhat due to anticipated irrigated output increasing for vegetables rice and Irish potatoes till 2030.

Table 1.6 Sources of production growth %

	2000-2015	**2016-2030**	**2000-2030**
Rainfed land			
Land	26	42	32
Yields	68	54	62
Cropping index	6	4	5
Irrigated land			
Land	9	8	8
Yields	60	62	61
Cropping index	32	30	31

The above data show a fundamental difference between expected sources of production growth under rainfed and irrigated agriculture; namely area expansion in the former and more intensive land use (higher cropping index) in the latter. The contribution from yield increases is almost identical for both production systems. In Nigeria land is available for expanding rainfed agriculture but is relatively limited for irrigation. The concomitant crop yield projections to meet production projections are presented in table 8.

Table 1.7 Area ('000 ha) yield (t/ha) and production('000 tonnes) projections

Nigeria	2000			2015			2030			annual yield growth %	
	AREA	YIELD	PROD	AREA	YIELD	PROD	AREA	YIELD	PROD	2000-2015	2016-2030
Wheat	46	1.63	75	66	2.06	137	99	2.36	235	1.60	0.90
Rice	2 199	1.41	3 109	2 366	1.74	4 118	2 566	2.14	5 484	1.40	1.40
Maize	4 002	1.18	4 734	4 590	1.4	6 404	5 293	1.53	8 108	1.10	0.60
Millet	5 757	1.02	5 865	7 099	1.23	8 708	8 233	1.39	11 443	1.30	0.80
Sorghum	6 832	1.09	7 437	8 115	1.31	10 628	9 067	1.47	13 332	1.20	0.80
Other cer.	137	0.55	76	155	0.60	93	174	0.64	112	0.60	0.40
Potato	126	4.68	590	166	6.55	1089	210	8.56	1 795	2.30	1.80
S. potato	3 168	9.03	28 613	2 849	9.94	28 299	2 580	10.82	27 916	0.60	0.60
Cassava	3 177	10.2	32 431	3 182	13.4	42 669	3 196	16.56	52 914	1.80	1.40
Other root	584	6.64	3 877	673	7.65	5 155	701	7.97	5 586	0.90	0.30
Plantain	283	6.92	1 957	367	7.26	2 664	422	7.48	3 156	0.30	0.20
Sugar	24	29.3	694	34	31	1064	50	33.72	1 681	0.40	0.60
Pulses	5 209	0.42	2 193	5 399	0.62	3 331	5 619	0.83	4 657	2.60	2.00
Vegetables	1 363	5.76	7 855	1 733	7.18	12 443	2 051	8.45	17 325	1.50	1.10
Citrus	730	4.45	3 247	812	6.06	4 926	880	7.40	6 515	2.10	1.30
Fruit	1 415	6.87	12 538	1 947	12	23 303	2 480	12.76	31 614	3.80	0.40
Oil crops	230	1.61	369	311	1.85	574	412	2.12	872	0.90	0.90
Oil palm	3 087	0.38	1 166	3 094	0.51	1 568	3 104	0.67	2 068	2.00	1.80
Soybean	584	0.73	425	755	0.84	634	955	0.97	929	0.90	1.00
Groundnut	2 689	1.05	2 826	3 708	1.15	4 248	4 959	1.26	6 259	0.60	0.60
Sesame	149	0.48	71	198	0.53	106	256	0.60	154	0.70	0.80
Coconut	36	4.45	160	43	4.75	204	50	5.06	254	0.40	0.40
Cocoa	892	0.34	301	601	0.60	361	667	0.60	400	3.90	0.00
Coffee	7	0.55	4	8	0.55	4	9	0.56	5	0.00	0.10
Tobacco	22	0.36	8	27	0.49	13	32	0.63	20	2.10	1.70
Cotton	531	0.74	394	742	0.91	672	908	1.04	940	1.40	0.90
Fibres	1	0.92	1	1	1.17	1	1	1.10	1	1.60	-.40
Rubber	320	0.33	107	355	0.56	200	386	0.78	300	3.60	2.20

Table 1.8 Fertilizer consumption tonnes nutrients

	N	P	K	Total
2000	112 011	40 934	37 877	190 822
2015	160 430	60 595	66 390	287 415
2030	219 026	84 476	91 897	395 398

The yield estimation procedure is presented in Annex 1. Thus taking into account the likelihood of and possibilities for output growth through area expansion and intensification fertilizer use will have to approximately double from some 200 000 tonnes of nutrients at present to about 400

000 tonnes of nutrients in 2030 (Table 9) implying an annual increase of approx 2.3 percent over the period 2000 to 2030. Given that fertilizer use in Nigeria has not changed significantly since 2000 (Figure 2) this translates into an annual increase of approximately 3.2 percent for the period 2008 to 2030. Further delays in increasing fertilizer use will result in higher more challenging annual increases in fertilizer use.

The outcome of the calculation is that crop fertilizer use is projected to double from about 200 000 nutrient tonnes of fertilizer in 2000 to some 400 000 tonnes in 2030.

Input requirement model

In this approach fertilizer demand estimates are based on i) recommended rates of application of macronutrients and micronutrients in compound fertilizer formulations for 30 crops considered; and ii) arable land expansion derived from the increased output of crop commodities. The preliminary estimate thus arrived at assumes that all farmers will use the recommended fertilizer application on all their arable land for the 30 crops. And based on historic experience the final estimate is arrived at by assuming one third of the arable land area will receive fertilizer application on account of multiple cropping practices.

Table 10 presents the outcomes of fertilizer demand projection over the selected planning horizon 2007-2016. The potential fertilizer demand for ten years amounts to 34 million MT of nutrients which averages 3.4 million MT of nutrients per annum or 7.9 million MT of fertilizer products per annum. On the other hand the actual demand for ten years amounts to 11.3 million MT of fertilizer nutrients which averages 1.1 million MT of nutrients per annum or 2.6 million MT of fertilizer products per annum.

Table 1.9 Demand projection for fertilizer 2007-2016 '000 tonnes nutrients

	Potential				Actual	
Year	**N**	**P**	**K**	**N+P+K**	**N+P+K**	**Products**
2007	1 171	704	705	2 580	860	2 004
2008	1 241	746	747	2 735	912	2 124
2009	1 316	791	792	2 899	966	2 252
2010	1 395	839	840	3 073	1 024	2 387
2011	1 478	889	890	3 257	1 086	2 530
2012	1 567	942	944	3 453	1 151	2 682
2013	1 661	999	1 000	3 660	1 220	2 843
2014	1 761	1 059	1 060	3 879	1 293	3 013
2015	1 866	1 122	1 124	4 112	1 370	3 194
2016	1 978	1 190	1 191	4 359	1 453	3 386
Annual average				3 401	1 134	2 642

1.3.2 Geographic indication of projected fertilizer demand

Knowing where future demand for fertilizer is likely to materialize geographically would help plan distribution and assist strategy preparation. Based on the effective demand approach an approximate indication of the probable location of anticipated demand was derived from projected fertilizer use for major crops and the AEZs in which these crops are most likely to be produced. This is shown in Table 11 which includes projected production in 2030 for selected crops (from

Table 7) projected fertilizer use by these crops for 2030 and the distribution of this use per AEZ.2 Fertilizer use per AEZ was extrapolated from projected crop production for these AEZs (Table 8). Considering the fertilizer demand projections developed above it is realistic to assume that total agro-ecological zones' fertilizer consumption would be proportional to total national consumption projection (Table9 Table 10).

Table 1.10 Projected crop production and fertilizer use for selected crops in Nigeria according to agro-ecological zones (2030)

	Crop production '000 tonnes	Fertilizer use tonnes	Dry semi-arid	Moist semi-arid	Sub-humid	Humid	Fluvio soils/ gley soils
Crop							
Rice	5 484	35 220			3 170	1 056	30 994
Maize	8 108	102 808		18 505	76 078	8 225	
Millet	11 443	42 907		15 875	11 585	858	10 298
Sorghum	13 332	39 829	4 291	5 974	27 479	398	3 584
Sweet potato	27 916	765	2 389	176	467	15	107
Irish potato	1 795	775		141	598	36	
Cassava	52 914	29 317		1 759	20 522	7 036	
Other roots	5 587	19 748		5 135	10 466	395	3 752
Vegetables	17 325						
Fruit	31 614						
Groundnuts	6 259	22 505	675	11 477	10 127	225	
Soybeans	110	10 774		5 448	7 326		
Cotton	940	25 900		6 734	19 166		
Pulses	4 657	21 896	2 190	7 883	10 948	219	656
Total	82%[1]	357 584	9 545	79 107	197 932	18 463	49 391
			3%	22%	56%	5%	14%

[1] Crop-fertilizer use of fourteen selected crops as percentage of projected consumption (2030) shown in Table 8.

Total projected production for the eight major tradable food crops (rice maize millet sorghum sweet potatoes cassava vegetables and fruit) is 82% of total projected production for the 28 crops included in Table 8. Anticipated fertilizer use for these crops excluding fruit and vegetables is 90% of projected fertilizer use for the 28 crops. Given that reasonable amounts of fertilizer are used particularly for vegetable production it can thus be assumed that most of the anticipated fertilizer use in 2030 will be primarily applied in sub-humid regions.

While these major food crops are grown in varying quantities in most parts of Nigeria a good indication of where they are mainly produced can be derived from the description of the countries' AEZs and the main crops grown in these AEZs (section 4). By matching estimates of anticipated fertilizer use in the five AEZs shown in Table 11 with production conditions in the nineteen AEZs described in Figure 1 projected fertilizer use in 2030 in the three categories of AEZs shown in Table 2 will be for 65% in the class high for 25% in the class medium and for 10% in the class low.

Any fertilizer strategy should consequently focus improved distribution mainly in AEZs E F G I L M O S (high) followed by C H J N Q (medium) and then A B D K P R (low) as shown in Figure 1 and Table 2. This broad geographic estimate should not prevent localised high fertilizer use in any of the preceding AEZs resulting from higher than average demand from green belts around cities and towns and irrigation schemes.

1.4 Major Nigerian Soil Groups and Agriculture

A major difficulty encountered in discussing soils in Nigeria is that their description so far has neither been based on a uniform classification nor on a standardized scale. Until the recent setting up of the National Soil Correlation Committee and the subsequent creation of the Federal Department of Agricultural Land Resources, different workers or groups of workers have tended to concentrate their efforts in different areas of the country.

1.4.1 Soil Resources of the Northern Nigerian Savanna Region

Four major soil types occur in the Nigeria savanna region (Fig. 1.2). These are Entisols/Inceptisols, Alfisols, Ultisols, and Vertisols (USDA Soil Survey Staff 1975) or Regosols and Cambisols (FAO/UNESCO, 1974). Oxisols are also present but on a much smaller scale and restricted only to the southern-most fringes of the region. The main characteristic features of these various soils may be summarized as follows:

(i) Entisols and Inceptisols

These are recently formed (young/immature) sandy, well-drained shallow soils with weak profile development or differentiation and little or no distinct horizons. They are derived primarily from recent aeolian deposits and are almost always low in organic matter, available phosphate and CEC. Their weak profile development is as a result of the inter-play of three factors viz: the sandy nature of the parent materials, the dry or semi-arid climatic conditions and the constant deposition of recent alluvial materials through fluvial processes. These three factors have given rise to three main sub-orders within the Entisol Order and they include the Psamments, Orthents and Fluvents.

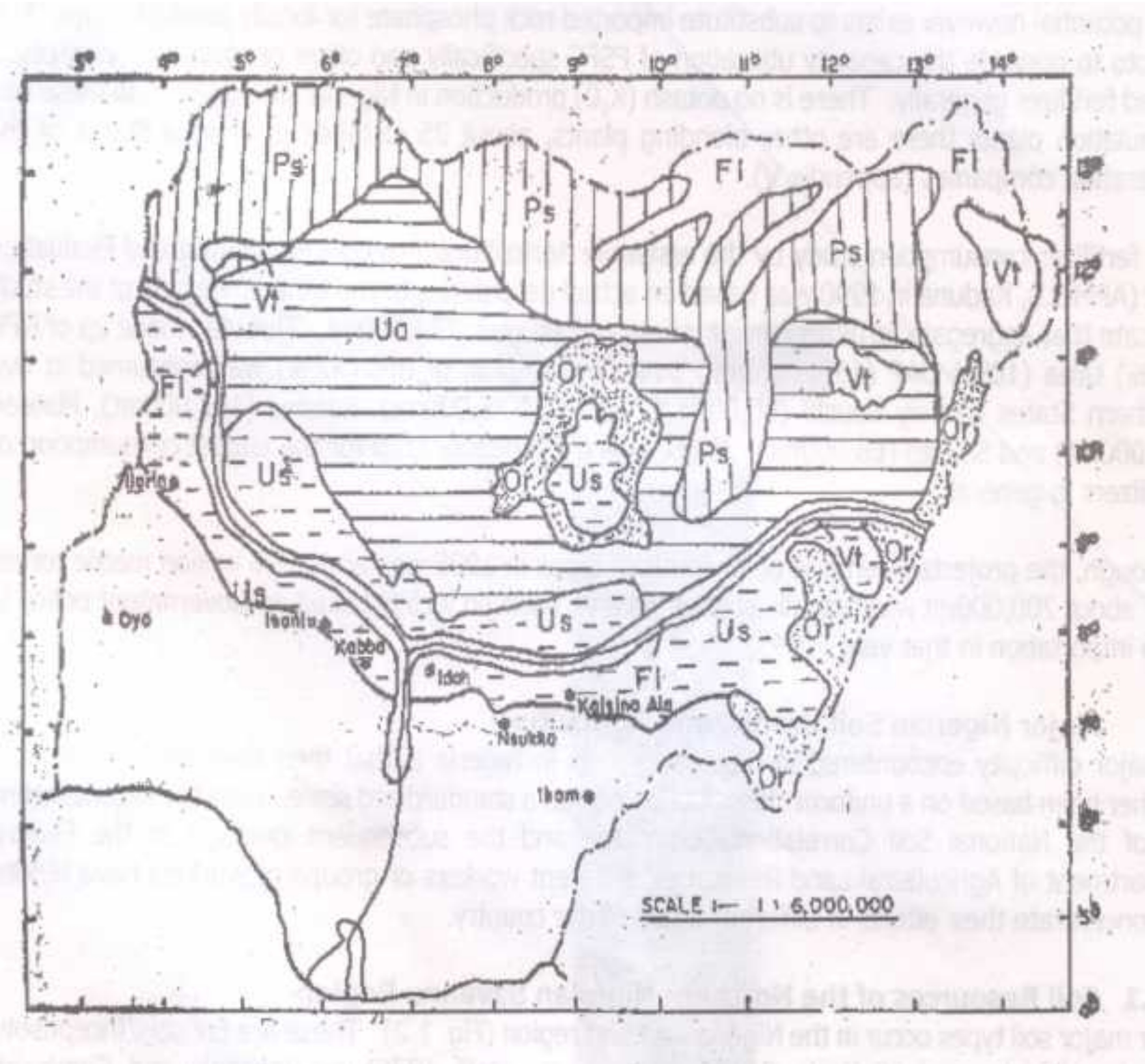

Fig. 1.2 Soil Resources of Northern Nigeria

ENTISOLS - *RECENTLY FORMED, WEAKLY DEVELOPED SOILS*

- Psamments - very sandy, droughty soils
- Fluvents - recently deposited alluvial soils
- Orthents - very shallow and rocky soils

ALFISOLS	-	*MODERATELY WEATHERED AND LEACHED, HIGH BASE STATUS SOILS*
	-	Ustalfs - reddish - brown, high base status soils sometimes associated with plinthite
ENTISOLS	-	*STRONGLY WEATHERED AND LEACHED, LOW BASE STATUS SOIL*
	-	Ustults - reddish - brown, low base status soils with plinthite
VERTISOLS	-	*SHRINKING AND SWELLING DARK CLAY SOILS*
	-	Usterts - dark coloured, cracking clay soils with ustic soil moisture regimes
OXISOLS	-	*INTENSIVELY WEATHERED AND HIGHLY LEACHED IRON RICH*
	-	Ustox - reddish highly weathered sesquioxidic soils with ustic soil moisture regime

Psamments (USDA) or Regosols (FAO/UNESCO): are the very sandy soils occurring mainly in the Sudan and Sahel Zones (Northern Borno, Kano, Katsina and Sokoto States). Millet, sorghum, groundnuts, cowpeas and cotton are the major crops grown in these areas.

Fluvents (USDA) or *Fluvisols* (FAO/ UNESCO): These are hydromorphic soils formed from recently deposited sediments on flood plains of rivers and streams. They have fluctuating water-table and are locally termed "Fadama" soils. They are generally very fertile although naturally limited in extent, being mainly associated with rivers but are very popular for dry season cultivation of vegetables as well as the growing of sugar cane and paddy rice when flooded.

Orthents (USDA): are very shallow and rocky soils. They are often associated with hills and mountains or recent erosional surfaces. The erosion may be geologic or may have been induced by cultivation or other factors, but any former soil that existed has been completely removed or so truncated that diagnostic horizons for all other orders are absent. A few orthents are in recent loamy or fine aeolian deposits, in debris from recent landslides and mudflats and in recent sandy-skeletal alluvium.

ii *Alfisols (USDA) or Luvisols* (FAO/UNESCO, 1974): These are generally slightly or mildly acid, less leached soils derived from Pre-Cambrian crystalline Basement Complex rocks and found mainly in the Guinea and Derived Savanna Zones (with rainfall averaging about 1,600mm). They are generally coarse-textured soils with pH (H_20) ranging from 5.5 to near 7.0. Organic matter content in the surface soils is generally low and total N content rarely exceeds 0.1%; available phosphate is also low, often less than 10ppm but the soils are generally moderate in exchangeable cations. The dominant clay mineral is kaolinite; therefore cation and water retention capacities are low. The CEC is also often very low usually falling below 5me/100g of soil. The soils are generally poorly structured in the plough layer and so the bulk density tends to rise rather rapidly after cultivation thereby impeding root development.

iii) *Ultisols (USDA) or Acrisols (FAO/UNESCO):* The ultisols are basically similar to the Alfisols but are much more developed, weathered and leached than the Alfisols. Consequently, they posses a much lower base status than the latter. The organic matter content and cation exchange capacity are low and reflect the Kaolinitic and oxide clay mineralogy. Extractable aluminum levels in the soils are generally high, making the soils to be rather acidic and nutrient improverished.

The Ultisols in northern Nigeria are developed on the Nupe sandstone in Niger State, while some are developed on metamorphic rocks like the Keffi area of Nasarawa State.

iv) *Vertisols:* These are heavy, cracking clayey soils with more than 35% clay and a high content of expanding clay minerals. They shrink and swell with changes in moisture contents and occur mainly in north eastern Nigeria within Borno, Gongola and Bauchi States as well as in some parts of Sokoto and Plateau States.
The soils are high in cations notably Ca, Mg and K but are generally low in organic matter N, P and micronutrients. The soils are capable of supporting profitable production of wheat, rice, cotton and sorghum, but problems associated with tillage, poor drainage, flooding and erosion militate against their large-scale utilization.

All the vertisols in Nigeria are Usterts which are equivalent to Pellic and Chromic Vertisols in the FAO/UNESCO system.

v) *Oxisols (USDA) or Nitosols (FAO/UNESCO):* These are extremely weathered and leached soils which consist of mixtures of kaolinite, iron oxides and quartz. The soils are deep, well drained and reddish in colour with excellent granular structure. They posses very low fertility status and are generally associated with the practice of shifting cultivation.

The soils are the least extensive in northern Nigeria and are restricted to the most southern tip of the region in the Ankpa area, where the rainfall is unusually high (averaging about 1,800mm per annum).

1.4.2 Soils of South-Eastern Nigeria

The soils of south-eastern Nigeria may be conveniently divided into 5 classes based on their morphology and the degree of profile development (Fig. 1.3 and mapping unit (Table 1.1)

(i) *Entisols-Orthents (USDA) or Regosols (FAO/UNESCO):* These are shallow and stony soils on steep slopes where profile development is retarded due to erosion. They are formed over resistant rocks (Fig. 1.3, Unit A) and sandy or silty (Unit B). Although they are relatively fertile soils, the steep topography is a limiting factor in their utilization.

(ii) *Entisols-Fluvents (USDA) or Fluvisols (FAO/UNESCO):* Young soils Derived from Recently Deposited Materials: These soils are without well developed horizons and are derived from recent alluvium deposited by river or sea water and are sub-divided into (Fig. 1.3)

a) Soils of fresh water swamps (Unit C)
b) Soils of salt water swamps (Unit D) and
c) Soils of the beach ridges (Unit E)

Most of the soils are uncultivated at the present but some River Basin Authorities are utilizing some areas for rice production.

(iii) *Alfisols/Ultisol (USDA) or Luvisols/Acrisol: (FAO/UNESCO)*: Ferruginous- These are soils rich in free iron oxides and with a mineral reserve which may be appreciable. Kaolinite and iron oxides predominate in the clay fraction. The cation exchange capacity is low but the degree of base saturation is relatively high. These soils are formed from basalts (Fig. 1.3, Unit F) and acid crystalline parent materials (Unit G). The soils on basalts have excellent physical properties and are rich in nutrients from the weathered basic rocks. They are the most valuable soils in south-eastern Nigeria and are particularly suited to the production of cocoa, bananas and plantains. Most of the soils are deficient in phosphorus and have high P-retention properties.

(iv) *Ultisol/Oxisols (USDA) or Acrisol/Nitosols (FAO/UNESCO):* Ferralitic Soils: These soils are rich in free iron but have a lower mineral reserve and lower fertility than the Ferruginous Tropical Soils. The cation exchange capacity and base saturation are low. The soils are derived from Basement Complex rock (Fig. 1.3, Unit H), from coastal plain sands. (Units 1 and J) and from various complexes of sandstones and shales on well - drained sites (Unit K). They are of low natural fertility, indicating multiple deficiency (especially those formed on coastal plain sands, due to low mineral reserve and high leaching intensity) and respond well to fertilizer applications. The soils are very acidic. They could be classified as Ultisols/Oxisols.

(v) *Inceptisol (USDA) or Cambisol (FAO/UNESCO):* Hydromorphic Soils. These soils are influenced by seasonal water - logging caused by underlying impervious shales from which they are derived (Fig. 1.3, Unit L). Scattered ironstone concretions are a common feature. The natural fertility of the soils is relatively low, as the shales contain only limited amounts of weatherable minerals. Rice production on these soils has expanded rapidly in recent years. The above classification of soils in south-eastern Nigeria is credited to Jungerius 1964. In recent times a number of attempts have been made to improve on this and classify the soils according to USDA and FAO/UNESCO guidelines. The most recent study was carried out by the Federal Department of Agricultural Land Resources which has produced 45 mapping units for the region. Although, the mapping units are rather numerous, the study shows that most of the agricultural soils are classified as Ultisols (USDA) or Nitosols and Acrisols (FAO/UNESCO). A rough matching of Jungerius (1964) units against those of FDALR is as shown below:

Table 1.11 Soil Mapping Units - Jungerius and FDALR

MAPPING UNITS			CLASSIFICATION SYSTEM
JUNGERIUS (1964)	**FDLAR (1985)**	**USDA (1975**	**FAO/UNESCO (1974)**
A	453	Entisol	Regosol Lithosol
B	437	Entisol	Acrisols
C	401	Entisol	Gleysol
D	440	Entisol	Gleysol
E	439	Entisol	Nitosol/Regosol
F	455	Alfisol/Ultisol	Luvisol/Acrisols
G	453	Utisol/Alfisols	Acrisol/Nitosol
H	453	Ultisol/Oxisol	Acrisol/Nitosol
I/J	431	Ultisol/Oxisol	Acriso/Nitosol
K	414 423 413	Ultisol/Oxisol	Acrisol/Nitosol
L	407	Inceptisol	Cambisol

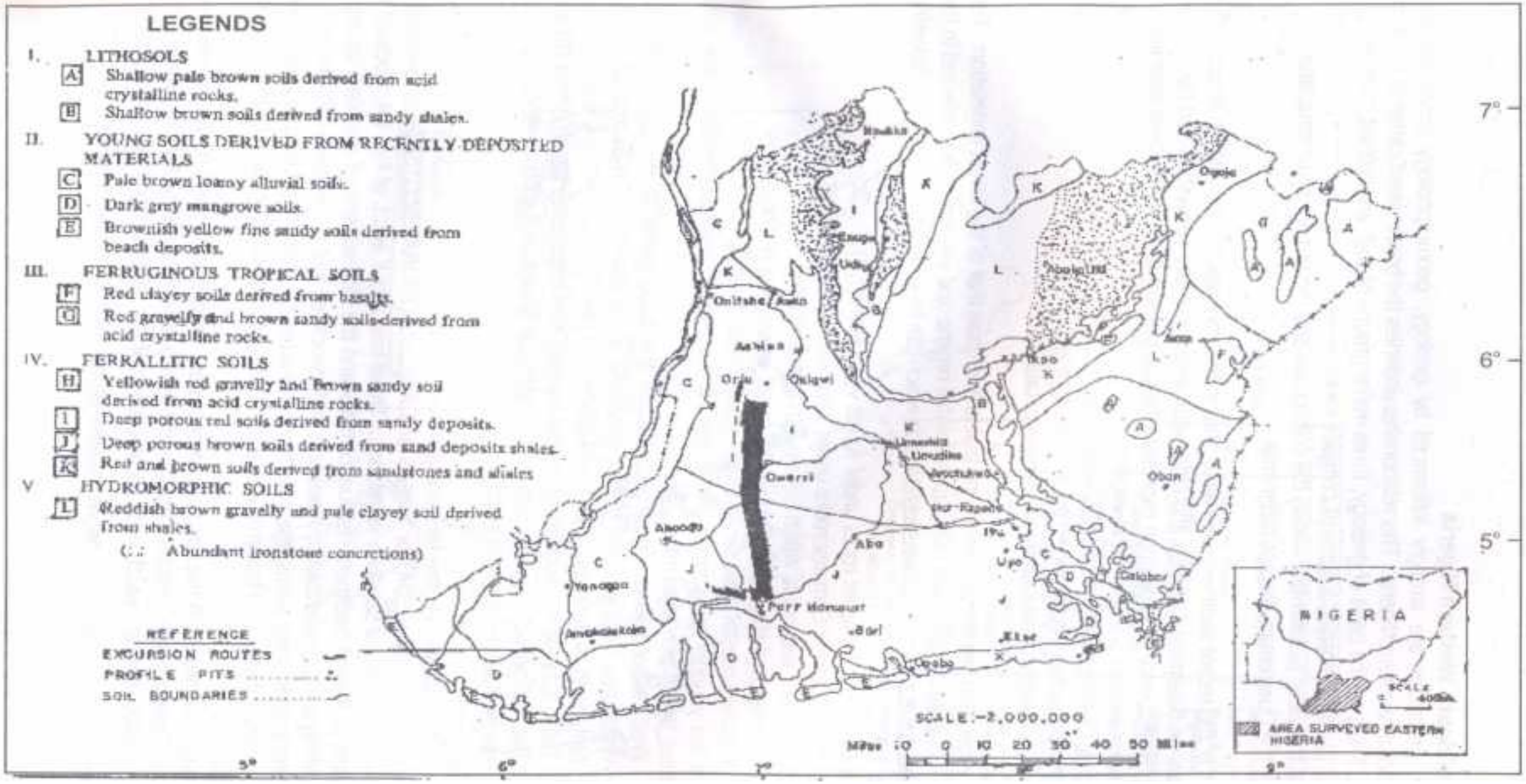

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Fig. 1.3 Soil Resources of South Eastern Nigeria

1.4.3 Soils of South Western Nigeria

Soil formation processes are strongly influenced by geology, geomorphology processes and vegetation in South Western Nigeria. This relationship underlies the broad classification of the soils in the region. Thus, on the basis of geology, three major groups of soils are defined, namely:-

- Soils of the metamorphic basement complex rocks
- Soils of the older sedimentary rocks, the cretaceous and the tertiary sediments, and
- Soils of the Quarternary Recent sediments

While the soils of the recent sediments are all located in the very wet forest southern fringe of the region, the soils on Basement Complex and older sediments have two vegetation and two rainfall zones. Thus, the influence of vegetation expresses itself in the sub-divisions of these soils into:

- Basement Complex soils on forest vegetation
- Basement Complex soils on savanna vegetation
- Soils of sedimentary rocks under forest vegetation and
- Soils of sedimentary rocks under savanna vegetation

The Savanna vegetation has a moisture regime that is drier than that of the forest vegetation. The totality of the influence of geological formations, rainfall regime and vegetation is expressed in the differences among the soils of south-western Nigeria which can be summarized under the following headings (Fig. 1.4):

- Soils of Basement Complex rocks under forest vegetation (I, J)
- Soils of the Basement Complex rocks under savanna vegetation (K, L)
- Soils of the older sediments which can be differentiated into:
  - a) Non-leached shale group under dry forest or savanna (F and G)
  - b) Leached coastal plain sands under moist forest cover (E)
- Soils of the younger quarternary and recent alluvium which are essentially wetland soils. These can be differentiated into:
  - a) Fresh water alluvium that occurs along the flood plains of the Niger before it distributes itself into the deltaic plain and along the major rivers that drain the hinterland of the region into the Gulf of Benin (A)
  - b) The coastal saline mudflats or coastal swamps that include the beach ridges (B) and
  - c) The mangrove swamps, watered by the maze of deltaic distributaries and bathed partly in saline water at high tides (C).

The characteristics of these soils can be summarized as follows:

(i) Alfisols and Entisols (USDA) or luvisols and Regosols (FAO/UNESCO) Soils of Basement Complex Rocks Under Savanna Vegetation. These are units K and L of Fig. 1.4. Located in the north of Ibadan pediment residual complex and the Ekiti watershed complex, savanna zone which are characterized by inselbergs and associated foot of inselberg colluvial rubble and gently undulating plains, the soils have characteristic loamy sand surface layers over more clayey subsoil. The textures vary a great deal according to the rapid changes in rock lithology.

The major soil groups in the Soil Taxonomy system are oxic paleustalfs (Owutu series) and Typic *Ustipsamments* (Temidire series) while Grossahenic Paleustalfs (Apomu series) occur in the valley bottom which with the exception of the valley bottom soils are normally

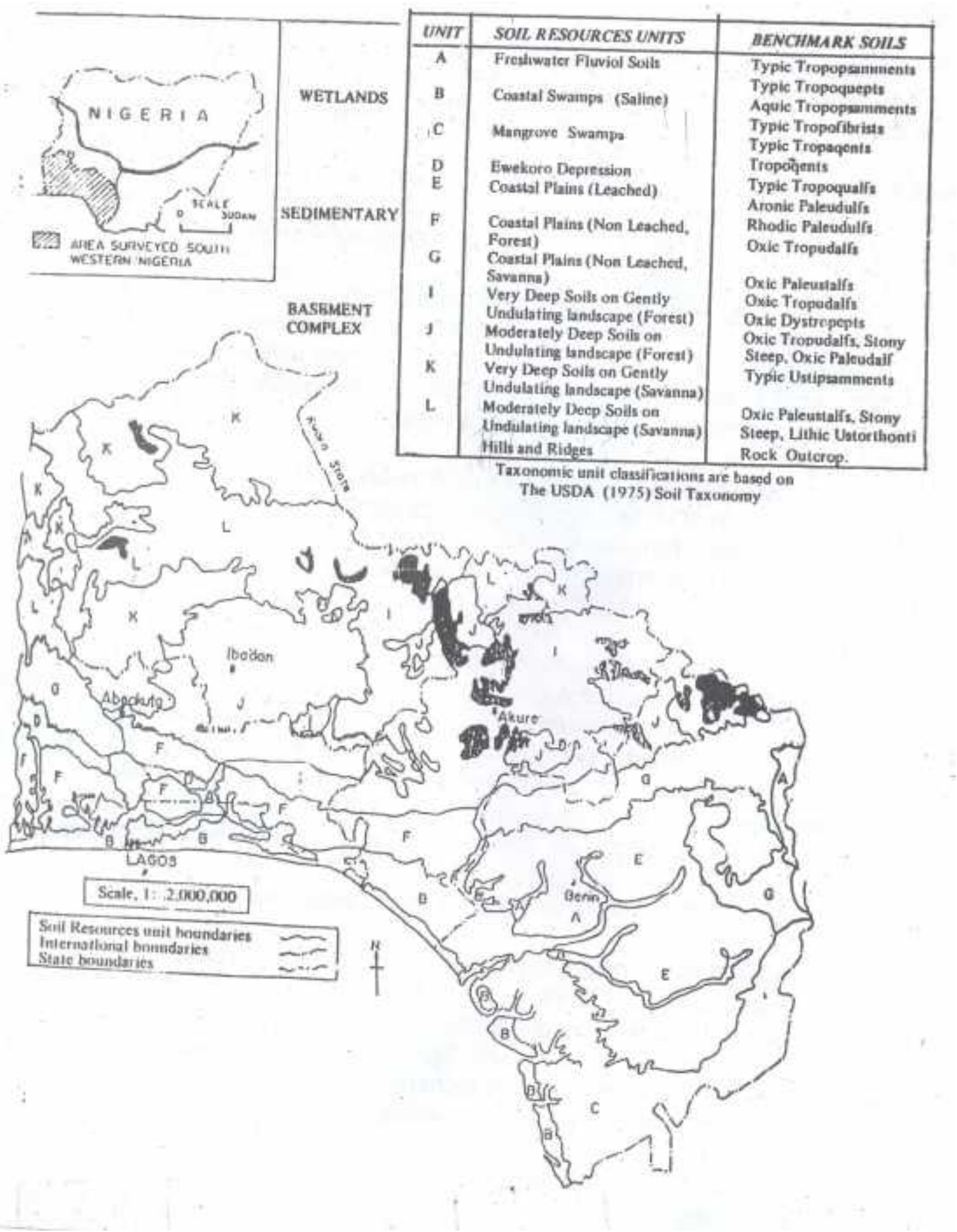


Fig. 1.4 Soil Resource Units of South-Western Nigeria incorporating Benchman Soils

characterized by the development or presence of iron-manganese concretionary or lateritic layer. Entisols (Ekiti series) are associated with rock outcrops or soils on poorly weathered rocks.

The soils are expected to be nutritionally richer because of lower rainfall than those of forest regions but may be very low in nutrients, especially nitrogen and sulphur (lost in annual bush fires that ravage the grasses) and zinc, boron and molybdenum.

(ii) Alfisols and Inceptisols (USDA) or Luvisols and Cambisols (FAO/UNESCO) Soils of Basement Complex rocks under forest vegetation. Soils Units I and J are located in the central portion of the region under dry rainforest. The landscape is substantially devoid of inselbergs.

The soils are typically deep and have a finer surface layer (sandy loam) over heavier sandy clay loam or sandy clay. A layer of quartz below surface and/or iron concretions is always found below the surface soil. The soils contain moderate levels of nutrients and are some times described as ferruginous soils. The soils are permeable and friable because of the good structure, thereby reducing the risk of erosion.

(iii) Alfisols and Ultisols (USDA) or Luvisols and Acrisols (FAO/UNESCO) - Non-leached Shale Group Soils: The soils of Units F and G vary in characteristics with the lithology of the rocks: the Abeokuta and Ilaro formation, or Bende Ameki group and the vegetation type. Under savanna, extensive development of iron manganese laterite layers occur but are replaced by rather deep, non-concretionary soil under forest.

(iv) Alfisols and Ultisols (USDA) or Luvisols and Acrisols (FAO/UNESCO) - Leached Coastal Plain Sands: Commonly called the Benin sands, the soils of this unit are the most extensive of the Tertiary sediments. It is most extensive in the eastern portion (Bendel State) of the region under a cover of high forest. The topography varies from nearly flat, as in central Bendel State, to rolling as scattered around the zone e.g. at Oke-Odan in the West.
The soils are heavily leached, being Oxic Tropudalfs or Arenic and/or Rhodic Paleudults Alagba, Ahiara, Owode and Iju are among the most commonly occuring series.

(v) Entisols and Inceptisols (USDA) or Regosols and Cambisols (FAO/UNESCO) Fresh Water Alluvium.
Apart from the Niger floodplains and the floodplains and the floodplains of the major North-South flowing rivers, narrow strips occur in the hinterland. The soils are mainly coarse textured Tropaquents and Tropaquents of the Soil Taxonomy, being characterized by high water table. Common soils series include Japo, Oshun and Ikire. They are usually of high fertility because of the frequent nutrient recharge from blood water. The soils are good for sugarcane, rice and dry season vegetable production.

(vi) Entisols and Alfisols (USDA) or Regosols and Luvisols (FAO/UNEScO) - Mudflats or Coastal Swamps. The soils are young and of poor pedogenic development and therefore, dominantly Tropaquents or Troposamments but some are Tropaqualfs. They are poorly drained with dominant grey colours. Except drained, they cannot be used for crop production.

(vii) *Soils of Mangrove swamps* - This is an extensive group of soils in the Niger Deltas. They are characterized by greyish colour because of their poor drainage. They are Tropofibrists (organic soils or organic matter rich soils) or Tropaquents. These soils are perhaps the most poorly drained soils, and except under a massive reclamation exercise, cannot be used for crop production.

1.5 Soil Management and Conservation for Effective Fertilizer Use

Agricultural productivity in Nigeria is low because of a host of factors. The soils are regarded as being relatively infertile and it is generally believed that without the addition of commercial fertilizers, along with other agricultural inputs such as improved seed varieties and pesticides food production will continue to fall short of the demand.

Fertility under uncleared natural forest in our environment is satisfactory. Such forest soils have a dark layer of top soil of varying thickness which is rich in nutrients necessary for plant growth. Once a piece of land is exposed by cutting down the forest, subsequent cultivation is accompanied with a continuing but variable decline in fertility, destruction to the ecosystem and creation of environmental problems.

Lower productivity, however, need not necessarily follow when the land is cleared of forest and put to agricultural use. The changes in the soil that decrease its productivity for crops, may stem from three processes, namely ecosystem cropping, leaching and soil erosion. The most menacing of these processes is that of soil erosion, especially in the humid rainforest zone of southern Nigeria.

Even if adequate applications of fertilizer were made to highly eroded soils, its efficiency would be much curtailed. It becomes extremely difficult to bring the soil back to full production once the top soil is eroded. Although good agronomic practices including fertilizer use may increase the productive capacity of an erosion affected soil, the same methods would have resulted in such larger yields if the soils had not been impaired in the first place. It becomes imperative therefore that adequate soil management and conservation practices be employed in order to sustain crop production at a reasonably high level.

From the point of view of soil conservation, two broad aspects of crop production need to be recognized: the land clearing method used and the post-clearing management practices. In Nigeria today, more land is being put under cultivation through land clearing. Improper land clearing can very rapidly bring about soil degradation resulting in a decrease in crop yield. The broad guidelines for proper land clearing stipulates that:

- **steep slopes and inferior soils should not be cleared**
- **clearing should be done manually where possible**
- **soils should not be left bare to adverse climatic conditioning**
- **Cover crops which protect the soil should be planted.**

Manual land clearing which uses hoes, cutlasses, saws, axes, diggers etc and *in-situ* burning, despite their ecological benefits in terms of preserving satisfactory physical and chemical conditions as exist under forest, is best suited to small hectarage and is not likely to be acceptable to large scale farmers who inevitably have to resort to mechanical clearing. From the point of view of soil conservation, proper mechanical land clearing will require the proper use of appropriate land clearing equipment such that:

(i) the leaf litter, roots and stumps are not removed
(ii) the top soil is not scrapped off, disturbed or compacted
(iii) the land is not cleared when the soil is wet

In this regard, there is need for farmers to make use of the limited available research information which point to the fact that the use of the bulldozer or crawler tractor with a shear blade attachment is perhaps the best option that will satisfy these conditions especially in the forested zone. In the savanna regions of the country with small size trees and low tree population, chain clearing is recommended.

It cannot be overemphasized that fertilizer use efficiency is greatly influenced by post-clearing soil management, seed bed preparation which is designed to facilitate crop establishment by controlling weeds, encouraging seed-soil contact and conserving soil and water must be done appropriately. Of the three methods-chemical, biological and mechanical used for this purpose, the last has the highest influence on fertilizer use efficiency because it tends to accelerate soil erosion and decrease soil quality. There is therefore the need to adopt appropriate seed bed preparation and tillage practices. Although the no till or minimum tillage practice has definite advantages for conserving soil and water, it has not been found to be applicable for all soils, and crops. Where it is feasible, the method should not be used. Similarly, mounds ridges or heaps should not be used indiscriminately. For marginal soils, such as poorly aerated or shallow soils, ridges and mounds are sometimes inevitable. The high soil temperature, rapid depletion of soil moisture and organic matter and the exposure of the soil to the erosive forces of rainfall and wind make them inadvisable in several ecological zones in the country. Besides, the concentration of water in the inter-mound areas can facilitate rill and gully erosion.

One cardinal principle of soil conservation is that the soil should be used in accordance with its capabilities and limitations. Such strict adherence is perhaps difficult because of certain socio-economic considerations. For instance, steep slopes in areas of heavy rainfall are better left under forest vegetation because of severe erosion which could ensue. In the south-eastern part of the country steep slopes are cleared because of severe human population pressure. In such and other circumstances, necessary steps should be taken to make up for such deficiencies by proper erosion control measures.

1.6 Fertilizer - Soil Relationships

Before considering in detail the fertilizer management practices for various crops, it is desirable to have an overview of some of the general principles involved in fertilizer use and to out-line the major pre-requisites for formulating a rational and efficient fertilizer programme.

1.6.1 Determining Fertilizer Needs of Crops

Fertilizers are used to increase crop yields and also to improve crop quality. Nutrients removed from the soil by crops, lost by leaching, erosion, fixed or immobilized by micro-organisms or volatilized due to high temperature should be replaced to ensure optimum crop performance. One of the most important pre-requisites for formulating a sound fertilizer recommendation for a given crop in a given area, therefore, is the knowledge of the nutrient status of the soil, which is realisable only through a rational and systematic soil fertility evaluation.

Soil fertility evaluation is basically the processes by which nutritional problems in the soil and plants are diagnosed and fertilizer recommendations made. Several methods or approaches are employed in evaluating soil fertility. The most popular and wide-spread ones are those based on soil testing, plant analysis and missing element techniques or calibration involving simple fertilizer trials.

Nutrient deficiencies may be inherent or induced when one nutrient is present in excessive quantity in the soil, thereby limiting the uptake of other elements. Soil fertility evaluation is, therefore, concerned mainly with the level of nutrient availability and nutrient balance including the appropriate methods of assessing these factors.

The easiest and fastest methods of correcting nutrient deficiencies are through the use of fertilizers which are mostly applied directly to the soil or directly to the crop foliage in liquid form. The amount of fertilizer applied in any given season may depend on both method of application (e.g. banded or broadcast) and the expected maximum net return on the immediate crop and thus neglecting residual effects, or calculating the total requirement for a number of years and then applying it at the most appropriate time in order to realize the greatest net returns.

1.6.2 Factors Affecting Fertilizer Use

(i) *Crop Factor*

Fertilizer application cannot be effective unless the crop can respond to it. Certain crops need larger amounts of particular nutrients than others. Legumes, for instance, require large amounts of phosphorus, cereals require proportionately more nitrogen while most tree crops and all root crops require more potassium. Improved varieties are more responsive to higher doses of fertilizer. Screening of crop varieties or ascension for tolerance or adaptability to a given mineral nutrient condition or stress in the soil is also an important factor affecting fertilizer use and consumption. A plant can be referred to as nutrient efficient or inefficient. A nutrient efficient plant develops the natural capacity to respond to stress by altering its metabolism to make the element available. Whereas, a nutrient inefficient plant does not respond to measures to reduce stress and hence develops a nutrient deficiency effect.

(ii) *Soil Factor*

The ability of soils to supply plant nutrients differs significantly from place to place and from time to time. Physical properties of the soil, such as depth, texture and structure, also contribute to its productivity. Each soil has an inherently productive potential. Applications of appropriate rates of fertilizer can be profitable on soils that have high productive potential but which are low in fertility.

(iii) *Climatic Factor*s

In areas of low rainfall soils lose little from leaching and so their inherent fertility level is relatively high. However, if only a limited amount of water is available there is no justification for raising fertility levels much higher. Soils of humid regions often lose much of their available nutrients through leaching and weathering. The water supply is adequate for high crop production but nutrient supplies are inadequate. In this case fertilizer application will pay.

(iv) *Economic Factors*
Increased use of fertilizer is encouraged by low fertilizer prices and decreased by higher prices. Crop prices have the opposite effect because a high price for the crop will give a profitable return for large fertilizer application. Increase in crop yield due to increased fertilizer applications follow the law of diminishing returns. Applications of optimum rates of fertilizers result in the greatest return per kg of nutrient applied. Further applications give progressively lower increases in yield. Eventually, a point could be reached where an increase in the amount of fertilizers only increases yield enough to pay for the cost of this extra fertilizer.

(v) *Management Factors*
Increased crop yields usually require increased fertilizer inputs. Maximum yields depend on many factors including soil type, climate, present and past crop type and variety, cropping history, present and past fertilizer application, soil amendments, tillage practices, pest control, the timing of operations and water management.

In conclusion it should be stressed that fertilizers are good for reducing soil fertility problems. However, adding more fertilizer will bring little or no increase in production when other factors are limiting. Excessive use of fertilizers may even reduce yields because it leads to imbalance in availability of nutrients.

1.6.3 Role of Plant Nutrients and their Deficiency Symptoms

In addition to the three major fertilizer elements, NPK, which have been known to be deficient in most Nigerian soils, secondary elements such as S, Mg and micro nutrients such Zn, Mo are also fast becoming important for some crops in the country. The crop-use efficiency of any given fertilizer is a function of several factors, some relating to the chemical and physical nature of the fertilizer materials, while some relate to soil factors and the crop agronomic practices and management. The deficiency symptoms of some of the essential mineral nutrients in the leaves and other organs of the plant are shown below:

1.6.3.1 Symptom Descriptions

It is unusual to find any one leaf or even one plant that displays the full array of symptoms that are characteristic of a given deficiency. It is thus highly desirable to know how individual symptoms look, for it is possible for them to occur in many possible combinations on a single plant. Most of the terms used below in the description of deficiency symptoms are reasonably self evident; a few however have a distinct meaning in the nutrient deficiency field. For example, the term *chlorotic,* which is a general term for yellowing of leaves through the loss of chlorophyll, cannot be used without further qualification because there may be an overall chlorosis as in nitrogen deficiency, interveinal, as in iron deficiency, or marginal, as in calcium deficiency. Another term used frequently in the description of deficiency symptoms is *necrotic,* a general term for brown, dead tissue. This symptom can also appear in many varied forms, as is the case with chlorotic symptoms.

Nutrient deficiency symptoms for many plants are similar, but because of the large diversity found in plants and their environments there is a range of expression of symptoms. Because of their parallel veins, grasses and other monocots generally display the affects of chlorosis as a series of stripes rather than the netted interveinal chlorosis commonly found in dicots. The other major difference is that the marginal necrosis or chlorosis found in dicots is often expressed as tip burn in monocots.

Figures show deficiency symptoms for macronutrients and micronutrients in tomato.

Magnesium. The Mg-deficient leaves (Fig. …..) show advanced interveinal chlorosis, with necrosis developing in the highly chlorotic tissue. In its advanced form, magnesium deficiency may superficially resemble potassium deficiency. In the case of magnesium deficiency the symptoms generally start with mottled chlorotic areas developing in the interveinal tissue. The interveinal laminae tissue tends to expand proportionately more than the other leaf tissues, producing a raised puckered surface, with the top of the puckers progressively going from chlorotic to necrotic tissue. In some plants such as the Brassica (i.e., the mustard family, which includes vegetables such as broccoli, brussel sprouts, cabbage, cauliflower, collards, kale, kohlrabi, mustard, rape, rutabaga and turnip), tints of orange, yellow, and purple may also develop.

Fig. 1.5 Magnesium deficiency symptoms in tomato. (Epstein and Bloom 2004)

Magnesium deficiency

Red and purple tints; intervenal chlorosis and necrosis

Fig. 1.6 Magnesium deficiency Symptoms in Maize Leaves

Manganese. These leaves (Fig. …..) show a light interveinal chlorosis developed under a limited supply of Mn. The early stages of the chlorosis induced by manganese deficiency are somewhat similar to iron deficiency. They begin with a light chlorosis of the young leaves and netted veins of the mature leaves especially when they are viewed through transmitted light. As the stress increases, the leaves take on a gray metallic sheen and develop dark freckled and necrotic areas along the veins. A purplish luster may also develop on the upper surface of the leaves. Grains such as oats, wheat, and barley are extremely susceptible to manganese deficiency. They develop a light chlorosis along with gray specks which elongate and coalesce, and eventually the entire leaf withers and dies.

Fig. 1.7 Manganese deficiency symptoms in tomato. (Epstein and Bloom 2004)

Molybdenum. These leaves (Fig. ….) show some mottled spotting along with some interveinal chlorosis. An early symptom for molybdenum deficiency is a general overall chlorosis, similar to the symptom for nitrogen deficiency but generally without the reddish coloration on the undersides of the leaves. This results from the requirement for molybdenum in the reduction of nitrate, which needs to be reduced prior to its assimilation by the plant (see textbook Chapter 12). Thus, the initial symptoms of molybdenum deficiency are in fact those of nitrogen deficiency. However, molybdenum has other metabolic functions within the plant, and hence there are deficiency symptoms even when reduced nitrogen is available. In the case of cauliflower, the lamina of the new leaves fail to develop, resulting in a characteristic whiptail appearance. In many plants there is an upward cupping of the leaves and mottled spots developing into large interveinal chlorotic areas under severe deficiency. At high concentrations, molybdenum has a very distinctive toxicity symptom in that the leaves turn a very brilliant orange.

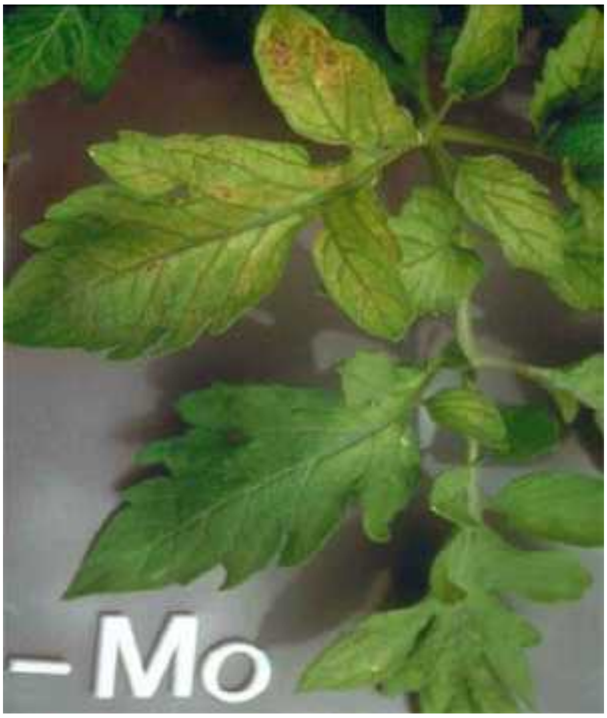


Fig. 1.8 Molybdenum deficiency symptoms in tomato. (Epstein and Bloom 2004)

Nitrogen. The chlorotic symptoms (Fig. ….) shown by this leaf resulted from nitrogen deficiency. A light red cast can also be seen on the veins and petioles. Under nitrogen deficiency, the older mature leaves gradually change from their normal characteristic green appearance to a much paler green. As the deficiency progresses these older leaves become uniformly yellow (chlorotic). Leaves approach a yellowish white color under extreme deficiency. The young leaves at the top of the plant maintain a green but paler color and tend to become smaller in size. Branching is reduced in nitrogen deficient plants resulting in short, spindly plants. The yellowing in nitrogen deficiency is uniform over the entire leaf including the veins. However in some instances, an interveinal necrosis replaces the chlorosis commonly found in many plants. In some plants the underside of the leaves and/or the petioles and midribs develop traces of a reddish or purple color. In some plants this coloration can be quite bright. As the deficiency progresses, the older leaves also show more of a tendency to wilt under mild water stress and become senescent much earlier than usual. Recovery of deficient plants to applied nitrogen is immediate (days) and spectacular.

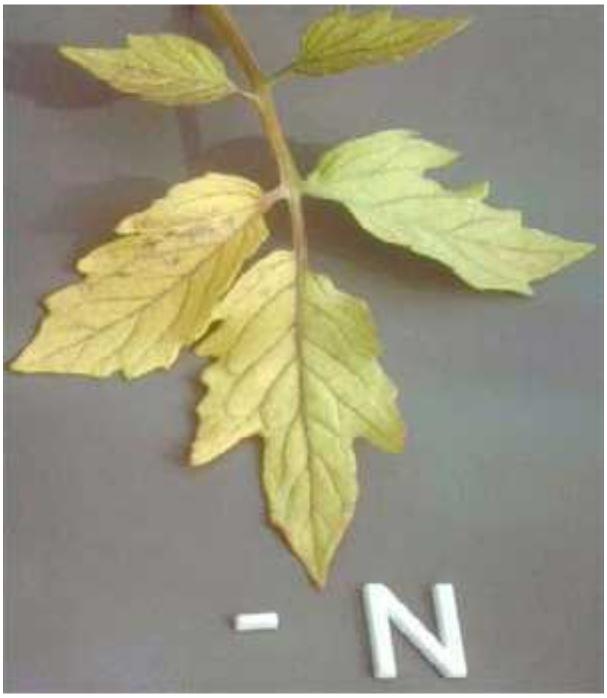


Fig. 1.9 Nitrogen deficiency symptoms in tomato. (Epstein and Bloom 2004)

Phosphorus. These phosphorus-deficient leaves (Fig. ….) show some necrotic spots. As a rule, phosphorus deficiency symptoms are not very distinct and thus difficult to identify. A major visual symptom is that the plants are dwarfed or stunted. Phosphorus deficient plants develop very slowly in relation to other plants growing under similar environmental conditions but without phosphorus deficiency. Phosphorus deficient plants are often mistaken for unstressed but much younger plants. Some species such as tomato, lettuce, corn and the brassicas develop a distinct purpling of the stem, petiole and the under sides of the leaves. Under severe deficiency conditions there is also a tendency for leaves to develop a blue-gray luster. In older leaves under very severe deficiency conditions a brown netted veining of the leaves may develop.

Fig. 1.10a Phosphorus deficiency symptoms in tomato. (Epstein and Bloom 2004)

Phosphorus Deficiency

Leaves strong purple tints;

Fig. 1.10b Phosphorus deficiency symptoms in Maize Plant

Sulfur. This leaves (Fig. ……) show a general overall chlorosis while still retaining some green color. The veins and petioles show a very distinct reddish color. The visual symptoms of sulfur deficiency are very similar to the chlorosis found in nitrogen deficiency. However, in sulfur deficiency the yellowing is much more uniform over the entire plant including young leaves. The reddish color often found on the underside of the leaves and the petioles has a more pinkish tone and is much less vivid than that found in nitrogen deficiency. With advanced sulfur deficiency brown lesions and/or necrotic spots often develop along the petiole, and the leaves tend to become more erect and often twisted and brittle.

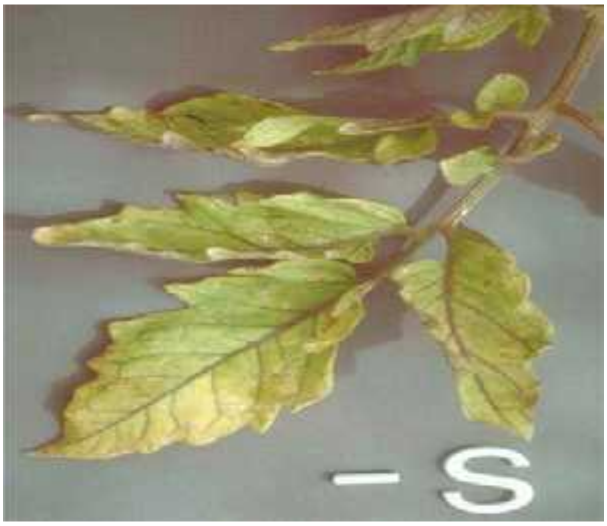


Fig. 1.11 Sulfur deficiency symptoms in tomato. (Epstein and Bloom 2004)

Zinc. This leaves (Fig. …..) show an advanced case of interveinal necrosis. In the early stages of zinc deficiency the younger leaves become yellow and pitting develops in the interveinal upper surfaces of the mature leaves. Guttation is also prevalent. As the deficiency progress these symptoms develop into an intense interveinal necrosis but the main veins remain green, as in the symptoms of recovering iron deficiency. In many plants, especially trees, the leaves become very small and the internodes shorten, producing a rosette like appearance.

Fig. 1.12 Zinc deficiency symptoms in tomato. (Epstein and Bloom 2004)

Boron. These boron-deficient leaves Fig. …..) show a light general chlorosis. The tolerance of plants to boron varies greatly, to the extent that the boron concentrations necessary for the growth of plants having a high boron requirement may be toxic to plants sensitive to boron. Boron is poorly transported in the phloem of most plants, with the exception of those plants that utilize complex sugars, such as sorbitol, as transport metabolites. In a recent study, (Brown et al. 1999) tobacco plants engineered to synthesize sorbitol were shown to have increased boron mobility, and to better tolerate boron deficiency in the soil.

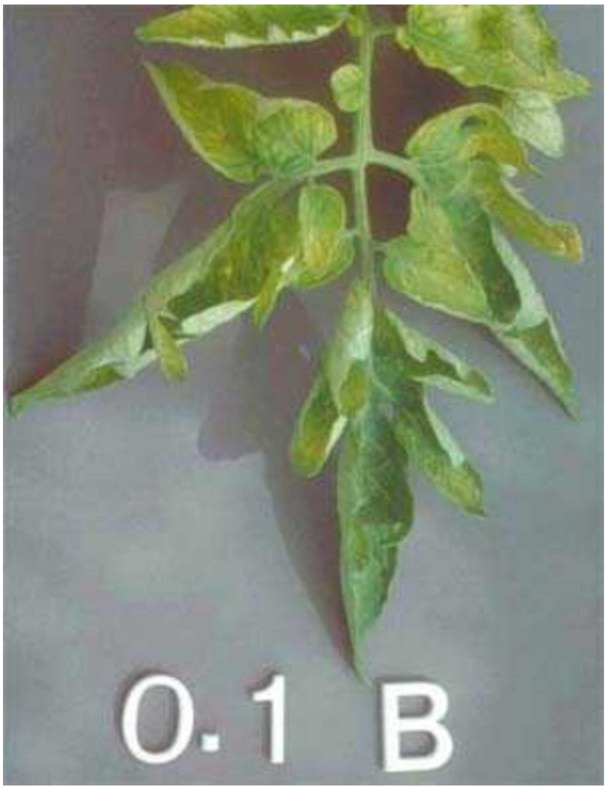


Fig. 1.13 Boron deficiency symptoms in tomato. (Epstein and Bloom 2004)

In plants with poor boron mobility, boron deficiency results in necrosis of meristematic tissues in the growing region, leading to loss of apical dominance and the development of a rosette condition. These deficiency symptoms are similar to those caused by calcium deficiency. In plants in which boron is readily transported in the phloem, the deficiency symptoms localize in the mature tissues, similar to those of nitrogen and potassium. Both the pith and the epidermis of stems may be affected, often resulting in hollow or roughened stems along with necrotic spots on the fruit. The leaf blades develop a pronounced crinkling and there is a darkening and crackling of the petioles often with exudation of syrupy material from the leaf blade. The leaves are unusually brittle and tend to break easily. Also, there is often a wilting of the younger leaves even under an adequate water supply, pointing to a disruption of water transport caused by boron deficiency.

Calcium. These calcium-deficient leaves (Fig. ….) show necrosis around the base of the leaves. The very low mobility of calcium is a major factor determining the expression of calcium deficiency symptoms in plants. Classic symptoms of calcium deficiency include blossom-end rot of tomato (burning of the end part of tomato fruits), tip burn of lettuce, blackheart of celery and death of the growing regions in many plants. All these symptoms show soft dead necrotic tissue at rapidly growing areas, which is generally related to poor translocation of calcium to the tissue rather than a low external supply of calcium. Very slow growing plants with a deficient supply of calcium may re-translocate sufficient calcium from older leaves to maintain growth with only a marginal chlorosis of the leaves. This ultimately results in the margins of the leaves growing more slowly than the rest of the leaf, causing the leaf to cup downward. This symptom often progresses to the point where the petioles develop but the leaves do not, leaving only a dark bit of necrotic tissue at the top of each petiole. Plants under chronic calcium deficiency have a much greater tendency to wilt than non-stressed plants.

Fig. 1.14 Calcium deficiency symptoms in tomato. (Epstein and Bloom 2004)

Chloride. These leaves (Fig. ….) have abnormal shapes, with distinct interveinal chlorosis. Plants require relatively high chlorine concentration in their tissues. Chlorine is very abundant in soils, and reaches high concentrations in saline areas, but it can be deficient in highly leached inland areas. The most common symptoms of chlorine deficiency are chlorosis and wilting of the young leaves. The chlorosis occurs on smooth flat depressions in the interveinal area of the leaf blade. In more advanced cases there often appears a characteristic bronzing on the upper side of the mature leaves. Plants are generally tolerant of chloride, but some species such as avocados, stone fruits, and grapevines are sensitive to chlorine and can show toxicity even at low chloride concentrations in the soil.

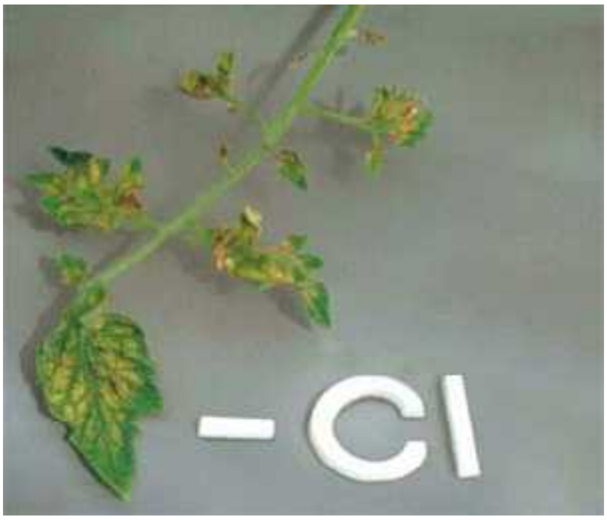


Fig. 1.15 Chloride deficiency symptoms in tomato. (Epstein and Bloom 2004)

Copper. These copper-deficient leaves (Fig. ….) are curled, and their petioles bend downward. Copper deficiency may be expressed as a light overall chlorosis along with the permanent loss of turgor in the young leaves. Recently matured leaves show netted, green veining with areas bleaching to a whitish gray. Some leaves develop sunken necrotic spots and have a tendency to bend downward. Trees under chronic copper deficiency develop a rosette form of growth. Leaves are small and chlorotic with spotty necrosis.

Fig. 1.16 Copper deficiency symptoms in tomato. (Epstein and Bloom 2004)

Iron. These iron-deficient leaves (Fig. ….) show strong chlorosis at the base of the leaves with some green netting. The most common symptom for iron deficiency starts out as an interveinal chlorosis of the youngest leaves, evolves into an overall chlorosis, and ends as a totally bleached leaf. The bleached areas often develop necrotic spots. Up until the time the leaves become almost completely white they will recover upon application of iron. In the recovery phase the veins are the first to recover as indicated by their bright green color. This distinct venial re-greening observed during iron recovery is probably the most recognizable symptom in all of classical plant nutrition. Because iron has a low mobility, iron deficiency symptoms appear first on the youngest leaves. Iron deficiency is strongly associated with calcareous soils and anaerobic conditions, and it is often induced by an excess of heavy metals.

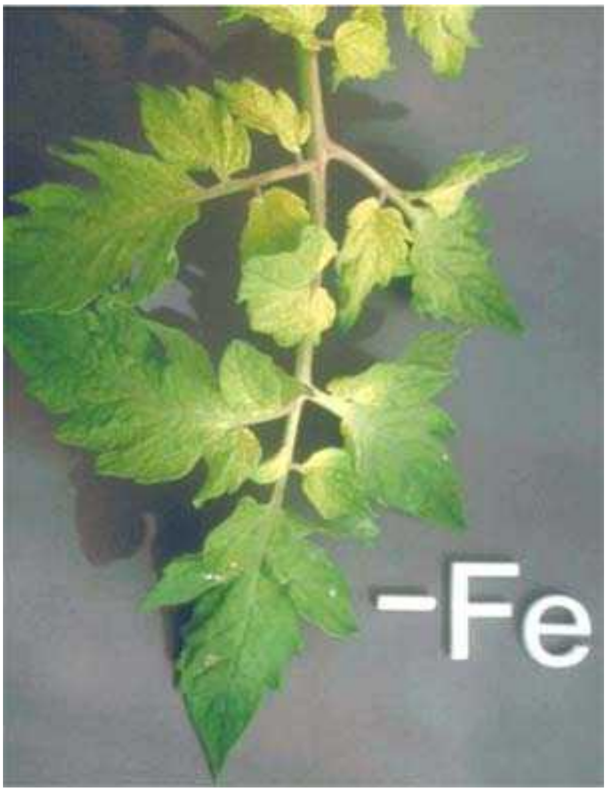
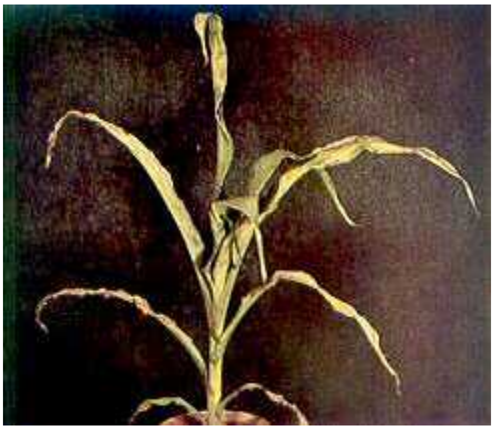


Fig. 1.17 Iron deficiency symptoms in tomato. (Epstein and Bloom 2004)

Potassium. Some of these leaves (Fig. ….) show marginal necrosis (tip burn), others at a more advanced deficiency status show necrosis in the interveinal spaces between the main veins along with interveinal chlorosis. This group of symptoms is very characteristic of K deficiency symptoms.

Fig. 1.18a Potassium deficiency symptoms in tomato. (Epstein and Bloom 2004)



Potassium deficiency

Internodes short, leaves elatively long; marginal and tip browning of leaves.

Fig. 1.18b Potassium deficiency in Maize Plant

The onset of potassium deficiency is generally characterized by a marginal chlorosis progressing into a dry leathery tan scorch on recently matured leaves. This is followed by increasing interveinal scorching and/or necrosis progressing from the leaf edge to the midrib as the stress increases. As the deficiency progresses, most of the interveinal area becomes necrotic, the veins remain green and the leaves tend to curl and crinkle. In some plant such as legumes and potato, the initial symptom of deficiency is white speckling or freckling of the leaf blades. In contrast to nitrogen deficiency, chlorosis is irreversible in potassium deficiency, even if potassium is given to the plants. Because potassium is very mobile within the plant, symptoms only develop on young leaves in the case of extreme deficiency. Potassium deficiency can be greatly alleviated in the presence of sodium but the resulting sodium-rich plants are much more succulent than a high potassium plant. In some plants over 90% of the required potassium can be replaced with sodium without any reduction in growth.

1.6.4 Fertilizer Use and Cation Balance in Soils

Fertilizer applications are generally considered in relation to their immediate effects on crop yields and all too often their residual effects are ignored. Yet when farming is continued on the same site for several years residual effects of fertilizer treatments may considerably affect the soil chemical properties and consequently the yield of crops grown in later years. One of these residual effects is on the relative abundance of the cations in the soil subsequent to fertilizer application. There is evidence to show that availability of cation to crops may depend less on the absolute amounts of each cation present in the soil than on the balance existing between the various cations in soil solution. It is known that the use of ammonium-containing N-fertilizers in savanna environments results in the development of soil acidity, loss of cations and a redistribution in the relative amounts of the various cations in soil solution. In both the savanna and forest zones of Nigeria, it has been observed that magnesium deficiencies in crops may be caused by absolute Mg shortage, but by excessive applications of potassium.

Cation imbalance is accelerated by the use of incomplete fertilizers and by improper management of crop residues. Use of straight fertilizers (e.g. Urea) chosen primarily on the basis of short-term economic returns can only aggravate the problem of cation imbalance in soils and must be discouraged. There is ample evidence to show that judicious use of inorganic fertilizers (right types and quantities of primary, secondary and trace elements) will maintain, and in some cases, improve soil fertility and crop yields for fairly long periods of continuous cropping.

1.6.5 Fertilizer Use Under Irrigation

Irrigation poses special problems in the use of fertilizers and also provides some unique ways to supply nutrients not encountered in non-irrigated agriculture.

First, irrigation imposes a greater demand for fertilizer nutrients. The failure to meet increased fertilizer requirements is one of the more common faults of most irrigation projects. Crop yields must be high for irrigation to be profitable and this is usually associated with greater nutrient uptake by crops. In order to maximize irrigation efficiency, nutrient needs of irrigated crops must be met by an adequate fertilizer programme.

Water availability is of paramount importance in nutrient absorption by plants and the ability of the soil to supply them. Wilting and ultimate death of the plant could be caused not only by low water potential but also by the concomitant impairment of the ability of the plant to absorb nutrients even in fertile soils. Fertilizer application under irrigation must take due cognisance of the mobility of nutrient ions. For instance, it is well established that the nutrient anions $N0_3^-$, Cl^- and $S0_4^{2-}$ are mobile in soil especially in the neutral and alkaline soils characteristic of most irrigated environments. The $N0_3^-$ form of N remains exclusively in the soil water and is subject to appreciable movement in all directions. Potassium, Ca^{2+} and Mg^{2+} like NH^{4+} are adsorbed by the exchange complex of the soil in an equilibrium with other ions in the soil solution. Ions in excess of absorption demands remain in solution and are free to move with the soil water. Movement of ions depends on the amount of water applied, the quantity and type of fertilizer, fertilizer placement and the exchange capacity of the soil. The micro-nutrient cations such as Zn, Cu, Co, Mn and Fe are so tightly held in well aerated soils except in sandy soils that movement is practically nil.

The three broad irrigation methods of furrow, flood and sprinkler have implications for fertilizer use efficiency. Furrow irrigation leads to marked redistribution of most mobile nutrients but has little influence on the movements of the immobile ions. Essentially the flow lines control the direction and magnitude of nitrate movement. In flood irrigation, movement of soluble ions is more effective. In comparing the effectiveness of sprinkler and furrow irrigation with regard to fertilizer use efficiency, attention must be given to the induced soil water potential and its uniformity in the root zone, the rate of fertilizer application and its movement in the soil water. In the final analysis the relative performance of the two irrigation systems is contingent on the flood or furrow irrigation. Similarly, sprinkler irrigation or even drip irrigation will be more effective on shallow rooted crops.

One of the cheapest and most convenient means of applying fertilizers is through irrigation water. The fertilizers suitable for use in irrigation water must be quickly and completely soluble, must not react with each other or with constituents of the water to clog nozzles. Nitrogen is by far the nutrient used in greatest quantities in irrigation water. Orthophosphoric acid (H_3PO_4) and solutions of K fertilizers are also being applied in irrigation water. The higher solubility of KNO_3 makes it more suitable in irrigation water than mutriate and sulphate of potash. Special care must be taken to have compatible mixtures to note that if direct fertilizer wastage is to be prevented there must be no loss of "tail water" from surface irrigation systems and the application rate from sprinklers must not exceed the percolation rate of the soils.

The need for periodic monitoring of soil and irrigation water for nutrient deficiencies and excesses cannot be overemphasized. It will enhance the formulation of proper and balanced fertilizer use. Sodium absorption ratio is one of the most important characteristics of irrigation water which needs to be monitored. Under poor drainage conditions, poor quality irrigation water coupled with bad irrigation scheduling, salinization and alkalination occur and have great potentials for decreasing the efficient use of applied fertilizers. Concomitantly, poor aeration conditions reduce oxygen diffusion rate and root respiration, increase the denitrification of nitrogen and decrease nutrient uptake. The preference of ammoniacal nitrogen for rice under flooded condition is attributable to a decrease in denitrification losses.

1.6.6 Soil Acidity and Liming

Soil acidity is a major factor influencing the natural distribution of plants, macro and micro fauna and micro flora. The adverse effects of soil acidity on plant nutrition are usually the deficiency of essential plant nutrients (e.g. Ca Mg and P) and toxicity of minor elements (e.g. Al, Fe and Mn). It is a soil condition common in all regions where precipitation is high enough to leach appreciable amounts of exchangeable bases from the surface layers of soils; it is sometimes developed by continuous use of acid-forming fertilizers.

Two major types of acid soils limit food production in Nigeria - the leached acid soils (ferallitic soils, pH 4.5) in high rainfall areas of the south, and the drained acid sulphate soils (pH 3.5) of the delta areas and marshy coasts. Poor growth of crops like maize and cowpea in these areas is attributable to the prevailing acid conditions.

Liming acid tropical soils to near-neutrality has not produced the desired effects. In trials conducted in ferallitic, and ferruginous soils in the Imo - Anambra areas, for example, liming acid soils to pH 6.5 and 7.0 for maize depressed plant growth and yield. Similar trials conducted on the acid soils of Agege and Ikenne have shown that the use of lime in combination with manure and some essential trace elements gave better yields than lime alone. The poor growth of crops in trials with liming alone has been attributed to the induced micro-nutrient deficiencies, particularly that of zinc, in the soil as a result of excessive liming. Liming on these soils should be aimed at the reduction of the level of exchangeable aluminum in the soil to a tolerable level, instead of attaining a given pH value. The use of acid-tolerant crop species is also recommended.

1.6.7 Soil Salinity and Alkalinity

Saline and alkaline soils occur in small patches in the semi-arid belt of northern Nigeria. Such soils rarely occur in the southern parts of the country where high rainfall affords considerable leaching of salts beyond the root zone.

Salinity surveys of irrigated schemes in northern Nigeria have shown that certain soils in Borno, Gongola, Kano and Sokoto States vary from non-saline to moderately saline. The level of salinity around South Lake Chad is generally very low; values of electrical conductivity in excess of 4mmhos/cm are uncommon and have a very random distribution throughout this area. Yau' Sheme soils on lowland or in slight depression areas are seriously affected with salinity problems. Areas around Daya in Borno State are strongly saline-sodic in the sub-soils. In the Hadejia River Basin Area, about 20 - 40% of the soils are slightly alkaline. Soils at Kalmalo, Tungun Rundu and Wurno in Sokoto State are slightly alkaline in nature.

1.6.8 Soil Fertility Maps

Using available chemical data, a first approximation to the soil fertility map has been produced for nitrogen, phosphorus and potassium for the various ecological zones of the country see Fig. 1.11 - 1.13. The criteria for soil fertility classes are as defined below:

Low	-	The value below critical level
Medium	-	The range above critical level where variable response to fertilization is expected
High	-	The range where response is unlikely and fertilization may not be necessary

Nitrogen is defined in terms of total nitrogen, phosphorus in terms of Bray 1 or Bray 2 P; potassium in terms of NH_4 OAc exchangeable potassium and organic matter in terms of Walkley and Black total organic matter.

1.6.8.1 Rating for Soil Fertility Classes

pH water

Strongly Acid	-	5.0 – 5.5
Moderately Acid	-	5.6 – 6.0
Slightly Acid	-	6.1 – 6.5
Neutral	-	6.6 – 7.2
Slightly Alkaline	-	7.3 – 7.8

NITROGEN (Total N)

Very Low	-	0.3 - 0.5
Low	-	0.6 - 1.0
Moderately low	-	1.1 - 1.5
Medium	-	1.6 - 2.0
Moderately High	-	2.1 - 2.4

PHOSPHORUS (Bray - 1-P) mg Kg^{-1}

Very Low	-	< 3
Low	-	3 - 7
Moderate	-	7 - 20
High	-	> 20mg

POTASSIUM (Exc. K)

Very Low	-	0.12 – 0.2
Low	-	0.21 - 0.3
Moderate	-	0.31 - 0.6
High	-	0.61 - 0.73

Organic Carbon (g kg^{-1} 0.m)

Very low	-	< 4.0
Low	-	4.0 - 10
Moderate	-	10 - 14
High	-	14 - 20
Very High	-	> 20

Zinc (DTPA) mg kg^{-1}

Low	-	< 1.0
Medium	-	1.0 - 5.0
High	-	> 5.0

Boron (Hot H2O sol) mg kg^{-1}

Very Low	-	< 0.35
Low	-	< 0.35 - 0.5
Medium	-	0.5 - 2.0
High	-	< 2.0

It is necessary to emphasize that the criteria for soil fertility classes, as defined above, do not apply to nitrogen and organic matter, since these parameters are not commonly employed in interpreting nitrogen fertilizer needs of soil.

1.7 Supplements to Chemical Fertilizers

The following can be used as partial substitutes for or compliment to chemical fertilizers.

1.7.1 Crop Residues

The value of crop residues as supplement to inorganic fertilizers depends on the crop species and the use of to which the residues is put. Where the farmer removes completely the residues in case of sorghum, the nutrient content particularly N and K is lost to the soil. The release of nutrient from the residue is influenced by the C/N ratio; where the C/N is below 25, application of low rate of N will accelerate mineralization.

Mulch farming using minimum of zero tillage will enhance the nutrient contribution from the mulch. The cropping system such as cowpea followed by maize or maize inter-planted with cassava is a viable system in the sub-humid tropics that allows recycling of maize residue.

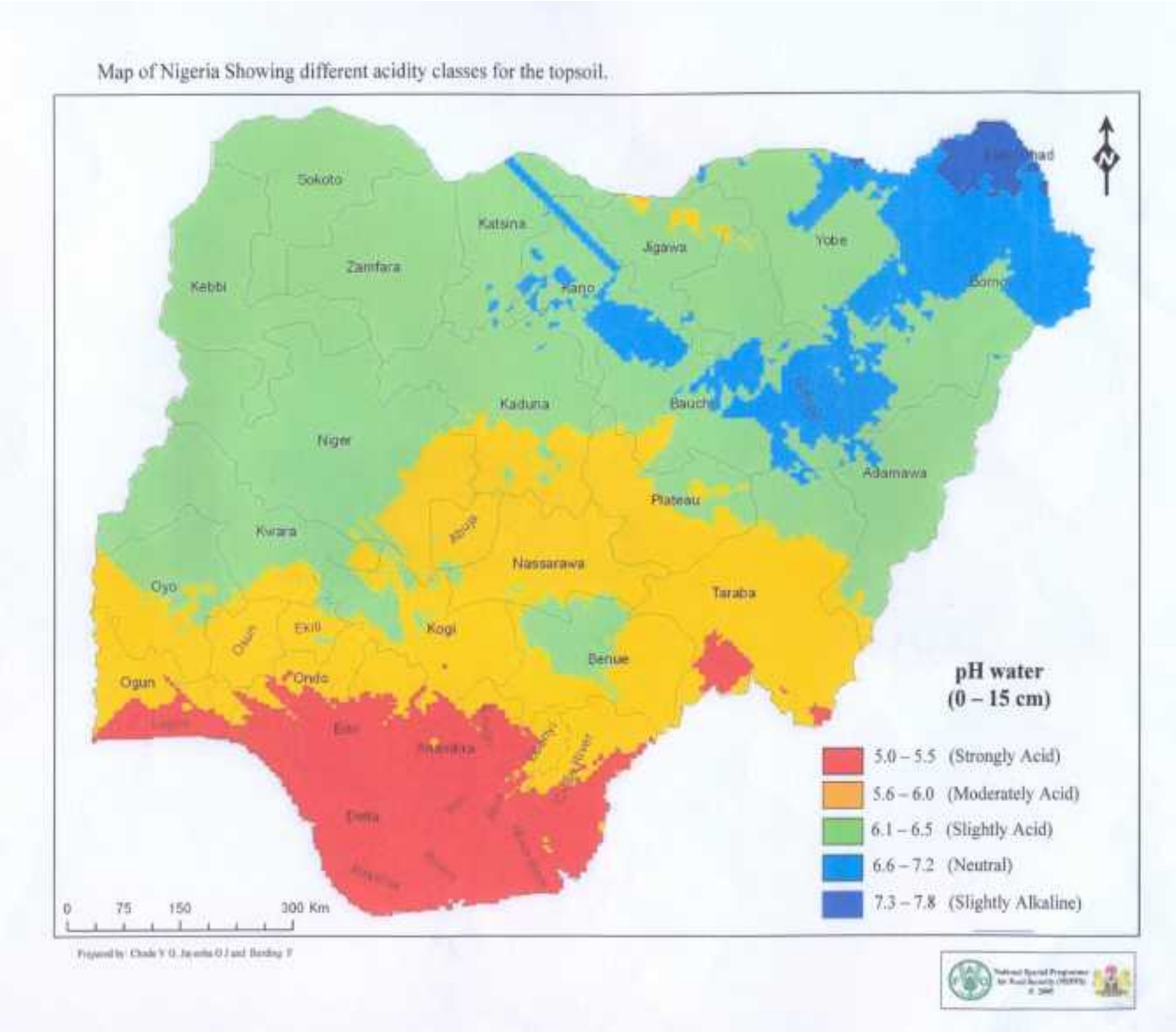


Fig. 1.19 pH water Fertility Map of Nigeria

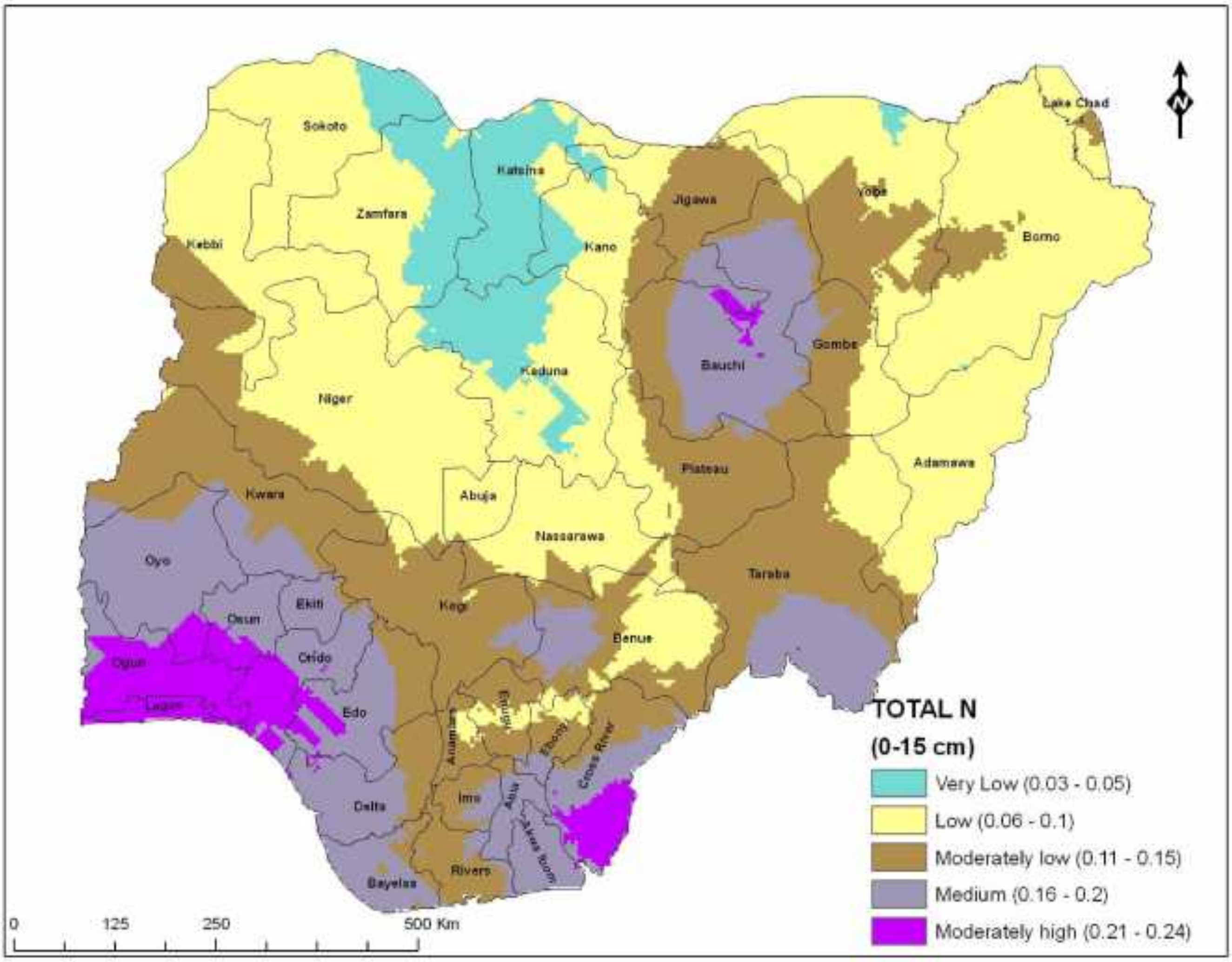


Fig. 1.20 Total Nitrogen Fertility Map of Nigeria

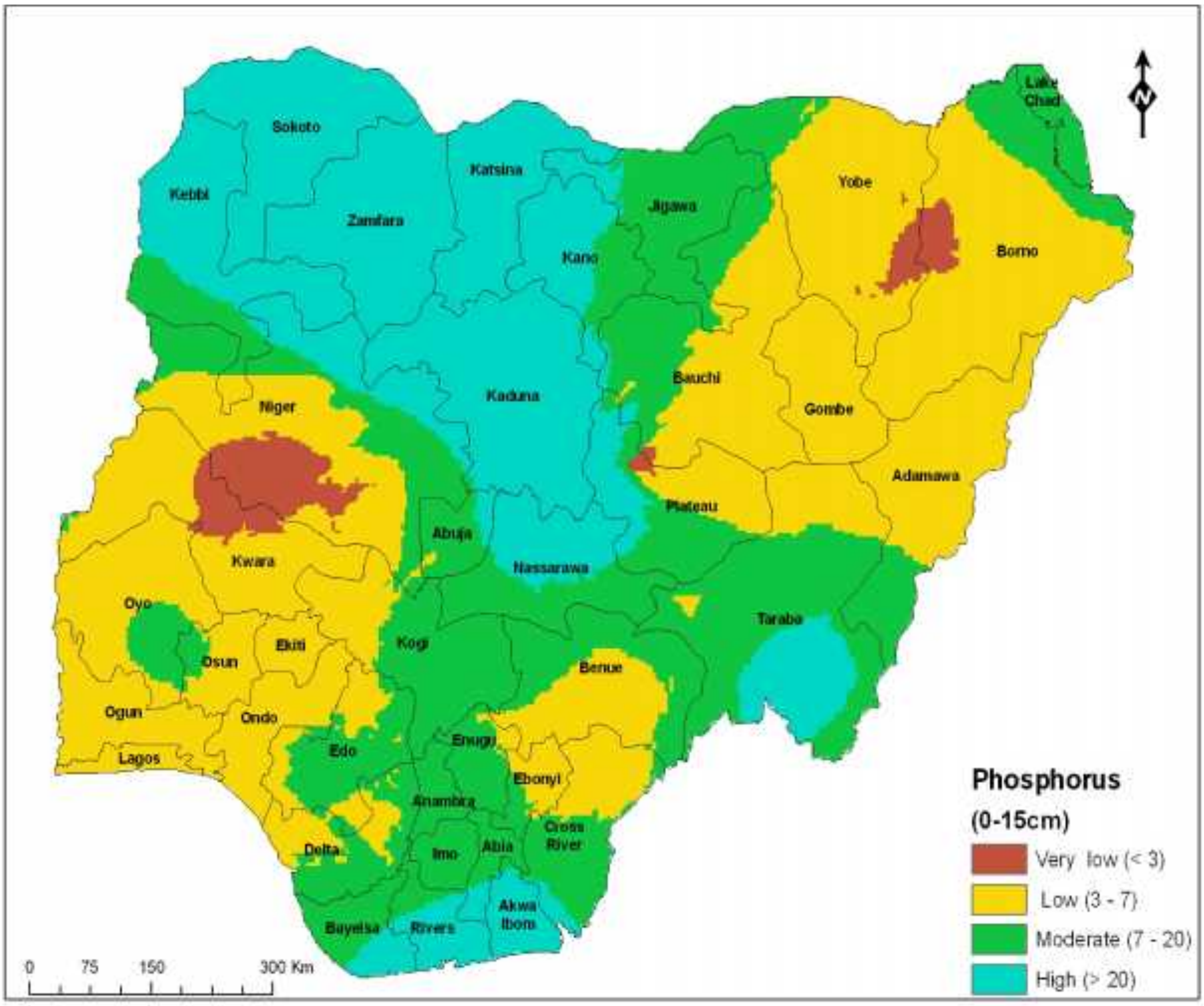


Fig. 1.21 Phosphorus Fertility Map of Nigeria

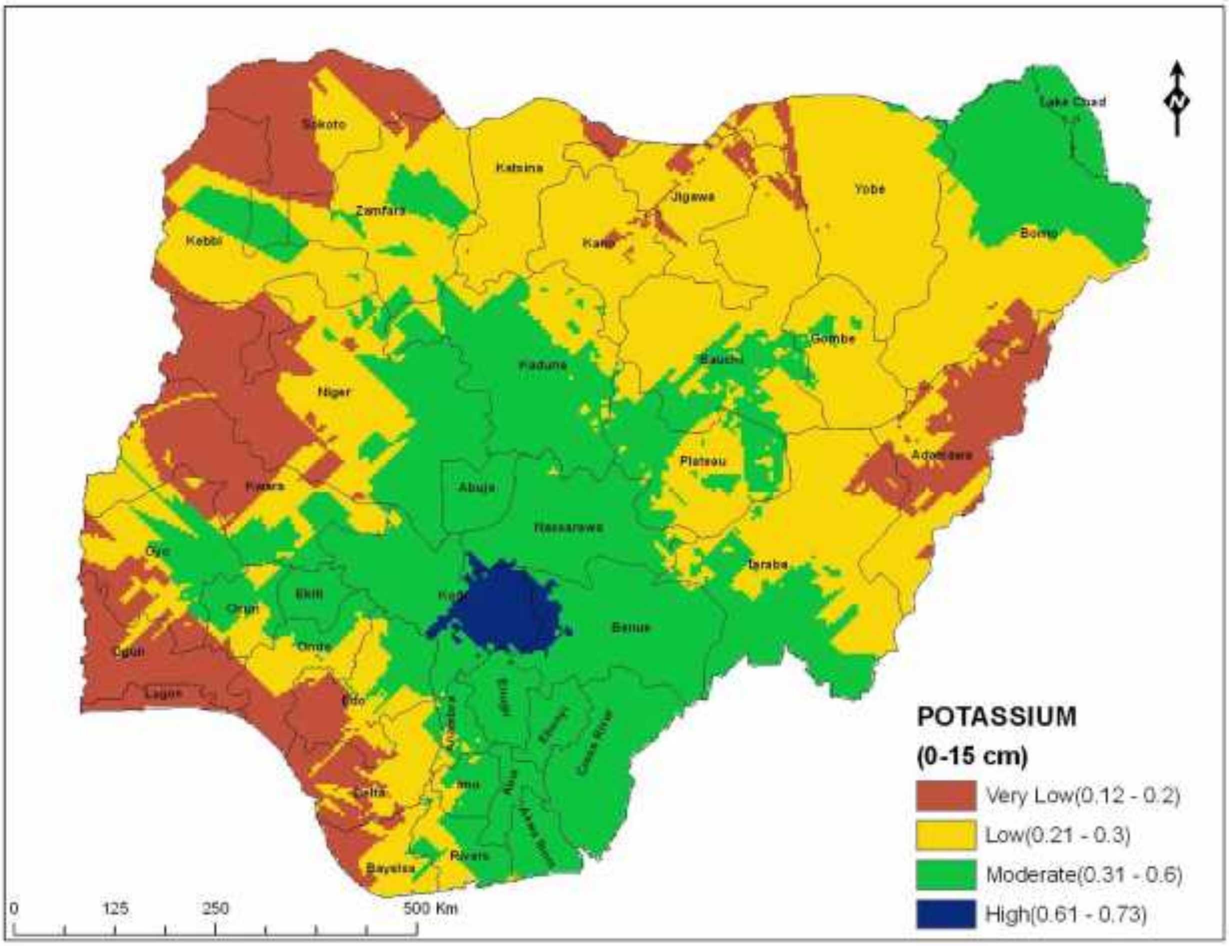


Fig. 1.22 Potassium Fertility Map of Nigeria

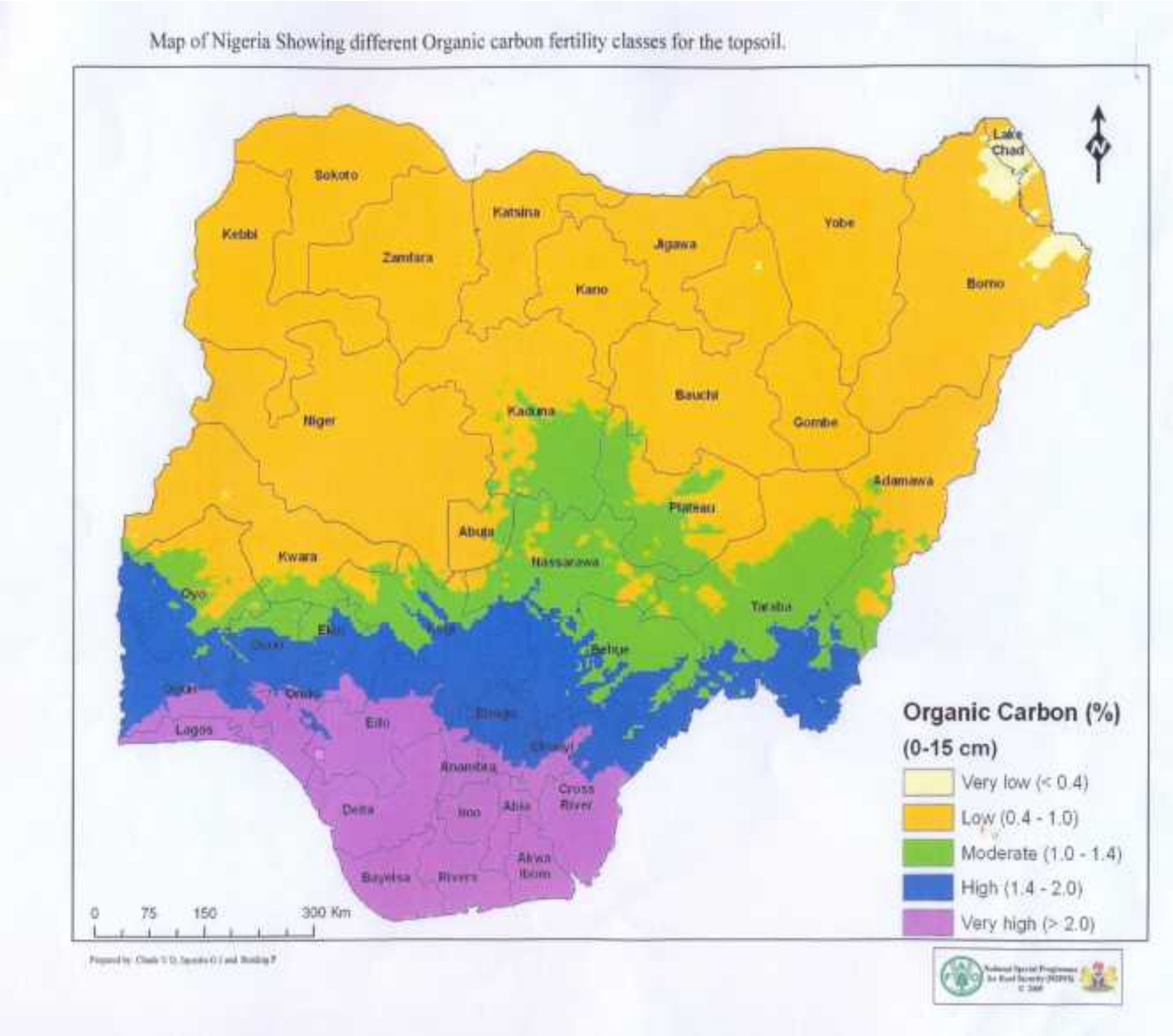


Fig. 1.23 Organic Carbon Fertility Map of Nigeria

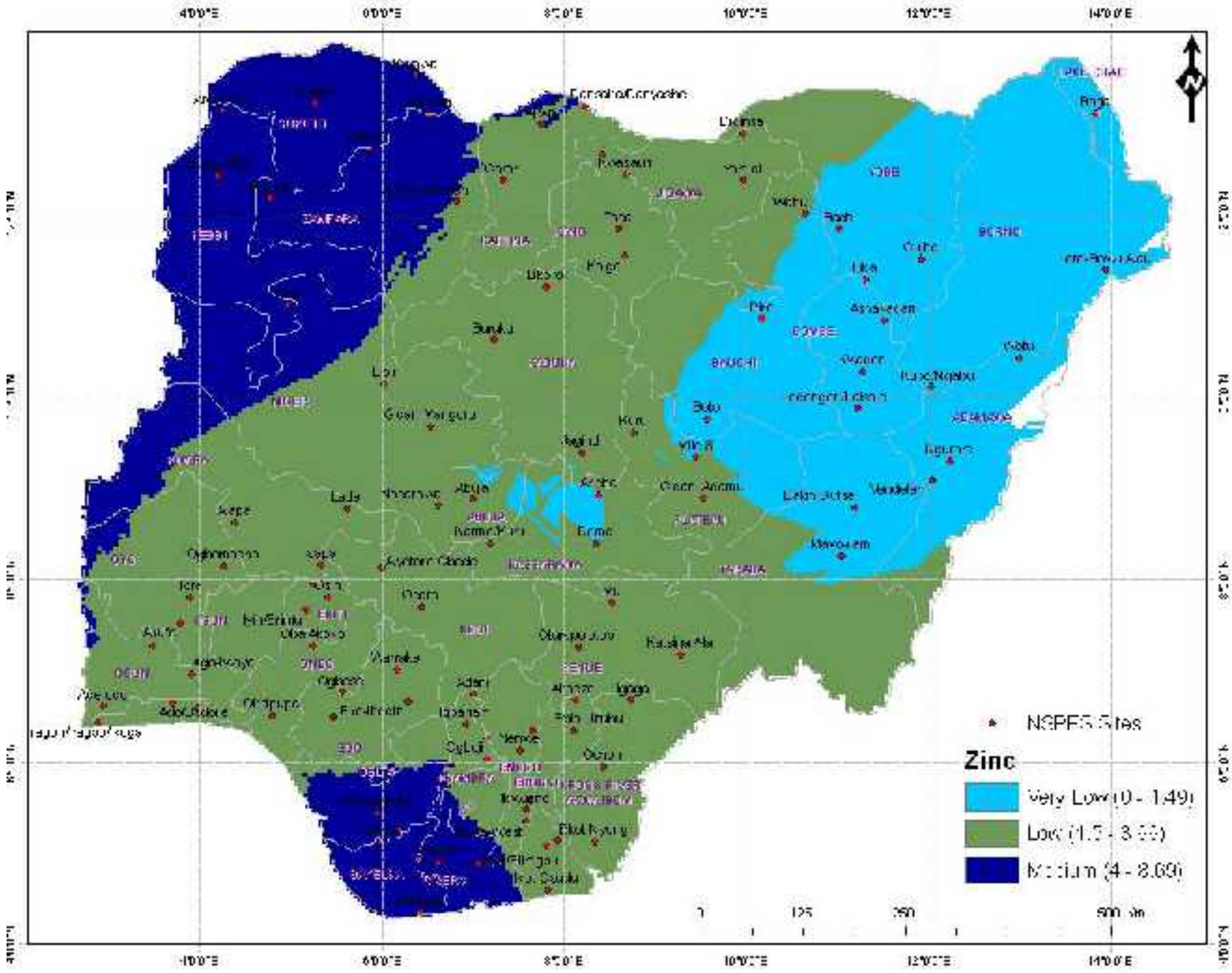


Fig. 1.24 Zinc Fertility Map of Nigeria

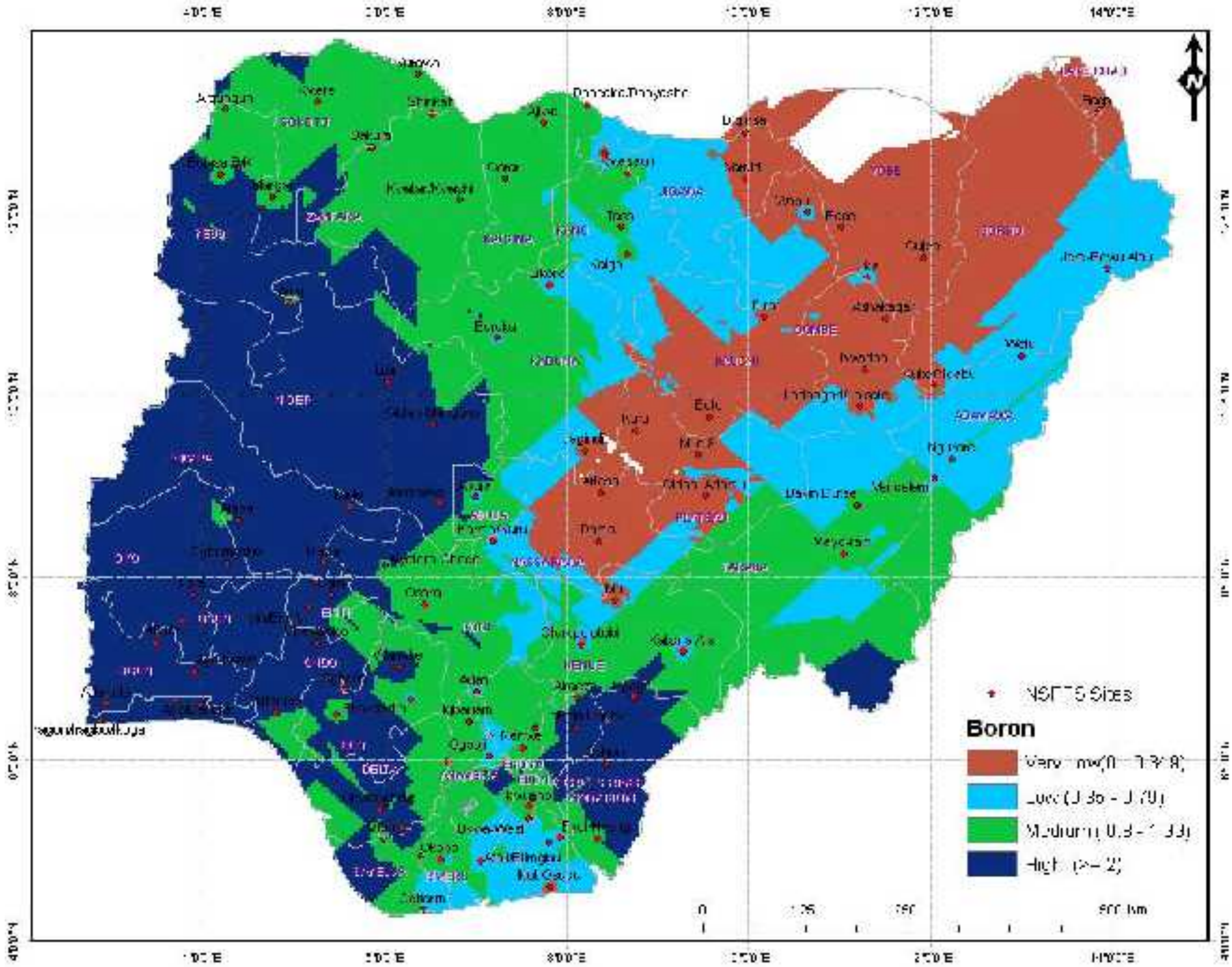


Fig. 1.25 Boron Fertility Map of Nigeria

In such systems, tillage practice and the cropping system must be studied before a firm recommendation is made. In the semi-arid area, sorghum followed by cotton and cowpea is another suitable rotation which allows recycling of the residue in the system. The problems of mulch farming includes planting through the rubbles which necessarily need to be by hand or small machine, effective weed control which will require suitable herbicide, instead of hand weeding. The advantage of mulch farming is that organic matter can be maintained at high level, resulting in the release of K and Ca to soil. Also leaching of nutrients and soil structure degradation is minimized.

1.7.2 Animal Manures and Household Refuse

The use of poultry dung, cow dung and household refuse increases the efficiency of inorganic fertilizers by providing secondary and micro-nutrients not present in the inorganic fertilizers. Long term studies in northern Nigeria (Lombin and Abdullahi 1977), showed that 5t/ha of dung annually combined with 100kg N and 50kg P_20_5 will maintain yield under continuous cultivation.

In an Ultisols at Agege in South Western Nigeria, maize yields were doubled from 1.2 to about 2.5ton/ha for the duration of the study (1962 - 1967) by addition of 5t/ha of dung annually. From the analysis of the dung and also other treatments included in the study, the dung provided lime effect, Mg and micronutrients deficient in the soil.

1.7.3 Nitrogen Fixation

Legumes fix atmospheric nitrogen and therefore require minimum inorganic nitrogen fertilizer. In general these legumes, whether grain or pasture, fix nitrogen which should be considered when combined or in rotation with other crops.

Groundnut, cowpea and soyabean are grain legumes that have been grown in association with cereals crops. Groundnut contribute about 50kg N/ha while soyabean contributes 225 - 30kg N, depending on the yield of the legume which is affected by phosphate fertilization (Amon and Adetunji 1973, Bromfield, 1967). The advantage of pasture legumes is that it reduces weed infestation and provides cover to the soil during the rains thereby reducing soil erosion and degradation.

The use of leguminous herbaceous species such as Gliricidea in alley cropping also contributes about 50kg N/ha, while the branches could be used as stakes for yams and other crops in the savanna area where short grasses are dominant species in the bush fallow.

1.7.4 Precaution on the use of organic and inorganic fertilizer

Organic manures are excellent sources of organic matter but relatively low in nutrients. Therefore, to obtain optimum yields from continuous cropping, additional nutrients from inorganic fertilizers will be needed to compliment organic fertilizer.

However, it should be noted that fertilizer-use, though highly desirable for increased crop yield, its application can be subjected to abuse or serious misuse. Misuse of fertilizers can emanate from the poor knowledge or awareness of the users of fertilizers, the distribution channels, the soil fertility or chemical status, crop specific needs and farming systems adopted by the farmers. The practice of providing fertilizer recommendations that are not based on adequate soil and sometimes plant tissue tests the use of generalized (blanket) application of fertilizer rates for all crops and errors in calculation of crops needs and mode of application constitute misuse and should be avoided. Fertilizer users should, therefore, be adequately informed and advised by extension agents so as to derive maximum benefits from the use of fertilizers.

1.8 Fertilizer Handling

Certain occupational hazards are inherent in the handling of fertilizers, as some of them are corrosive, particularly the nitrogenous types. Handling of lime may also be dangerous. This is especially so when large quantities are involved and the handling procedures are manual (as is presently the case in Nigerian ports). Stingling sensations, blisters, itching, irritations and erythema of the skin are common complaints among dock workers handling fertilizers. At the farmer's level, the risk of undue exposure is minimal since he handles only a small quantity in a relatively short space of time, during the growing season. However, skin complaints have also been received among fertilizer warehouse handlers or workers.

To minimize body contacts with the commodity both at the ports and ware houses, bagging now includes a thick polythene inner layer and a woven polypropylene ultra violet stabilized outer layer. Simple precautionary measures such as wearing of hand gloves, rubber sole shoes/boots, and protective clothing should be adopted.

1.8.1 Transport

The corrosive nature of some types of fertilizers affect the rate of ageing of the metal parts of trucks used for conveying the commodity. Exposure to weather conditions also reduces the quality of the fertilizers. Tarpaulins should therefore be used to cover all trucks carrying fertilizers within any distance, to protect if from the weather. Inter State transportation should be done with 30 tonnes net capacity trucks while intra State transport could be done with any truck of a lesser net capacity depending on truck availability and road conditions.

1.8.2 Storage

The quality of some fertilizers deteriorates rapidly when they come in contact with moisture or other soil amendments like lime. As far as possible, fertilizers should be protected from rain and water. Stored fertilizers at the port warehouses, and at field depots of Ministries of Agriculture and other distribution or user agencies should be properly covered with tarpaulin.

Farmers should construct simple stores within family grounds or compounds. Different fertilizer types should be stacked separately in any store; stacking height should be 18 - 20 bags to prevent slippage, reduce breakages, and for ease of stocking taking. Fertilizers should be stacked on strong wooden pallets to allow for enough dunnage in the warehouse or store. Fertilizer stacks or columns should be about 2 - 3m from the walls of the store for free movement and air circulation.

1.8.3 Supplies and Sales

Fertilizer supplies to all States and user agencies should be completed at least three months before the rainy season begins to allow time for distribution. Vehicles carrying fertilizers should be provided with tarpaulins against moisture and to minimize breakages. Such vehicles should not be allowed to carry other loads on top fertilizer consignments. Fertilizers should not be stored together with any consumable commodity and the store should not contain other inputs e.g. grains and chemicals. Ideally a fertilizer store should be within 10 - 15km of every farming community and well stocked throughout the year. Where this is not possible, stores should be stocked at such strategic periods as land preparation and periods of nitrogen application for cereals. Fertilizers should also be provided for late season farming.

Fertilizer sales should be continuous all the year round and may involve one or a combination of the following channels.

a) directly from Government stores

b) through commissioned agents contracted for the purpose who also sell other agricultural inputs
c) through cooperative societies
d) agro-service centers
e) local community organizations e.g. farmers unions and young farmers club etc.

1.9 Principles of Fertilizer Application

Once the choice of fertilizers has been made and the amount determined for a given crop, there remains the important problems of determining how and when the job should be done to obtain the best yields. This is particularly important when a limited supply of fertilizers is to be used to obtain optimum increases in crop yields. The selection of the best method of fertilizer application depends on a number of factors, notably the kind of soil, its moisture status, its fixing power for the different nutrients, previous management, the crop to be treated, its root development and the ability to extract nutrients in the soil as well as the kind and amount of fertilizer to be used.

Generally, the method used for applying fertilizers may be grouped into two: broadcasting and placement.

1.9.1 Fertilizer Broadcasting

The main objectives in broadcasting are, firstly to distribute the fertilizer evenly and to incorporate it with part of, or throughout, the plough layer. Secondly, broadcasting is used when applying large quantities of fertilizers that can be easily applied at the time of planting. In broadcasting, the fertilizer is spread over the entire soil areas to be treated, either before the land is ploughed, immediately before planting or while the crop is growing. The later is usually referred to as side dressing if the crop is in wide rows, and as top-dressing if the crop is in narrow rows or not in rows.

Delayed applications of nitrogen are made, commonly as top-dressing; top dressing of P and K are ordinarily made only on pasture that occupy the land for several years.

1.9.2 Fertilizer Placement

Placement refers to applying fertilizers into the soil, but with special reference to the location of the seed or plant. When the fertilizer is placed close to the seed or plant the application is said to be localized. The placement of solid fertilizers can be done with the help of simple implement (e.g. ploughs) and such hand-tools as hoes. Hill or row placement refers to applying the fertilizers either in bands or localized areas near the plants or along the planted row, but often in a definite space relationship to the seed or plant. This method allows for a greater availability of nutrients by reducing losses of P and K through fixation than when fertilizers are mixed with the soil. The greatest hazard of placing fertilizers near the seed is that germination may sometime be hindered or the young plant damaged by an excessive concentration of soluble salts, if the materials are put too close to the seed or plant. Such injury is greatest in dry sandy soils.

1.9.3 Fertilizing Tree Crops/Plants

The method of fertilizer application to tree plants is often a compromise between broadcasting and localized placement. Often, the fertilizer is broadcast under the tree to a distance of 30 - 60cm beyond the spread of the branches. On the other hand, when a cover or green manure crop is grown between the trees a large part of the fertilizer may be applied to this crop. In forest zones and on very sandy soils the fertilizer application may be repeated several times during the season.

1.9.4 Foliar Application of Fertilizer

Liquid fertilizer is applied direct to the foliage of a crop for maximum utilization. This is often advantageous when the soil contains insufficient moisture or when its physical and chemical conditions are otherwise unfavourable. This method is useful in correcting micronutrient deficiencies in tree or orchards, and arable crops.

1.9.5 Fertilizers and the Environment

Fertilizers are agro-chemicals. When applied appropriately and in the correct dosage, fertilizers, by enhancing vegetative growth in plants keeps the environment healthy. Leaf canopy protects the soil from the direct impact of rain drops which could result in soil erosion. The life of micro-organisms living beneath the soil and animals is protected. During eutrophication, fertilizer elements are eroded into the rivers and lakes for the nutrition of aquatic life. The ecosystem is maintained and biodiversity rejuvenated.

In urban and rural areas, organic wastes, consisting of human excrements animal dungs, bird guano sawdust and bush burning, domestic and industrial wastes, and others, abound, if not adequately managed can constitute potential environmental hazard. However, when converted technologically or biologically into organic fertilizers and used as feeds for animals, fishes in the ponds and rivers, bio degradation of the organic matter helps in improving the environment and making it safe from pollution.

1.9.6 Socio-economic and Policy Aspects of Fertilizer Use

a) Sociological considerations

The principal socio-economic factors affecting fertilizer use are knowledge, attitude and practice of small-scale farmers about the input. The relevant areas requiring improved knowledge and right attitudes as well as best practices include the following:

a) Type(s) of fertilizer required for specific crops and particular agro-ecologies;
· Rate and number of fertilizer application required to obtain maximum yield and income;
· Nature of fertilizer as it affects safe handling, storage and transportation;
· Possible side effects of fertilizers used on the crops, soil and environment.

In regard to these sociological considerations, the government provides extension services to ensure that the knowledge, attitudes and practices of small-scale farmers in these areas are compatible with the goal of farm production. This goal involves sustained increase of farm output and incomes consistent with maintenance of the soil environment and good health of the population.

b) **Extension Services with Reference to Fertilizer**

Since mid-1970s, delivery of agricultural extension service is through the World Bank - assisted Agricultural Development Projects (ADPs). Each state of the federation has an ADP with mandate for providing effective extension services backed-up with revamped input delivery to the farm population, among other agricultural support services.

In this context, fertilizer has featured prominently in the packages of recommendation and it ranks very high on the priority list of technical farm inputs that their delivery systems involve direct support of the government.

Under the ADP system generation of improved fertilizer technologies for the purpose of extension is achieved through the research - extension linkages. This involves the various research institutes as the major source of improved fertilizer technologies through applied research, to be subjected to experimental trials on station and on-farm. Farmer participation in the on-farm trials initiates a sequence of adoption process for particular fertilizer technologies under consideration. The process is subsequently reinforced through the series of Monthly Techndlogy Review Meetings (MTRM), fortnight trainings (FT) and ultimately farm visits.

c) **Yield and Income Effects of Fertilizer Use**

Fertilizer - induced productivity of crops may be determined by way of yield and income effícts of the crops in response to fertilizer use. An economic analysis of data obtained from fertilizer trials in the five agro-ecological zones provides a basis for assessing such effects for the whole country (Ayoola 1990).

In terms of the calibration trials incremental yields of maize attributable to fertilizer nutrients were in order of P followed by N and K. These yield effects were associated with average net returns in the order K, followed by P and followed by N. This implies that economic efficiency of nutrient use is in descending order of K followed by P followed by N.

In terms of the Nitrogen - source trials incremental yields of maize attributable to different sources of N is in the order of granulated urea (Gu, covered), followed by CAN (uncovered) and followed by regular urea (Ru, uncovered). The yield effects were associated with average net returns in the descending order of CAN, Gu followed by Gu and followed by Ru. This implies that economic efficiency of different nitrogen sources was in the descending order of CAN, followed by Cu and followed by Ru.

In terms of compound fertilizer evaluation trials in the middle - belt zone, incremental yield of maize attributable popular formulations were in the order of 15-15-15, 27-13-13 and 25-10-10., the order of 15-15-15; 25-10-10 and 27-13-13. This implies that economic efficiency of the popular formulation, was in the descending order of 15-15-15 followed by 25-10-10 and followed by 27-13-13.

d) **Command Areas in Fertilizer Marketing**

In 1990, the issue of command areas arose within the context of proposed liberalization of the fertilizer sector. In that context, private sector investors would be encouraged to enter the market to diversify the production base of the different formulations. And given the capital intensity of fertilizer manufacture through granulation plants, it was envisaged that the new entrants would rather be able to establish bulk blending plants in the short run. As a matter of policy, the federal government desired to achieve an optimal distribution of such enterprises by restricting their activities to definite areas of influence. In essence, the bulk blending plants represent down-strearn production units in the marketing chain of fertilizers.

Thus on the advice of NFTC the country was demarcated into definite agricultural areas for the operation of assigned numbers of fertilizer bulk blending plants. It was envisaged that within an area of mandatory jurisdiction a factory would formulate and market slated types and quantities of fertilizers. The practical role of the bulk blending plants in specific command areas include:

- As a means of ensuring,-effective penetration and coverage of the fertilizer market
- As a means of reducing the holding time of the blended fertilizer in transit and storage to prevent segregation before use.
- As a means of promoting agro-ecological specialization in fertilizer marketing services and use
- As a means of facilitating warranted intervention procurement and selling as well as residual subsidy administration.

The optimal density of bulk blending plants was based on a number of considerations particularly the preponderance of small-scale farmers and aggregate demand for fertilizer in each area. Also distance is of the essence so as to reduce the rigour of obtaining fertilizers to the bearest minimum. The normative density established was about 150 km radius wherein a blending plant should be centrally located. This led to the recommendation of twelve number of blending plants for the whole country, distributed among groups of states. However as observed, the anticipated distribution was not complied with.

e) **Fertilizer Market Intervention Policies**

The goal of market intervention policies of the fertilizer sector is to promote sustained use of the input at increasing rate. Prior to 1976 the various states of the federation undertook procurement and distribution of fertilizers in their respective areas of influence. The Federal Government subsequently established the Fertilizer Procurement and Distribution Division (FPDD) to intervene in the market as the dominant role player in supplying and distributing fertilizers in the country. The government also implemented a policy of price subsidy for the input. Specifically, two granulation plants were established, one for nitrogenous products and the other for phosphatic fertilizer, prior to the emergence of bulk blending plants in the 1990s. The implementation of initial policies was characterized by chaos emanating from perennial excess demand for the input in the face of inefficient distribution networks and mounting subsidy burden.

Thus the need for fertilizer sector reform became self-evident following the implementation of the structural adjustment programme (SAP), launched since 1986. After a series of initial false starts and absence of political will to institute fertilizer sector reform, the government formally adopted a liberalization policy in 1994. A study of "Liberalization of Nigerian Fertilizer Sector" was commissioned to IFDC and Nigerian experts, which made a number of far reaching recommendations (IFDC 1994). These include the following:

- That fertilizer trade covering importation, wholesaling, and retailing should be in the hands of the private sector;
- That fertilizer prices be decontrolled and determined by market forces, while all forms of controls inhibiting trade should be removed;
- That fertilizer subsidy should be progressively withdrawn over three years;
- That government's role should be redefined and limited to policy formulation, and legislation, quality control, product specifications, monitoring and evaluation, research and development, buffer stock operations as well as institutional restructuring.

The Federal Government withdrew from fertilizer importation in 1995 and from local procurement of the input in 1997. Thus since these times the policy of central procurement and and distribution of fertilizer has stopped except the one instance of intervention buying of a limited quantity locally in 1999 (120,000mt). The 1997 budget speech of the President formally declared the liberalization policy involving the fertilizer sector. The import of this policy as enunciated was that the organized private sector was free to manufactory, import, and distribute the products to meet set quality standards and within a regulatory framework. The government reserved the right to intervene in the market when the need arose through cautious procurement and distribution as well as buffer stock operations with a view to stabilizing market prices and cushion any adverse effects of the market on farmers. The demand and supply situation with the sector from 1992 is presented in Table 1.3.

Table 1.12 Fertilizer Demand and Supply, 1992-2000

YEAR	AGGREGATE DEMAND BASED ON INDENTS FROM STATE (mt)	AGGREGATE ORDER BY FEDERAL GOVERNMENT (mt)		ACTUAL SUPPLY (mt)	
		LOCAL	IMPORT	LOCAL	IMPORT
1992	2,444,339	800,000	610,000	534,886	373,018
1993	2,000,000	765,000	600,000	372,000	562,000
1994	2,049,998	800,000	650,000	278,870	632,546
1995	2,900,000	835,000	-	699,260	-
1996	2,900,000	600,000	-	577,930	-
1997	-	-	-	NA	60,150
1998	-	-	-	NA	212,021
1999	-	-	-	36,190	62,958
2000	-	-	-	166,468	168,233

Source: FFD, Nigeria Port Authonty (NPA) and private suppliers.
No action to demand, order or supply
NA = not available

1.9.7 Fertilizer Extension: Issues and options

Small holder farmers' decisions to adopt fertilizer and their subsequent decisions about application rates is influenced by agroecology, type of crop cultivated, age of farmer, educational status, access to credit, access/ distance to fertilizer market and gender. Soil fertilizer extension issues generally include:

- Generalized/ blanket fertilizer recommendations, regardless of the complexity and diversity of the context in which farmers are operating. This often leads to an imbalance in nutrients and soil degradation where the nutrients are under-applied.
- Low adaptation of fertilizer recommendations to farmers' socioeconomic conditions/ relative annual changes in economic conditions which imply changes in optimal/ most profitable rates of fertilizer for farmers to use. Fertilizer recommendations as currently made available are not dynamic/ responsive to these changes that take place within the farming system.
- Lack of technical knowledge by farmers on appropriate fertilizer use.
- Limited or no access to soil test results/ soil testing laboratories.
- Limited access to extension services.
- Other demand and supply issues

Expanding fertilizer use is widely considered to be a pre-condition for broad-based farm productivity growth. Existing literature show that a wide range of research efforts aimed at developing of a range of resource management strategies to improve soil fertility are in place. Generally combinations of both organic and inorganic inputs have been reported to be more promising technologies for sustainable soil fertility management in Nigeria. Improved fertilizer use (both organic and inorganic) in combination with improved land husbandry practices can lead to higher agricultural productivity growth, improved food security, and increase in rural income. The goal of fertilizer extension program in Nigeria would therefore be to improve the productivity and income of farmers through their widespread adoption of best fertilizer management practices.

The key fertilizer extension research challenges arising from this are the need for options which optimize the use of fertilizer research results amongst Nigerian farmers as well as to identify participatory extension strategies required for achieving sustainable increase in fertilizer adoption and intensity of use. Soil/ fertilizer research, extension and fertilizer input providers will need to put increasing emphasis on participatory strategies of working with farmers to identify best (bet) fertilizer management options. Farmers need to participate in the development of these strategies for the adoption of new fertilizer use and management innovations based on equal partnerships between farmers, researchers and extension agents.

The concept of Research Extension Farmer Input Linkage System (REFILS) to facilitate extension approaches and learning processes with farmers has gained a particular attention in recent times and is currently practiced in Nigeria. REFILS is the organization of research, extension and input agencies to improve productivity of farmers through cost-effective implementation of all their activities. Nationally, REFILS provides the framework for the coordination of all research and extension linkage activities. The concept of REFILS encompasses all contributors to agricultural production (in this case fertilizer use and management- farmers, fertilizer distributors, retailers, manufacturers etc). The farmer, researcher, extension and fertilizer input/ service providers are viewed as partners in technology development, extension and adoption. REFILS is therefore predicated that the farmer is involved in the whole process of technology development and application resulting from

a. problem identification
b. technology generation
c. technology adaptation
d. technology dissemination

Components of REFILS

It consists of 4 major components for effective and successful agricultural production viz:

1. R-research –to generate technologies
2. E-extension-to disseminate technologies to farmers
3. F-farmers-to create awareness and enhance adoption
4. I-input –(agencies)–provide input
5. L-linkage (communication) for success and sustainability.

Participatory extension efforts are more effective by the establishment of a networking system for all stakeholders.

An existing issue confronting fertilizer extension is the need to promote/ strengthen linkages and partnerships between research, extension, farmer and the fertilizer input sector. Participatory extension efforts combined with fertilizer distribution innovations would ensure that farmers are sensitized on the benefits and techniques of using fertilizer for improved land productivity.

1.9.8 Extension Strategies for Facilitating Increased Fertilizer Use-

Farmers Empowerment and training: Farmer empowerment and participatory strategies are required build capacity of farmers to adopt relevant technical recommendations. Interventions designed to promote increased use of fertilizer should empower farmers to make their own decisions on the most appropriate way to manage soil fertility in their particular farming context. Farmers need to assume their place in the driver's seat of research and extension and therefore play a major role in decision-making and managing their own affairs. Also, to change farmers' behaviour, the extension programs need to be designed to change farmers' attitudes, increase the receptivity of farming communities and modify traditional practices. This will involve strengthening soil-crop research and extension through a strategic framework for local capacity building. This will also involve the use of participatory learning and action research (PLAR) tools.

Improvement in access to knowledge/ technical information on fertilizer issues: This is aimed at improving quality and dissemination of information. There is a large variety of channels for disseminating agricultural information, and its ranking by farmers generally varies. However, radio is the mass media tool most appreciated by farmers. Both print and electronic media tools will however be used based on specific situations/ objectives. This will involve translations of guides and technical bulletins on fertilizer use into local languages. Sustainable improvement of efficiency of dissemination of agricultural knowledge to relevant stakeholders is dependent on a site-specific knowledge transfer tailored according to the local agronomic, social, economic and societal parameters. This will involve development and deployment of simplified decision support tools.

Fertilizer recommendations therefore do not only have to be site-specific but should also provide farmers with knowledge and tools to use in modifying these recommendations to make them more appropriate for the particular circumstances farmers might face. Simplified decision-aids will therefore be required to assist farmers in modifying the recommendations by integrating information about the particular resource constraints, changing prices for fertilizer and crop, location characteristics, etc. There is therefore critical need to increase the capability of farmers and other stakeholders especially extension agents before introducing the simplified decision-aids tools on nutrient management.

Promotion of fertilizer use as part of a wider strategy/ Promotion of improved soil management at large scale: Interventions designed to promote increased use of fertilizer should be developed within the context of a wider sector strategy that recognizes the importance of supplying complementary inputs, strengthening output markets, and appropriately sequencing interventions. I.e., in order to provide an economic outlet for food supplies generated by increased fertilizer use and irrigation, markets, transportation facilities and the overall rural infrastructure need to be developed. It will also involve improving farmers' ability to purchase fertilizer, improved seeds and other inputs by improving access to credit, etc.

CHAPTER TWO

2.0 FERTILIZER PRACTICES FOR SOLE CROPPING

2.1 General Concept

Fertilizer recommendations for sole crops emanate almost exclusively from extensive laboratory and/or field trials over time and space. Such trials result in average recommendations for a crop within an area which are normally put out by approved extension agencies for adoption by farmers. Where an approved fertilizer practice is considered inadequate or where no formal recommendation is available, the Fertilizer Use Committee has put forward suggested practices on the basis of existing information, individual or common knowledge and experience.

Improved Crop Husbandry

In discussing the fertilization of crops in this chapter brief mention has been made about related husbandry practices which could influence the effectiveness of applied fertilizers and the efficiency of their use. It should be noted that unlike unimproved (local) varieties of crops which are characterized by a low-yielding potential, improved varieties generated by the various breeding programmes are more responsive to such improved technologies like the use of chemical fertilizers. It should similarly be noted that since most crops are grown on ridges spaced 1m apart or more, there is narrow limit placed on the arrangement of plants and on the plant populations that could be attained relative to flat planting. Because there are, rarely significant inherent advantages (excepting root and tuber, crops) in planting on, mounds or ridges, it is suggested that wherever possible and, particularly with regard to large scale farmers, crops should be sown in well prepared flat seed beds.

It is thus reasonable to expect that there is a lot to be gained from the use of appropriate and adequate fertilizers under improved agronomic packages involving the use of correct crop variety seed dressing (Aldrex - T or Fernasan-D), spacing and seeding rate as well as in timely sowing and effective weed, pest and disease control. In contrast the farmer who habitually sows late using unimproved crop varieties, the seed of which is rarely dressed and invariably incorrectly spaced with a consequent poor germination and sub-optimal plant population, would hardly be justified to expect much benefit from the use of fertilizers, particularly if these are incorrectly and/or insufficiently applied. The active ingredients content of common fertilizer materials used in Nigeria or mentioned in this document are summarised in Appendix II.

2.2 Cereals

2.2.1 Maize *(Zea mays* **L***)*

a) Area under crop:

An estimated 2 - 3 million hectares are currently under maize in Nigeria and its cultivation in the Savanna continues to increase.

(b) Nutrient Deficiency Symptoms

(i) *Nitrogen Deficiency:* Leaves yellow; older leaves dying at tips and progressively along mid-vein; stalks slender; stunting.

(ii) *Phosphorus Deficiency:* Leaves turn purplish during early growth; slow maturity; irregular ear formation and stunting.

(iii) *Potassium Deficiency:* Yellow or yellowish-green streaks especially on lower leaves, followed by marginal scorch; short inter-node; weak plants easily lodged.

(iv) *Magnesium Deficiency:* A general loss of green colour which starts in the bottom leaves and later moves up the stalk. The leaf vein, remains green. Stalks are weak with long branched roots. Definite and sharply defined series of yellowish-green, light yellow or even white streak throughout entire leaf. Leaves curve upward along the margins.

(v) *Sulphur Deficiency:* Young leaves turn light green with even lighter veins. Stalks are short, slender and yellow in colour. Growth is slow and plants are stunted.

(vi) *Zinc Deficiency:* Pale yellow leaf base, light yellow streak of the leaf blade between the veins, stunting and delayed maturity.

(vii) *Boron Deficiency:* Boron causes one-sided shriveling of kernels. In severe cases, lack of seeds rnay occur.

(c) Fertilizer Sources and Rates

Fertilizer recommendations and/or suggestions for maize in the major agro-ecological zones of the country may be summarized as in Tables 2.2 and 2.3:

(d) Fertilizer Application -Time and Method

(i) In the Sahel Northern and Southern Guinea Savanna zones, apply half of the N at planting or 2 -3 weeks after planting (WAP) and the remainder, about 5 - 6 WAP. For the Sahel, Sudan and Northern Guinea Savanna, in particular, basal N should be dibbled along a 5cm deep groove about 8cm away from the row of plants at 3 WAP and cover with sod. P and K are applied in furrows as single sources or compared to NPK fertilizers before splitting

(ii) In the forest zone, apply all the N, P and K at planting or at 2 - 3 WAP. However, under continuous cropping, split-apply the N at planting and 5-6 WAP.

e) *Varieties*

The improved maize varieties currently recommended in the various agro-ecological zones of the country are given in Table 2:1

Table 2.1 Recommended Maize varieties for different Agro-ecological Zones

AGR0-ECOLOGICAL ZONE		RECOMMENDED MAIZE VARIETY
Sahel	Open pollinated Hybrid:	TZSR - Y TZSR - W 8644 - 27, 8341 - 5, 8322 - 13, 8425 - 8
Sudan	Open pollinated Hybrid:	As in Sahel + DMRSR - Y DMRSR - N DMRsR - N 8341 - 6 8341 - 5, 8322 - 13, 8425 - 8 8644 - 27
Northern Guinea Savanna	Open pollinated Hybrid:	As in Sudan As in Sudan
Southern Guinea	Early season Open pollinated	TZSR - Y, TZSR - W, TZB, TZPB, FARZ34, FARZ227 FARZ7 WESTERN YELLOW. NCA, NCB
Savanna and Forest	Hybrid: Late season Open pollinated Hybrid:	8329 - 15, 8329 - 22, 8329 - 19, 8425 - 18 8236 - 17, 8339 - 17, 8428 - 19, 8321 - 18, 8322 - 13 DMR-SR-Y, DMR-SR-W, EV8443-SR-W, EV8423-SR-Y 8341 - 6, 8341 - 5

Table 2.2 Fertilizer recommendations for maize (open pollinated) (based on soil test/soil fertility map)

NUTRIENT	FERTILITY CLASS	NUTRIENT RATES HA^{-1}	FERTILIZER RATE AND SOURCE/HA^{-1}
Nitrogen	Low	120kg N	Urea (260kg or 5 bags) or CAN (462kg or 9 bags or 20-10-10((600kg or 12 bags). Apply half the rate of N at planting or 2 - 3 WAP and the remaining half at 5 - 6 WAP .
	Medium	60kg N	Urea (133kg or 2½ bags) or CAN (231kg or 4½ bags) or 20-10-10 300kg or 6 bags)
	High	30kg N	Urea 63kg or 1½ bags or CAN 115kg or 2¼ bags 150kg 20-10-10 or 3 bags
Phosphorus	Low	60kg P_20_5	SSP (333kg or 7 bags) or SSP 3 bags at palnting or 2 - 3 WAP
	Medium	30kg P_20_5	SSP (167kg or 3 bags) at planting or 2 - 3 WAP
	High	Nil	-
Potassium	Low	60kg K_20	MOP (100kg or 2 bags) at planting or 2 - 3 WAP
	Medium	30kg K_20	MOP (50kg or 1 bag) at planting or 2 - 3 WAP
	High	NIL	NIL

Table 2.3 Generalized fertilizer recommendation for maize (open pollinated) (based on agro-ecological zones)

AGRO-ECOLOGICAL ZONE	RECOMMENDATION (NUTRIENT HA^{-1})	MATERIAL HA^{-1}
Sahel	**120kg N**	Urea 260kg or 5 bags) or CAN (462kg or 9 bags) 20-10-10 (300kg or 6 bags) at planting or 2 - 3 WAP and 2½ bags of Urea at 5 - 6 WAP
Sudan Northern Guinea Savanna	**60kg P_20_5** **30kg K_20**	SSP (333kg or 7 bags) MOP (50kg
Southern Guinea Savanna	**100kg N** **50kg P_20_5** **30kg K_20**	Urea (220kg or 5 bags) or CAN (385kg or 8 bags) or 20-10-10 (667kg or 13 bags) half N at planting or 2 - 3 WAP and half 5 - 6 WAP SSP (278kg or 6 bags) MOP (50kg or 1 bag)
Forest	**70kg N** **50kg P_20_5** **30kg K_20**	Urea (150kg 0r 3 bags) or CAN (250kg or 5 bags) or 20-10-10 (350kg or 7 bags) SSP (139kg or 3 bags) MOP (50kg or 1 bag) or 4 bags of 20-10-10, 1 bag Urea + 1 bag single super

- Fertilizer rates are the same for early and late seasons in the Forest and Southern Guinea Savanna; About 1½ times of the rate for open pollinated is recommended for hybrid maize In all agro-ecological zones.

(f) *Cultural practices:* Seed at 25kg/ha of grain to achieve 54,000 plants/ha (75cm x 25cm) for one, plant per stand or 90cm x 40cm for 2 plants per stand). In the southern Guinea Savanna and Forest zones where the rainy season is long enough for two crops, plant in March/April for the first (early) crop and in August for the second (late) crop. In the Nothern Guinea Savanna, Sudan and Sahel zones where only one crop is possible plant as soon as the rains are established.

With regard to weed control, atrazine is the herbicide currently recommended for use in most of forest zones. It is applied pre-plant (or latest 2 days after planting) at 3.6kg a.i/ha in 225 litres of water. Any of the following herbicide recommendations will effectively check weeds in the Southern Guinea, Northern Guinea and Sudan zones, except where specified.

(i) 1.33kg a.i Metolachlor + 0.6 7kg a.i Atrazine (4 litres Primextra)/ha. or
(ii) 1.0kg ad Metolachlor + I.Okg ad Atrazine (= 4 litre Primagram)/ha.
(iii) If *Rottboelia exallata* constitutes a problem (as in large mechanised schemes), use 2-0kg a.i Pendimethalin + 2.Okg a.i) Atrazine (6 litres stomp + 4 litres Gesaparim or Atranex 500 FW)/ha.
(iv) If *Cyperus esculentus* constitutes a problem (as in mechanised farms and irrigated schemes), use either (i) above, or 2.Okg a.i Alachlor + 1.0kg a.i Atrazine (=4 litres Lasso + 2 litres Gesaprim 500 FW) /ha pre-emergence.

(v) In case of *Cyperus rotundus/Cyperus tuberosus* infestation in irrigation schemes, use either - 3.Okg a.i, Butylate + I.Okg ai Atrazine(= 4 litres Eradicane + 2 litres Gesaprim 500 FW) / ha pre-plant incorporated.

(f) On the lighter soils of Sahel zone, the rates should, not exceed 2/3 of those given above. It should be noted that great caution, should be exercised in the selection and handling of all herbicides in view of their inherent hazards to crops and animals, including humans.

g) *Yield Expectancy:* Farmers maize yields vary widely between 200 and 2,000kg/ha of dry grain. The above recommended practices give grain yields ranging from 3,500 to 5,000kg/ha. The yields potential for maize is estimated at 7 -8,000kg/ha of grain in the Northern Guinea zone and between 4 - 5,000g/ha in Southern and Forest zones. Where a second'(late) crop is grown yields are generally lower. Oil may be commercially extracted from the maize germ and the content varies from 50 - 56%. Protein content averages about 9.5%

HYBRID MAIZE

Varieties: 8321 - 18)
8322 - 13) White Varieties
8428 - 19)
8425 - 8) yellow
8329 - 15)

- **Striga resistant**

Consult National Seed Service reputable private seed companies, IAR, Zaria and IAR&T Ibadan for the latest variety available.

Seedrate: 15kg/ha)
Planting Distance: 90 x 40cm)
2 plants/stand) Hand Planting
Planting Population: 55,555 plants/ha)

OR

Planting distance: 75 x 25 cm or 90 x 20cm at one plant/stand = 55,555
Fertilization: 300kg (6bags) 20-10-10 at planting.
2nd dose: 350kg (7 bags) CAN or 200kg Urea (4 bags)/ha.

This gives a total of 150kg N, 60kg P_2O_5 and 60kg K_2O/ha.
Add 100kg SSP + 5kg $ZnSO_4$/ha.
The Zn and SSP are required in the Savanna zone.

CAUTION: It is advisable to carry out soil test before fertilizer use.

POTENTIAL YIELD OF HYBRID VARIETIES

1. Forest/Transition/Southern Guinea Savanna: Average yield - 4.0t/ha.
2. Northern Guinea Savanna: Average yield: - 5.0t/ha.

2.2.2 Guinea Corn (Sorghum *bicolor*)

a) *Area under crop*

An estimated 6 - 6.5 million hectares is currently under guinea corn in Nigeria.

b) Nutrient Deficiency Symptoms

(i) Nitrogen Deficiency: In young sorghum plant there is a stunted spindly growth and yellowish green foliage; in later growth the leaves become definitely yellow

(ii) *Phosphorus Deficiency:* Mild deficiencies are characterized by stunted growth with no clear-cut symptoms more severe deficiencies usually cause browning of leaves, starting with older leaves and delayed maturity.

(iii) *Potassium Deficiency:* Produces bronze to yellow discoloration along the edges of lower leaves; marginal discoloration is continuous from tip to base of leaf.

(c) *Fertilizer Sources and.Rates*

Fertilizer recommendations for guinea corn (sorghum) may be summarised as in Tables 2.4 and 2.5

Table 2.4 ***Fertilizer Recommendations for Guinea Corn (Sorghum) (based on Soil Test/ Soil Fertility Map)***

NUTRIENT	FERTILITY CLASS	NUTRIENT RATES HA^{-1}	FERTILIZER RATE AND SOURCE HA^{-1}
Nitrogen	Low	64kg N	Urea (142kg or 3 bags) or CAN (246kg or 5 bags) or 20-10-10 (320kg or 6¼ bags)
	Medium	32kg N	Urea (71kg or 1½ bags) or CAN (123kg or 2½ bags) or 20-10-10 or (160kg or 3¼ bags)
	High	16kg N	Urea (35kg or ¾ bag) or CAN (61kg or 1¼ bags) or 20-10-(10 180kg or 1¾ bags)
Phosphorus	Low	32kg P_20_5	SSP (178kg or 4 bags) or (71kg or 1½ bags
	Medium	16kg P_20_5	SSP (89kg or 2 bags) (36kg or 1 bag)
	High	NIL	NIL
Potassium	Low	30kg K_20	MOP (50kg or 1 bag)
	Medium	15kg K_20	MOP (25kg or ½ bag)
	High	NIL	NIL

Table 2.5 Generalized fertilizer recommendations for guinea corn (sorghum) (based on agro-ecological zones)

AGRO-ECOLOGICAL ZONE	RECOMMENDATION (NUTRIENT HA^{-1})	MATERIAL HA^{-1}
Sahel	**64kg N**	Urea (142kg or 3 bags) or CAN (246kg or 5 bags) 20-10-10 (220kg or 6½ bags)
Sudan Northern Guinea	**32kg P_20_5**	SSP (178kg or 4 bags)
Savanna	**30kg K_20**	MOP (50kg or 1 bag)
Southern Guinea	**32kg N**	Urea (71kg or 1½ bags) or CAN (123kg or 2½ bags) or 20-10-10 (160kg or 3¼ bags)
Savanna and	**16kg P_20_5**	SSP (89kg or 2 bags)
Forest	**15kg K_20**	MOP (50kg or 1 bag)

(d) *Fertilizer application: Time and Method*

The existing recommended practice is to apply P fertilizer in furrow bottoms before splitting the old ridges; N fertilizer is applied in two splits half at 2 - 3 weeks after planting and the other half at 6 - 8 weeks after planting. It is suggested that applying P and K fertilizers in old furrows before re-ridging and planting and the placement of all the N in grooves 8cm from the row of plants at 3 - 4 weeks after planting would result in improved yields and a reduction in application costs.

(e) *Varieties*

Improved guinea corn varieties currently recommended for the four major agro-ecological zones are as follows:

Table 2.6 Improved guinea corn varieties

AGRO-ECOLOGICAL ZONE	RECOMMENDED GUINEA CORN VARIETY
Sahel	SRN 4841, KSV4, KSV3, KSV11, KSV12, KSV15, SAMSORG-5 & 6
Sudan	SRN 4841, KSV2, KSV5, KSV7, SAMSORG-13-14, KSV8
Northern Guinea Savanna	SRN 4841, SSV2, SV33, SSV6, SSV7, SSV9, SSV10, NSVI NSV2, SAMSORG-22 & 23
Southern Guinea Savanna and Forest	SRN 4841, MSV1, MSV2, MSV3, SAMSORG 17 & -18 Hybrid SSH2, SSH3, SSH5, SAMSORG17 & 18

(f) *Cultural practices*

Seed at 10 - 20kg/ha of grain to achieve 37,000 - 66,000 plants/ha (90 x 30cm - 60 x 25cm) depending on variety, plant arrangement and level of management. Since guinea corn is largely grown in the Savanna and Sudan zones, it should be planted as soon as the rains are well established and immediately after a good rain. Any of the following herbicide recommendations will effectively check weeds in the Southern and Northern Guinea and Sudan zones, except where specified.

Compound fertilizers can be used to supply half of N and all the P & K at planting or a t 2 - 3 WAP. The remaining N can be given as urea or CAN at 6 - 8 WAP.

(i) 0.75kg a.i Terbutryne + 0.75kg a.i Terbuthylazine (3 litres Sorghum) ha^{-1}

(ii) 0.8kg a.i. Atrazine + 0.8kg a.i Terbuthylazine (1.6 litres Gaseprim 500 FW + 1.6 litres Gardprim)/ha. On lighter soils of northern areas lower rates (about 0.5kg a.i. each are preferred).

(iii) 1.0kg Atrazine (= 2 litres Gesaprim 500 FW)/ha. A lower rate, 0.5 - 0.8kg a.i. is preferred for lighter soils. Great caution must be exercised in the selection and handling of all herbicides.

(g) Yield Expectancy

Farmers' yields of guinea corn vary widely between 600 and 1,700kg ha^{-1} of dry grain. By adopting recommended practices yields of up to 3,000kg ha^{-1} are possible. The yield potential for guinea corn is estimated at 4 - 5,000kg ha^{-1}. Protein content is estimated at about 10%.

2.2.3 Millet (Pennisetum *typhoideum*)

a) *Area under crop*

It is estimated that about 5 - 5.5 million hectares of land is cropped to millet annually.

b) Nutrient Deficiency symptoms

i) Nitrogen Deficiency: Same as for guinea corn

(ii) Phosphorus Deficiency: Same as for guinea corn

(iii) Potassium Deficiency: Same as for guinea corn.

c) Fertilizer source and Rates:

Fertilizer recommendations for millet may be summarized as in Tables 2.7 and 2.8.

Table 2.7 Fertilizer recommendations for millet (based on soil test/soil fertility map).

NUTRIENT	FERTILITY CLASS	NUTRIENT RATES HA^{-1}	FERTILIZER SOURCES AND RATE HA^{-1}
Nitrogen	Low	60kg N	Urea (131kg or 3 bags) or CAN (231kg or 5 bags) or 20-10-10 (300kg or 6 bags)
	Medium	30kg N	Urea (65kg or 1½ bags) or CAN (115kg or 2½ bags) or 20-10-10 or (150kg or 3 bags)
	High	15kg N	Urea (32kg or ¾ bag or (CAN 57kg or 1 bag) or 20-10-10 (75kg or 1½ bags)
Phosphorus	Low	30kg P_20_5	SSP (167kg or 3 bags) or TSP (67kg or 1 bag)
	Medium	15kg P_20_5	SSP (83kg or 1½ bags) or TSP (33kg or ½ bag)
	High	NIL	NIL
Potassium	Low	30kg K_20	MOP (50kg or 1 bag)
	Medium	15kg K_20	MOP (25kg or ½ bag)
	High	NIL	NIL

Table 2.8 General fertilizer recommendations for millet (based on agro-ecological zones)

AGRO-ECOLOGICAL ZONE	RECOMMENDATION (NUTRIENT HA^{-1})	MATERIAL HA^{-1}
Sahel	**60kg N**	Urea (131kg or 3 bags) or CAN (231kg or 5 bags) 20-10-10 (300kg or 6 bags)
Sudan Northern Guinea	**30kg P_20_5**	SSP (167kg or 3 bags)
Savanna	**30kg K_20**	MOP (50kg or 1 bag)
Southern Guinea	**30kg N**	Urea (65kg or 1½ bags) or CAN (115kg or 2½ bags) or 20-10-10 (150kg or 3 bags)
Savanna and	**15kg P_20_5**	SSP (82kg or 1½ bags)
Forest	**15kg K_20**	MOP (25kg or ½ bag)

d) Fertilizer Application. -Time and Method

Spread P and K in old furrow bottoms before making new ridges and planting. Drill all the N at 3 weeks after planting in grooves about 8cm from the row of plants and cover with soil. Where 20-10-10 is used, apply all the recommended rates and 3 WAP.

(e) *Varieties*

Millet can be classified into 3 types:

i) *Gero* is short season variety which takes 90 days to mature . The variety "Ex Borno" is recommended for the Sahel and Sudan zones

(ii) *Maiwa* is a longer season millet, taking upwards of 120 days to maturity. The selections "Ex-Gashua", "Ex-Riyom" and- "Ex-Tukur" are recommended for the Northern Guinea and Southern Guinea Savanna.

(iii) *Dauro-* is a transplanted long season millet which generally grows shorter than Maiwa. No varieties are recommended and it is suggested that the best local varieties should be used.

(f) *Cultural Practices*

Seed at 10 - 15kgha^{-1} of grain to attain 44 - 60,000 plants/ha (90 x 25cm - 75 x 25cm). Plant 'gero' millet at the onset of established rains and 'Maiwa' 3-6 weeks later. Any of the under-listed herbicide recommendations will control weeds in the main millet-growing areas of the Sudan, Northern and Southern Guinea Savanna zones.

(i) 0.5kg a.i Atrazine + 0.5kg a.i Terbuthylazine (1 litre Gesaprin 500FW + 1 litre Gardoprin)/ha.

(ii) 0.8kg a.i Atrazine + 0.8kg a.i Propazine 1.6 litres Gesaprin 500 FW + 0.8 1. Lorox 50WP)/ha.

It should be noted that great care needs to be taken in selecting and handling herbicides.

(g) *Yield Expectancy*

Farmers' grain yields range between 450 and 1,400kg/ha. Under improved cultural practices yields of 2,000 - 3,500kg/ha are possible. Protein content is estimated at 9.7%.

2.2.4 Rice (*Oryza sativa* L.)

a) *Area Under Crop*

An estimated 3 million hectares is under rice annually out of the potential land area of 4.6 – 4.9 million hectares for rice production.

(b) *Nutrient Deficiency/Toxicity Symptoms*

(i) *Nitrogen Deficiency:* Characterized by stunting, and poor tillering. Leaves are narrow, short, erect and yellowish-green. Old leaves die when straw is coloured.

(ii) *Phosphorus Deficiency:* Plants are stunted with a lirnited number of tillers. Leaves are narrow, short, erect and dirty-dark green. Old leaves die when brown coloured. A reddish or purplish colour may develop on leaves if the particular rice variety has a tendency to produce anthocyanin pigment.

(iii) *Potassium Deficiency:* Stunted and weak plants. Leaves short, droopy and dark green. Sometimes; brown spots may develop on the dark green leaves.

(iv) *Magnesium deficiency:* With mild deficiency, no clear-cut symptoms more severe deficiencies usually cause wavy and droopy leaves. Interveinal chlorosis occur on lower, leaves, sometimes, characterized by orange yellow colour.

(i) Sulphur Deficiency: Yellowish colouration of young leaves.

(vi) *Zinc Deficiency:* The more common symptoms are the appearance of brown blotches streaks on the lower leaves, followed by stunted growth. In the field, uneven growth and delayed maturity are characteristics of Zn deficiency.

(vii) *Iron Deficiency:* Uppermost leaves of the plant become chlorotic with some green colour retained around the veins. The young leaves take on a bleached appearance. Older leaves retain their green colouration at first, but as the deficiency progresses, they become chlorotic with marked interveinal chlorosis. Iron deficiency in rice occurs in irregular patches in the field; green and chlorotic stands have often been seen to grow side by side. Iron deficiency is often associated with soils high in pH (e.g saline -sodic, sodic soils and vertisols).

(viii) *Iron toxicity:* At first, yellowing and tiny brown spots appear on the lower leaves starting from the tips and spreading towards the base. Subsequently, younger leaves become affected and many older leaves completely die. In susceptible cultivars, the leaf colour may be orange, yellowish - brown, reddish - brown, brown or purplish brown, depending on the variety and severity of iron toxicity. Roots of affected plants are generally coarse, sparse dark brown and damaged. Iron toxicity occurs in strongly acid Ultisols and Oxisols, deltaic and estuarine acid sulphate soils and in histosols, and often associated with other stresses such as salinity, phosphorus and zinc deficiencies and low base status.

(c) *Fertilizer Sources and Rates*

Fertilizer recommendations and/ or suggestions for rice maybe summarized as in Tables 2.9

(d) *Fertilizer Application -Time and Method:*

(i) For lowland rice (shallow swamp, irrigated, hydromophic and inland valley swamp) apply half the N and all P and K at planting/transplanting and the remainder broadcast at 6 - 7 weeks after planting/transplanting or at panicle initiation stage.

(ii) For lowland rice (deep water and floating and mangroove ecologies), apply all N, P and K at planting.

(iii) For upland rice in Sahel, Sudan and Northern Guinea, apply half N and all P and K at 1 - 2 weeks after planting, broadcast the remainder of N at 6 weeks after planting.

(iv) For upland rice in Southern Guinea and Forest zones, apply all N, P and K. 1 - 2 weeks after planting and first weeding.

a) (e) *Varieties*

Basically, two types of rice are grown:

(i) Upland rice grown under rainfed, free draining soil conditions between mid May and mid June. Improved upland rice varieties currently recommended for the six major agro-ecological zones are as given in Table 2.12

(ii) Lowland rice grown on flood plains, irrigated schemes and deep flooded areas. Improved lowland rice varieties currently recommended for the six major agro-ecological zones are as given in Table 2.13.

(f) *Cultural Practices:*

For lowland rice use 60 - 70kg ha^{-1} seed, drilled directly on flat 20cm x 20cm, or seed 40 - 45kg ha^{-1} for nursery bed and then transplant 1 - 2 seedlings per hill spaced at 20 x 20cm at 21 – 28 days old seedling or use 50 - 60kg ha^{-1} seed for direct seeding. For deep water rice use 40 - 45kg/ha seed broadcast or drill on the flat at 30 x 30cm. For both upland rice and direct seeded lowland rice, plant when the rains are regular. Note that seeds for planting should be treated with seed treatment chemicals such as Apron Stat or seed plus to control insects and fungi attack.

Table 2.9 Fertilizer recommendations for upland and lowland rice (based on soil test/soil fertility map)

NUTRIENT	FERTILITY CLASS	UPLAND RICE	LOWLAND RICE
N	Low Medium High	80kg N 60kg N 40kg N	100kg N 80kg N 40kg N
P	Low Medium High	30 - 40kg P_20_5 30kg P_20_5 NIL	40 - 50kg P_20_5 "b" 40kg P_20_5 NIL
K	Low Medium High	30 - 40kg K_20 30kg K_20 NIL	30 - 40kg K_20 30kg K_20 NIL

- Fertilizer sources and rates

100kgN	20:10:10	5 bags basal
	Urea	2 bags topdress
80kgN	20:10:10	4 bags basal
	Urea	1½ bags topdress
60kg N	20:10:10	3 bags basal
	Urea	1½ bags topdress
40kg N	20:10:10	2 bags basal
	Urea	1 bag topdress
100kgN	15:15:15	7 bags basal
	Urea	2 bags topdress
80kgN	15:15:15	5 bags basal
	Urea	1½ bags topdress
60kg N	15:15:15	4 bags basal
	Urea	1¼ bags topdress
40kg N	15:15:15	3 bags basal
	Urea	1 bag topdress

For both upland and lowland rice, additional application of Boost Xtra at the rate of 1l/ha for 4 times forliarly starting from 4 weeks of planting/transplanting using a spray volume of 200l/ha water will enhance rice growth

Improved rice varieties currently recommended for the six major agro-ecological zones are as given in table 2.12 and 2.13

Table 2.10 Recommended upland rice varieties for the different agro-ecological zones

AGRO-ECOLOGICAL ZONE	RECOMMENDED UPLAND RICE VARIETY
Sahel	FARO 45, FARO 46 EX-China, FARO 55 (NERICA 1)
Sudan	FARO 45, FARO 46, EX-China, FARO 38, FARO 39 FARO 55 (NERICA 1)
Northern Guinea Savanna	FARO 46, FARO 39, FARO 38, FARO 11, FARO 45 FARO 55 (NERICA 1), FARO 56 (NERICA 2) FARO 58 (NERICA 7), FARO 59 (NERICA 8), FARO 62 (OFADA 1), FARO 63 (OFADA 2)
Southern Guinea Savanna	FARO 46, FARO 48, FARO 49, FARO 43, FARO 41 FARO 55 (NERICA 1), FARO 56 (NERICA 2) FARO 58 (NERICA 7), FARO 59 (NERICA 8), FARO 62 (OFADA 1), FARO 63 (OFADA 2)
Forest	FARO 46, FARO 48, FARO 49, FARO 43, FARO 41 FARO 55 (NERICA 1), FARO 56 (NERICA 2) FARO 58 (NERICA 7), FARO 59 (NERICA 8), FARO 62 (OFADA 1), FARO 63 (OFADA 2)

Table 2.11 Recommended lowland rice varieties for different agro-ecological zones

AGRO-ECOLOGICAL ZONE	RECOMMENDED LOWLAND RICE VARIETY
Hydromorphic and inland valley swamp	FARO 44, FARO 52, FARO 31, FARO 15, FARO 28, FARO 51 FARO 62 (OFADA 1), FARO 63 (OFADA 2), FARO 60 (NERICA L19), FARO 61 (NERICA L34)
Shallow swamp and irrigated swamp	FARO 44, FARO 52, FARO 51, FARO 27, FARO 29, FARO 37, FARO 60 (NERICA L19), FARO 61 (NERICA L34)
Deep water and floating	FARO 15, CK 73, DA 29, BKN 6986 – 17, ROK 5, IR 54
Mengrove	FARO 15, ROK 5, WAR 77-3-2-2, FARO 28, IR 54

Any of the under-listed herbicides recommendations will control weed in upland and lowland rice:

(i) Propamil + oxadiazon at 3.0kg a.i. ha^{-1} (5 liters Ronstar 400 EC/ha) or
(ii) Glyphosate e.g Roundup (4 - 6 litres ha), 2 weeks before planting followed by either
(iii) Propamil + bentazon at 3.0kg a.i. ha^{-1} or
(iv) Propamil + Fluorodifen at 3.0kg a.i. ha^{-1}or
(v) Propamil + thiobencarb at 3.0kg a.i. ha^{-1} 2 - 3 weeks after planting
(vi) Butachlor at 4l/ha pre-emergence
(vii) Oxadiazon at 4 – 5l/ha pre-emergence but must be applied at least a week before transplanting of rice
(viii) Propanil at 4l/ha Post-emergence
(ix) Propanil + Triclopyr at 4l/ha Post-emergence.

(g) Yield Expectancy

Farmers' yields range between 1,200 and 3,000kg ha^{-1} for swamp rice and 1,000 - 1,500kg ha^{-1} for upland rice. With improved practices yields of up to 5,000 -

6,000kg and 2,500 - 3,000kg ha^{-1} of paddy are possible for swamp and upland rice, respectively.

2.2.5 Wheat (*Triticum aestivum*)

(a) Area Under Crop

At present the production of wheat is largely confined to dry season irrigated scheme in areas where weather conditions are favourable for.its cultivation. An estimated 250,000 hectares of land is cultivated presently under wheat annually and the area is likely to increase as irrigation facilities are developed.

(b) *Nutrient Deficiency Symptoms:*

(i) *Nitrogen Deficiency:* Stunted spindly growth and yellowish - green foliage..

b) (ii *Phosphorus Deficiency:* Mild deficiency is characterized by stunted growth but without clear-cut leaf symptoms; more severe deficiency causes purpling and browning of leaves and delays maturity.

(iii) *Potassium Deficiency:* Leaves become bluish-green; older leaves turn yellow, then brown and finally die at tips and margins; stalks short and weak; plants show profuse tillering but flowering stems are few.

(c) Fertilizer Sources and .Rates

The fertilizer recommendations summarized in Table 2. 14 are considered adequate for the present:

Table 2.12 Fertilizer recommendation for wheat

AGRO-ECOLOGICAL ZONES	RECOMMENDATION (NUTRIENT HA^{-1})	MATERIAL HA^{-1}
Sahel	**100kg N**	Urea (220kg or 4 bags) or CAN (385kg or 8 bags) or 20-10-10 (400kg or 8 bags)
and Sudan	**45kg P_20_5** **30kg K_20**	SSP, (250kg or 5 bags) MOP, (50kg or 1 bag)

(d) *Fertilizer Application - Time and Method*

Nitrogen can be applied as a single dose prior to planting by broadcasting, except on very sandy soils when N should be split - applied at planting and 4 weeks later. The second application may be top-dressed and immediately followed by light irrigation. Both P and K should be applied at seedbed preparation.

(e) Varieties.

The following varieties are well adapted to conditions in the areas of production, and also have high-yielding potential and possess desirable (bread) baking qualities. Siete Cerros,. Senora 6 3, Floreme Aurore 8 19 3, GB 5 5 - GB 5 6 (Lee x N 10 - B), Indus and Sompi.

(f) Cultural Practices

Seed at 90 - 100kg ha^{-1} of good quality seed dressed, with Aldrex - T. The existing practice is to drill wheat in 60cm rows. For maximum yield, planting should be done in mid November and the crop matures by March. Irrigated wheat can be kept relatively free of weeds by using any one of the following herbicides:

(i) 1.2kg a.i. Bantazone (= 2.5 litres Basagram)ha^{-1} applied post-emergence when broad - leaved weeds and sedges are present.

(ii) 0.8kg a.i Chlortoluron (= 1kg a.i. Dicuran 500FW) ha^{-1} applied post - emergence when broad - leaved weeds and grasses are present. Caution needs to be exercised in the selection and handling of all herbicides.

(g) Yield Expectancy

Farmers' yields of wheat range between 900 and 1,900kg ha^{-1} of dry grain. By adopting improved practices yields can be increased to 2,500 - 3,500kg ha^{-1}. The yield potential at Kadawa is currently estimated at up to 4,500kg ha^{-1} yields are lower at other existing areas of production. The protein contents of wheat grain is estimated at 12.2%.

2.2.6 Barley (*Hordeum vulgare*)

(a) Area Under Crop

Barley is a relatively new crop being introduced into the country and production is presently confined to experimental fields at irrigation sites in the north where growth conditions are favourable.

(b) Nutrient Deficiency Symptoms..

(i) *Nitrogen Deficiency:* Leaves are yellowish-green; older leaves dry up, stalks slender, erect and purplish-green; tillers are few, heads are small.

(ii) *Phosphorous Deficiency:* Slow growth; leaves may be dark-green with purple cast.

(iii) *Potassium Deficiency:* Leaves bluish-green and older leaves turn yellow, then brown and finally die at tips and margins; stalks are short and weak; profuse tillering but few flowers.

(c) Fertilizer Sources and Rates

Not much research work has been done on fertilizer requirements, of barley in Nigeria. Until more information is available, the recommendations summarized in Table 2.15 are suggested.

Table 2.13 Fertilizer recommendation for barley

AGRO-ECOLOGICAL ZONES	RECOMMENDATION (NUTRIENT HA^{-1})	MATERIAL HA^{-1}
Sahel	60kg N	Urea (130kg or 3 bags) or CAN (230kg or 5 bags) or 20-10-10 (300kg or 6 bags)
and Sudan	40kg P_20_5	SSP (220kg or 4 bags)

(d) *Fertilizer Application - Time and Method*

Apply about _ of the N (i.e 50kg ha^{-1} 1 bag of Urea or 75kg ha $^{-1}$ 1½ bags of CAN) at planting and the balance (i.e. 80kg ha^{-1} = 2 bags of Urea or 155kg ha^{-1} 3.5 bags of CAN) about 3 weeks later as a top-dressing, followed by light irrigations. Phosphorus should be applied at seed bed preparation.

(e) *Varieties*

The following 5 varieties have consistently proved superior in terms of yield and/or malting qualities; Zephyr, Ark Royal, Tellus, Pirouttle (all long-season, maturing in 120 -140 days) and Ketch (a short-season variety, requiring 90 - 100 days to mature).

(f) *Cultural Practices*

It is suggested that barley should be sown by the middle of November at 100kg ha^{-1} of seed. The existing practice is to drill barley in rows 60cm apart.

(g) *Yield Expectancy*

Yields of 2,500 - 4,500kg ha^{-1} of grain have been obtained under experimental conditions at Kadawa. The protein content of barley grain is estimated at 10 - 11%.

2.2.7 Sugarcane (*Saccharurn officinarum*)

(a) *Area Under Crop*

Chewing sugarcane is grown in about 47,000 hectares in Nigeria

(b) *Nutrient Deficiency Symptoms*

(i) *Nitrogen Deficiency*: Leaves are yellowish-green to yellow, drying off prematurely at tips and margins; older leaves are reddish purple; leaves narrow and stems thin: There is reduced tillering.

(ii) *Phosphorus Deficiency:* Leaves show narrow bluish-green lines; older leaves turn yellow and show tip die-back; stalks are slender with short internodes stunted turn pale yellow and show definite reddish colouration on upper surface of mid-rib

(iii) *Potassium Deficiency:* Young leaves are initially dark-green; as they grow older leaves turn pale yellow and show definite reddish coloration on upper surface of mid-rib older and lower leaves die-back at tips and margins but before they dry up they show minute chlorotic spots between veins followed by necrosis; stalks are short; juice quality reduced.

a) *(c) Fertilizer Sources and Rates*

The fertilizer recommendations in Tables 2.16 and 2.17 are suggested,

Table 2.14 Fertilizer recommendations for sugarcane (industrial and chewing) based on soil test/soil fertility map

NUTRIENT	FERTILITY CLASS	NUTRIENT RATES HA^{-1}	FERTILIZER RATE AND SOURCE HA^{-1}
Nitrogen	Low	200kg N	Urea (435kg or 9 bags) or CAN (769kg or 15 bags) or 20-10-10 (500kg or 10 bags)
	Medium	100kg N	Urea (217kg or 7½ bags) or CAN (383½kg or 7½ bags) or 20-10-10 or (500kg or 10 bags)
	High	50kg N	Urea (109kg or 2¼ bags) or CAN (192kg or 4 bags) or 20-10-10 (250kg or 5 bags)
Phosphorus	Low	100kg P_20_5	SSP (556kg or 11 bags) or TSP (222kg or 4½ bags)
	Medium	50kg P_20_5	SSP (278kg or 6 bags) or TSP (111kg or2 bags)
	High	Nil	NIL
Potassium	Low	100kg K_20	MOP (167kg or 3 bag)
	Medium	50kg K_20	MOP (83kg or 2 bags)
	High	NIL	NIL

Table 2.15 Generalized fertilizer recommendations for sugarcane (based on agro-ecological zones)

AGRO-ECOLOGICAL ZONES	RECOMMENDATION (NUTRIENT HA^{-1})	MATERIAL HA^{-1}
Sahel and Sudan and Northern Guinea Savanna	**200kg N** **100kg P_20_5** **50kg K_20**	Urea (435kg or 9 bags) or CAN (769kg or 15 bags) or 20-10-10 (400kg or 8 bags) SSP (556kg or 11 bags) or TSP (222kg or 4¼ bags MOP (83kg or 2 bags)
Southern Guinea Savanna and Forest	**120kg N** **50kg P_20_5** **50kg K_20**	Urea (261kg or 3 bags) or CAN (462kg or 9 bags) or 20-10-10 (300kg or 6 bags) SSP (278kg or 6 bags) or TSP (111kg or 2 bags) MOP (83kg or 2 bags)

NB: *No P and K should be applied where N source is 15-15-15.*

(d) *Fertilizer Application - Time and Method*

Apply half fertilizer rate at planting as basal and then the other half at 5 – 6 months after planting during earthing up. Cowdung organic fertilizer at 5t/ha can be incorporated into the soil a month before planting

(e) Varieties

Local clones of sugar cane vary from place to place, but for commercial cultivation, the following varieties are recommended in Table 2.18.

Table 2.16 Recommended sugarcane varieties for agro-ecological zones

AGRO-ECOLOGICAL ZONE	RECOMMENDED SUGARCANE VARIETY
Sahel Sudan Northern Guinea Savanna Southern Guinea Savanna Forest	All ecologies: Co 997, Co 957, Co 62175, B494 19 NCS - 001, NCS – 002, NCS-003, NCS – 006, NCS – 007 and NCS - 008

(f) *Cultural Practices*

For propagation use stem cuttings from mature sugarcane stalk with viable buds. Use 3 – 4 budded seed setts which is laid end to end horizontally along the planting furrow and covered lightly with damp soil at a spacing of 1m x 1m. Generally between 7 – 8 tonnes of cane setts are required for one hectare (i.e 40 – 60,000 stalks). Sugarcane can be intercropped with water melon, tomato, amaranthus, sweet potato, garden egg, roselle, ground nut, cowpea, soybean and bambara nut If grown on upland (e.g. in the Forest Zone) plant in March/April when the rains are steady; for swampy patches and flood plains, (e.g. in the Savanna to Sahel Zones) plant in late August/September. Where the crop is irrigated as in commercial estates, planting is preferred between October and November for twelve-month old canes.

Chemical weed control:

I. Roundup or Touchdown at 3.0kg a.i/ha as pre-plant treatment to control stubborn weeds such as Spear grass, Bahama grass and Cyperus.
II. Diuron 2.0 – 3.0kg a.i/ha
III. Terbumetrn 3kg a.i/ha; Atrazine 2.5 – 3.0kg a.i/ha; CGA 362 + Ametryne 3.0kg a.i/ha; Atrazine + Pendimethalin 2.0 – 2.5kg a.i/ha pre-emergence
IV. Diuron + hexazinone 2.0 + 0.5kg a.i/ha as pre and post-emergence.
V. Dimethemetryne 3.0kg a.i/ha

(g) *Yield Expectancy:*

Under local practices sugar cane yields range between 7 - 38 tonnes ha^{-1} of cane; under improved, practices yield could average 40 - 60t ha^{-1}. Potential sugarcane yield is estimated up to 100t ha^{-1}.

2.2.8 Acha (*Digitaria exilis*)

(a) *Area Under Crop*

Acha is grown mostly in the uplands of Plateau and Southern Kaduna States and parts of Bauchi, Kebbi, Taraba, Kano and Katsina States and total area is probably not more than 10, 000 hectares.

(b) Fertilizer Sources and Rates

Fertilizer recommendation is 30kgN/ha; 30kgP_2O_5/ha and 30kgK_2O. Four bags of NPK 15:15:15 should be applied per hectare preferably 2 – 3 weeks after planting using broadcast method of application.

(c) *Varieties*

There are no improved varieties of acha and, therefore, none is recommended. It is suggested that the best local varieties should always be used. Two species are prominent: *Digitaria exilis* Kippis Stapf which is straggling in growth nature and *Digitaria iburua* which is erect.

(d) *Cultural Practices*

Planting should be done in May - June as this allows the crop to be harvested under cool and dry weather. Broadcast seeding is common among the farmers. Broadcast seeding should be at 25kg/ha seed rate and the seed should be properly mixed with soil for good germination. Drilling of seeds at 20cm apart with seed rate of 30kg/ha is preferable and then slightly cover the seeds with soil. There is no recommended herbicide for weed control in Acha. Hand weeding is still mostly used. The first weeding should be at 3 – 4 weeks after seeding and the second at 7 – 8 weeks after seeding.

(e) *Yield Expectancy,*

Farmers are known to have obtained yield which vary between 300 and 1,000kg ha^{-1} of threshed dry grain.

2.3 FAT AND OILSEEDS

2.3.1 Groundnut (*Arachis hypogaea*)

(a) *Area Under Crop*

Land area put to groundnut annually is estimated at 0.8 - 1.5 million hectares.

(b) Nutrient Deficiency Symptoms

(i) *Nitrogen Deficiency :* Leaves become light green; lower leaves are affected first but, other leaves soon follow; lower leaves fade to pale yellow, then brown with later shedding.

(ii) *Phosphorus Deficiency:* Leaves are dark green; petioles spindly and stunted and leaf- lets tilt upwards.

(iii) *Potassium Deficiency:* Leaves become light green with necrotic areas along margins which may merge to produce scorched effect.

(c) Fertilizer Source and Rate

The fertilizer recommendation for groundnut in the main agro-ecological zones of the country is summarized in the Table 2.19.

Table 2.17 Fertilizer recommendations for groundnut in different agro-ecological zones

AGRO-ECOLOGICAL ZONES	RECOMMENDATION (NUTRIENT HA^{-1})	MATERIAL HA^{-1}
All Zones	**54kg P_20_5**	SPP (300kg or 6 bags) or TSP (120kg or 2½ bags)
	25kg K_20	Muriate of potash (42kg or 1 bag)
		As above

(d) Fertilizer Application -Time and Method

Both P and K should either be applied in old furrows before splitting the ridges or they should be side-dressed at or shortly after planting. It should be noted that if -a source of P other than SSP is used, then sulphur must be supplied.

N.B. In case of N deficiency, apply 2 bags of 15-15-15 and 4 bags of SSP. In the Savanna Zone, 0.6kg/ha Boron in the form of Sodium Borate (Borax) is recommended.

(e) *Varieties*

The suitability or otherwise of any one variety is not only a function of the soil condition, but also depends on the rainfall in relation to early planting and timely harvest the start, distribution, total amount, duration and termination of the rains. As a rule of thumb, early varieties with a maturity period of 100 - 110 days are agronomically suited to the Sudan and Sahel conditions while the late varieties which require between 120 - 140 days to mature are more suited to the Northern and Southern Guinea conditions. Medium maturing varieties, requiring 110 - 120 days to mature and typified by F. 439 - 2 and F.45 2 - 4, will perform well in the Sudan Zone.

It is on the basis of the above that the following varieties shown in Table 2.20 have been recommended for the main groundnut agro-ecological zones:

Table 2.18 Groundnut varieties suitable for different agro-ecological zones

AGRO-ECOLOGICAL ZONE	*RECOMMENDED GROUNDNUT VARIETY*
Sahel	Spanish 205, T.47 - 56 Natal common.
Sudan	Spanish 205, T.47 - 56, 55 - 437 (ex - Dakar) Red Bulk Nata common, 55 - 437, 48 - 115B (IAR Cross-breed)
Northern Guinea Savanna	Samaru 38, MSS 39, MS 358, DS 5418, RMP 12, M554 - 76
Southern Guinea	MK 374, MS 539, Samaru 61, G.153
Savanna and Forest	M.25 - 68*, T.37 – 47

(a) *Cultural Practices.*

Existing practice calls for seeding at 33 - 45kg ha^{-1} depending on seed-size and spacing. Plant at 20cm apart on 90cm ridges to give 55,000 plants ha^{-1}. The use of 75cm ridges is, however, preferred, thus giving 66,000 plants ha^{-1}. Under high level of crop husbandry and/or favourable growth conditions, it is suggested that planting on the flat to give 100,000 - 150,000 plants ha^{-1} (60 x 16cm - 60 x 10 cm) results in improved yields, provided leaf-spot diseases are controlled.

Plant groundnut early, as soon as rains are established. Although there are no formal recommendations at present for chemical weed control, it is suggested that the following measures are applicable to partially mechanized farms.

Southern Guinea

i) 1.5kg a.i Metolachlor or Alachlor (3 litres Dual 500EC or 3 litres Lasso) ha^{-1}.

a) ii) 1.0kg a.i Metolachlor or Alachlor + 0.5kg a.i Terbutryne (2 litres Dual 500EC or I litre Lasso + 630g Igran 8OWP or I litre Igran 500FW) ha^{-1}.

a) ii) 200EC Metolachlor + 200EC Terbu tryne (4 litres Igran Combi).

iv) Dithane M-45 (Mancozeb) Calizin-m, BAS - 350 to control leaf spot rust

Northern Guinea
Apply (i), (ii) or (iii) above , and in addition, 1.5kg a.i Bentazone (3 litres Basagran ha^{-1} post-emergence).

Sudan Zone
Apply (i) or (ii) but not (iii) In addition apply 1.5kg a.i. Bentazone (3 liters Basagran ha^{-1} post-emergence).

Rainfed Groundnut on Irrigation Schemes
1.5kg a.i Metolachlor or 3.Okg. a.i Alachlor (3 litres Dual 500EC or 6 litres Lasso ha^{-1}, followed by 1.5kg. Bentazone (3 litres Basagran). This treatment may require supplementary hoe-weeding and/or earthing up. As always, caution must be exercised in the selection and handling of all herbicides.

All zones: use Actelic dust at 5 ppm to control insects in stored groundnut.

(g) *Yield Expectancy*
Farmers' yields of groundnut range between 500 - 700kg ha^{-1} of dry (unshelled) pods. With improved practices the yield range is 2,500 - 3,000kg ha^{-1} of pods. The yield potential in the Northern Guinea and Sudan zones is 2,500 - 3,500kg ha^{-1}. 0il content of groundnut varies from 28 - 54% and protein content 24 - 29%.

2.3.2 Beniseed (*Sesamum indicum*, L.)

(a) *Area Under Crop*
Over 155,000 hectares is under beniseed annually in Nigeria.

(b) *Nutrient Deficiency Symptoms*
No information

(c) *Improved Varieties of Beniseed*
Early maturity: (90 – 100 days): SAMSEN-1 (E-8)
Medium maturity: (101 – 125 days): = NCRI
BEN-01M NCRI BEN-02M and Yandev 55
Late maturity: (126 – 140 days) NCRI BEN-03L

(d) *Fertilizer Application*
Beniseed does not require much fertilizer, where the soil fertility is very low, apply NPK fertilizer. The recommended rate/ha is 60kgN, 30kg P_20_5 and 20 kg K_20 which is equivalent to 2.5 bags of Urea, 3.3 bags of SSP and1 bag of MOP or use average of 2 bags of NPK 15:15:15 for optimal yield. The fertilizer is broadcast and preferably worked into the soil before planting.

(e) *Cultural Practices*
For broadcast seeding, 5kg/ha seed rate is required. For drilling on flat, 4kg/ha seed rate is required and for ridge planting 2.5 – 3kg/ha seed rate is needed. Flat row planting spacing would be 60cm x 10cm thinned to one plant/stand at 3 weeks after

sowing while ridge sowing spacing is 75cm x 15cm thinned to 2 plants/stand. Planting can be done between April/May in the Guinea Savanna for early planting and mid July/August for late planting. Planting in late June to the first week in July is suitable for Sudan Savanna while for Sahel, planting is best immediately after the first rain which may be between June and July.

(f) *Weed Control*

(i) Hand weeding as weeds appear
(ii) Hoe weeding is done thrice, 3, 6 and 9 weeks after planting

(g) *Chemical Weed Control*

For grasses use as pre-emergence:
(i) Lasso at 3L/ha
(ii) Dual at 3L/ha
(iii) Butachlor at 3/ha
(iv) Pendimethalin at 3L/ha

For both grasses and broad leave weeds use at pre-emergence

(i) Galex at 4Lha
(ii) Pursuit plus at 4L/ha

Supplementary hand weeding may still be necessary

(h) *Disease and Pest Control*

Plant seeds that are disease free. Dressing seeds with fungicides such as Apron plus or Apron star help in reducing the incidence of seed borne diseases. Usually administering fungicide to field crops is not recommended because of the build-up in overhead cost of production however where disease build-up is on the increase, it is advised to spray fungicides to reduce the incidence.

Rodents and birds should be scared away from the field within the first 10 days after planting. This will prevent the picking up of sown seeds and seedlings by birds and rodents before and immediately after germination. For insects control, spray plant with a systematic fungicide such as cyprintine.

(i) *Yield Expectancy*

Under farmers' conditions beniseed yield is between 200 and 450 kg/ha of dry seed. However, up to 500 - 800kg/ha can be obtained by adopting improved practices with a plant population of 25 - 40,000 plants ha^{-1}. Beniseed contains about 50% semi-drying oil; commercial extraction varies from 35 - 50% according to method.

(j) *Harvesting*

The crop is harvested when the lower/bottom capsules turn from green to yellow, but before they open. Harvesting should not be delayed to prevent seed loss through shattering. Harvest with a sickle, and tie the harvested materials in bundles to a long peg in upright position and allow to dry.

(k) *Threshing*
Threshing is done by gently lifting each bundle and turning upside down on a tarpaulin. Slight shattering is desirable in order to recover over 95% of the matured seed.

(l) *Winnowing*
The threshed material is winnowed to remove plant debris and obtain clean seeds.

(m) *Storage*
Clean seeds should be kept in polythetine bags stalked on a raised platform. In event of insect infestation during storage, introduce tables of phostoxin. Excessive fumigation should be avoided to minimize residual chemical contamination by the fumigant used.

2.3.3 Sunflower (*Helianthus annuus* L.)

(a) *Choice of Land*
Most soils that will support good crops of maize and cereal are suitable for sunflower seed Production. That is, any light-textured, well-drained sandy loam soils will support good crops of sunflower.

(b) *Land and Seed bed Preparation*
To ensure even germination, use any land preparation method - mechanical or 'manual to obtain a firm seedbed. This helps to bring moisture close to the surface required for rapid and even emergence. Ploughing should be done to a depth of about 10 to 15cm.

c) Varieties
Plant the available local varieties supplied in your ecological zone. However the grey seeded varieties (e.g. 'Saturn') are higher yielding than the black seeded types (e.g. 'Pole Star' 'Jupitar' or 'Southern Crown').

(d) *Time of Sowing*
Early season crop: Planting should start from the last week of April up till third week of May, provided the rains are steady.

Late season crop: Planting should start from the last week of July up till the last week of August. It is recommended that the high rain-forest areas should be avoided for profitable sunflower seed production.

(e) *Spacing and Sowing Depth:*
Plant in 60cm rows on flat with an intra-row spacing of 30cm. Depth of planting should be between 3 and 5cm; sow 2 seeds per stand for seed production and for silage 3 - 4 seeds per stand.

(f) *Nutrient Deficiency Symptoms*

Nitrogen Deficiency: Nitrogen deficiency in sunflower inhibits the vigorous growth and establishment of the crop. Leaves become yellow. Excess N should also be avoided as this causes lodging, delays ripening, a decrease in oil content and a higher percentage of empty seeds.

(g) Phosphorus Deficiency

It is the main requirement for the growth of sunflower. Phosphorus deficiency causes stunted growth with leaves showing a purplish or bronzed discolouration. P deficiency also adversely affects flowering, fruit formation and seed production. Flower size is reduced to about one-half the normal size while fruit head is decreased to one-third.

(h) *Potassium Deficiency*

Potassium uptake by sunflower plant is very high, but the amount removed by the seeds is relatively low. Adequate K supply has favourable influence on the oil content, and thus counteracts the negative effect of excessive nitrogen. Low K supply accentuates lodging and fungal disease infection.

(i) *Fertilizer Rates and Time of Application:* Basal dressings of phosphorus and potassium should be applied about 3 days before planting at the rate of 50kgN ha^{-1} (108kg ha^{-1} or 2 bags urea) 50kg ha^{-1} P_20_5 (285kg ha^{-1} or 5½ bags SSP) 30kgkg ha^{-1} or 1 bag of MOP K_20 given as muriate of potash. Top - dress with 50kg ha^{-1} N as urea at 3 to 4 weeks after planting. The nitrogen fertilizer should be applied in shallow trenches on either side of the row about 8cm away from the plants.

(J) *Weed Control*

Destroy all weeds with herbicides before planting. Hand weeding should be done as necessary during the early stages of the crop establishment. Carry out the first weeding 10 - 15 days after planting or as soon as found necessary. Regular inspection of the farms is recommended to determine the time for other weeding. The sunflower plant is very susceptible to damage by most of the available herbicides. Chemical weed control is therefore NOT recommended as of now.

(k) *Diseases and Pest Control*

Plant clean seeds of resistant varieties to avoid disease infestation. Uproot and burn infected plants.

(l) *Birdscaring*

Birds may destroy sunflower seeds from isolated fields. It is strongly recommended that birdscaring should be done during seed ripening from 3 weeks after flowering. This is important.

(m) *Harvesting*

Sunflower heads should be harvested for mature seed 5 to 6 weeks after flowering, depending on the variety and ecological zone. Remove a few seeds and test; if the seeds are hard and black, the crop is mature for harvesting. Cut off the sunflower heads at the stem ends and hand thresh to recover the seeds. Clean and sundry to a constant weight. Store sunflower seeds at a Moisture content of about 10%.

(n) *Drying*

Harvesting - sunflower with high moisture content normally results in higher yields, less bird damage and less head dropping. Thus drying becomes mandatory for commercial seed production. Sunflower dries easily. On commercial scales, bin, batch and continuous flow dryers have been used successfully. The large seeds allow air to pass easily. It has been found that drying temperature of 71^0C up to 104^0C do not appear to have an adverse effect on oil content or fatty acid composition. On a small scale such as peasant farmers level, the harvested seeds can be sun-dried to a constant weight. It is important to allow the dried seeds to cool to air temperature before storing.

(o) Expected Yield

Yields of 2 - 3 tonnes ha^{-1} of sunflower seeds should be expected. Sunflower seeds contain 36 - 45% oil, depending on the variety,

(p) Utilization

Sunflower is one of the most important oilseeds. It is a good source of vegetable oil for cooking and manufacture of margarine. The oil is also used in paints, soaps and cosmetics. The hull is used in the manufacture of furfural for yeast and alcohol production. The cake after oil extraction is a protein rich meal for livestock.

2.3.4. Miscellaneous Fat and Oilseeds

No fertilizer and other agronomic information are available in respect of the following other fat and oilseed crops:

i) Nigerseed *(Guizotia abyssinica)* - contains 38 - 50% oil

ii) Castor *(Ricinus communis)* - contains 33 - 55% oil

iii) Sheanut *(Butyrosperum parkii)* - whole seed contains 34 - 44% fat and the kernel usually 40 - 55% fat.

c) (iv Crambe *(Crambe abyssinica)*.

(v) Linsed flax *(Linum usitatissimum)* - Oil content of seed varies according to type and management from 35 - 44%, and commercial extraction varies from 32 - 36%.

(vi) *Neem (Azadirachta indica and Melia azadirachta)* - Oil content of kernel is 40 - 45%.

(vii) Rape Seed *(Brassica campestris and B. napus)* - ' Oil content of - B. napus 40 - 46% and *B. campestris 40 - 4417o.*

(viii) Safflower *(Cartharnus tinctorius)*- Current commercial seed types have an oil content of about 36 - 45%

2.4 GRAIN LEGUMES

2.4.1 Cowpea (*Vigna unguiculata*)

(a) *Area Under Crop*

An estimated 3 - 3.5 million hectares of land is put to cowpea annually, most of this being in the Northern Guinea and Sudan Savannas.

(b) *Nutrient Deficiency Symptoms*

(i) *Nitrogen Deficiency:* Leaves become pale green with a yellowish tinge; later leaves become distinctly yellow over their entire surfaces; symptoms first appear on leaves at the base of plants and progressively spread to the upper parts.

(ii) *Phosphorus Deficiency:* Retarded rate of growth; spindly plants with small leaflets; - leaves turn dark or bluish-green; delayed maturity.

(iii) *Potassium Deficiency:* Leaflets are more or less mottled. This is followed by necrosis and ragged appearance after necrotic tissues fall out.

(c) *Fertilizer Sources and Rates;*

The following fertilizer programmes are recommended in Table 2.21 and 2.22.

Table 2.19 Fertilizer recommendations for cowpea and soyabean (based on soil test/soil fertility map)

NUTRIENT	FERTILITY CLASS	NUTRIENT RATES HA^{-1}	FERTILIZER RATE AND SOURCE HA^{-1}
Nitrogen	Low	20kg N	Urea (44kg or 1 bag) or CAN (74kg or 1½ bags) or 20-10-10 (100kg or 2 bags)
	Medium	10kg N	Urea (22kg or ½ bag) or CAN (37kg or ½ bags) 20-10-10 (50kg or 1 bag)
	High	NIL	NIL
Phosphorus	Low	40kg P_20_5	SSP (222kg or 4½ bags) or TSP (89kg or 2 bags)
	Medium	20kg P_20_5	SSP (111kg or 2 bags) or TSP (44kg or1 bag)
	High	NIL	NIL
Potassium	Low	20kg K_20	MOP (33kg or 1 bag)
	Medium	10kg K_20	MOP (16kg or ½ bag)
	High	NIL	NIL

Table 2.20 Fertilizer recommendations for cowpea and soyabean (based on agro-ecological zone)

AGRO-ECOLOGICAL ZONES	RECOMMENDATION (NUTRIENT HA^{-1})	MATERIAL HA^{-1}
Sahel and Sudan	**20kg N** **40kg $P_2 0_5$** **25kg $K_2 0$**	Urea (44kg or 1 bag) CAN (74kg or 1 ½ bags) 20-10-10 (100kg or 2 bags) SSP (222kg or 4½ bags), TSP (89kg or 2 bags) Muriate of potash (33kg or _ bag)
Guinea Savanna and Forest	**10kg N** **36kg $P_2 0_5$** **20kg $K_2 0$**	Urea (22kg or ½ bag) CAN (37kg or ¾ bag) SSP (200kg or 4 bags), TSP (80kg or 1½ bags) Muriate of potash (33kg or _ bag)

If cowpea is planted following a fertilized cereal crop within the same year (as it is often the practice in Forest zone where the rainy season is long enough for two crops) then further fertilization is not necessary if soil tests show that there is no need to apply this fertilizer.

(d) Fertilizer Application -Time and Method:
When applied pre-plant, the fertilizers should be broadcast and incorporated into the seedbeds before ridging. If application is made at or within 1 -2 days after planting, the fertilizers should be dibbled along grooves made from the line of planting holes.

(e) *Varieties*
The cowpea varieties in Table 2.23 are recommended for cultivation.

Table 2.21 Recommend cowpea varieties for different agro-ecological zones

AGRO-ECOLOGICAL ZONE	COWPEA VARIETY
Southern Sudan	ACCS. 341, 339 - 1, 1768 and 593; IT60, IT84E - 108 ACCS. 355 & 335, ITS4E – 124
Northern Guinea Savanna	ACCS. 341, 1768, 3391 - 1, 1696 588/2; IT84E - 108, TVX3236 ACCS. 335, 355 and 353 Ife Brown, IT84E – 124
Southern Guinea Savanna	ACCS. 339 - 1 and 341; IT84e - 108 TVX 3236 ACCS. 335 and 353; Ife Brown IT 84E - 124
Forest	KANO 1696, Vita 5. Modupe, Ife-Bimpe, Ife Brown

Note that with the exception of ACC, 1696 where maturity period varies from 80 to 120 days depending on the time of planting all other varieties mature in 90 - 105 days. IT 60. IT84E - 108 mature in 60 days.

(f) *Cultural Practices*

In order to obtain high seed quality it is desirable that the planting date should be such as to enable the crop mature at the end of the rainy season. Consequently, cowpea should be planted during the first week of July in the Sudan, by mid-July in the Northern Guinea, by the third to fourth week July in the Northern half of the Southern Guinea and as soon as the late season rains starts in the savanna and forest zones about mid-August to early September.

The existing practice is to space cowpea 30cm between plants on ridges 60 - 90cm apart at 25 - 30kg/ha seed rate. For higher yields closer spacing are suggested: 25cm between plants on 75 or 60cm ridges. Cultivation on the flat enables not only the attainment of even higher population densities (e.g. 30 x 30cm at 50 - 55kg/ha seed rate), but also ensures judicious use of space. In terms of weed control, any of the following herbicide recommendations is suggested.

Savanna Zone

(i) 1.5kg a.i. Metolachlor + 1.0kg a.i. Prometyne (3 litres Dual 500EC + 2 litres Gesagard 500FW (4 litres Codal 400EC)/ha .

(ii) 1.5kg a.i. Metolachlor + 0.8kg a.i. Diuron (3 litres Dual 500EC + 1kg Karmex 80WP)ha^{-1}

(iii) 0.4kg a.i. Norflurazone + 0.8 a.i. Diuron (0.5kg Zorial 80WP + 1.0kg Karmex 80WP)ha^{-1}

iv. 1.5kg a.i. Metolachlor + 1.0kg Metobromuron (3 litres dual 500EC + 2.0 litres Potoran 50WP)ha^{-1}

Forest Zone

(i) 1.5kg a.i. Metolachlor + 1.0kg a.i. Metobromuron (3 litres dual 500EC + 2. Litres potoran 50WP)ha^{-1}

(ii) 1.0kg a.i. Metolachlor + 1.0kg a.i. Metobromuron (4 litres Galex 500EC)ha^{-1}

Only half the rates recommended will be needed for soils with less than 0.6% organic matter. Great care should be exercised in the handling of all herbicides.

The control of pest and disease is a must for all existing cowpea varieties. In the Forest Zone it is recommended that the crop should be sprayed weekly with Nuvacron 40%EC or Azodrin 60%EC (Monocrotophus) at 30ml/9 litres of water beginning from the 5th week after planting and for four consecutive weeks. (Care should be taken in handling Nuvacron). In the Savanna the existing practice is to apply any of the following chemicals to control insect pests.

i. 50g a.i. Cymbush 10EC (2.0% Cypermethrin ULV at 2.5 litres ha^{-1}

ii. 50g a.i. Sherperplus (1.25 litres Cymbush Cypermethrin) 10%EC + 3 litres Dimethoate (Rogor or Perfekthion) 40%EC)ha^{-1}

iii. 12.5g a.i. Decis 25%EC + 500g a.i. Dimethoate (1.25 litres Deltamethrin 2.5%EC + 3 litres Perfekthion 40%EC ha^{-1}.

Because of the importance of scab (sphaceloma sp) brown blotch (collectotrichum capsic) and septoria leafspots (septoria spp), diseases in parts of the main producing areas (Northern Guinea and Sudan), it is suggested that a mixture of Dithane M-45 (2.5kg ha^{-1}) + Benlate (0.6kg ha^{-1}) applied bi-weekly, beginning at 4 - 5 weeks, would check all three diseases.

(g) *Yield Expectancy*
Under local conditions cowpea yields vary widely between 230 and 1,000kg ha^{-1} of dry grains. By adopting recommended practice and good management, yields of between 1,500 and 2,000kg ha^{-1} are easily possible. The potential grain yield is estimated at 3,500kg ha^{-1} of grain. Cowpea generally contain between 23 - 35% crude protein.

2.4.2 Soyabean (*Glycine max*)

a) *Area under Crop*
An estimated 50,000 hectares of soyabean is cultivated annually, most of this being in Benue State

b) *Nutrient Deficiency Symptoms*
(i) *Nitrogen Deficiency*: Leaves become pale green with a yellowish tinge; later the entire leaves become distinctly yellow; deficiency symptom usually appears first on leaves at the base of plant
(ii) *Phosphorus Deficiency:* Plants are delayed in blooming and in maturity; leaves show brown spots after flowering; root development is poor leaf blades are tilted upwards
(iii) *Potassium Deficiency:* Irregular yellow mottling around edges of leaflets particularly in the lower parts of the plant; chlorotic spots merge to form continuous yellow borders around the tips and along the sides of leaves; necrosis of chlorotic areas follows with a downward cupping of the leaf edges; dead tissues then fall out; giving the leaflets a ragged appearance.

c) *Fertilizer Sources and Rates*
30kgN/ha, 60kgP_2O_5/ha and 30kgK_2O/ha. Mix 3 bags of NPK 15:15:15 and 4 bags of Single Superphoshate properly and broadcast before harrowing or applied 4 weeks after planting by side dressing.

d) Fertilizer Application – Time and Method
All fertilizers including N (if used) should be broadcast and incorporated before planting. In newly opened land fertilizder should be placed in grooves 8cm away from the roaw of seed at planting or immediately after germination.

e) Varieties
The soyabean varieties listed in Table 2.24 are recommended for cultivation.

Table 2.22 Recommended soyabean varieties for different agro-ecological zones

AGRO-ECOLOGICAL ZONE	SOYABEAN VARIETY
Sudan	TGX 844 - 29D
Northern Guinea Savanna	TGX 536 - 02D, SAM Soy - 1, SAM Soy - 2, TGX 855 - 29D
Southern Guinea	TGX 536 - 02D, SAM Soy - 1, SAM Soy - 2, TGX 855 - 29D
Savanna and Forest	TGM 579, M312, TGX 306 - 036C

Note that with the exception of TGX 844 - 29D which has a maturity period of 100 days, all other varieties mature in 100 - 140 days.

(f) *Cultural Practices*

Plant between late June and July. For early and medium duration varieties, plant at spacing of 50cm x 5cm while for the late duration varieties, 75cm x 5cm is recommended. Thin to one plant/stand at 3 – 4 weeks after planting. Drill planting is also good for soybean. Seed rate is 40 – 50kg/ha. Hand weed at 3 and 6 weeks after planting. Pre-emergence application of either Lasso, Dual or Pendimethalin at 4l/ha can be used for weed control in soybean.

(g) *Yield Expectancy*

Farmers' yields average 700 - 800kg ha^{-1} of threshed grain. Under research conditions yields of over 3,000kg ha^{-1} have been recorded. Soyabean contains 13 - 20% oil according to variety and about 38 - 44% crude protein.

2.4.3 Miscellaneous Grain Legumes

No fertilizer and other agronomic information are available in respect of the following:-

(i) Lima or Butter Beans *(Phaseolus lunatus)* - contains about 27% crude protein.
(ii) Bambarra Nuts (Voandzeia Subterranea)
(iii) Pigeon Peas *(Cajanus cajan)* - contain about 20.9% crude protein.
(iv) Green-Gram *(Phaseolus auraus)* - contains about 24% crude protein.
(v) Dry of Kidney or Haricot Beans *(Phaseolus vulgaris)* - contains 22 - 25% crude protein
(vi) Sword Beans (Canavalia ensifonnis)
(vii) Yam Beans (Sphenostry stenocarpa).
(viii) Chick Peas *(Cicer arietinum)* contain about 20% crude protein.

2.5 FIBRE CROPS

2.5.1 Cotton *(Gossypium hirsutum* and G. *barbadense)*

(a) *Area Under Crop*

An estimated 0.6 - 0.8 million hectares of land is put to cotton annually. The major production areas are Katsina, Kaduna, Sokoto, Kano, Plateau, Bauchi, Borno and Adamawa Taraba, Zamfara, Kebbi and Jigawa States.

(b) Nutrient Requirements and Fertilizer Use

(i) Nutrient Deficiency Symptoms

Nitrogen Deficiency : Yellowing and drying of lower leaves; lower leaves finally turning brown.

Phosphorus Deficiency: Dark green leaves; dwarfed plants; maturity delayed.

Potassium Deficiency: Leaves show yellowish-white mottling, changing to light Yellowish green; yellow and necrotic spots occur between veins, tips and margins curl downwards; leaves finally become reddish brown, dry and are shed pre-maturely; boils are improperly developed, giving fibres of poor quality.

Boron Deficiency: Die-back involving terminal buds, resulting in multiple branched plant, young leaves yellowish-green; flower buds chlorotic; early indications are banded petioles and ruptured peduncles.

(ii) *Fertilizer Sources and Rates:* The fertilizer programmes given in table 2.25 are recommended.

Table 2.23 Fertilizer recommendations for cotton

AGRO-ECOLOGICAL ZONES	(NUTRIENT/HA^{-1})	MATERIAL/HA^{-1}
Sahel, Sudan and Northern Guinea Early Crop	60kg N 25kg P_20_5 20kg K_20 0.75kg Bo	Urea (125kg or 2½ bags) CAN (125kg or 4 ½ bags) B SPP, 140kg (3 bags) KCl, 33kg (1 bag) or 20-10-10 (6 bags) in Boronated SSP
Late crop	40kg N 20kg P_20_5 0.35 Bo 20kg K_20	Urea (87kg or 1¾ bags) CAN (96kg or 2 bags) SSP (61kg or (1 bag) KCl (1 bag)
Forest	35kg N	CAN, 135kg (3 bags) or SA, 175kg (3½ bags) or compound (20-10-10) 175kg (3½ bags)

(iii) Fertilizer Application: Apply boronated super-phosphate and muriate of potash during seed-bed preparation or soon after planting by placing in holes 5rm deep and 8cm away from the seed. Avoid delay in application

It is preferable to apply nitrochalk (CAN) in two split doses, one half at 3 weeks (just after thinning) and the second half at 8 weeks after sowing. Apply this fertilizer into shallow grooves about 8cm away from the plants and cover with soil immediately after application.

It should be noted that nearly all the single super-phosphate currently used on cotton is in the boronated form; the recommended rates of the fertilizer, therefore, satisfy the needs for both P and B. In the event that single super-phosphate is used, then enough boron-containing material preferably borax, ($Na_2B_40_7$. $10H_20$) should be added to give the appropriate rate of boron. Borax contains 10.6%B.

c) *Varieties and other Practices*

(i) *Varieties:* Varieties that have been developed and released as cultivars include SAMCORT 1, 10. Variety recommended for planting in the Northern and Southern Cotton Zones. SAMCOT - 8 variety is recommended for the Eastern Cotton Zone . For clarification the Northern Zone includes Kano, Jigawa, Sokoto, Kebbi, Kaduna, Zamfara, Katsina, Plateau States, northern half of Niger State and Borgu area of Niger State.

The Southern Zone includes Oyi, Ilorin, Asa, Moro and Irepodun Local Governments in Kwara State, and entire Benue State.

The Eastern Zone includes Borno, Bauchi and Adamawa and Taraba States, cotton variety SAMCOT 7, 8 & 9 is still very popular in Okpebho, Agbazilo, Etsako and Akoko-Edo Local Government Area of Edo State

(ii) *Cultural Practices*

Planting should be done in Mid-June on 90cm ridges with intrarow spacing of 45cm. 4 - 6 seeds should be planted per hole and later thinned to two plants per stand.

Although most of the cotton is planted after mid-July, the best yields are attainable with mid-June planting. Use of Herbicides may be profitable under large scale production. A mixture of Diuron with either Norflurazon or Fluridone or Alachlor or pendimethalin is effective at the recommended mixing ratios applied pre-emergence. For example, application of Diuron plus Norflurazon at 0.8 + 0.8kg a.i. should be used per hectare pre-emergence. Alternatively, a mixture of Diuron plus Fluridone at 0.8 + 0.8kg a.i. respectively per hectare is recommended pre-emergence. For sites with heavy soil (high clay and organic matter) application of a mixture of Diuron and Alachlor at 0.8 plus 3.0kg a.i. respectively per hectare is recommended. Sites with high itchgrass infestation and heavy soil will require a mixture of Diuron and Pendimethalin at 0.8 + 3.0kg a.i. respectively per hectare pre-emergence.

Pest and Disease control is highly necessary to enhance good field performance of cotton.

All well-grown cotton (like the June - sown crop) must be protected against insect pests by using any of the following insecticides:

(i) Vetox 20 (Didigam Audugatox) at 5.6 litres/225 litres of water/ha
(ii) Sevin (Vetox 85 - Dicarbam 85) at 11kg/225 litres of water/ha or Sevin (25% ULV) at 2.5 - 3.0 litres/ha
(iii) Endosulfan 25% ULV (Thiodan ULV) at 2.5 - 3.0 litres/ha
(iv) Decamethrin 0.7% ULV at 2.5 litres/ha
(v) Cypermethrin 2.0% ULV at 2.5 litres/ha
(vi) Fonalerate 3.0% ULV at 2.5 litres/ha
(vii) Permethrin 3.0% ULV at 2.5 litres/ha
(viii) Brono-cot, Apron plus 50DS, marshall 25STD and Rovral TS singly or in combination with Brono cot are effective for the control of soil and soil borne disease and arthropods

Begin spraying 9 - 10 weeks after planting and apply a total of six sprays at regular weekly intervals for large volume spray and a total of three sprays at six weekly intervals for ULV sprays, particularly pyrethroids. Enforcing full pest control measures on a poor cotton crop, like those late in July on nearly August planting is uneconomical.

d) *Yield Expectancy*

In general cotton yields about 82kg of seed for each 45kg of fibre. Farmers usually obtain yields averaging 300 and 500kg ha^{-1} of cotton for July (late) and June (Early) sown cotton, respectively. With improved seeds and good management, including sowing about mid- June of up 2,500 - 3,000kg ha^{-1} may be obtained. Under-corticated cotton seed has an oil content, ranging according to variety from about 15 - 25%; the commercial extraction rate is usually, 13 - 18%

2.5.2 Kenaf (*Hibiscus cannabinus*)

a) Area Under Crop

Kenaf is grown in almost every part of the country largely in small, backyard gardens, thus it is difficult to estimate the land area it occupies in any one year; it is probably not more than 20,000 hectares.

b) Nutrient Requirements and Fertilizer Use

(i) *Deficiency Symptoms* - Not much information is available on the nutrient deficiency symptoms of kenaf but characteristic deficiency symptoms for the three major macro-nutrient elements may resemble those on cotton.

(ii) *Fertilizer Sources and Rates:-*

The fertilizer recommendations for kenaf are in table 2.26

Table 2.24 Fertilizer recommendation for kenaf

ZONES	NUTRIENT HA^{-1}	MATERIAL HA^{-1}
North Seed Production	24kg N	CAN, (95kg 2 bags), (Urea 50kg) or (1 bag or 20-10-10 75kg or 1½ bags)
North Fibre Production	30kg N	CAN, 115kg (2½ bags), urea (62kg - 1½ bags) 20-10-10, (2½ bags)
South-West Fibre Production	25kg N	Compound 135kg (2½ bags) of 20-10-10

(iii) Fertilizer Application - Apply fertilizer just before or just after sowing.

c) Recommended/Improved Varieties

(i) Cuba 108, Tianung 1 & 2, Ife Ken 100, Ife Ken 400 and Ex-Shika 24

(ii) Cultural Practices:- Seeding rate for fibre production is about 13kg ha^{-1} of seed and for -seed production about 30kg ha^{-1}. Prepare a level and fine seed bed. Dibble the seeds thinly in rows 20-25cm apart. Sow as early as the rains are established. Do not grow kenaf after cowpea; both crops are very susceptible to root knot nematodes (eelworm) which can kill the kenaf plants.

d) *Weed Control*

(i) *Hand Weeding*

First weeding 14-21 days after planting or as soon as necessary. A second weeding will be done as at when due before kenaf outgrows available weeds.

(ii) *Herbicide application*

Apply Atrazine, Codal, Stomp and Premextral pre-emergence at the rate 1 small milk tin full/4.5 liters (1 gallon) of water on a clean seed bed.

Application of 50% flowable (PW) at the rate of 1 small tomato tin full/4.5 liters (1 gallon) of water.

Application of 80% wettable powder at the rate of one standard match box full/4.5 liters (1 gallon) water.

e) *Yield Expectancy*

Under experimental condition yields of 1,3.00:- 1,500kg ha^{-1} of ribbon are relatively easy to obtain.

f) *Methods of Planting*

Kenaf can be planted by broadcasting or drilling.

Kenaf can be planted on flat, moulds or beds.

Where drainage is a probem, planting is done on crest or peak of moulds.

Depth of planting is between 3 – 5 cm.

Plant immediately after land preparation to allow kenaf to get ahead of weeds.

g) *Plant Population*

The optimum plant population is in the range of 250,000 to 400,000 plants/ha.

Sowing at 20 by 50 cm at rates of 15 kg/ha has given reasonable stands with a population of between 270,000 and 300,000 plants/ha (germination is between 85 and 90%).

Lower populations result in branching and an increase in stem thickness, which may make harvesting difficult.

Populations higher than 400,000 can lead to a reduction of stem diameter and this in turn may cause lodging of the crop.

h) *Expected Yield*

If the above recommendations are followed and rainfall is adequate expect the followings:

Whole plant biomass: A yield range of 19.6 to 25.5 t/ha.
Fiber: A yield range of 4.6 to 5.5 t/ha.
Seed: A yield range of 1.0 – 1.5 t/ha.

2.5.3 Miscellaneous Vegetable Fibres

No fertilizer and other agronomic information are available in respect of the following fibre crops:

i. Roselle (*Hibiscus sabdariffa*)
ii. Silk cotton (*ceiba pentandra*)
iii. Jute (*corchorus capsularis* and C. *Olitorius*)
iv. Sisal (*agave sisalana*)

2.6 ROOT AND TUBERS

2.6.1 YAM (Dioscorea spp)

(a) Area Under Crop

Between 2.0 to 2.8 million hectares of land are put to yams annually with the bulk of production in the middle belt and southern parts of the country, annual production is 29.1 million tones as at 2010.

Table 2.25 Improved yam varieties

S/No	Name of variety	Original name	National code	Outstanding characteristics
1	TDR 89/02677	TDR 89/02677	NGDR-01-1	Stable yield, very good cooking and pounding qualities, cream tuber parenchyma, 25% tuber dry matter content.
2	TDR 89/02565	TDR 89/02565	NGDR-01-2	Stable yield, very good cooking and pounding qualities, cream non-oxidizing parenchyma, 35% tuber dry matter content.
3	TDR 89/02461	TDR 89/02461	NGDR-01-3	Stable yield, very good cooking and pounding qualities, cream tuber parenchyma, 26.7% tuber dry matter content.
4	TDR 89/02665	TDR 89/02665	NGDR-01-4	Stable yield, very good cooking and pounding qualities, cream non-oxidizing parenchyma, 35.3% tuber dry matter content.
5	TDR 89/01213	TDR 89/01213	NGDR-01-5	Stable yield, very good cooking and pounding qualities, white non-oxidizing parenchyma, 29.8% tuber dry matter content.
6	TDR 89/01438	TDR 89/01438	NGDR-01-6	Stable yield, very good cooking and pounding qualities, white non-oxidizing parenchyma, 29.3% tuber dry matter content.

7	TDR 95/01924	TDR 95/01924	NGDR-01-7	Stable yield, very good cooking and pounding qualities, white non-oxidizing parenchyma, 32.8% tuber dry matter content.
8	DRN 200/4/2	DRN 200/4/2	NGDR-01-8	High yielding, pests and diseases tolerant, very good for fufu, frying and boiling.
9	TDa 98/01176	TDa 98/01176	NGDR-01-9	High yielding, pests and diseases tolerant, good for pounded ym, frying and boiling, suitable for both rainy and dry season yam production.
10	TDa 98/01168	TDa 98/01168	NGDR-01-10	High yielding, pests and diseases tolerant, very good for fufu, frying and boiling.
11	TDa 98/01166	TDa 98/01166	NGDR-01-11	High yielding, pests and diseases tolerant, good for pounded ym, frying and boiling, suitable for both rainy and dry season yam production.
12	UMUCASS 36	TMS 01/1368		High yielding, high gari/fufu value, high cassava flour and starch chains. High beta carotene (pro-vitamin A). Early maturing. Broadly adapted to different environments, Tolerant to drought.
13	UMUCASS 37	TMS 01/1412		High yielding, high gari/fufu value, high cassava flour and starch chains. High beta carotene (pro-vitamin A). Early maturing. Broadly adapted to different environments, Tolerant to drought.
14	UMUCASS 38	TMS 01/1371		High yielding, high gari/fufu value, high cassava flour and starch chains. High beta carotene (pro-vitamin A). Early maturing. Broadly adapted to different environments, Tolerant to drought.
15	UMUCASS 39	NR 03/0211		High yielding, high gari/fufu value, high cassava flour and starch chains. High beta carotene (pro-vitamin A). Early maturing. Broadly adapted to different environments, Tolerant to drought.
16	UMUCASS 40	NR 03/0155		High yielding, high gari/fufu value, high cassava flour and starch chains. High beta carotene (pro-vitamin A). Early maturing. Broadly adapted to different environments, Tolerant to drought.

Table 2.26 Selected Yam landraces

S/N	NAME OF CULTIVAR	SPECIAL CHARACTERISTICS OF THE CULTIVAR
1.	D. rotundata cv. Nwaopoko "DRN 006)	High dry matter good quality when pounded. Yields high 30-40t/ha, fairly resistant to anthracnose. Widely adapted but best in Guinea Savannah
2.	D. rotundata cv. Obiaturugo (DRN 010)	High food quality for pounding, boiling, roasting, resistant to nematodes, Yield 30t/ha, high dry matter. Widely adapted but best in Guinea Savannah.
3.	D. rotundata cv. Okwocha (DRN 005)	Best in forest zones, stores very long, resistant to pests, long dormancy, yields 5-20 t/ha, good for genetic improvement for storage.
4.	D. rotundata cv. Ekpe (DRN 001)	Early maturing. Widely adapted to riverine areas in the forest zone. High yielding 40t/ha.
5.	D. rotundata cv. Abii UD Prunosa (DRN 004)	Very resistant to pests and diseases, high yielding 40t/ha but poor food quality Good for breading as male parent,
6.	D. rotundata cv. Akali (DRN 003)	Rotund shapes, amendable to mechanization good eating quality, stores well up to 4-5 months
7.	D. alata cv Um 680	Widely adapted but best for Guinea Savannah. Very high yielding 50t/ha, resistant to anthracnose, matures early 200-240days, good for livestock feed, high multiplication ratio
8.	D. alata (DRN 087) Ominelu	High yielding, 50t/ha. Produces bulbils, early maturing, poor food quality, but good for livestock feeds

(b) Nutrient Requirements and Fertilizer use

(i) Fertilizer sources and Rates. The fertilizer recommendations for yam are shown in Table 3 and 4 below.

Table 2.27 Fertilizer recommendation for yam

FERTILITY CLASS	NUTRIENT HA^{-1}	FERTILIZER Rates (Kg HA^{-1})
Low	Nitrogen kg ha^{-1}	
Medium	90	196kg (4 bags) Urea
High	45	98kg (2 bags) Urea
	20	44kg (1 bag) Urea
	Phosphorus kg ha^{-1}	
Low	5	278 (5 ½ bags) SSP
Medium	25	139kg (2 ¾ bags) SPP
High	0	-
	Potassium kg ha^{-1}	
Low	75	90kg K_20 or (1.8 bags) of MOP
Medium	40	48Kg – or (1 bag) of MOP
High	0	-

Table 2.28 Other fertilizer recommendations for yams

NUTRIENT/ha	MATERIAL ha^{-1}	RECOMMENDATIONS
15-15-15	12 bags	Southern States
20-10-10	9 bags	Northern States

Magnesium should be applied as a basal dose at 10 kg as magnesium oxide (Mg0) per hectare. This will be supplied through application of 1.25 bags of magnesium fertilizer per hectare. Whenever the soil pH is less than 4.5 application of lime during land preparation at 500kg per hectare is recommended.

(i) **Time of Fertilizer Application**: Apply fertilizers about eight weeks after planting in ring or side band 15 cm from base of the vine at about 3-5 cm deep. Avoid contact of fertilizer with vine. For November planted yam, apply fertilizer by March/April in the next year.

(ii) Cultural practices

Planting method and time;

Yam is planted in November (early) and between February and April (late yam). The seed rate is 2-3t/ha of seed yam. Planting may be in mounds, holes or ridges. Planting on ridges should be 1m x 1.5m of ware yam and 25cm x 1m for mini-sett. Mounds or holes should be 1m x 1.5 m apart for ware yams only.

Weed control

Two options for weed control are available to yam farmers, the traditional methods which involves hand puling or hoeing and the use of herbicides. Three to four hand weeding carried out at 3, 8, 12 and 16 weeks after planting have been found effective for the control of weeds in both ware yams and yam production. The critical period of weed interference for seed yams using the minisett technique is 12 to 16 weeks after planting (WAP), while that of ware yams is between 4 and 16 WAP.

Table 2.29 Herbicide recommendation for yam

HERBICIDE	RATE (kg ha $^{-1}$)	TIME OF APPLICATION
Forest Zones		
Fluometuron + metalachlor (Cotoran Multi)	2.0 – 3.0	Pre-emergence
Atrazine + Metalachlor (Primextra)	2.5 – 3.0	"
Atrazine + Pendimethalin	1.0 – 2.0	"
Diuron + paraquat	2.0 – 2.8	Apply as directed at 4.6 WAP
Fluometuron	3.0	Pre-emergence
Guinea Savannah Zone		
Metalachlor + prometryne	4.0	"
Diuron Metalachlor	2.0- 2.0	"
Alachlor + Diuron	2.0 – 2.0	"
Paraqunat + Diutpm	2.8	Apply as directed spray 3 WAP, Post emergence

Note: Pre-emergence treatments may require supplementary weeding 8-12 weeks after treatment.

(d) Yield expectance

Yield may vary from 7-40 ha $^{-1}$ under farmer's conditions depending on set size and seed bed preparation.

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2.6.2 Cultural Practices for production of seed yam from minisetts.

A minisett is a section from a clean healthy yam tuber weighing approximately 25g. About 15 to 20 setts can be obtained from an average seed yam.

(a) **Treatment of Minisetts**

Freshly cut minisetts ranging from 150-200 in number are put in a plastic basin containing a packet of national Toot Crops Research Institute Minisett Dust. The container is then covered with another plastic material of the same shape and size and shaken to ensure that the minisetts are thoroughly dusted. The dusted minisetts are allowed to dry out. This treatment is to prevent insect and nematode attack which predisposes them to rot. Fungicides/insecticides mixture can be used in the absence NRCRI Minisett Dust.

(b) **Planting of Minisetts in the Field**

Planting of minisetts should be on well prepared ridges, flats, or mounds at a spacing of 1m x 0.25m. This gives a plant population of 40,000 to a hectare. Depth of planting should be 5 to 7cm. it takes 4 to 8 weeks for the minisetts to sprout, depending on the cultivar and soil moisture content.

The best time for planting minisetts in Southern Nigeria is May, when the rains are more regular. In the Northern states, planting may extend up to mid July.

Weed control
Herbicide
In the acid and sandy loam soils of southern Nigeria, the following herbicides are recommended for weed control in seed yam production, using the minisett technique. Fluometuron (mfg CIBA-Geigy), Amiben (mfg, Amchen), Diuron (mfg Du Point), Paraquant (mfg Chevron) Simazine (mfg Chevron) and Atrazine (mfg CIBA-Geigy) mixture 1, 4, 3.7, 1.6, 5.7 and 3.8kg active ingredient (a.i) per hectare respectively applied 3 weeks after planting.

Table 2.30 Fertilizer Recommendation for yam minisett

FERTILITY CLASS	NURTIENT	FERTILIZER RATE (kg ha $^{-1}$)	FERTILIZER SOURCE
	N kg ha $^{-1}$		
Low	60	130kg (2.6 bags)	Urea
Medium	30	65kg (1.3 bags)	Urea
	20	43kg (1 bag)	Urea
High			
	P kg ha $^{-1}$		
Low	10	23kg (P_20_5 or 14kg (2.9 bags)	SSP
Medium	5	12kg (P_20_5 or 72kg (1.5 bags)	SSP
High	0	-	
	K kg ha $^{-1}$		
Low	60	72kg (K_20 or (2.4 bags)	MOP
Medium	40	48kg K_20 or (1.6 bags)	MOP
High	0	-	

(iii) Magnesium Recommendation
Apply as basal dose 6kg Mg ha^{1} (10kg Mg0 ha^{-1} = 1.25 bags) of magnesium sulphate fertilizer to the hectare.

(d) Staking
Two methods are recommended.
(i) Trellis – two poles, 5 metres apart and connected with a strong string may be used to stake as many as 30-40 stands
(ii) Pyramid: small but durable stake about 1 metre high may support 8-10 plants. Earthling up during weeding is desirable because heavy rains erode the soil, exposing developing tubers.

(g) Harvesting.
Minisetts planted in May should be harvested in December. Those planted in June or July should be harvest in January or February the following year.

(h) Yield Expectance
Yields ranging from 9 – 14 t per hectare depending on management and variety have been obtained under experimental conditions.

2.6.3 CASSAVA (manihot esulenta)

(a) Area under crop

Cassava is a hardy crop that is widely cultivated in the forest and savannah zones of the country. It is estimated that 5 million hectares of land is devoted to cassava annually. The annual cassava root production is about 53 million tones as at 2010.

Table 2.31 Improved cassava varieties and their characteristics

S/No	Name of variety	Original name	National code	Outstanding characteristics
1	NICASS 1	TMS-30572	NGME 91-1	High yielding
2	Nlow cyanideICASS 2	TMS-4(2)-1425	NGME 91-2	High yielding, low cyanide
3	NICASS 3	TMS-90257	NGME 96-3	Early bulking, high yielding
4	NICASS 4	TMS-8453	NGME 96-4	High yielding
5	NICASS 5	TMS-82/00058	NGME 96-5	High yielding
6	NICASS 6	TMS-82/00661	NGME 96-6	High yielding
7	NICASS 7	TMS-81/00110	NGME 96-7	High yielding
8	NICASS 8	MS-6 (Antiota)	NGME 96-8	High yielding, non-branching, resistant to pests and diseases, good gari and lafun qualities.
9	NICASS 9	MS-3(Odongbo)	NGME 96-9	Non-branching, high dry matter, good gari quality, stores well in the soil, good for intercropping.
10	NICASS 10	TMS-30555	NGME 96-10	Moderate yielding.
11	NICASS 11	NR-8208	NGME 96-11	High yielding.
12	NICASS 12	NR-8083	NGME 96-12	High yielding.
13	NICASS 13	NR-83107	NGME 96-13	Resistant to pests and diseases.
14	NICASS 14	NR-8082	NGME 96-14	High yielding, resistant to pests and diseases.
15	NICASS 15	TMS-50395	NGME 96-15	High biomass
16	NICASS 16	NR-8212	NGME 96-16	High yielding.
17	NICASS 17	NR-41044	NGME 96-17	High yielding.
18	NICASS 18	TMS-30001	NGME 96-18	Moderate yielding
19	NICASS 19	TMS-91934	NGME 96-19	High yielding
20	NICASS 20	TME-419	NGME 05-20	

(b) Nutrient Deficiency Symptoms and Fertilizer use.

(i) Nutrient Deficiency Symptoms. There are some deficiency symptoms often observed but it is not possible at present to attribute them to a specific nutrient. Such symptoms include stunted growth, yellowing of leaves and scorching of leaf margin.

(ii) Fertilizer Sources and Rates: - Very rich soils do not require fertilizers but for poor or sandy soil, the fertilizer recommendations are as listed in Table 8.

Table 2.32 Fertilizer recommendations for cassava

FERTILITY CLASS	NURTIENT	FERTILIZER RATE (kg ha $^{-1}$)	FERTILIZER SOURCE
	N kg ha $^{-1}$		
Low	90	196kg (4 bags)	Urea
Medium	45	98kg (2 bags)	Urea
High	20	44kg (1 bag)	urea
	P kg ha'		
Low	20	47kg P_20_5 or 288kg (5.8 bags)	SSP
Medium	10	24kg P_20_5 or 144kg (2.9 bags)	SSP
High	5	12kg P_20_5 or (72kg (1.5 bags)	SSP
	K kg ha'		
Low	75	90kg K_20 or (1.8 bags) or	MOP
Medium	40	48kg K_20 or (1 bags)	MOP
High	0	-	-

Table 2.33 Other recommended fertilizers for cassava

NUTRIENTS/ha	MATERIALS ha^1	RECOMMENDATION
15-15-15	12 bags	600kg ha $^{-1}$
20-10-10	9 bags	450kg ha $^{-1}$
12-12-17+2Mg0	15 bags	750kg ha $^{-1}$

(iv) Time and method of fertilizer application
Apply in ring form 6cm deep and 10cm from plant or broadcast with car around the plant making sure the fertilizer does not touch the stem or leaves. Apply at 8 weeks after planting.

Complementary use of inorganic fertilizer and organic manure
3 t of poultry manure + 200 kg NPK (20: 10:10) per hectare

(c) Varieties Other Cultural Practices
Varieties:- Many improved varieties are currently available, some of which are listed Table 10

Table 2.34 Recommended cassava varieties for different zones of Nigeria

South-Eastern states includes Abia, Akwa-Ibom, Anambra, Bayelsa, Cross River, Ebonyi, Enugu, Imo, Rivers	NR 8082, NR 8083 TMS 30572, TMS 30555, TMS 4(2) 14 Nwugo
South-Western states including Delta, Edo, Ekiti, Kwara, Lagos, Ogun, Ondo, Olsun, Oyo	TIMS 30572, NR 8082, NR 8083
Northern States including Adamawa, Bauchi, Benue, Borno, Gombe, Jigawa, Kaduna, Katsina, Kebbi, Kogi, Nasarawa, Niger, Plateau, Sokoto, Taraba, Yobe, Zamfara, FCT.	TMS 30572 4 (2) 1425 NR 8082, NR 8083

(ii) *Cultural Practices/Planting Method*

Stem cuttings are the main mode of propagation of cassava. For best yields cassava should be planted as soon as rains are established, around April in the South and June in the North. However, because most farmers give priority to other fields crops, cassava is often planted late; because of high incidence of diseases, cassava should be planted as early as possible. Cuttings should be 25 cm long and planted in a slating position at spacing of 1m x 1m. Three quarters of the total length should be buried in the soil.

Weed control:

Table 2.35 Herbicides recommendation for cassava

HERBICIDE APPLICATION	RATE OF APPLICATION a.i. (kg ha $^{-1}$)	TIME OF
Primetra	3.2	Pre-emergence
Gramoron + Paraquant	1.4, 2.5	Pre- emergence
Fluometeron + paraquant	3.0, 2.5	Pre- emergence

Yield Expectancy

Yield of 11-15 ha^{-1} may be obtained under farmer's conditions depending on management.

2.6.4 IRISH POTATO (*Solanum tuberospin*)

(a) Area Under Crop

A relatively new crop in the country, Irish potato grows well in area around Zaria, Kano and the Jos Plateau. The total land area under the crop is presently about 0.3 million hectares, total production is 1.48 million tones per annum as at 2010.

(b) *Nutrients Requirement and fertilizer Use*.

Nutrients Deficiency Symptom:

Nitrogen Deficiency: Leaves are light green; older leaves turn yellow and shed, stems are few and slender, growth is upright, tubers are small.

Phosphorus Deficiency:- Leaves roll forward and show marginal scorch, the older ones drop; growth is upright and spindly; tubers may have internal lesions.

Potassium Deficiency:- Leaves first bluish-green, older leaves become yellow followed by necrosis and browning starting from the tips of margins; leaflets are cupped and crowed together, tuber flesh is bluish.

Table 2.36 Fertilizer recommendations for Irish Potato

FERTILITY CLASS	NUTRIENT	FERTILIZER RATE (kg ha^{1})	FERTILIZER SOURCE
	N kg ha^{-1}		
Low	100	217kg (4.3 bags)	Urea
Medium	50	130kg (2.6 bags)	Urea
High	20	43kg (1 bag)	Urea
	P kg ha^{-1}		
Low	40	93kg P_20_5 or 581kg (11.5 bags)	SSP
Medium	20	47kg P_20_5 or 291kg (5.8 bags)	SSP
High	10	24kg P_20_5 or (145kg (2.9 bags)	SSP
	K kg ha^{-1}		
Low	70	84kg – or 140kg (2.8 bags)	MOP
Medium	35	42 K_20 or 70kg (1.4 bags)	MOP
High	10	12 K_20 or 20kg (0.4 bags)	MOP

(iii) *Time and method of fertilizer application*.
The fertilizer material should be applied 2 weeks after planting. Fertilizer should be applied round each plant 10-15 cm from each plant and covered with soil.

(c) *Varieties and other cultural practices*.

(i) Varieties: recommended varieties and their characteristics are as follows.

Table 2.37 Recommended varieties for Irish Potato

VARIETIES	TUBER YIELD (tha^1)	% DRY MATTER	MATURITY CLASS	RESISTANCE TO BLIGHT	RESISTANCE TO BAC.WILT	RESISTANCE TO SCAB
Rc767-1	25	20.4	Late	SS	SS	SS
Rc777-3	25	20.1	Very late	R	SS	R
B9462-1	30	16.0	M/L	S	HS	S
B776-3	26	18.1	M/L	R	S	R
Kondor	35	18.1	Med	R	S	R
Micola	30	17.1	Med	HS	S	R
Diamant	30	19.6	M/L	S	S	SS
Desiree	25	17.4	Med	SS	SS	S
Delcora	20	18.7	Med	SS	SS	S
Arka	28	18.7	Med	S	S	SS
Famosa	20	15.7	Late	SS	S	SS
Greta	20	20.2	Med	HR	FR	R

M/L - Medium Late; FR - Fiarly Resistant; SS - Slightly Susceptible
E/M - Early medium; R - Resistant; S - Susceptible
HS - Highly susceptible; HR - Highly resistant.

(d) *Planting and spacing:* - Propagation of Irish Potato is by vines and seed tubers. Vines 20cm long, are inserted to a depth of 8-10 cm in the soil. Spacing for the wet season crop is 1m x 0.30m. for the dry season (irrigated) crop spacing of 2.25m x 1m is recommended.

Weed Control:-

Mechanical weed control

Traditionally weeding in potato production in Nigeria is mostly done manually by use of hoes, machetes and hand pulling. Weeds re-established quickly when only the above-ground parts are cut off, leaving a short stem and roots in the soil. It has been established that keeping potato plots weed free beyond 4 weeks after planting has no yield advantage over keeping it weed free for only 4 weeks after planting. If potato plots are kept weed free for 4 weeks after planting it will take another 3-4weeks for weeds to re-establish and interfere with potato growth and development. Tuber initiation and bulking starts from 3-4 weeks after planting. By the end of 8 weeks after planting some early varieties are ready for harvest especially when well sprouted seed tubers are planted. Great care is required in mechanical weeding of potato to minimize the damage of potato roots and stolons.

Chemical weed control

Weed is also controlled by use of herbicides. Several herbicides have been screened and found effective for the control of weeds in potato in Jos Plateau, Nigeria.

The herbicide recommendation for Irish potato is given on Table 2.40

Table 2.38 Herbicide recommendation for Irish Potato

HERBICIDE	CROP	RATE	TIME OF APPLICATION
Sencor	Sole Potato	0.8kg a.i.$^{-1}$ or 68g/201	Pre-emergence
Lasso/atrazine	Potato/maize	41 ha^{-1} or 255ml/20L	Pre- emergence
Galex	Potato/cowpea/soyabean	51 ha^{-1} 425ml/20L knapsack	Pre- emergence
Metazcachlor	Sole potato	0.7kga.i. ha^{-1} or 67/20Lknapsack	Pre- emergence
Basagran PL2	Potato/maize	41 ha^{-1} or 225ml/20L	Pre- emergence

Disease and Pest Control:- Pesticides for Irish Potato are shown in Table 15

Table 2.39 Pesticide recommendations for Irish potato

PESTICIDE	RATE kg ha^{1}	VOLUMES OF WATER	FREQUENCY OFAPPLICATION
Cupravit	5.5	250	Weekly
Rido m1 m2	2.5	250	Fortnightly
Drthane m.25	3	250	Weekly
Kaurihl	5	250	Weekly
Rodimil +	0.9+	250	Weekly
Polygram combi	2.5	250	Weekly
Brestan Cone	0.2	250	From 6 – 8 weeks
Brestan 10	0.4	250	From 9 weeks to maturity
Brestan 10	2.5	250	weekly

Yield Expectancy

Yields ranging from 15-30 tonnes ha^{-1} may be obtained under farmer's condition depending on set size and management.

2.6.5 COCOYAM (Colocasia spp and Xanthosoma spp)

(a) *Area Under Crop*

Cocoyam is a crop of the wet regions of Nigeria. But it is grown extensively in all parts of the country, even as far north as the Sudan zone. An estimated 0.3 – 0.89 million hectares of cocoyam is cultivated each year in the Country. The county's anunnal production is 4.5 million tones as at 2010.

(b) Nutrient Requirements and Fertilizer

(i) Deficiency symptoms:- Some of the symptoms often observed include stunted growth, yellowing of leaves and general chlorosis of leaves presumably due to N deficiency.

(ii) Fertilizer source and rates:- the fertilizer recommendations for cocoyam are as shown in Table 16.

Table 2.40 Fertilizer recommendation for cocoyam

FERTILITY CLASS	NUTRIENT	FERTILIZER RATE (kg ha^{-1})	FERTILIZER SOURCE
	N kg ha^{-1}		
Low	60	130kg (2.6 bags)	Urea
Medium	40	87kg (1.7 bags)	Urea
High	10	22kg (0.5 bag)	Urea
	P kg ha^{-1}		
Low	10	23kg P_20_5 or 144kg of SSP	SSP
Medium	5	12kg P_20_5 or 75kg of SSP	SSP
High	0	4.8kg P_20_5 or 30Kg of SSP	SSP
	K kg ha^{-1}		
Low	50	60kg K_20– or (2 bags) of MOP	MOP
Medium	30	36kg K_20 or (1.2bags) of MOP	MOP
High	20	24kg K_20 or (0.84 bags) of MOP	MOP

The fertilizer should be applied at 6-8 weeks after planting or 2 weeks after sprouting.

Table 2.41 Fertilizer (Compound fertilizer) requirement for cocoyam in South Eastern Nigeria based on soil test.

Soil fertility	Compound fertilizer	
Class	NPK 15 15 15	NPK 20:10:10
Low	400kg/ha (8 bags)	300kg/ha (6 bags)
Medium	200kg/ha (4 bags)	150kg/ha (3 bags)
High	133kg/ha ($2^2/_3$ bags)	100kg/ha (2 bags)

It has been established that organic fertilizer (manure) such as poultry manure, rice mill waste, pig manure etc can be used alone or in combination with NPK fertilizer. Manure is applied at planting. Other rates of application of organic manure + mineral fertilizers are:

10 t/ha rice mill waste + 4 bags of NPK 15 15 15;
4 t/ha poultry manure + 4 bags of NPK 15 15 15 (400 kg/ha);
20 t/ha rice mill waste alone

Apply organic manure at planting as recommended followed by mineral fertilizer at 6 weeks after planting. Eatrhening up is a cultural management that should be carried out about 6-8 weeks after planting. Check soil erosion.

Control of Cocoym Root Rot Blight Complex (CCRRBC) in Xanthosoma spp

Application of 5.00 t/ha rice mill waste (RMW) + 4.00 t/ha poultry manure (PM) + NPK (400 kg/ha) appeared promising in the control of cocoyam root rot blight complex in Xanthosoma spp.

(i) Variety:- the following varieties are presently recommended:
Xanthosonia spp:
NCY 001 (white fleshed cultiver, (Ede Ocha)

NCY 002 (pink fleshed cultivar, (Ede uhie)
NCY 003 (Yellow fleshed cultivar, (Okorokoro)

Colocasia spp
NCY 004 (cocoindia)
NCY 005A (green petiole,(Ede Ofe)
NCY 005B (purple petiole (Ede Ofe)
NCY 005C (Giant (Ede Ofe)
NCY 007 (Ede Mbe)
NCY 008 (Gana)

Planting: The time of planting extends from March/April when the rains start, to July, Optimum planting time is the south is between May and June. Depending on location, planting is done either on mounds, ridges or flat, spacing for ware cocoyam production is 1m x 0.5m while minisett cocoyam (25g sett size) is 1m x 0.25m). For rapid multiplication using Gocken Rapid Multiplication Technology (GRMT) which involves the use of about 7g micro setts or micro cormels), the spacing is 1 m x 0.20 m to get a plant density of 50,000 plants/ha.

(ii) Weed control:

Manual: - hand weeding at 6 and 12 weeks after planting and underbrush just before dry season.

Herbicide: - The herbicide recommendation is for cocoyam are as shown in table 18.

Table 2.42 Herbicide recommendations for cocoyam

HERBICIDE	RATE a.i. (kg ha^{-1})	TIME OF APPLICATION
Colocasia spp (upland)		
Prometryne	2.0 to 3.0	Pre-emergence
TCA + Diuron	5.0 + 3.0	-do-
TCA + Atrazine	5.0 + 3.0	do-
Colocasca sp (Flooded)		
Nitrogen	2.0+6.0	do-
Prometryne	2.0+3.0	do-
Ametryne	2.0+3.0	do-
Xanthosoma sp		
Diuron	2.0+4.0	do-
TCA + Diuron	4+2.0	do-

Yield Expectancy

Yield of 5 – 15t ha-1 under farmers conditions are possible depending on specie, set size and management.

2.6.6 SWEETPOTATO (*Ipomoea batatas*)

(a) *Area Under Crop*

Sweetpotato is widely gown in many parts of the country, including the Sudan Zone, but it performs best under wetter. Area under sweetpotato cultivation is estimated at 0.96 million hectares annually. Total production in 2010 was 2.74 million tones.

(b) Nutrient Requirement and Fertilizer Use

(i) Nutrient Deficiency Symptoms

Nitrogen – Typified by chlorotic leaves, purplish colour potassium – old leaves shown chlorosis at margins between veins with downward cupping and some shedding stems are few, growth is reduced.

(ii) Fertilizer Sources and Rates – The fertilizer recommended for sweetpotato are shown in Table 19.

Table 2.43 Fertilizer recommendation for sweetpotato

FERTILITY CLASS	NUTRIENT	FERTILIZER RATE (kg ha^{-1})	FERTILIZER SOURCE
	N kg ha^{-1}		
Low	60	130kg (2.6 bags)	Urea
Medium	40	87kg (1.7 bags)	Urea
High	20	44kg (1 bag)	Urea
	P kg ha^{-1}		
Low	15	35kg P_20_5 or 219kg of SSP	SSP
Medium	10	23kg P_20_5 or 144kg of SSP	SSP
High	5	12kg P_20_5 or 75Kg of SSP	SSP
	K kg ha^{-1}		
Low	75	90kg K_20– or 150kg of MOP	MOP
Medium	50	60kg K_20 or 100kg of MOP	MOP
high	20	24kg K_20 or 40kg of MOP	MOP

NOTE: 12 bags of -15-15 may be used on soil of low nutrients status, 8 bags for medium levels of N and K. The fertilizer should be applied 4-6 weeks after planting by controlled broadcast.

(i) Varieties: The following varieties have been found to have high yielding potentials TIS 87/0087, TIS 8164, TIS2532 O.P. 1.13.

(ii) Planting: Propagation of sweetpotato is by vines, 20cm long, which are inserted to a depth of 8-10cm in the soil. Vines are spaced 30cm part on 1m ridges. In areas where the rainfall is relatively low, the crop should be planted as soon as the rains are well established.

(iii) Weed Control:- The herbicide re commendations for sweetpotato are shown in Table 20.

Table 2.44 Herbicide recommendation for sweetpotato

HERBICIDE	RATE (a.i. kg ha^{-1})	TIME OF APPLICATION
Forest zones		
Fluometuron	2.5	Pre-emergence
Atrazine + Metolachlor	2.5	-do-
Guinea Zone		
Fluometuron	2.0	Pre-emergence
Atrazine + Metolachlor (Pre mextra)	2.0	-do-

Yield Expectancy

Under farmer's conditions, yields ranging from 7-25t ha^{-1} have been obtained depending on management.

2.6.7 GINGER (*Zingiber Officiale)*

(a) Area under crop

This crop which hitherto had not been popular is now considered a high value cash crop if grown under organic farming. It is mainly grown in limited areas of the country such as Southern parts of Kaduna, Cross River, Akwa Ibom, Rivers, Abia and Imo States Total land area under ginger cultivation is 0.11 million hectare, annual production is 0.44 million tone.

(b) Nutrient Requirements and fertilizer use.

The current fertilizer recommended for Ginger are shown in Table 2.44

Table 2.45 Fertilizer recommendations for ginger

FERTILITY CLASS	NUTRIENT	FERTILIZER RATE (kg ha^{-1})	FERTILIZER SOURCE
	N kg ha^{-1}		
Low	45	100kg (2 bags)	Urea
Medium	25	55kg (1 bag)	Urea
High	10	22kg (0.5bag)	Urea
	P kg ha^{-1}		
Low	20	47kg P_20_5 or 294kg of SSP	SSP
Medium	15	35kg P_20_5 or 219kg of SSP	SSP
High	5	12kg P_20_5 or 75Kg of SSP	SSP
	K kg ha^{-1}		
Low	50	60kg K_20– or 100kg of MOP	MOP
Medium	30	42kg K_20 or 100kg of MOP	MOP
high	20	24kg K_20 or 40kg of MOP	MOP

The fertilizer materials should be applied broadcast in two doses, half at land prepares and the 2^{nd} halt at 12 WAP.

Complementary use of inorganic fertilizer and organic manure

4 t poultry manure mixed with 45 kg ha NPK 15:15:15

(C) Varieties and other cultural practices

(i) Varieties: Two popular varieties are recognized throughout the country. They are yellow ginger(UG I) and Black ginger (UG2).

(ii) Spacing: Plant on the flat at spacing of 20cm x 20cm.

(iii) Weed Control: The herbicide recommendations for Ginger are given in Table 22

Table 2.46 Herbicide recommendation for ginger

HERBICIDE	RATE a.i. (kg ha^{-1})	TIME OF APPLICATION
Fluometuron + Alachlor	0.75 + 0.75	Pre-emergence
Fluometuron	1.5 + 1.50	-do-
Chloramben	1.5 – 3.0	-do-
Chloramben + Alachlor	1.5 – 3.0	-do-
Oxadizone	0.75 + 0.75	-do-
	1.0-2.0	-do-

Note :- Supplementary weeding may be required at 8-12 weeks after planting.

Yield Expectancy

Yields of 8 – 10t ha^{-1} may be obtained under farmer's conditions depending on sett size and management.

2.6.8 Carrots (*Daucus carota*)

(a) *Area Under Crop*

Carrot grows well in sandy loam or silt loam soils which are deep and free drainage pH of 6.5 is ideal.

(b) Nutrient Requirements and Fertilizer Use

(i) Nutrient Deficiency Symptoms

Nitrogen Deficiency: Leaves are light-geen, then become yellowish; petioles weak.

Phosphorus Deficiency: Leaves are dull green with purple cast; older leaves die, petioles-are upright.

Potassium Deficiency : Leaves are slightly chlorbtic, followed by browning; roots are spindly.

Fertilizer Sources and Rates: Carrots remove a lot of potash from the soil and wood ash at the rate of 400kg/ha should be applied to the bed before sowing. Fertilizer Recommendations are as shown in Table 2.46.

Table 2.47 Fertilizer recommendations for carrots

NUTRIENT ha^{-1}	MATERIAL ha^{-1}	RECOMMENDATION
50kg N 38kg P_20_5 60kg K_20	SA, 250kg (5 bags) CAN 195kg (4 bags) SSP, 210kg (4 bags) KCL 100kg (2 bags) K_2SO_4 115kg (2¼ bags)	Existing practice for carrots in northern States = 50kg ha^{-1} N, 38kgha^{-1} P_20_5 + 60kg ha^{-1} K_20

(ii) Method and Time of Fertilizer Application: Apply woodash, phosphate and

Potash during seed bed preparation and incorporate thoroughly. Nitrogen is split applied at 2 and 6 weeks after planting.

(c) *Varieties and Other Cultural Practices*

(i) Varieties: Use the varieties Nantes Touchon, Chantenay or any good local variety

(ii) *Cultural Practices:-* Make 1cm deep drills along the, bed and dibble the seed thinly. Rows should be 20 - 25cm apart. Because of the small-size of the seed, they should be mixed with some dry sand and sown together. If necessary, thin to 2.5cm between seedlings. The Crop is sown when the rains are established but dry season (irrigated) carrots are planted in November.

Yield Expectancy

Accurate yield data are not available but up to 6 - 10t ha^{-1} of fresh carrots have been obtained under good management.

2.7 VEGETABLE CROPS

2.7.1 Tomato (*Lycopersicum esculentum*)

(a) *Area Under Crop*

Tomato is perhaps the most popular vegetable crop grown all over the country. Both wet and dry season cropping contribute immensely to the national requirement, but the bulk of production is from the dry season cropping particularly under irrigation in the Northern States and near perennial river banks in the Southern States. Total land area covered annually is over one million hectares with most of the production from the Northern Guinea and Sudan Savannas.

(b) *Nutrient Requirements and Fertilizer Use*

Nutrient Deficiency Symptoms

(i) *Nitrogen Deficiency:* Leaves are light are green lower; lower leaves turn yellow and dry up veins become deep purple; stems are hard and purple, flower buds turn yellow and drop.

Phosphorus Deficiency: Leaves are olive-green: foliage is sparse; plants are stunted.

Potassium Deficiency: Lower leaves become yellowish or greyish-green along margins and at tips, followed by necrosis, dead areas turn brown giving the lower part of the plant a bronzed appearance; stalks are slender and may show necrotic areas, in extreme cases, fruit ripens unevenly and lacks solidity.

(ii) *Fertilizer Sources and Rates:* Wherever possible, farm yard manure should be used up to 25 tonnes/ha. The recommended fertilizer programmes for tomato are as shown in Table 2.47.

(iii) *Methods and Time of Application*

Nursery The compound fertilizer 15-15-15 or any alternative should be applied (ground) to the seedbed at the rate of 25kg (one match box full) per square. The fertilizer should be worked into the soil and seed bed gently consolidated. The surface should be raked to leave a fine tilth. If poor growth of seedlings is observed, there may be need for addition of nitrogen fertilizer. A dose of 6.3g of nitrogen should then be applied per square meter. For example, this may be supplied from 24g of CAN per square meter of 30g of sulphate of ammonia in 10 liters of water at 5 liters per square meter thoroughly worked into the soil.

Field: The recommendations are summarized in the Table 2.47. Application of combination of farm yard manure and inorganic fertilizers is recommended during land preparation.

Varieties and Other Cultural Practices

(i) Varieties

Table 2.47 shows some improved varieties

Table 2.48 Fertilizer recommendations for tomato

NUTRIENT ha^{-1}	MATERIAL ha^{-1}	RECOMMENDATIONS
20-10-10 i.e. 20kg N 10kg P_20_5, 10kg K_20	20-10-10 50kg (1 bag) plus 40kg CAN (app. 1 bag of CAN)	Existing recommendation for nursery bed in the savanna areas at 50kg of compound 20-10-10 plus 40kg of CAN
FYM 20-10-10	FYM, 25 tonnes 20-10-10 50kg plus 40kg CAN (i.e. 1½ bags 15-15-15 and 1 bag of CAN	Existing recommendation for field in the savanna areas = FYM at 25 tonnes/ha or 70kg compound plus 300kg Can as top dressing split applied at 2 weeks after transplanting and 3 weeks after first set of fruits
125kg N, 50kg P_20_5, 10kg K_20	20-10-10 312kg = 6¼ bags plus 290kg CAN (6 bags) or 160kg Urea (3 bags)	Suggested practices under irrigation in the savanna areas = 125kg N/ha + 50kg P_20_5, + 50kg K_20 ha^{-1}. Apply the N in three splits at 0.3 and 6 weeks after transplanting P and K are broadcast in furrow bottoms before splitting ridges
15kg N, 15kg P_20_5, 15kg K_20	20-10-10 75kg at 1½ bags	Existing practice in south - western Nigeria = 20-10-10 at 25kg/ha split applied at 0 and 6 weeks after planting
60kg N, 45kg P_20_5, 33kg K_20	20-10-10 at 250kg, 5 bags at 300kg (6 bags) plus 57kg (1 bag) CAN or 33kg (¾ bag) urea	Suggested practice in the savanna zone of south western Nigeria = 60kg N ha^{-1} + 50kg P_20_5 + 33kg N_20 ha^{-1} + B as Borax as may be necessary
30kg N, 90kg P_20_5, 67kg K_20	Urea at 65kg (1 bag) Can at 115kg (2 bags) plus SSP at 500kg (10 bags) plus $MgS0_4.7\ H_20$ at 310kg (6 bags) MOP (112kg or 2 bags)	Suggested practice in the forest zone of southern Nigeria = 30kg ha^{-1} N + 90kg P_20_5 + 67kg K_20 + 30kg MgO
60kg N, 60kg P_20_5, 60kg K_20	20-10-10 400kg (8 bags) or 12-12-17-2 500kg (10 bags)	Existing practice in south-eastern Nigeria = 300 kg/ha of compound 20-10-10 or 500kg ha^{-1} 10 bags of compound 12-12-17-2

Table 2.49 Recommended improved tomato varieties currently used

AREA	PROCESSING TOMATO CULTIVARS	FRESH MARKET TOMATO CULTIVARS
Wet Season Tomato Southern - Western Nigeria Southern - Eastern Nigeria	Ronita Roma VF	Ife No. 1 H9 - 1 - 6 Mar Globem Veliant Dwarf Gem. Bonny Best, Money-Maker, Zuarunau, Roma VF
Sudan Savanna	Cirio-56, Marzanino Piacenza 0164, Harvester Chico. La Bonita. Roma VF, Chico	La Bonita, Ife No. 1, Enterpriser
Northern Guinea	Cirio-56, Marzanino Piacenza 0164, Harvester, Gamade, Gemed F., Roma PVF	La Bonita, Ife No. 1, Enterpriser
Southern Guinea	Cirio-56, Marzanino Piacenza 0164, Harvester, Gamade, La bonita	La Bonita, Ife No. 1, Enterpriser
Dry Season Tomato South Western Nigeria South Eastern Nigeria	Harvester, Ronita Roma VF, Marzanino	Ife No. 1 H9 - 1 - 6 Mar Globe, Valienti, Dwarf gem. Bonny best, money-maker Zuarunau Rome VF.
Sudan Savannah	Roma VF Marzanino Harvester, Ronita	Enterpriser, Ife No. 1
Northern Guinea	Chico, Marzanino La Bonita, Ronita Piacenza 0164	Enterpriser, La Bonita
Southern Guinea	Roma VF, Marzanino, Harvester Ronita, Piacenza 0164	Enterpriser, La Bonita
Bauchi-Plateau Area	Marzanino, Harvester, Ronita, Piacenza 1064 La Bonita	Enterpriser, La Bonita

(ii) *Cultural Practices:* Successful production of tomato involves both nursery and field management. The seeds are usually sown in the nursery and later transplanted into the field to facilitate a good field establishment. Both the wet and dry season productions are feasible provided irrigation water is not limiting in the dry season which produces the best crop due to limited pests and disease infestation.

Seedlings should be raised in beds 1 - 1.5m wide, and as long as necessary (about 10m). For good seedling emergence and establishment, Nemagon 20 should be applied to control soil nematodes. It should be put into the soil at $7g/m^2$ and the granule incorporated into the seed bed to a depth of 15 -20cm. Farenox may also be used at 3 - 4 in 1,100 litres of water per ha^{-1} at 2 weekly intervals. For most varieties, double rows of 45 x 60cm spacing is recommended.

(iii) *Weed Control:* Apply metribuzin (sencor) at the rate of 1.5 - 2.0kg a.i. per hectare at the time of transplanting. Mixtures of metri buzin with diphenamid, metolachlor or alachlor without supplementary hoe - weeding.

Chemical control of tomatoes leaf diseases during wet season. Apply fungicidal sprays of very low volume (VLV) captasol (Ditolatan 80WP or Ditolatan 5 can obtain a net profit of at least ₦10,000 ha^{-1}. Already lines with resistance to septaria have been identified of which T.420 has been the most outstanding.

Yield Expectancy

Farmers obtain about 6t/ha of fresh tomatoes. Under improved management, yields of up to, 30t/ha are obtainable under irrigation; while up to 15 t/ha are obtained und er rain- fed conditions.

2.7.2 Onion (*Alliun cepa*)

(a) *Area under Crop*

Onion is mainly grown for its bulb and is widely grown in parts of northern states, especially in Sokoto, Kaduna, Plateau and Borno States. An estimated total land area of 0. 1 to 0.2 million hectares is cropped annually.

(b) Nutrient Requirement and Fertilizer Use

i) Nutrient Deficiency Symptoms

Nitrogen Deficiency : Leaves are light green, older leaves show bleached yellowish colour; leaves are narrow grow stiff and upright.

Phosphorus Deficiency: Older leaves wilt, showing tip die-back and mottling of green area.

Potassium Deficiency: Older leaves first show slight -yellowing followed by wilting and death; drying and dying start at tips of older leaves; bulb formation is poor.

(ii) Fertilizer Sources and Rates: The following fertilizer recommendations (Table 2.49) are based on conditions existing in the northern guinea and Sudan savannas.

Table 2.50 Fertilizer recommendations for onion

NUTRIENT ha^{-1}	MATERIAL ha^{-1}	RECOMMENDATION/SUGGESTION
38kg P_20_5	SSP, 210kg (4 bags)	Existing recommendation for the nursery = 21g/m of finely ground SSP. Where possibe also use FYM
65kg N 45kg P_20_5	Urea at 140kg (1 - 3 bags) or Can at 250kg (5 bags) SSP (250kg or 5 bags)	Existing recommendation for the field = 65kg N ha^{-1} + 45kg P_20_5 ha^{-1}. Where possible use FYM at 5 - 6t ha^{-1}.

(iii) *Method and Time of Fertilizer Application*

Nursery: If seedling growth is slow, about 14g of CAN should be dissolved in 4- 5 litres of water and applied to 2 square metres of seed bed area. After the fertilizer applications, the seedling should be watered using a watering can. Seedlings should be ready for transplanting 6 – 8 weeks after planting and should have been 15cm -23cm high at this stage.

Field: About 5 – 6t ha^{-1} FYM and 125kg ha^{-1} of single superphosphate should be applied at land preparation. The nitrogen fertilizer should be applied to the field plots in two equal doses at 2 - 3 weeks and 6 – 7 weeks after planting.

(c) *Varieties and other cultural practices*

(i) *Varieties:* It is advisable to use the best local onion variety available. Promising improved Varieites (not yet released) include D77, RD 777. Composite 1 and Composite 4.

NIHORT has developed six improved varieties of onion SAMONI - 1, SAMONI - 2, SAMONI - 3, SAMONI - 4, SAMONI - 5 and SAMONI – 6, from local onion germplasm,. They have a yield range of 10 – 35 tonnes ha^{-1} of bulb as well as good storage qualities composed with local strains which are usually performed by as much as 60 – 72 %.

(ii) *Cultural Practices: Pr* oduction of seed crop is from setts or bulbs whilst the edible part (bulb) is normally from seed. A good sized onion is cut horizontally and the bottom half with roots is planted in a well prepared seedbed. Once bulbs are formed they are cut and planted out; within 3 - 4 months flowers are formed and seeds produced. To produce the edible onion, seeds are sown in well manured nursery bed; 1 - 1. 5m wide and as long as desired (10m); seedlings are ready for transplanting after 6 - 8 weeks and are spaced 10cm apart within rows 15 - 20cm apart. Three crops of onion are produced annually under northern states conditions. Seeds of the first crop of onion are produced annually under northern states conditons. Seeds of the first crop are sown in the nursery late in April, transplanted in mid-June. and harvested between August and September. For the second crop, the seeds are sown in June transplanted between July and August and harvested between November and December. The second crop invariably requires supplementary irrigation. The third crop is grown entirely during. the dry season under irrigation; seedlings are raised between September and October, transplanted between November and December on flat beds (1m x 2m) and the crop is ready for harvest in March/April.

Herbicide Use: Apply 2.0kg a.i.ha^{-1} of oxadiazon or 10kg a.i.ha^{-1} of chlorthal - Dimethyl just before transplanting. Apply one or two days before transplanting.

Yield Expectancy

Yields are highest with the dry season crop where 25t ha^{-1} bulbs are possible. Delay in harvesting of onion causes bulbs to regenerate new growth which flower and subsequently produce seeds.

2.7.3 Okra (*Hibiscus esculentus*)

(a) *Area Under Crop*

Okra is one of the most popular vegetable crops commonly grown in every part of the country and an estimated total land area devoted to this crop ranges from 1 - 2 million hectares.

(b) Nutrient Requirement and Fertilizer Use

(i) Nutrient Deficiency Symptoms

Nitrogen: Light-green to yellow leaves coupled with retarded growth.

Phosphorus: Slow growth, characteristic foliage symptoms are less pronounced than in other plants. The leaves fade to a lighter green colour.

Potassium: Characteristic small spots at the margins of the leaves resulting in marginal yellowing and later browning as the edges turn downward and die.

(ii) *Fertilzer Sources, Rate and Application:* Like most vegetables okra benefits from the application of organic manures; wherever possible apply FYM at the at the rate of 25t ha^{-1} worked into the soil at land preparation. The recommended Fertilizer practices are as shown in Table 2.50.

Table 2.51 Fertilizer recommendation for Okra

NUTRIENT/ha	MATERIAL/ha	RECOMMENDATION/SUGGESTION
50kg N	110kg urea (2 bags) or 200kg Can (4 bags) plus 250kg SSP (5 bags)	Existing recommendations for the field 50kg N ha^{-1} plus 45kg P_20_5 ha^{-1}. Apply 250kg SSP to the seed bed before or just after planting plus 110kg urea or 200kg CAN per hectare. The nitrogen should be split applied at 2 weeks after planting and at first set of fruits. The use of organic manure at the rate of 30 tonnes ha^{-1} and that of inorganic fertilizer (Nitrogen phosphorus) at 30 kg ha^{-1} and kg/ha respectively have been observed to reduce considerably the incidence of viral diseases in cultivated Okra.

(c) Varieties and Other Cultural Practices

(i) Varieties: Not many improved varieties are available at this time and farmers are encouraged to use local varieties of good quality. "White Velvet" is popular in many parts of the Northern states while'Lady's finger' is widely grown in the southern parts of the country. The following improved varieties have produced very good results and are at advanced stage of release Table 2.51.

Table 2.52 Improved okra varieties

SN	FOR SOUTHERN STATES	FOR NORTHERN STATES
1	Ilora Local	White Velvet
2	V2	' Yar-balla' (Improved Local)
3	V35	V35
4	TAE 38	TAE 38
5	U.I. 104	
6	Jokoso	
7	Aka Nwango	
8	NHAE 47 - 4	
9	Awgu Early	
10	Lady's fingers	

(ii) *Cultural Practices:* In places where the rainy season is long enough for only one crop, okra can be sown any time between April and July; but because of pest problem at the onset of the rains farmers invariably sow late. In the Southern states two crops of okra are possible - the first (early crop) is sown in March/April at the start of the rains and the second (late crop) in August. Tall varieties should be spaced 60cm between plants on 75cm ridges; dwarf varieties should be planted closer (30cm apart). Planting at even higher plant densities (e.g 30cm x 40cm) results in considerable yield increases. Okra is a warm season crop, consequently, seed germination and the rate of growth of the plant and pods are adversely affected by cold weather. Hence the performance of most varieties of Okra during the cold harmattan weather is generally poor.

(iii) *Herbicide Recommendations:* Apply either prometryne or metolachlor (Dual) at 2.0kg a.i/ha at sowing.

Yield Expectancy

Early Planted okra invariably yields higher than the late planted crop. Yields under local conditions generally vary between 6 - 12 t ha^{-1} of fresh pods; yields of up to 22t ha^{-1} have been obtained under experimental conditions using improved varieties, and high level of crop husbandry.

2.7.4 Peppers and Chillies (*Capsicum spp*)

(a) *Area Under Crop*

Peppers are widely grown in Nigeria and probably occupy as much as 10,000 - 20,000 hectares of land annually. They are broadly classified into two main groups, the sweet and mild (Tatassi/Tatashe) known as *Capsicum annum* L., and the hot (known as chilli) classified as *Capsicum frutescens* L. The latter contains a high level of capsaicin which is a measure of the degree of hotness in peppers while the sweet peppers (tatasai group) contain trace or little capsaicin.

(b) *Nutrient Requirements and Fertilizer Use*

i. *Nutrient Deficiency Symptoms:* The mottling of leaves at margins and betweenveins as well as the crinkling of leaf surface is believed to be due to deficiency of potassium.

ii. *Fertilizer Sources and Rates:-* The fertilizer recommendation is shown in Table 2.52. A naturally fertile soil or the use of organic matter may be adequate in the absence of inorganic fertilizers.

iii. *Method and Time of Fertilizer Application:* The phosphorus applied to the nursery bed should be finely ground and worked into the top 8cm of the soil before seeding. For- field application, super-phosphate should be spread in old furrows and the ridges split over before transplanting. The nitrogen should be applied in two equal splits, at 2 weeks after transplanting and at the first set of fruits.

(c) Varieties and Other Cultural Practices

i. *Varieties:* There are a wide variety of peppers and chillis which vary in pungency, size, colour and fruits. The two main species in Nigeria are *Capsicum annum* (Nigeria blind-eye, chilli or green peppers) and *Capsicum frutescens* (red-hot peppers). Varieties of C *annum* include 'tatassi' and 'California Wonder' and those of *C. frutescens* include Sakarho or 'Dan Mahere.' Recommended varieties of peppers are shown in Table 2.53.

Table 2.53 Fertilizer recommendations for peppers and chillies

NUTRIENT ha^{-1}	MATERIAL ha^{-1}	RECOMMENDATION/SUGGESTION
38kg P_20_5	SSP at 210kg (4 bags)	Existing recommendation for the nursery bed.
52kg N 45kg P_20_5	CAN at 200kg (4 bags) plus 250kg SSP (5 bags)	Existing recommendation for the field. FYM may be applied where possible.
30kg K_20	MOP at 50kg or (1 bag)	

Table 2.54 Improved pepper varieties

SN	TATASSI GROUP	CHILLI GROUP
1	Samaru Mild	L. 2089
2	Ex-Hunkuyi	L. 2096
3	Green Toba	L. 3874
4	Square Big	Jemage
5	Caloro	L. 2188
6	Hungarian Yellow Wax	Dan Mahere
7	Anaheim M	L. 2289
8	Bell Boy	L. 2025
9	California Long Slim	Sakarho
10		Kashin Burgu
11		Kimba

(ii) C*ultural Practices:* The crop requires a warm rainy season with good rainfall. Both wet and dry season planting are common. Seedlings are raised in nursery in the first week of June and transplanted after 3 - 4 weeks at a height of 7 - 15cm. Seedlings should be spaced at 30 - 60cm apart on 75 - 90cm ridges.

Herbicide Recommendations. Apply simazine at the rate of 2 - 3kg a.i.ha^{-1} at two stages; first just before transplanting and second at 12 - 16 weeks after transplanting. Galex could also be applied at 3kg a.i.ha^{-1}.

(d) *Yield Expectancy* Peppers and chillies lose 65 - 79% of their fresh weight on drying. Farmers yields commonly range between 450 and 1,000kg ha^{-1} of fresh weight (120 - 260kg ha^{-1} of dry weight). With improved practices *C. Annum* can yield up to 10 - 15t ha^{-1} of fresh pepper; (2 - 3t dry weight ha^{-1}) the *C. frutescens* yields about 3 - 4t ha^{-1} of dry pepper.

2.8 TREE CROPS

2.8.1 Cocoa (*Theobroma. cacao* L.)

(a) Area Under Crop

Cocoa is a major crop of Southern Nigeria and particularly in the South - Western zone. The total land area presently under cocoa is estimated at 0.6 - 0.8 million hectares.

(b) Nutrient Requirements and Fertilizer Use

i. *Nutrient Deficiency Symptoms:* Deficiency symptoms of macro-nutrients (Nitrogen phosphorus, and potassium) are not very prevalent at present on mature cocoa.

Nitrogen Deficiency : Uniform chlorosis of mature leaves which are also small in size.

Phosphorus Deficiency: Has not been observed.

Potassium Deficiency : Orange coloration along the edges of older leaves; later developing into marginal necrosis; considerable defoliation may occur in severe cases.

Zinc Deficiency : Occurs more frequently in nurseries than in mature cocoa farms. Symptoms consist principally of foliar malformations, including "sickly leaf" or long narrow leaves which may be twisted.

Boron Deficiency: Profuse flushing; branching. and chupon formation; frequent flashing without much fruit set; tree develops dense foliage.

(c) Fertilizer Sources and rates: (see Table 2.54).

(d) Varieties and Other Cultural Practices

(i) *Varieties:* The main variety of cocoa in current production is the F3 generation 'Amazon' cocoa which has replaced the Amelonado which was less vigorous and low yielding. Other varieties which are distributed to farmers in Nigeria include crosses of Amazon with the Amelonado and Trinitario types. The hybrids are known to be high yielding.

(ii) *Cultural Practices:* Cocoa is grown from seeds sown in nurseries. Four to six month-old seedlings are transplanted out in the field between May and

June when the rains are established. Seedlings should be spaced at 3m x 3m giving a population of 1,111 trees ha^{-1}. The provision of shade is vital for the young cocoa plants for the first three years; shade trees may be planted before the cocoa seedlings are transplanted. It is essential to spray cocoa against pests. Capsids *(Distantiella theobroma, Sablbergella singularia and Halopeltis spp).* Mealy bugs and pod husk miller are increasingly becoming important in the cocoa belt of Western Nigeria. Cocoa grown on soils derived from sedimentary rocks shows potassium deficiency more than those on soils of metamorphic origin.

Table 2.55 Fertilizer recommendations for cocoa

CROP	NUTRIENT	FERTILITY CLASS	FERTILIZER RATES	FERTILIZER SOURCES
Cocoa 1st year of transplanting	Nitrogen (N)	Low Medium High	22g/seedling 11g/seedling None	Urea Urea Urea
	Phosphorus P_20_5	Low Medium High	50g/seedling 25g/seedling None	SSP SSP SPP
	Potassium (K_20)	Low Medium High	8g/seedling 5g/seedling None	KCl KCl KCl
2nd and 3rd year after planting	N P_20_5 P_20_5 K_20		54g/tree* 55g/tree* 125g/tree** 179g/tree*	Urea SSP SSP KCl
4th to 6th year after planting	N P_20_5 P_20_5 K_20		108 - 216g/tree* 150g/tree* 135 - 270g/tree** 50g/tree	Urea SSP SSP KCl
Matured Amazon	N P_20_5 K_20 B		336g/tree 337g/tree 87g/tree 30g/tree	Urea SSP KCl Solubor

- **(For plot cleared from cocoa and arable crops)**
- **(For plot cleared from forest fallows)**

NOTE KCI to be omitted on soils derived from metamorphic rocks & Solubor is a special spray of dried Sodium borate (Borax) having (66.2% B_20_3 or 20.5%B.

Yield Expectancy

Cocoa starts bearing fruits 3 - 5 years after transplanting but does not reach the peak of its productivity unit after the 10th year. Yields of 500kg/ha^{-1}/yr of dry cocoa beans are obtained by the farmer. Under good management Amelonado yields up to 3,000kg ha^{-1}/year.

2.8.2 Coffee (*Coffee robusta* and C. *Arabica*)

(a) *Area Under Crop*
Only about 10,000 hectares is under coffee in Nigeria today, with about 600 hectares located in the Mambilla Plateau of Gongola State.
Coffea robusta is mostly grown in the lowlands of Southern Nigeria while *Coffea arabica* has been successfully established in the high altitude parts of Gongola State, especially the Mambilla Plateau.

(b) *Nutrient Requirements and Fertilizer Use*
No recommendations yet. However, the guidelines shown in Table 2.55 on nutrient use will produce a good crop of coffee.

Table 2.56 Fertilizer recommendations for coffee

NUTRIENT	FERTILITY CLASS	NUTRIENT RATES (Kg ha^{-1})	FERTILIZER RATE SOURCE/ha
Nitrogen	Low Medium High	135N 65N None	Urea (293kg or 6 bags) Urea (142kg or 3 bags)
Phosphorus	Low Medium High	34 P_20_5 15 P_20_5 None	SSP (189kg or 4 bags) SSP (83kg or 2 bags)
Potassium	Low Medium High	145 K_20_5 70 K_20 None	Kcl (242kg or 5 bags) Kcl (117kg or 2 bags)

(c) *Cultural Practices*
Coffee is grown from seed; seedlings are raised in nurseries and transplanted into the field 6 months after sowing, between April and June. Mulch at transplanting and prune as necessary. Spacing is 3.1m x 3.1m giving a population of 1,000 trees per hectare.

(d) *Yield Expectancy*
Yield of dry beans is about 800 - 1,500kg ha^{-1}.

2.8.3 Kola (*Cola nitida* and C. *acuminata*)

(a) *Area Under Crop*
Land area presently under kola is estimated at 50,000 - 80,000 hectares. The two main species in Nigeria are *Cola nitida* (local name gbanja) and *Cola acuminata (local name* abata). *Cola nitida* is of greater importance in international trade.

(b) *Nutrient Requirements and Fertilizer Use*
i) *Nutrient Deficiency Symptoms:* Deficiency symptoms of boron and copper have been identified as being very prevalent in kola grown on soils derived from basement complex rocks. Deficiency of boron results in abnormal development of the leaves, flowers and fruits.

(c) *Fertilizer Application*

For Zn, apply 0.07% $ZnSO_4$ at 2 litres per tree and spray twice a year. For boron apply 1% solubor at 2 liters/tree or 10g Borax. For copper spray with 0.05% copper Sulphate at 2 litres/tree or 100g solid copper per hectare.

(d) *Cultural Practices*

Kola is normally grown from seed, although it can also be propagated by budding, mar-cottage and cuttings. Seedlings are transplanted into the field between April and June and spaced 7.8m x 7.8m for Cola nitida (166 trees ha^{-1}) and 3.6m x 3.6m for C. acuminata (833trees ha^{-1}).

(e) *Yield Expectancy*

Budded seedlings fruit in about 4 years while unbudded seedlings fruit 6-7 years after transplanting. Studies show that up to 50% of trees of C. nitida (local kola) yield only 0 -100 nuts per year and that 72% of the total yield is produced by only 21% of the trees. Thus, the national average yield of kola is estimated at 500kg ha^{-1} (250 nuts/tree) of fresh nuts per annum.

2.8.4 Cashew (*Anacardium Occidentale* L)

(a) *Area Under Crop*

Cashew is grown in most parts of Nigeria but large hectarage can be found only in Anambra, Imo and Oyo States. Area under crop is estimated at 10,000 hectares.

(b) *Soil and Climatic Requirement*

Cashew requires deep, friable, well-drained sandy loam soils. Presence of hardpan has an adverse effect on the root system of cashew. The nutrient status should be moderate while the rainfall should range between 1500 and 2000in annually.

(c) *Land Preparation*

Land clearing should be carried out at the end of the dry season while planting is done. when the rains are well established. Complete land clearing is recommended to avoid competition for moisture and nutrients with other plants. Normal planting distance is 10 x 10m and this should be done at stake. Only viable seeds from heavy density cashew nuts of the current season should be planted and there is need to protect emerging seeds against rodent attack by the use of wire collars.

(d) *Nutrient Deficiency Symptoms*

(i) *Low pH :* Prolific leaf production, but very tiny leaves.
(ii *Nitrogen Deficiency*: Leaves are yellow and die off. Plant growth is poor.
(iii) *Phosphorus deficiency*: Leaves are coloured purple and the plant growth is stunted
(iv) *Potassium deficiency:* Marginal scorch starting from the tip of the leaves.
(v) *Magnesium deficiency:* The interveinal area of the leaves become yellow starting from the older leaves.

(b) *Fertilizer Sources and Rates:*

The table given below, summarizes the fertilizer types and rates to be used on matured Cashew plants. Table 2.56.

Table 2.57 Fertilizer Types and Rates for mature cashew plants

FERTILIZER RECOMENDED Kg/100 CASHEW TREES	BELOW 3 YEARS	3 TO 6 YEARS	ABOVE 6 YEARS
Sulphate Ammonia	16	32	64
Single Super-phosphate	25	50	100
Muriate of Potash	5	10	20

(f) *Varieties*

There are no distinct varieties, as of now, of cashew but the yellow and the red landrace exist whereby the red landrace is more tolerant to acidic situations than the yellow land- race.

(g) *Cultural Practices*

Cashew seedlings are very sensitive to competition with weeds but in many areas, especially, on sloping land, all the vegetation cannot be removed before planting and clean weeding cannot be done during the young stages of the Cashew trees because of the danger of water and wind erosion. In large areas of Cashew plantations, it is necessary to leave strips of natural vegetation to maintain the population of the insects required to pollinate-the Cashew flowers.

If the area where the Cashew plantation is to be established is not erosion proned, all the trees and shrubs are removed before planting.

The removal of stumps, though expensive, is a necessary part of the land clearing pro- cess as these stumps might regrow and constitute very great dangers to the cashew during their early and later growth period.

Without prospects of irrigation, Cashew is better sown at the beginning of rainy season. The seeds are sown insitu. Although this method of sowing is cheap, quick (about 400 to 500 can be planted daily) and helps the cashew plant to develop its natural root system naturally, rodents sometimes eat up the sown seeds. Sowing in polythene bags of 19 x 15cm in the nursery for at least one month before transplanting is sometimes preferred.

When Cashew seeds are sown insitu, the sowing depth should be about 5 - 10cm and the site covered with mulching materials to reduce evaporation and aid the Cashew seedlings to overcome difficult starting as well as prevent drying out during the planting operation. Planting holes recommended are 30 x 30 x 30cm to 60 x 60 x 60cm. On very fertile soils, planting holes could be left out. However, for less fertile soils manure and mineral fertilizers should be mixed with the soils used to fill the planting hole.

Usually more than one seed of Cashew is sown per hole and later the more vigorously growing seedlings are selected.

(h) *Spacing*

More frequently, a spacing of 10 x 10m or 14 x 14m is used for Cashew. By 10 x 10m spacing, there are 100 plants per, hectare while the 14 x 14m spacing gives only 50 plants.

(i) *Weeding*

Cashew does better if properly weeded especially at the initial stages. The need for weeding increases considerably on shallow soils especially' during the dry periods.

During the first three years of growth, ring weeding should be done. At first the diameter of the ring should be about one and half meter extending gradually to three meters in the third year. Weeds outside the ring should be slashed and used to mulch the Cashew plant. Once the plants have developed a canopy of several meters, ring weeding could be stopped but weeding between the trees with a hoe should now be done.

Timing the weeding is absolutely important. Weeding should be completed before the end of the rainy season. In areas with very tall weeds like elephant grass, the first weeding during the first half of the rainy season is advisable. Chemical weeding, using round-up or Gramazone could be done if funds are available.

(j) *Fire Protection*

Because of the high quantity of litter produced by Cashew plants under their canopy, fire traces must be cut out as soon as the dry season sets in. Great damage can be done to fruiting and flowering especially as these occur during the dry season. A strip of about 10 -1 5cm wide is recommended to be cut round the farm as fire tracing.

(k) *Diseases of Cashew*

(i) *Inflorescence dieback:-* This disease is associated with the inflorescence stalk and the casual agent is *Basiodiplodia theobromae*. Control is by applying a mixture of 0.15% Difolatan 80W and 0 - 10% Gammalin 20.

(ii) Rot of Pseudoapple of cashew is caused by *Geotrichum cardidum, Mucor Spinosus, Penicillium citri, Fusarium sp, or Aspergillus sp*. The plant part most affected is the mature pseudoapple of cashew. Control is by early harvesting.

(iii) Leaf spot disease of cashew seedling is caused by *Curvularia senegalensis*. This disease affects the leaf of cashew seedlings with manifestations of Fe deficiency. Control is by correcting the Fe deficiency with soil application of 50kg/ha Fe chelate.

(iv) Leaf blight of cashew is caused by *Pestalolia paeoniae*. It affects the leaves of mature cashew plant. Control is achieved by spraying 1.5% Difolatan.

(v) Root rot of cashew seedlings is caused by *Phythium ultimum*. The disease is completely controlled by the soil application of 113.6kg/ha of Dexon (P-dimethylarnino benzehediazo sodium sulphonate).

(vi) Kernel rot of cashew affects the kernels of cashew nuts. 1t is caused by *Aspergillus flavus, Ghocladium. sp, Aspergillus niger, and Fusarium sp*. Control is achieved by cleaning of nuts and improved methods of storage.

(viii) Damping-off of cashew seedlings. This is caused by *Sclerotium rolfsii*.. Complete control is achieved by the application of Fernasan-D as seed treatment at the rate of 0.2gm/ 100g of cashew nuts.

(l) *Yield Expectancy*

The economic life span of the cashew tree is still a matter for speculation. However, harvesting is done by picking mature nuts that have dropped on the ground. Yield at full production may vary from 500 to 1,500 nuts/tree.

2.8.5 Tobacco (*Nicotiana tabacum*)

(a) *Area Under Crop*

Annual production of tobacco in Nigeria is estimated at between 7 - 10 million kg from a total land area of 10,000 - 20,000 hectares. About 70% of the crop is produced in the Northern States, with Sokoto, Kaduna and Kano being major producing states. At present most of the tobacco is grown under contract for tobacco companies.

(b) Nutrient Rfquirements and-Fertilizer Use

(i) *Nutrient Deficiency Symptoms*

Nitrogen Deficiency:- Effects are generally on whole plant; yellow and drying up or firing of lower leaves; plants turn light green.

Phosphorus Deficiency:- Plants are dark green; lower leaves initially yellow and may dry to greenish brown and finally black colour; stalks are short and slender if element is limiting in later growth stages.

Potassium Deficiency - lower leaves are molted or chlorotic with spots of dead tissue; small spots of dead tissue occur between the veins at leaf tips and margins which are tucked or cupped under; stalks are generally slender.

(ii) *Fertilizer Sources and Rates*-- Probably because of the direct involvement of private commercial companies in the production of tobacco in Nigeria, little or no re- search has so far been undertaken on the crop. But from available information and experience it is obvious that phosphorus and nitrogen are the most important nutrient elements needed by tobacco. Nitrogen is used especially for cigar tobacco. Excess N may result in too much vegetative growth, causing a dull coloration with a greenish tinge and a consequent lowering of the quality of especially flue-cured -tobacco. Air-cured tobacco seems to tolerate more N. Potassium is reported to improve the burning quality of tobacco; in this respect the sulphate form (K_2S0_4) is preferred to the chloride (KCI) which causes the burnt ash to fuse. The level of soil calcium required for the best growth of flue-cured tobacco is generally considered to be low; for good quality, the ratio K:Ca in the leaf should be about 1:1. Tobacco requires different amounts of fertilizers at different stages of growth. The type and rates of fertilizers used by tobacco growers is usually supplied by tobacco. companies and packaged as type A or B. The Fertilizer recommendation in Table 2.57 is an interim measure:

Table 2.58 Fertilizer recommendations for tobacco

NUTRIENT ha^{-1}	MATERIAL ha^{-1}	RECOMMENDATION/SUGGESTION
5kg N	SA, 25kg (½ bag) or CAN 20kg (½ bag) or Urea 11kg (¼ bag)	Suggested for seed bed 5kg/ha N + 25kg ha^{-1} P_20_5 + 5kg ha^{-1} K_20
25kg P_20_5	SSP 140kg (3 bags)	
5kg K_20	K_2S0_4 10kg ($^1/_5$ bag)	
10kg N	SA 50kg (1 bag) or CAN, 40kg (1 bag) or Urea 22kg (½ bag)	Suggested for fertile and fadama soils
30kg P_20_5	SSP 170kg (2¼ bags); TSP 70kg (1½ bags)	10kg ha^{-1} N + 30kg ha^{-1} P_20_5 + 50kg ha^{-1} K_20
50kg K20	K_2S0_4 100kg (2 bags)	For more sandy soils use 20kg ha^{-1} N + 30kg P_20_5 + 50kg ha^{-1}

It should be emphasized that if potassium is used on tobacco grown in the savanna, the source should be K_2S0_4, not KCl. Recommendations presently used by the Nigerian Tobacco Company (NTC) is as follows:

- 500kg (10 bags) 12-12--17 + 2Mg0 ha^{-1} at Planting plus 200kg (4 bags) CAN top dressed 3 weeks after planting.

(iii) *Fertilizer Application:* Phosphorus potassium and compound fertilizers should be applied (broadcast) to the seedbed before or at transplanting. In view of the small quantity of nitrogen required, it should be applied all at once about 3 - 4 weeks after transplanting.

(c) Varieties and other Cultural Practices Seedlings are raised in the nursery and transplanted after 6 - 8 weeks. The Sokoto crop is mostly grown on residual moisture in 'fadama' after annual flood has subsided. The crop around Zaria is grown after millet, about the second half of August. Spacing varies from 20 x 40cm to 60 - 120cm depending on the variety. Bright, hot sunshine is"required for high quality leaf and a dry season for harvesting; harvesting takes place from late November to early December.

d) *Yield Expectancy*
Farmers' yields vary between 400 and 600kg ha^{-1} of cured tobacco. Under improved management, yields of 1,000 - 2,000 kg ha^{-1} are possible. Tobacco seeds contain between 33 - 43% oil depending on variety and management.

2.8.6 Oil Palm (*Elaeis guineensis, jacq*)

a) *Area Under Crop*
Recent surveys of the Oil Palm resources of Nigeria showed that the country had about 2.1 million hectares of wild/natural oil palm grooves and about 440,000 hectares planted with improved and unimproved varieties. Major oil palm producing areas are in Cross River, Akwa lbom, Rivers, Ebonyi, Abia, Imo, Enugu, Anambra, Delta, Edo, Ondo, Ekiti, Ogun and Osun States. There is also some cultivation in Lagos, Kwara, Kogi, Oyo, Benue, Taraba, Niger, Nasarawa, FCT

and Kaduna States. New schemes are underway to increase the planted area and to rehabilitate the grooves with improved varieties.

b) *Nutrient Requirements and Fertilizer Use*

(i) *Nutrient Deficiency Symptoms*

Nitrogen Deficiency: Pale leaves followed by yellowing and necrosis. Leaflet mid-ribs and rachis become bright yellow with narrow and curling laminae.

Potassium Deficiency: Mid-crown yellowing characterized by general yellowing of the middle whorls of the palm. Marginal necrosis and yellow or orange patches on the leaflets are also symptoms of K deficiency. Severe cases result in premature dessication of older leaves, thin trunks and tapering crown.

Magnesium Deficiency : Prevalent in nurseries and fields in coastal lowlands. Characterized by chlorosis of older leaves and in the mild form, the symptom is yellow coloration of leaves from tips towards the base of the leaflets and frond while in severe cases it turns to a bright orange.

Boron Deficiency: Deficiency is characterized by stunted growth and malformation on the leaf which include little leaf, hooking of the apex and puckering of the laminae.

Occurrence of nutrient deficiency symptoms in the plantation indicates a reduction in yield potentials, therefore, farmers should not wait for these symptoms to appear before the application of fertilizers.

(ii) *Fertilizer Rates and Time of Application for Nursery:*

Pre-nursery seedlings grow normally and vigorously for 2-3 months when raised in soils rich in organic matter and nutrient. It is therefore necessary to use high quality soil for pre-nursery planting.

For the main nursery apply 42g per seedling of 12: 12: 17 + 2MgO compound fertilizer in three split of 14g each of 3, 5 and 8 months of seedling age. Alternatively, apply 84g per seedling straight fertilizer mixture in the ratio of 1:1:1:1 by weight of ammonium sulphate, single superphosphate, or nitriate of potash and magnesium. Application is also in three equal split. The fertilizer should be spread in a ring around the seedlings about 7.5 cm away from the stand. After application, the seedlings are watered, and is poured gently on the seedlings to wash of any residual fertilizer on it to avoid scorching and stock

(iii) *Fertilizer Sources, Rates and Time of Application*

(The tables 2.58 - 2.63) indicate the sources, rates and time of fertilizer application for most of the oil palm growing areas of Nigeria.

Table 2.59 Fertilizer recommendation for oil palm on the moderately wet acid sands of the forest zone (1,700 - 2,000mm/year rainfall)

NUTRIENT /ha		MATERIAL			RECOMMENDATION
		Kg/PALM	Kg ha^{-1}	NO. OF BAGS	
6.67kg N	Urea	0.1	14.5	_	The year of transplanting into the field = 6.67kg N + 6.5kg P_20_5 +34.8kg K_20 + 2.32kg $MgOha^{-1}$. Or 36.3 Kg 12-12-17 + 2Mg0 or 15-15-15 per hectare
6.5kg P_20_5	SSP	0.25	36.3	¾	
34.8kg K_20	MOP	0.40	58.0	$1^{1}/_{6}$	
2.32kg MgO	Kieserite	0.1	14.5	_	
	12-12-17+2Mg0 or 15-15-15	0.25	36.3	¾	
13.34kg N	Urea	0.2	29.0	$^{3}/_{4}$	The 1st year after transplanting into the field = 13.34kg N + 13.05kg P_20_5 + 43.5kg K_20 + 4.64kg MgO per hectare OR 72.5kg 12-12-17 +2Mg0 or 15-15-15 per hectare
13.05kg P_20_5	SSP	0.5	72.5	$1^{2}/_{5}$	
34.8kg K_20	MOP	0.5	72.5	$1^{2}/_{5}$	
2.32kg MgO	Kieserite	0.2	29.0	$^{3}/_{5}$	
	12-12-17+2Mg0 or 15-15-15	0.50	72.5	$1^{2}/_{5}$	
33.35kg N	Urea	0.5	72.5	$1^{2}/_{5}$	The 2nd year after transplanting into the field = 33.35kg N + 26.1kg P_20_5 + 87kg K_20 + 5.8kg MgO per hectare OR 108.8kg 12-12-17 +2Mg0 or 15-15-15 per hectare
26.1kg P_20_5	SSP	1.0	145	$2^{7}/_{8}$	
87kg K_20	MOP	1.5	217.5	$2^{7}/_{8}$	
5.8kg MgO	Kieserite	0.5	72.5	$^{3}/_{4}$	
	12-12-17+2Mg0 or 15-15-15	1.0	145	$2^{1}/_{6}$	
33.4kg N	Urea	0.5	72.5	$1^{2}/_{5}$	For the 3rd year after transplanting into the field = 33.4kg N + 39.2kg P_2O_5 + 174.0kg K_2O + 17.4kg MgO per hectare OR 217.5kg 12-12-17+2MgO or 15-15-15 per hectare
39.2kg P_2O_5	SSP	1.5	217.5	$4^{1}/_{3}$	
174.0kg K_2O	MOP	2.0	290.0	$5^{4}/_{5}$	
17.4kg MgO	Kieserite	0.75	108.8	$2^{1}/_{6}$	
	12-12-17+2MgO Or 15-15-15	1.5	217.5	$4^{1}/_{3}$	

- **- Fertilizer application in subsequent years would be determined by results of soil and foliar analysis.**

Table 2.60 **Fertilizer recommendation for oil palm on the relatively wet acid sands of the forest zone (2,000 - 3,000mm/year rainfall)**

NUTRIENT /ha		MATERIAL			RECOMMENDATION
		Kg/PALM	Kg ha^{-1}	NO. OF BAGS	
16.70kg N 6.53kg P_20_5 43.5kg K_20 2.32kg MgO	Urea SSP MOP Kieserite 12-12-17+2Mg0 or 15-15-15	0.25 0.25 0.25 0.1 0.25	36.6 36.3 36.3 14.5 36.3	¾ ¾ $1^{2}/_{5}$ _ ¾	The year of transplanting into the field = 16.70kg N + 6.53kg P_20_5 + 21.78kg P_20_5 + 2.32kg MgO ha^{-1}. Or 36.3 Kg 12-12-17 + 2Mg0 or 15-15-15 per hectare
16.70kg N 13.05kg P_20_5 43.5kg K_20 11.6kg MgO	Urea SSP MOP Kieserite 12-12-17+2Mg0 or 15-15-15	0.25 0.5 0.5 0.5 0.5	36.3 72.5 72.5 72.5 72.5	$^{3}/_{4}$ $1^{2}/_{5}$ $1^{2}/_{5}$ $1^{2}/_{5}$ $1^{2}/_{5}$	The 1st year after transplanting into the field = 16.7kg N + 13.05kg P_20_5 + 43.5kg K_20 + 11.6kg MgO per hectare OR 72.5kg 12-12-17 +2Mg0 or 15-15-15 per hectare
33.25kg N 26.1kg P_20_5 87kg K_20 11.6kg MgO	Urea SSP MOP Kieserite 12-12-17+2Mg0 or 15-15-15	0.5 1.50 1.0 0.5 0.75	108.8 217.5 145 36.3 108.8	$1^{2}/_{5}$ $2^{7}/_{8}$ $2^{7}/_{8}$ $1^{2}/_{5}$ $2^{1}/_{6}$	The 2nd year after transplanting into the field = 33.25kg N + 26.1kg P_20_5 + 87kg K_20 + 11.6kg MgO per hectare OR 108.8kg 12-12-17 +2Mg0 or 15-15-15 per hectare
33.4kg N 39.2kg P_2O_5 174.0kg K_2O 23.2kg MgO	Urea SSP MOP Kieserite 12-12-17+2MgO Or 15-15-15	0.5 1.5 2.0 1.0 1.5	72.5 217.5 290.0 145 217.5	$1^{2}/_{5}$ $4^{1}/_{3}$ $5^{4}/_{5}$ $2^{7}/_{8}$ $4^{1}/_{3}$	For the 3rd year after transplanting into the field = 33.4kg N + 39.2kg P_2O_5 + 174.0kg K_2O + 23.2kg MgO per hectare OR 217.5kg 12-12-17+2MgO or 15-15-15 per hectare

- - **Fertilizer application in subsequent years would be determined by results of soil and foliar analysis.**

Table 2.61 Fertilizer recommendation for oil palm on the basement complex soils of South-Eastern Nigeria

NUTRIENT /ha		MATERIAL			RECOMMENDATION
		Kg/PALM	Kg ha^{-1}	NO. OF BAGS	
3.34kg N 2.61kg P_20_5 21.78kg K_20 11.61kg MgO	Urea SSP MOP Kieserite 12-12-17+2Mg0 or 15-15-15	0.05 0.1 0.25 0.5 0.25	7.25 14.5 36.3 72.5 36.3	$^{1}/_{7}$ _ ¾ $1^{2}/_{5}$ ¾	The year of transplanting into the field = 3.34kg N + 2.61kg P_20_5 + 21.78kg P_20_5 + 11.6kg MgO ha^{-1}. Or 36.3 Kg 12-12-17 + 2Mg0 or 15-15-15 per hectare
6.68kg N 6.53kg P_20_5 43.5kg K_20 17.4kg MgO	Urea SSP MOP Kieserite 12-12-17+2Mg0 or 15-15-15	0.1 0.25 0.5 0.75 0.50	14.5 36.3 72.5 108.8 72.5	_ ¾ $1^{2}/_{5}$ $2^{2}/_{6}$ $1^{2}/_{5}$	The 1st year after transplanting into the field = 6.68kg N + 6.53kg P_20_5 + 43.5kg K_20 + 17.4kg MgO per hectare OR 72.5kg 12-12-17 +2Mg0 or 15-15-15 per hectare
13.3kg N 13.05kg P_20_5 43.5kg K_20 30.2kg MgO	Urea SSP MOP Kieserite 12-12-17+2Mg0 or 15-15-15	0.2 0.5 0.5 1.3 0.75	29.0 72.5 72.5 188.5 108.8	$^{3}/_{5}$ $1^{2}/_{5}$ $1^{2}/_{5}$ $3^{3}/_{4}$ $2^{1}/_{6}$	The 2nd year after transplanting into the field = 13.3kg N + 13.05kg P_20_5 + 43.5kg K_20 + 30.2kg MgO per hectare OR 108.8kg 12-12-17 +2 Mg0 or 15-15-15 per hectare
16.7kg N 15.7kg P_2O_5 65.3kg K_2O 46.4kg MgO	Urea SSP MOP Kieserite 12-12-17 +2MgO or 15-15-15	0.25 0.6 0.75 2.0 1.5	36.25 87.0 108.8 290.0 217.5	$^{3}/_{4}$ $1^{3}/_{4}$ $2^{1}/_{6}$ $5^{4}/_{5}$ $4^{1}/_{3}$	For the 3rd year after transplanting into the field = 16.7kg N + 15.7kg P_2O_5 + 65.3kg K_2O + 46.4kg MgO per hectare OR 217.5kg 12-12-17+2MgO or 15-15-15 per hectare

- **- Fertilizer application in subsequent years would be determined by results of soil and foliar analysis.**

Table 2.62 Fertilizer recommendation for oil palm on the soils of the sub-recent terrace (Sombreiro - Warri deltaic plain)

NUTRIENT /ha		MATERIAL			RECOMMENDATION
		Kg/PALM	Kg ha^{-1}	NO. OF BAGS	
13.34kg N 6.5kg P_20_5 43.5kg K_20 4.64kg MgO	Urea SSP MOP Kieserite 12-12-17+2Mg0 or 15-15-15	0.2 0.25 0.5 0.2 0.25	29.6 36.3 72.5 29.0 36.3	$^{3}/_{5}$ ¾ $1^{2}/_{5}$ $^{3}/_{5}$ $^{3}/_{5}$	The year of transplanting into the field = 13.3kg N + 6.5kg P_20_5 + 43.5kg P_20_5 + 4.64kg $MgOha^{-1}$. Or 36.3 Kg 12-12-17 + 2Mg0 or 15-15-15 per hectare
13.34kg N 13.05kg P_20_5 52.2kg K_20 9.28kg MgO	Urea SSP MOP Kieserite 12-12-17+2Mg0 or 15-15-15	0.2 0.5 0.6 0.4 0.5	29.0 72.5 87.0 58.0 72.5	$^{3}/_{5}$ $1^{2}/_{5}$ $1^{3}/_{4}$ $1^{1}/_{6}$ $1^{2}/_{5}$	The 1st year after transplanting into the field = 13.34g N + 13.05kg P_20_5 + 52.2kg K_20 + 9.28kg MgO per hectare OR 72.5kg 12-12-17 +2Mg0 or 15-15-15 per hectare
33.35kg N 26.1kg P_20_5 87kg K_20 11.6kg MgO	Urea SSP MOP Kieserite 12-12-17+2Mg0 or 15-15-15	0.5 1.0 1.0 0.5 1.0	72.5 262.5 262.5 362.5 72.5	$1^{7}/_{8}$ $2^{7}/_{8}$ $2^{7}/_{8}$ $1^{2}/_{5}$ $2^{7}/_{8}$	The 2nd year after transplanting into the field = 33.35kg N + 26.1kg P_20_5 + 87kg K_20 + 11.6kg MgO per hectare OR 145kg 12-12-17 +2Mg0 or 15-15-15 per hectare
66.7kg N 65.25kg P_2O_5 217.5kg K_2O 58kg MgO	Urea SSP MOP Kieserite 12-12-17 +2MgO or 15-15-15	1.0 2.5 2.5 2.5 2.0	145.0 362.5 362.5 362.5 290.0	$2^{7}/_{8}$ $7^{1}/_{4}$ $7^{1}/_{4}$ $7^{1}/_{4}$ $5^{4}/_{5}$	For the 3rd year after transplanting into the field = 66.7kg N + 65.25kg P_2O_5 + 217.5kg K_2O + 58kg MgO per hectare OR 290.0kg 12-12-17 +2MgO or 15-15-15 per hectare

- **- Fertilizer application in subsequent years would be determined by results of soil and foliar analysis.**

Table 2.63 Fertilizer recommendation for oil palm on the marginal areas of middle belt (1,200 - 1,500mm/year rainfall)

NUTRIENT /ha		MATERIAL			RECOMMENDATION
		Kg/PALM	Kg ha^{-1}	NO. OF BAGS	
16.70kg N 6.53kg P_20_5 21.78kg K_20 2.32kg MgO	Urea SSP MOP Kieserite 12-12-17+2Mg0 or 15-15-15	0.25 0.25 0.25 0.1 0.25	36.3 36.3 36.3 14.5 36.3	¾ ¾ ¾ _ ¾	The year of transplanting into the field = 16.70kg N + 6.53kg P_20_5 + 21.78kg K_20 + 2.32kg MgOha^{-1}. Or 36.3 Kg 12-12-17 + 2Mg0 or 15-15-15 per hectare
33.25kg N 13.05kg P_20_5 34.5kg K_20 4.644kg MgO	Urea SSP MOP Kieserite 12-12-17+2Mg0 or 15-15-15	0.5 0.5 0.5 0.20 0.50	72.5 72.5 72.5 29.0 72.5	$^{3}/_{5}$ $1^{2}/_{5}$ $1^{2}/_{5}$ $^{3}/_{5}$ $1^{2}/_{5}$	The 1st year after transplanting into the field = 13.34g N + 13.05kg P_20_5 + 43.5kg K_20 + 4.64kg MgO per hectare OR 72.5kg 12-12-17 +2 Mg0 or 15-15-15 per hectare
49.59kg N 39.15kg P_20_5 87kg K_20 5.8kg MgO	Urea SSP MOP Kieserite 12-12-17+2Mg0 or 15-15-15	0.75 1.50 1.0 0.25 0.75	108.8 217.5 145 36.3 108.8	$2^{1}/_{6}$ 4_ $2^{7}/_{8}$ ¾ $2^{1}/_{6}$	The 2nd year after transplanting into the field = 49.59kg N + 39.15kg P_20_5 + 87kg K_20 + 5.8kg MgO per hectare OR 145kg 12-12-17 +2Mg0 or 15-15-15 per hectare
50.0kg N 39.2kg P_2O_5 130kg K_2O 11.6kg MgO	Urea SSP MOP Kieserite 12-12-17+2MgO Or 15-15-15	0.75 1.5 1.5 0.5 1.5	108.8 217.5 217.5 72.5 217.5	$2^{1}/_{8}$ $4^{1}/_{3}$ $4^{1}/_{3}$ $1^{2}/_{5}$ $4^{1}/_{3}$	For the 3rd year after transplanting into the field = 50.0kg N + 39.2kg P_2O_5 + 130kg K_2O + 11.6kg MgO per hectare OR 217.5kg 12-12-17+2MgO or 15-15-15 per hectare

- **- Fertilizer application in subsequent years would be determined by results of soil and foliar analysis.**

(Generally to increase organic matter content and soil fertility, it is good practice to retain pruned leaves and also return empty fruit bunches to the plantation. These organic materials are leaped in alternate rows in the plantations. This practice would invariably reduce the quantity of recommended inorganic fertilizer applied).

Fertilizer recommendations for oil palm/food crops mixture e.g. maize/melon/cassava/yam

Apply recommended rates to oil palm stands, in a ring 50cm - 100cm from palm base, plus the following rates to the food crops depending on soil fertility by band application 10cm away from the crop. (Table 2.65).

Table 2.64 Recommendations for oil palm/food crops mixture

SOIL FERTILITY	UREA	P_20_5 (Kg ha^{-1})	K_20	OR COMPOUND FERTILIZER
Low	120 N (5.33 bags) Urea	120 P (13.3 bags) SSP	120 K (4 bags) MOP	15-15-15 (16 bags/ha^{-1}
Medium	80 N (3.56 bags) urea	60 P (6.67 bags) SSP	60 K (2 bags) MOP	15-15-15 (8 bags/ha^{-1})

In cases of severe potassium and magnesium deficiencies apply 4kg sulphate or muriate of potash and 2kg magnesium sulphate per palm respectively. If commercially formulated NPK and magnesium compound fertilizer, 12-12-17 + 2Mg0, is to be applied, Table 2.63 shows the recommended rate and time of application.

Table 2.65 Recommendation rates for NPK, magnesium, compound fertilizer (12-12-17+2Mg0) for oil palm

NUTRIENT/ha		MATERIAL			RECOMMENDATION
		Kg/PALM	Kg ha^{-1}	NO. OF BAGS	
4.5kg N 4.5kg P_20_5 6.4kg K_20 0.8kg MgO	Compound fertilizer	0.25	37.5	¾	6 weeks and 6 months after transplanting into the field = 4.5kg ha^{-1} N + 4.5kg ha^{-1} P_20_5 + 6.4kg $ha^{-1}K_20$ + 0.8kg ha^{-1} MgO
9.0kg N 9.0kg P_20_5 12.8kg K_20 1.6kg MgO	Compound fertilizer	0.5	75	$1^1/_2$	1st year after transplanting into the field early in the rains = 9.0kg ha^{-1} N + 9.05kg ha^{-1} P_20_5 + 12.8kg $ha^{-1}K_20$ + 1.6kg ha^{-1} MgO
13.5kg N 13.5kg P_20_5 19.2kg K_20 2.4kg MgO	Compound fertilizer	0.75	112.5	2¼	2nd year after transplanting into the field = 13.5kg ha^{-1} N + 13kg $ha^{-1}P_20_5$ + 19.2kg ha^{-1} K_20 + 2.4kg ha^{-1} MgO
36kg N 36kg P_20_5 51kg K_20 6kg MgO	Compound fertilizer	2.0	300	6	The 3rd and onwards year after transplanting into the field = 36kg ha^{-1} N + 36kg ha^{-1} P_20_5 + 51kg ha^{-1} K_20 + 6kg ha^{-1} MgO

Method of Fertilizer Application
Fertilizer should be applied by broadcasting in the ring weeded areas around the base of the palms.

(c) *Varieties and other cultural practices*

(i) *Recommended Variety:-* The *tenera* variety which is thin-shelled, with high fruit to bunch ratio, high oil to fruit ratio, early yielding and vascular with resistant is recommended. It is also known as the E.W.S., (Extension Work Seed). The seeds are supplied as germinated nuts and as such must be planted within a few days of delivery. Where a farmer does not have the fertilizers and know-how to raise seedlings, he is advised to purchase seedlings from NIFOR or State Ministries of Agriculture.

(ii) *Choice of Land or Site* :- The suitability of a site for oil palm plantation development is determined by soil and climatic factors. The land should be of minimum depth of 90 - 100cm. Sandy loam to sandy clay with clay texture are most suitable. The land must be well drained and with a pH range of 4.0 - 6.0. Annual rainfall of about 2,000mm evenly distributed is most ideal with about 5 hours sunshine.

iii. *Land preparation:-* Use any method (manual, partial mechanical, fullmechanical) depending on the type of vegetation of the area, size of plantation and system of weed control to be adopted.

iv *Field Planting:-*
Time of Planting:- Planting should start as soon as the rains become established about March/April and should be completed by the end of May or June. Planting could go on into July if the need arises.

Method of Planting:- Polybag seedlings are best transplanted with all the soil. During transplanting, care must be taken in removing the bag without injuring the roots of the seedlings. Ensure that the ball of earth levels up with the surrounding soil surface after transplanting by digging the planting hole to the size and depth of the polybag. Alternatively, transplanting with naked roots where the plantations are too distant from the nursery or point of collection, the roots should be freed of soil but kept moist by treating with clay slurry and enveloped in a polybag. The leaf area of the seedlings should be reduced by half in order to reduce transpiration and avoid dessication. In planting naked-root seedlings the planting holes should be shaped like a cross with a slight elevation in the center. The roots must be distributed evenly in the four arms of the cross, then fill the holes with top soil and compact firmly.

Fixing of Wire Collars:- The seedlings should be protected with wire collar netting against the attack of rodents. For this a collar of 1.2cm netting, 45cm (18in) high with a circumference of 75cm (30in) is carefully fixed around the seedlings and must be retained around the plants for about 18 - 24 months.

Planting Population: One hectare takes 150 oil palm seedlings planted at a distance of 8.8 metres triangular

Sowing of cover Crops: Three species of legumes are recommended for planting oil palm plantation. These are *Pueraria phaseoloides, Calapogonium muscunoides and Centrosema pubescens.* NOTE: The objectives of the legume culture are to protect the soil after clearing and burning, suppress weeds and improve -soil fertility through nitrogen fixation. Legume seeds are mixed in the ratio of 2 parts *of Pueraria,* 2 parts of *Calapogonium* and 1 *part Centrosema* 5.5kg of this mixture should be sown per hectare.

Intercropping :
Food crops like cassava, maize, cocoyam, cowpea can be planted in the interrows of the oil palm plantations in the first 4 years of oil palm establishment. To allow sufficient interception of light by oil palms, cassava should be planted 2m away from palm stands while plantain should be planted at a lower density than the normally recommended one.

Also, it is possible to interplant oil palm with cocoa using a special planting arrangement such as avenue or hollow square.)

Field Maintenance

Weed Control: This involves the management of weeds in:
(i) interrow spaces
(ii) the ring weeded areas around the base of the palms and
(iii) the removal of parasitic and epiphytic weeds from growing on the palms
(i) Interrow: Manual slashing up to about 4 – 6 times a year in young and old plantations, respectively
Chemical: Apply appropriate herbicides to actively growing weeds, to achieve efficiency of the herbicide treatment. Recommended herbicides include:

	Herbicide(s)	Remarks
a.	Triclopyr (as Garlon 4) applied at the rate of 0.36 – 0.72 kg a.i. ha^{-1}	Effective Siam weed (*Chromolaena odorata* Syn *Eupatorium odoratum*) and other annual and semi-perennial broad leaf weeds.
b.	Hexazinone (as Velpar K4) at 2.0 kg a.i. ha^{-1}	Effective against Siam weed, Guinea grass (*Panicum maximum*) and other annual weed species.
c.	Glyphosate 1.5 – 3.0 kg a.i. ha^{-1}	Effective against Siam weed, Guinea grass and other annual weed species.
d.	Glyphosate + diuron at 0.36 + 2.7 kg a.i. ha^{-1}	Effective against Siam weed and other annual broad leaf weed species.
e	Folar 52S (as Glyphosate + terbuthylazine) at 2.1 – 2.62 kg a.i. ha^{-1}	Gives prolonged weed control. However, it should be alternated. Effective against Siam weed and broad leaf species. (Also suitable for circle weeding). Care should be taken to avoid contact with leaves of young palms.
f.	Imazapyr (as Arsenal) at 0.5 kg a.i. ha^{-1}	Effective against Siam weed and other broad leaf weeds. Repeated application reduces the

		incidence of Siam weed. Care should be taken to avoid contact with the palms. Could induce bud rot / little leaf in palms.
g.	2,4-D amine	Use in only mature plantations where all fronds and leaves are well above ground level. Effective in the control of broad leaves only including some woody perennials.

Mechanical: Tractor slashers should be used to slash the interrow vegetation in plantations prepared for mechanical maintenance.

(ii) Manual: Use cutlass or matchet to cut all the weeds to the ground in a ring of 1.5 meter diameter in young plantations and 2.5 meter diameter in older plantations Chemical: Apply appropriate herbicides to the weeded circle of palms. Usually pre-emergence herbicides are recommended. However, some herbicides combine both post-emergence and pre-emergence activity and therefore can be used where weeds have already emerged in the weeded circle. Recommended herbicides include:

	Herbicide(s)	Remarks
a.	Diuron 2.0 – 3.0 kg a.i. ha^{-1}	Applied pre-emergence to the weeded circle.
b.	Glyphosate + diuron 0.18 + 2.7 kg a.i. ha^{-1}	Applied when weeds have already emerged. Gives prolonged weed control.
c.	Hexazinone (as Velpar K4) at 2.0 kg a.i. ha^{-1}	Applied both as pre-emmergence and early post-emergence.
d.	Glyphosate + terbuthylazine (as Folar 52S) at 2.1 – 2.6 kg a.i. ha^{-1}	With diuron to prevent build-up of annual ngrasses
e.	Glyphosate 1.5 – 2.4 kg a.i. ha^{-1}	Effective for post-emergence weed control in the weeded circle. Care should be taken to avoid spray contact with fronds and leaves.

Pruning of Adult Palms: Prune at least once a year during the dry season. All dead leaves should be cut off.

(iii) *Diseases and Pest Control*

a) *Diseases*

(i) Freckle: Control is achieved by spraying using a fungicide Dithane M45 at the rate of 2g/litres of water supplemented by pruning of ail the badly affected leaves.

(ii) *Basal Stem Rot (Ganoderma Trunk Rot):* Land preparation with emphasis on the removal of all stumps as well as stems of oil palms or rubber prior to field planting is the most practicable method of minimizing the disease.

(iii) *Vascular Wilt (Fusarium oxysporum):* The most satisfactory and practical method of control is the removal of old stumps of palms and other trees prior to transplanting with wilt-tolerant Extension Work Seeds.

b) *Insect Pests*
Major insect pests are

i. *Oil Palm Leaf Miner (Coelaenomenodera elaeidis mauli*
Control is by prunning the affected leaves, at a period of larval abundance in high humidity areas. At high infestation level, the application of of ultracide 40EC at 3 liters/hectare using the canon boom sprayer is recommended.

(ii) *Weevil (Rhyncophorus and Oryctes species* : Control is mainly by cultural methods which include elimination of breeding sites, for example, refuse dumps, compost, bunch waste, burning of old stumps of oil palm and removal or destruction of larvae and adults. Chemical control includes, spraying of Nuvacron 40EC at 10 to 20ml (undiluted) in two equal lots. The caterpillars are controlled by Nogos 50 EC. Basudin 60 EC at the rates of 3 - 6ml/litre of water and ultracide 40EC at 3ml in 300 litres of water.

(c) *Rodent*
Rodents e.g. grasscutter and porcupine which constitute serious problems in newly established plantations are controlled by the use of wire collar bamboo fencial and rodenticides.

Expected Yield
If the recommendations are followed and rainfall is adequate, mature yield, 5 - 8 tonnes fresh fruit bunches (ffb)/ha^{-1}/year giving 1 - 1.6 tonnes of palm oil and 0.2 0.32 tonnes of palm kernel/ha^{-1}/year is expected in the marginal areas of the middle belt; 10 - 14 tonnes ffb/ha^{-1}/year giving 2 -2.8 tonnes of palm oil kernel/ha^{-1}/year in the relatively dry rain-forest zone and 15 -18 tonnes ffb/ha^{-1}/year 3 - 3.6 tonnes of palm oil and 0.6 - 0.72 tonnes of palm kernel in the very wet forest zones. Oil content of the pulp varies considerably but a fair average would be 56% Palm kernels yield about 50% oil.

2.8.7 Coconut Palm (*Cocos nucifera*)

(a) *Area Under Crop*
An estimated 10,000 hectares is under coconut cultivation mostly in Lagos and Rivers States. The Nigerian Institute for Oil Palm Research (NIFOR) has established seed gardens at its main station near Benin City, (Edo State), Badagry, (Lagos State) and at Abak (Akwa Ibom State).

(b) *Nutrient Requirements and Fertilizer Use*

i) Nutrient Deficiency Symptoms:

Nitrogen: Nitrogen deficiency leads, first to paling of the leaves then to yellowing of the entire crown. As the deficiency advances the older leaves become golden yellow and may be prematurely dropped. The mid ribs turns yellow while the margins remain pale green. In bearing palms, severe nitrogen deficiency leads to reduction in the number of female flower per inflorescence, abortion of whole bunches and premature fall of young nut.

Potassium: Potassium deficient trees show yellowish appearance with a reddish brown discoloration of the older leaves which later, became necrotic. Yellowing starts at the tip of the leaflets and progresses along the margin towards the base. Finally the tips of the leaflets dry up, resulting in a characteristic scorched appearance of the apical part of the lower leaves. Severe deficiency leads to premature nut fail, narrow trunks and short internodes.

Magnesium: The tips of the leaflets of older leaves are yellow while the basal parts of the leaflet, remain green. Gradually, the yellowing proceeds to younger leaves and the older ones turn to a yellow orange and then to orange colour. The intensity of the discoloration depends on the degree of exposure to sunlight.

Fertilizer Sources, Rates and Time of Application: The coconut palm requires large doses of nitrogen and potassium for optimum production. Fertilizer recommendations for coconut palm are as shown in Table 2.64. Biomass recycling through residue management will improve soil organic matter, soil structure and soil nutrients. Mulching with coconut husks and retaining of dropped leaves in the plantation is good management practice.

NOTES:

1. Fertilizers should be applied at the time of planting but not later than three months after planting.

2. P and Mg fertilizer applications will only be necessary on soils deficient in these nutrients because of the relatively low requirements of P. Compound fertilizer NPK Mg 12-12-17+2, can be applied at the rate of about 0.5kg/palm/year (i.e. $102.5kg/ha^{-1}$/year) for young palms and 1.5 - 2kg/palm/year, ($307.5 - 410kg/ha^{-1}$/year) for mature bearing palms.

   Time and Method of Application
   Apply fertilizers at the beginning of the rains by broadcasting in a ring of about 2m radius around the palm. Fertilizers can also be applied in two split doses at the beginning and at the end of the rainy season in October.

(c) *Varieties and Other Cultural Practices*
Recommended Varieties : There are three varieties namely, Tall, Dwarf and Hybrid. The dwarfs vary in colour - yellow, orange, green and are mainly grown as ornamentals. The tall. variety is generally grown on commercial scale because of their bigger nuts. For commercial farming, the hybrids between tall and dwarf varieties are recommended as they flower earlier (4 - 6 years) than the talls.

(d) Land Preparation and Sowing Technique
Nursery: The polybag nursery site should be cleared and prepared ready by March with the soil ploughed and rotavated or hoed to loosen the soil.

The sand- bed nursery must be about 50 cm deep using river sand except when a natural sandy area is used. The nuts are sown in a horizontal position into furrows of about 15 cm deep, with furrows spaced 50 cm apart. Germinated nuts at the two- leaf stage are transplanted into black polythene bags.
Where the lethal yellowing disease is prevalent, famers are advised to plant Malayan Green Dwarf or Chowghat Green Dwarf which are resistant to LYD

Field: In very wet coastal lands subjected to annual flooding some drainage may be necessary.

(e) *Time of Planting:* Plant into the field in April or May as soon as the rains get established. The seedlings are transplanted when they are 12 months old. Seedlings should be selected for vigour using girth size (13cm or more) and number of leaves (at least six healthy leaves) as criteria.

(f) Method of Planting: Prepare planting holes 75cm x 75cm. The pits are filled, preferably with two layers of coconut husk or oil palm bunch refuse alternating with the top soil and leaving a depth of 60cm. For planting of seedlings raised in sand beds, the seedlings should be lifted carefully and not pupped out by their leaves. They should be carefully dug out with least disturbance to the roots. Polybag seedlings are best transplanted with the entire soil in the polybag. During planting, the polybag is carefully removed without injuring the roots. The soil around the seedling should be firmly compacted without covering the collar of the seedlings.

Fixing of Wire Collars: The collar of wire (46cm x 122cm) is fixed 15cm away from the base of the. seedlings encircling it completely.

Spacing: Field spacing is 7.5m triangular for the tall and 6m for dwarfs and hybrids.

<u>NOTE</u>: Coconut is very sensitive to water stress. On soils with low moisture retention or low water table, irrigation of the palms may be necessary in the dry season following planting and even in the first year after planting in the field to ensure establishment and avoid deaths.

(g) Plant Population

(i) Nursery: A hectare of land will accommodate 30,000 - 40,000 seedlings plantedat 50cm square.

(ii) *Field:* The 6m and 7-5m triangular spacing will give a Plant Population of 320 and 205 palms per hectare, respectively.

(h) *Sowing of Cover Crops:* In plantation where inter-cropping is not done, leguminous cover crops could be established. *Pueraria phaseloides, Calapogonium mucunoides and centroserna pubescens* are recommended in a 2: 1: 1 ratio at a sowing rate of 5-.5kg/hectares.

(i) *Intercropping:* Inter-cropping in the initial years with food crops like cassava, yams, plantain and pineapple would help the farmer to derive good income till the coconut palms attain normal bearing. Including cowpea in the mixture has been shown to increase coconut yields and overall productivity of the system. In older

plantations mixed cropping with cocoa is a profitable venture. However, the intercrops should be properly spaced, the density reduced and separately manured.

(j) *Weed Control:* Cover crops and weeds in the interrows should be slashed about 2-3 times a year. Rings about 1.5 - 2m radius should also be maintained clean of weeds around the palms. Ring slashing can, be done with the cutlass or herbicides. Where the plantation was prepared mechanically for planting, the interrow weeds can be maintained using tractor drawn slashers.

(k) Diseases and pest Control

Nursery: The most common diseases include leaf spot, blast, wither tip, and crinkling.

Leaf Spot: Caused by the Fungus Pestalotis,

Control Measures: Cutting and burning the diseased parts or removal and destruction of diseased plants will prevent further spread. To be successful, this control measure must be carried out in the early stages of the disease out-break.

- *Resistant Varieties:* Resistant varieties may be used.
- *Spaying* Copper formulation such as perenox and Bordeaux mixtures are very useful.

Blast

Control Measures

Seednuts should be sown early in the rainy season.

Seedlings should be mulched with bunch refuse after planting in the nursery.

Adequate water should be supplied particularly towards the end of the rainy season.

Shading of the nursery during dry months of October - February reduces the incident of blast. There is at present no satisfactory chemical control.

Diseases

Coconut Die-Back Disease

Coconut Lethal Yellowing Disease (LYD): LYD is caused by phytoplasma like organism. It is not detectable through cultural media, except using molecular technique.

Control: There is no effective control measures so far. However, the following measures would check the spread of the disease.

1. Destruction of diseased palms.
2. Avoid collecting dead nuts from the disease affected palms as well as from palms in the area where the disease is prevalent.
3. Planting tolerant varieties e.g. Malayan dwarf.

Premature Nut fall: This disease is caused by a fungus *Botrypdiplodia* spp. The disease is controlled by spraying with Benlate T. (50ppm a.i.) Poor mineral nutrition can also cause premature nut fall.

Insect Pests: The most destructive insect pest is *Oryctes monocerus* and is controlled culturally by the destruction of the breeding sites and by hand picking at low infestations.

Rodents: Protect from rodents with wire collars as described under field planting.

(l) *Expected Yield* : With reasonable management, improved coconut palms could yield up to 100 nuts/plant per year. Improved hybrids could yield up to 180 - 200 nuts/palm/year. The hybrids also have higher copra content (yield is about 7.3kg/palm/ year) than the dwarfs (3.3kg/palm/year) or tall (1.4kg/palm/year). Oil content of good copra is between 60 - 72% depending upon variety.

Table 2.66 Fertilizer recommendation for coconut palm

NUTRIENT /ha		MATERIAL			RECOMMENDATION
		Kg/PALM	Kg ha^{-1}	NO. OF BAGS	
9.2kg N 3.6kg P_20_5 24kg K_20 3.2kg MgO	Urea SSP MOP Kieserite 12-12-17+2Mg0 or 15-15-15	0.1 0.1 0.2 0.1 0.2	20 20 40 20 40	½ ½ $^4/_5$ ½ $^4/_5$	The year of transplanting into the field = 9.2kg N + 3.6kg P_20_5 + 24kg P_20_5 + 3.2kg MgO/ha^{-1}. Or 40 Kg 12-12-17 + 2Mg0 or 15-15-15 per hectare
18.4kg N 7.2kg P_20_5 60kg K_20 6.4kg MgO	Urea SSP MOP Kieserite 12-12-17+2Mg0 or 15-15-15	0.2 0.2 0.5 0.2 0.5	40 40 100 40 100	$^4/_5$ $^4/_5$ 2 $^4/_5$ 2	The 1st year after transplanting into the field = 18.4g N + 7.2kg P_20_5 + 60kg K_20 + 6.4kg MgO per hectare OR 100kg 12-12-17 +2 Mg0 or 15-15-15 per hectare
46kg N 14.2kg P_20_5 120kg K_20 16kg MgO	Urea SSP MOP Kieserite 12-12-12+2Mg0 or 15-15-15	0.5 0.4 1.0 0.5 1.0	100 80 200 100 200	2 $1^3/_5$ 4 2 4	The 2nd year after transplanting into the field = 46kg N + 14.2kg P_20_5 + 120kg K_20 + 16kg MgO per hectare OR 108.8kg 12-12-17 +2Mg0 or 15-15-15 per hectare
46kg N 14.4kg P_20_5 180kg K_20 16.6kg MgO	Urea SSP MOP Kieserite 12-12-12+2Mg0 or 15-15-15	0.5 0.4 1.5 0.5 1.0	100 80 300 100 200	2 $7^3/_5$ 6 2 4	For the 3rd* year after transplanting into the field = 46kg N + 14.4kg P_20_5 + 180kg K_20 + 16kg MgO per hectare OR 200kg 12-12-17 +2Mg0 or 15-15-15 per hectare

• - **Fertilizer application in subsequent years would be determined by results of soil and foliar analysis.**

2.8.8 Date Palm (*Phoenix dactylifera*)

(a) *Area Under Crop*
The date palm grows between latitude 10^0N - 13^0N and longitude 4 -12^0E especially in Bauchi, Borno, Kano, Sokoto, Kaduna, Katsina, Adamawa, Jigawa, Yobe, Gombe, Kebbi and Zamfara States.

(b) *Nutrient Requirement and Fertilizer Use*
The primary nutrient requirement is nitrogen which can be provided, either by farmyard manure or inorganic fertilizer. Farmyard manure at the rate of between 12.5 to 37.5 tonnes per hectare is recommended. The amount of nitrogen to apply depends on the fertility status of the soil.

(c) *Varieties and other cultural practices*

i. *Varieties:* - The semi-dry dates with reducing type of sugar are recommended.

ii. *Land Preparation:* The usual land preparation techniques for crops grown in the northern states are applicable to date palm. For the compound crop, the soil near the source of water is loosened and seedling is planted at about 10crn lower than the soil surface to retain water during irrigation.

iii. *Field Planting:* Planting should start at the beginning of the rainy season. The site should be close to source of water for irrigation in the dry season. Normal planting distances are 10 x 10m, 9 x 9m, and 9 x 8m depending on variety. To ensure good quality varieties, the best manner of propagation is by offshoots from the base of the trunk.

iv. *Plant Population:* About 100 to 150 stands per hectare depending on the variety and planting distance.

v. *Cover Crop:* While the palm are young, leguminous cover crops supply most of the nitrogen required, but when they are 12 - 15 years old shade prevents the growing of a cover crop in most cases.

vi. *Weed Control:* Weeds are removed by hoeing as necessary.

vii. *Pest Control: The* control of fruit bats, moths and birds is by covering ripening fruits with old jute bags, mosquito nets or thorny leaves.

(d) *Expected Yield*
Yields range about 20 to more than 100 kg per tree/per year.

2.8.9 Raphia Palms (*Raphia spp*)

(a) *Area Under Crop*
Raphia palms are found in different parts of the country especially in the South South, South East and South West Zones with few in the North Central and North West. It is estimated that over 180 million Raphia palms Occur in the Wild Groves 2 million in home-stead, 1000 hectares plantation. These are mostly in freshwater swamp, coastal fringe, deltaic plains of major river and few upland

(b) *Nutrient Requirements and Fertilizer*

Nutrient Deficiency Symptoms: Potassium deficiency symptoms in the field are terminal and marginal necrosis of affected leaflets. The tissues of the leaflets are pale greyish-brown in colour, dry, brittle and disintegrate leaving the leaflet with a ragged irregular margin as in oil palm. This is dominantly shown in sandy soils. Another symptom is iron toxicity chlorosis resulting in overall leaf yellowing particularly in dominantly water- logged areas. This is averted by drainage.

(c) *Fertilizer Sources, Rates, Timing and Methods of Application.*

For the Nursery, Raphia seedling require combined application of NPK Mg 12 – 12 – 17- 2 and organic manure (Poultry manure) at the rate of 25g each / seedling applied 3 months after planting by broadcasting ensures healthy and vigorous seedlings production.

In the field, for hydromophic soils in fresh water swamp for optimum development of Raphia hookeri palms application application of 1.0kg Urea, 1.0kg Muriate of potash, 0.5kg Single Superphospate, and 0.2kg kieserite per palm per year, by broadcasting before the onset of rains usually January is recommended. Apply only 25%, 50%, 50%, 75% of the above rate in the year of transplanting, and 1st, 2nd, and 3rd year after transplanting respectively.

(d) *Varieties and other cultural Practices*

(i) *Recommended Varieties*. There are twenty Raphia species in Africa, eight of which are indigenous to Nigeria. The most important among these are: Raphia hookeri Raphia vinefera, Raphia sudanica and Raphia mambillansis.

(ii) *Choice of* Site: The crop performs excellently well in areas with deep soils free of gravels, or concretions and with high moisture retention, preferably of shallow water table. The crop will also grow well in coarse to medium texture, mainly sandy soils with 10 - 25% clay. A flat to gentle undulating topography is required to reduce run-off and possible waterlogging,

(iii) *Land Preparation:* The best period for land preparation is the dry season. In the very wet coastline and deltaic plains, this falls within November and December, when the flood has receded and the soil is fairly dry. On the spill plains inland, this falls within the peak of the dry season when the rivers are shallow and the spill plains dry. The operations involve:-
slashing of undergrowth;
felling of shade trees;
cross-cutting of felled trees,
lining and pegging.

(e) *Field Planting*. The palms should be planted within March in the very wet areas near the coast and within April and May inland during steady rains. Planting is by the ball-of-earth transplanting technique into a hole that completely buries the ball to surface level. The palms normally suffer from transplanting shock, but survival is high (over 90%).

(f) *Plant Population:*

Nursery: For swampy ecology Raphia palms should be planted at a spacing of 7m x 7m square to give a plant population of 204 palms/ha. While for upland ecology planting at 6m x 6m square to give a population of 278 palms/ha is recommended.

Field:

The following spacings are recommended:

i. For *Raphia Hookeri* Palms, 4.57m x 4.57m square giving a plant population of 480 palms per hectare on upland high rainfall areas. But about 5.2m square for waterlogged areas.

ii. For *Raphia vinifera, R. Sudanica and R. mathbillansis* which are suckering species, 6.1m square is recommended.

(g) *Nursery and Field Maintenance*

a. For seedlings to be transplanted into upland fairly well drained soils, it is preferable that the polybags should be perforated at the bottom to allow excess water to drain out. The space atop the soil level in the bag should be mulched with oil palm bunch refuse or organic debris, and watered effectively at periods of dry spell. For raising seedlings in dominantly waterlogged areas, it is preferable that the soil is waterlogged or at least saturated most of the time. This condition enhances profuse production of breathing roots (pneurmatophores) necessary for adaptive, establishment in the waterlogged field. However, waterlogging of the polybags should commence after three months of germination.

Field Maintenance: Weed control in Raphia plantation is by manual slashing about three times in a year. Weeds grow faster in the swamps than on dry land. The older and/or disease infested leaves should be regularly pruned.

(h) Disease and Pest Control

Nursery. Nursery pests are, mainly hoppers which feed on the foliage, termites that feed on the roots and rodents which feed on the cabbage. These are controlled by systemic carbamates (Furadan). Nogos and Ultracide 40EC, while rodents could be controlled by use of rodenticides or traps, and where necessary wire collars as for oil palm. Identified seedling diseases are those caused by fungi and leaf blight. These can be controlled by the following measures:

pruning affected leaves and burning them keeping polybags and surrounding nursery area weed free ensuring adequate watering of seedlings, particularly during the dry season to prevent moisture stress.

Field:

The common ones are:

Cerataphis variabilis - Control is by use of aphicides and introduction of coceinellids as biological control measure.

Pinelaphilla ghesquiered - It can be controlled by removal of infected leaves and collection of caterpillar and pupae. Spraying with 0.02% parathion or 0.1%. Eudrin is effective at high infestation.

Other pests like *Rhinoceros* beetles (Oryctes) and Termites (Armitermes evundifer) can be controlled by rogueing and burning of affected parts, proper disposal of organic refuse, rotting palms and vegetable matter.

(i) *Expected Yield*
For improved palms, the expected yield of palm wine *Raphia hookeri* is 800 - 2000 litres (under swamp condition) and 300 to 800 litres (under upland condition) or an average of 60 litres per day or 2,145 litres per 90 days.

2.8.9.1 Rubber (Hevea brasiliensis)

(a) *Area under Crop:*
Total land area under rubber is estimated at 0.2 – 0.5 million hectares, major producing States include Edo, Delta, Ogun, Ondo, Imo, Abia, Rivers, Akwa Ibom and Cross River. Rubber is also produced in some parts of Bayelsa, Kaduna, and Taraba States.

(b) *Choice of land:*
A good rubber soil should have the following physical and chemical characteristics:

i. Well drained with Depths of up to 100cm free of hard pan/rock outcrop
ii. Soil texture with about 20% clay to retain moisture and nutrients and also about 30% sand to allow for good aeration and drainage
iii. Friable consistency
iv. pH of 4.5 – 6.0
v. Water table should be deeper than 100cm
vi. Gently undulating terrain with insignificant soil erosion and surface run-off.

(c) *Land Preparation:*

i. Under brush, fell, crosscut or top all trees. Burn as soon as they are dry. And carry out stumping.
ii. Clear planting line, line out, hole and back fill.

(d) *Recommended Varieties:*
The main recommended clones include NIG 800, NIG 801, NIG 802, NIG 803, NIG 804, NIG 805, GT 1, RRIM 600, PB 28/59, and IAN 710.

(e) *Field Planting:*
Planting should be done about the middle of June to August when the rains are well established.

(f) *Plant Population:*
The spacings currently recommended for planting rubber are 6.7x 3.4m and the double row planting of 2.5x2.5x10m or 3.0x3.0x13m. This planting method makes intercropping profitable under small holding rubber plantation. At maturity, the plant population should be less than 450 trees per hectare.

(g) *Sowing of Cover Crops:*
Recommended cover crop is *Pueraria phasioloides,* a creeping legume. It should be sown when the rains are regular. This is effective for immature rubber

plantation. Regular trimming to prevent the cover crop from climbing and strangulation of the rubber tree is recommended.

(h) *Nutrient Deficiency Symptoms:*

Nitrogen deficiency: Reduction in growth, reduced leaf size and number, reduced girth, leaves are yellowish green in colour, first appearing on older leaves.

Phosphorus deficiency: Bronzing of under surface of leaves and frequent drying of leaf tip, symptoms are usually first found on leaves in the middle and upper storeys and considerable defoliation can occur.

Potassium Deficiency Symptoms: Development of a marginal and tip chlorosis, followed by necrosis; symptoms appear first on older leaves.

Magnesium deficiency: Development of chlorosis in the interveinal areas of the leaf, chlorosis spreads inwards from the leaf margins giving a 'herring bone' pattern.

(i) *Fertilizer Sources, Rates, Time and Method of Application:*

Nursery: At the nursery stage N and P are required in equal amounts. The need for K depends on the K content and supplying power of the soil. Mix fertilizers to supply N, P_2O_5 and K_2O in the ratio of 4:4:1 and apply this mixture first at land preparation at 50gm per meter square and at the rate of 50gm per meter when the seedlings are 3 months old on both sides of the planted row of seedlings.

Field Planting:

i. *Newly Planted Stumps:* Mix 115 grams of rock phosphate or 172.5g of super-phosphate in the top 15cm of planting hole. Apply 200kg/ha NPKMg (12-12-17-2) fertilizer if the rubber interrow is intercropped with annual and semi perennial crops.

ii. *Immature and Mature Rubber Planting:* Table 2.66 indicates the sources, rates, time, and method of fertilizer application for mature and immature trees.

(j) *Field Maintenance- Weed Control:*

i. *Cultural Control:* Clean weeding of rides and slashing of avenues 3 – 4 times a year.

ii. *Integrated Control:* Cultural method followed immediately by chemical control, using systemic herbicides, will reduce frequency of cultural control to 2 – 3 rounds a year.

iii. *Chemical Control:* Application of systemic herbicides such as glyphosate or contact herbicides for the control of weeds in the rubber rides and interrows at rates of 4 to 5 litres per hectare.

(k) *Diseases:*

White root rot: Treat with Formac 2 fungicide.

Mouldy rot of panel: Tapseal or difolatan can be used.

Pests Control: Termites are a major problem during the dry season in immature plantation. Termicides such as Termifos 40EC can be applied at 0.5% water emulsion for control of termites.

(l) *Exploitation:*

(i) *Opening:* Open field for tapping when 70% of the trees have reached 44cm girth at 100cm above ground level.

(ii) *Tapping:* Tapping starts as soon as opening of the field is completed. Tap properly, produce good quality latex or lumps. Remove all dirt to obtain high grade crumb, sheet or crepe.

Expected Yield:

Yields on farmers' fields range from 700 – 900kg ha^{-1} of dry rubber per year. With improved practices yields of 2,000kg ha^{-1} are possible.

Table 2.67 Fertilizer Recommendations for rubber

MONTH	**NUTRENT ha^{-1}**		**MATERIAL**			**RECOMMENDATION**
			g/tree	Kg ha^{-1}	NO. OF BAGS	
May	7.04kg P_2O_5	Rock phosphate single super-phosphate	115 172.5	39.1 58.7	4/5 -	Mix in top 15cm of planting hole
August	1.94kg N 3.87kg P_20_5 1.96kg K_20 0.44kg Mg0	Urea Single super-phosphate Muriate of potash Magnesium sulphate	12.4 63.3 11.5 8.1	4.22 21.52 3.91 2.75	1/12 2/5 1/13 1/18	Scratch furrow 10cm deep in circle 15cm from plant stem and apply fertilizer mixture evenly.
November	1.94kg N 3.87kg P_20_5 1.96kg K_20 0.44kg Mg0	Urea Single super-phosphate Muriate of potash Magnesium sulphate	12.4 63.3 11.5 8.1	4.22 21.52 3.91 2.75	1/12 2/5 1/13 1/18	In April, make a furrow 10cm deep from the plant stem and apply evenly while in October make band 30cm wide starting 30cm from the stem, loosen soil in the band and broadcast and cover with soil. Apply fertilizer mixture containing 3.88kg/ha N + 7.74kg/ha P_20_s + 3.9kg/ha K_20 + 0.88kg/ha MgO each in April and October
April and October	3.88kg N 7.74kg P_20_5	Urea Single super-phosphate Muriate of potash Magnesium sulphate	24.8 126.6 23.0 16.2	8.44 43.04 7.82 5.50	1/6 7/8 1/7 1/9	

MONTH	NUTRENT ha^{-1}		MATERIAL			RECOMMENDATION
			g/tree	Kg ha^{-1}	NO. OF BAGS	
April and October	5.82kg N 11.61kg p_2O_5 5.88kg K_2O 1.32kg MgO	Urea Single super-phosphate Muriate of potash Magnesium sulphate	37.2 189.9 34.5 24.3	12.65 64.57 11.73 8.26	¼ - $1^{2/2}$ 2/9 1/6	Make band 30cm wide starting 30cm from the stem, loosen soil in the band and broadcast and cover with soil. Apply fertilizer mixture containing 5.82kg/ha N + 11.61kg/ha P_2O5 + 5.88kg/ha K_2O + 1.32kg/ha MgO each in April and October respectively.
April and October	15.52kg N 30.96kg P_2O_5 15.68kg K_2O 3.52kg Mg0	Urea Single super-phosphate Muriate of potash Magnesium sulphate	99.2 506.4 92.0 64.8	33.73 172.18 31.28 22.03	$3^{4/9}$ - 4/9	Broadcast in a band 90cm wide and 90cm from the stem fertilizer mixture containing 15.52kg/ha N + 30.96kg/ha P_2O_5 15.68kg/ha K_2O + 3.52kg/ha MgO each in April and October.

Note: 1. If there is evidence of magnesium deficiency, apply magnesium in the ratio of 1:2 parts MgO to 3 parts of K_2O.

2. In area where there have been a good cover crop programme during immaturity and nitrogen fertilizer adequately used; nitrogen application at maturity should be done with caution, especially when trees in such areas are susceptible to wind damage. Proper soil and foliar analysis should provide the necessary guidelines.

3. There will be need for crop fertilization in all intercropping of annual, semi-perennial and perennial crops with immature rubber. The use of NPK Mg 12 -12 – 17 – 2 at the rate of 200kg/ha for the first two years of intercropping is recommended.

2.9.0 FRUITS, PASTURES, GRASSES AND LEGUMES

2.9.1 Citrus (*Citrus spp*)

(a) *Area Under Crop*
Citrus is widely grown in the country. It is one of the most popular and widely cultivated tree crop.

(b) *Nutrient Requirements and Fertilizer Use*
Fertilizer Requirement : Current fertilizer recommended is 500 - 600kg/ha 15-15-15 with supplementary 160kg/ha muriate of potash on mature citrus per year split applied in June and September.

(c) *Varieties and other cultural practices*
i. *Varieties:* The most popular citrus species in Nigeria are sweet orange and Tangelo.. Mandarin, grape-fruit and Lemon are also grown. The most promising varieties are:

Species	*Varieties*
Sweet Orange	Parson Brown

(C. sinensis)	Agege 1, Valencia, Washington Navel, Etinan Umudike.
Tangelo	Lake (Orlando)
(C. reticulata x C. paradisi)	Minneola
Grape fruit	Marsh seedless
(C. paradisi)	Red blush, Pumelo, Duncan
Mandarin	Clementine
(C. reticulata)	Dancy, Cleopatra, Algerian
Lemon	Lisbon
(C. Limon)	Lureka, Rough Lemon
Lime	Sweet lime
(C. aurantifolia)	Key lime, Tohiti lime

ii *Spacing/Planting Population:* Species characteristics and varietal growth habit determine the spacing of citrus. The following spacings are recommended:-

Sweet Orange	7m x 7m (204 plants/ha)
Tangelo	7m x 7m
Grape-fruit	7m x 8m
Lemon	5m x 6m
Lime	5m x 6m

iii. *Weed Control* : Mechanical slashing of the interrows may be carried out in sole crop orchards although proper stumping would have been carried out. The herbicides glyphosate (round-up) and paracol are recommended as follows;-

Paracol at 4 - 6kg ai/ha at 4 weeks after transplanting and repeated at intervals of 10 - 12 weeks.

Glyphosate may be used in place of paracol where *Imperata cylindrica* is a major problem. Application should be at the rate of 3 - 4kg a.i./ha applied when the weed is at knee height.

iv *Disease and Pest Control*

Diseases		**Control**
Gummosis		Prune dying stem. Remove infected bark at least 2.5 - 5cm beyond infected area and paint with Bordeaux mixture.
Scap	(i)	Spray with benlate at 2.5g/10 litres of water at regular intervals.
	(ii)	Use Bordeaux mixture with soil spray.
Root rot	(i)	Treat with carbon disulphide 20 - 30cm deep round each tree.
Tristeza	(i)	Control aphid vectors with Agrothion 20EC at 50ml/10 litre of water.
	(ii	Immunization of budded trees with aphid isolated virus.
Fruit Mould		Spray Dithane M45 or Difolatan 50 at 1 - 2 weeks before harvesting.

Pests		Control
Leaves and flushes damaging pests	(i)	Apply Agrothion at 25ml/10 litres of water.
	(ii)	Apply Sevin at 100g/10 litres of water
Fruit piercing moth	(i)	Routine application of Ambush 25EC at 5ml/10 litres of water.
Nematodes	(i)	Use clean seedlings.
	(ii)	Furadan 30 at 4 - 8g ai/ha or Mocap 100 at 6kg a.i ha^{-1} broadcast at the base of trees at rate depending on severity of infection.

2.9.2 Mango (*Mangifera indica*)

(a) *Area Under Crop*

This is a very popular tree crop widely grown in all States of the Federation

(b) Nutrient Requirement and Fertilizer Use

Fertilizer Requirement: Fertilizer application is on individual plant basis. NPK (15-15-15) fertilizer can be applied as follows:

Rainy Season Year 2	-	200g/plant in 3 split doses
Rainy Season Year 3	-	300g/plant in 3 split doses
Rainy Season Year 4	-	400g/plant in 3 split doses
Rainy Season Year 5	-	500g/plant in 3 split doses
Rainy Season Year 6	-	600g/plant in 3 split doses

Fertilizer placement should be in ring form which increases with the size of the tree and as close to the positions of absorptive roots as possible.

(c) *Varieties and Other Cultural Practices*

i. *Varieties:* Mango performs well in all the ecological zones of Nigeria. The recommended varieties are Palmer, Julie Alphonso, Edwards, Ogbomosho, Keitt, Haden, Saigon, Zill and Early Gold Grafted seedlings of these varieties are obtainable at the Capitals National Horticultural Research Institute, Ibadan.

ii *Site Selection:* Mango requires deep well drained soil to enable the deep tap root to penetrate effectively. Sandy loam to loam soils are most suitable. Soils with hard pans or rocks close to the surface can hinder tap root penetration. Mango does well under high rainfall and also tolerates scanty rainfall situations but long periods of water logging can have adverse effects.

iii. *Spacing:* Spacing is based on average tree size which is dependent on variety. The recommendations are as follows:

Small sized trees (Julie)		6m x 6m
Medium sized trees (Saizon), Zill, (Alphonso)	i.	8m x 8m

	ii.	10mx 10m
Large sized trees (Palmer, (Meith, Haden & Edward)		10m x 10m

iv. *Land Preparation:* The land preparation is as described for citrus

v. *Weed Control* : As in the case of citrus, mechanical slasher on a routine basis can be used. The herbicides can also be used as follows:
Paracol at 4-6kg ai/ha applied 4-5 weeks after field planting and repeated at 12 - 16 weeks interval. Where the weed *Imperata cylindrica* is a problem, the herbicide glyphosate (round-up) at 3 - 4kg a.i ha^{-1} would be used instead of paracol.

vi. *Disease and Pest Control:* Anthracnose caused by Glomella cingulata and wilt caused by *Ceratocystis fimbriata* are two major diseases of mango. Control measures are as follows:

Disease		Control
Wilt		Use Benlate at 2.5g/10 litres of water or Difolatan spray
Anthracnose	(i)	Weekly sprays of Benomyl at 12g/101 of water for 3 - 4 weeks
	(ii)	Thiabendazole at 10ml/101 of water weekly. Stop sprays when fruits are about ripening.

2.9.3 Pineapple (*Ananas Commosus.*)

(a) *Area Under Crop*
Pineapple production is most common in the southern part of the country although it is difficult to estimate total land area devoted to it.

(b) *Nutrient Requirement and Fertilizer Use*
Fertilizer Requirements: Although the fertility need of pineapple would depend on the soil fertilizer status, the recommended ranges are as follows:
200 - 400kg N ha^{-1}
100kg P_20_5 ha^{-1}
200 - 400kg K_20 ha^{-1}

The fertilizer should be applied in three split doses as follows

1st application	-	4 weeks after 1st application
2nd application	-	3 months after 1st application
3rd application	-	3 months after 2nd application

(c) Varieties and other Cultural Practices

(i) Varieties: Smooth cayene with a yield potential of 50 - 60t/ha is the recommended variety.

(ii) *Site Selection:* Light to moderately heavy well drained soils with fairly high organic matter content are most suitable. It is a shallow rooted crop. While pineapple can tolerate some dry period. Waterlogged soils are not suitable.

(iii) *Land Preparation:* After clearing and stumping, careful ploughing and harrowing is very essential for good growth of pineapple. As a shallow feeder, good top-soil is essential. The top-soil must be well preserved during the land clearing operation.

(iv) *Spacing Plant Population :* A double row system is recommended for better plant performance. A population of 40,000 plants ha^{-1} is however, recommended. Plant spacing and arrangement are as follows:-

Between bed centers	Between lines	Between plants	Plant Population per ha.
1.7m	0.6m	0.3m	40,000

(v) *Weed Control:* Field workers do sustain injuries during the process of hand slashing, caused by the thorns of the variety smooth cayene., thus making hand slashing in pineapple a very unattractive operation. The following herbicide constitute alternatives that can be used in pineapple.

i. Diuron at 4.5 - 6kg a.i ha^{-1}
ii. Ametryne at 4 -6kg a.i ha^{-1}
iii. Simazine at 4 - 6kg a.i ha^{-1}
iv. Bromacil at 3 - 4kg ai ha^{-1}

The application of diuron ametryne and simazine should be on clean fields (1 - 2 days) before or after transplanting. Bromacia on the other hand should be applied 2 - 4 weeks after transplanting. The application of the herbicide bromacil should be repeated after 16 weeks from first application.

(vi) *Disease and Pest Control*

Diseases	**Control**
Heart rot	Weekly sprays of Benomyl at 12g/10 litres of water or Thiabendozole at 10ml/10 litres of water twice a week in the rainy season using surfactant. Spraying should continue for 3 - 4 weeks.

Pests	**Control**
Planococcus citri	(i) Rosor 40EC at 20rnl/10Olitres of water, or (ii) Ambush at 5ml/10 litres of water for fruit treatment.
Carpophilus spp *Diapais bromehae* *Atherigona spp*	

Pests	**Control**
Fruit piercing moth *(A chea spp.)* fruit flies. *Coccus spp.*	(i) Agrothion 20EC at 50ml/ 10 litres of water. (ii) Ambush 25EC 5ml/10 litres of water. To be applied on a routine basis at fruiting stage. Apply Rogor 40EC at 5ml/ 10 litres of water.

Termites		Soil drench with Agrothion 20EC at 20ml/10 litres of water.
Nematodes	(i)	Furadan 3G at 4 - 8kg ai/ha depending on severity of infection.
	(ii)	Mocap 10G at 6kg ai/ha.

2.9.4 Plantain (*Musa paradisiaca, L.*)

(a) Area Under Crop

Plantain grows best in Southern Nigeria where there is good rainfall (1,000mm - 2,500mm and warm weather (20 - 35^{0}C). Plantain production is thus restricted to Rivers, Cross River, Akwa Ibom, Imo, Anambra, Edo, Delta, Ogun, Ondo, Ekiti and Oyo States.

(b) *Nutrient Requirements and Fertilizer Use*

Fertilizer Requirements: Results of several years of fertilizer research on plantain demonstrated the vital importance of the ratio, of fertilizer elements especially N and K in plantain production. Plantain needs about 100gN and 250g K per stand in split doses. Subject to soil test, apply 250 - 300kg N, 30 - 60kg P_20_5 550 - 625kg K_20 and 120 - 200kg Mg0 ha^{-1} either in three split doses at 2, 6 and 9 months after planting or in 4 split doses at 8, 16, 24 and 36 weeks after planting with the last dose at about flowering time. Potassium application at flowering ensures best fruit development. Also magnesium should be applied during the 3rd or 4th instalment. Lime may be applied to acidic soils at the rate of about 500g/ha. Application of fertilizer should be in a ring round each stand.

(c) Varieties and Other Cultural Practices

(i) Varieties: Plantain varieties are grouped 'into characteristic bunchy types namely, false horn, true horn, French horn and French. The commonest type in Nigeria is the false horn. High yielding varieties (5.2 - 16t ha^{-1}) include Agbagba, Red Ogoni, Bini, Kpite, Orishele and Double header, available at the National Seed Service, Iwo Road, lbadan, University of Ibadan and NIHORT Ibadan.

(ii) *Plant Population/Spacing:* Recommended plant population ranges between 1,111 - 2,500 plants ha^{-1}. Spacing of 2.5m x 2,5m (1,600 plants ha^{-1}) is recommended for sole cropping or when inter-planted with pineapple and cocoyam while a spacing of 3.5m x 3.5m (850 plants ha^{-1}) is required when planted to protect young cocoa trees. On the whole 2m x 3m or 2.5m x 2.5m give about 1,666 plants ha^{-1}; 2m x 2m and 2m x 2.5m give 2,500 and 2,000 plants ha^{-1} respectively while 2.5m x 3m and 3m x 3m give 1,333 and 1, 111 plants ha^{-1}, respectively.

(iii) *Land Preparation:* Choose fertile loamy soil, deep and well drained, not waterlogged soil. Swamps are not suitable but river banks provide good environment. Ensure the soil is rich in organic matter. In virgin or newly opened forest, fell the big trees only. Then cut down only the crowns and branches of small trees. Bulldozing and ploughing is not necessary. Only slash the undergrowth. Topsoil must remain undisturbed. Leave the weeds to grow for about two weeks and then spray with a systemic herbicide such as Glyphosate "Round up" or a combination of Gramoxone and Primextra.

Line up your field and dig holes 15 x 15cm x 20cm. If available, incorporate FYM or poultry manure (1kg/hole) before planting.

(iv) *Weed Control:* Where planting is carried out on a clean field, apply during at 3 - 4kg a.i. ha^{-1} on fairly clean field at planting and repeat at intervals of 12 - 16 weeks. Alternatively apply paracol at 4 - 6kg a.i.ha^{-1} 3 - 4weeks after field planting and repeat at intervals of 12 - 16 weeks. Where *Imperata Cylindrica* constitutes the dominant weed, the herbicide glyphosate (Round-up) at 3 - 4kg a.i.ha^{-1} should be used instead of paracol.

(v) *Disease and Pest Control*

Disease		**Control**
Sigatoka		Calixim (Tridemorphe) at 522g a.i.ha^{-1} in 25OL ha^{-1} Repeat treatment after 3 - 4 weeks.
Bunchy top	i	Gamalin or Agrothion 20EC at 25ml/10L of water
	ii	Destroy infected plants
Bacterial Wilt		Use of clean Planting material

Pests		**Control**
i.	Nematodes	Furadan at 2 - 3 g a.i./mat at planting and 5 - 7 months after planting .
ii	Borer or Weevil *(Cosmolites sordidins)*	"

(d) *Yielding Expectancy*

Farmers obtain between 5.5. - 12t ha^{-1}. By adopting recommended plant population of 1,600 plant ha^{-1} (2.5 x 2.5) and fertilization under sole cropping, up to 25 - 30t ha^{-1} had been recorded while at 2,500 plants ha^{-1} (2m x 2m) plantain yields of 40t ha^{-1} are feasible.

2.9.5 Pastures Grasses and Legumes

2.9.6 General agronomy

2.9.7 Areas of Production

Pasture grasses and legumes can be established in most parts of Nigeria. The specific conditions of the location, in terms of climate, soil as well as socio-economics will determine whether it is suitable for pasture production. A distinction can be made between the natural grasslands, mainly occurring in the northern, drier areas and sown pastures, which can also be found in the more humid parts of the country.

2.9.8 Pasture establishment

The first aim when establishing a pasture is to provide an environment which is favourable for seed germination, seedling emergence and growth, or favourable for planted vegetative material to initiate new roots and shoots. Another aim is the destruction or retardation of unwanted plants, which might otherwise dominate the sown species. A proper timing, an intelligent selection of species well adapted to the planting situation, and the use of high quality seed are other key factors determining the success of the establishment. A proper sowing rate should be employed and, especially in the case of legumes, it should be checked if any treatment is required to enhance

emerqence (sacrification, innoculation coating). Vegetative propagation is necessary for sterile plants (e.g. *Digitaria decumbens),* when seed supply is erratic or expensive or when the genetic stability of the seed is low (e.g. *Pennisetum purpureum)*. One should be aware that stem cuttings are more dependent on favourable moisture conditions. Older, hardened sterns are more reliable than young material. Planted pieces should preferably bear three nodes.
A proper fertilizer regime will enable the seedlings to establish more rapidly. The competitive strength of sown or planted species compared to weeds is increased by placement of fertilizer in a band below and preferably on one side of the seedling. Some fertilizers reduce pasture establishment if the seed is kept in contact. Rhizobia will be killed by acid single super-phosphate and reduction in viability of *Stylosanthes humilis* also occurs. Urea is damaging especially if the biuret content is high. The fluoride content of super-phosphate sometimes requires attention. These problems are greater on sandy than on clay soils.

No simple recipes are available for tropical pasture establishment. The farmer who understands the nature of the processes at work will be able to make decisions which will give maximum long term gains from the pasture.

2.9.9 Pasture management

The usual aim of pasture management is to keep animal production at optimum level. This requires an understanding of both the effect of the pasture on the animal performance and the effect of defoliation (removal of plant shoots through grazing or cutting) on the pasture. The, efficiency of pasture production can be considered in terms of three related systems:

(a) The amount of pasture grown per unit of environmental growth factor. This may be expressed in terms of radiation energy, water or soil nutrients.
(b) The amount of pasture harvested per unit of pasture grown.
(c) The amount of animal product obtained per unit of pasture harvested.

These factors interactively determine the overall productivity of a pasture. For instance when too much green material is removed the reproductive capacity of the pasture may be affected negatively leading to reduced yields both in forage quantity and in animal products. However, when insufficient material is removed, the pasture will mature rapidly resulting in reduced productivity and declining quality. It is the task of the pasture manager to keep the pasture in good condition to enable it to sustain optimal levels of animal production. The following points may be valuable when pursuing this objective.

<u>Frequency of defoliation</u>: How often plant material is removed.

<u>Intensity of defoliation</u>: How much plant material is removed, or how much remains.

<u>Timing of defoliation:</u> At which stage of the development of a plant and under what climatic conditions (for instance beginning or end of rainy season) the plant material is removed.

<u>Way of removal:</u> If the forage is cut the removal will be more uniform. If grazed, the removal will be less uniform and more spread in time, depending on stock density (number of animals in a field at one time), grazing pressure (relation between the amount of pasture and number of animals present) and the grazing system employed (rotational or continuous). Grazing animals recycle about 75 - 95% of the minerals ingested, however, the distribution is not uniform. For instance a single urination of a sheep may be equivalent to a fertilizer application of 430kg N ha^{-1} on the urine patch.

Fertilization: The quantity of minerals removed, either in the form of forage or animal products have to be returned to the pasture to maintain its productivity. So if high levels of production are to be achieved, high fertilizer levels have to be applied. A dry matter yield of 10 tonnes per hectare with a crude protein content of 15% will require at least an application of 240 kg N ha ' when no adjustments are made for leaching, volatilisation and immobilization in the soil.

Mixtures versus sole stands: Sole stands have the advantage that the forage being produced is uniform. The major disadvantage is the susceptibility to species-specific diseases and climatic hazards (i.e droughts, frost), which then will affect the whole pasture. Mixing of pastures will help to dilute these negative effects. However, difficulties may arise in maintaining the mixture. Heavy grazing may lead to disappearance of one species, whereas light grazing may offer one species the opportunity to out-shade the other. The problem is more severe in grass.

Legume mixtures: as the growth habit and rate of grass and legume species differ widely, the latter one being mostly the less productive in terms of total biomass. Legumes, however, can contribute to the nitrogen supply. of the pasture through their symbiosis with nitrogen- fixing bacteria, and to the, quality of the forage as their content of digestible nutrient is generally higher and decreases less rapidly than that of grasses.

2.9.9.1 Nutritive value of grasses and legumes

The quality of a pasture depends on the content of nutritive elements, the total production, the intake by the animal and the availability of nutrients. The two most important pasture elements related to pasture quality are digestibility and voluntary intake. This quality varies widely and is strongly influenced by factors such as: stage of maturity, fertilization, soil and climate. Generally, the quality of tropical grasses declines rapidly once the pasture matures. Tropical legumes have a higher quality (especially crude protein), which decreases less rapidly. Both in mature grasses and tropical legumes, the voluntary intake of grazing animals may reduce as the animal is facing more difficulties in selecting sufficient herbage of high quality.

2.9.9.2 Forage Species

In this section some of the important grass and legume species will be highlighted. However, it is not an exhaustive listing. (Tables 2.67 - 2.69).

2.9.9.3 Grasses

Before discussing some of the species in more detail, they have been briefly characterized in terms of advisable sowing rate, tolerance to drought and water logging, rainfall and soil requirements as follows:

Table 2.68 Agronomic Characteristics of grasses

TROPICAL GRASS	SOWING RATE kg/ha	TOLERANCE TO DROUGHT	WATER LOGGING	MINIMUM RAINFALL (mm)	SOIL PREFERENCE
Pennisetum purpureum Panicum	veg[1]	Fair	Poor	1,000	Versatile
Maximum	1 - 6	Good	Poor	600	Versatile
Andropogon	1 - 5	Good	Poor	600	Versatile
Gayanus Cynodon dactylon	1 - 3	Good	Fair	600	Versatile
Cynodon Plectostachynus	1 - 3	Good	Poor	500	Versatile
Brachiaria decumbens	3 - 6	Fair	Good	1,000	Versatile
Brachiria Mutica	2 - 5	Fair	Good	1,250	Versatile
Brachiaria rusisiensis	3 - 6	Fair	Good	1,000	Versatile
Chloris gayana	1 - 6	Good	Fair	650	Tolerate saline conditions
Cenchrus ciliaris	1 - 4	Very Good	Poor	350	Light-medium textured
Digitaria decimbens	veg[1]	Good	Fair	800	Versatile
Hyparrhenia rufa	1 - 4	Good	Fair	600	Versatile
Melinis minutiflora	1 - 4	Fair	Poor	1,000	Poor, well drained
Paspalum natatum	2 - 5	Fair	Good	750	Sandy light

Propagation vegetatively

Table 2.69 Recommended forage species for the different vegetation zone in Nigeria

SPECIES	COMMON NAMES	VEGETABLE ZONE				
		SDS	DS/SGS	NGS	SS	M
A. ***Grasses***						
Andropogon gayanus	Northen gamba	x	x	x	x	
Andropogon tectorum	Southern gamba	x	x			
Brachiaria decumbens	Signal grass	x	x	x		
Cenchrus ciliaris	Buffel grass	x	x	x	x	
Choris gayanus	Rhodes grass		x	x		
Cynodon dactylon	Bermuda grass	x	x	x		
Cynodon plectostachyus	Giant star grass	x	x	x		
Digitaria decumbens	Pangola grass					
Digitaria smutsii	Wolly finger grass		x	x		
Hyparrhenia rufa	Jaragwa grass	x	x	x		
Melinis minutiflora	Molasses grass	x	x	x		
Panicum maximum	Guinea grass	x	x	x		
P. maximum cv. gatton	Gatton panic		x	x	x	
P. maximum var trichoglume	Green panic		x	x	x	
Pennisetum clandestinum	Kikuyu grass					x
P. Pedicellatum	Kyaswa				x	
P. Purpureum	Elephant grass	x	x	x		
P. typhoides cv. Maiwa	Maiwa millet			x	x	
Setaria anceps	Setaria		x	x		
sorghum almum	Columbus grass			x	x	
Tripsacum laxum	Guatemala grass	x	x	x		x
B. ***Legumes***						
Calanus cajan	Pigeon pea	x	x	x	x	x
Centrosema pubescens	Common centro	x	x	x		
Desmodium intortum	Green leaf desmodium		x	x		x
D. scorpiurus	Samoan clover		x	x		
Gliricidia sepium	Almond blossom	x	x	x		
Lablab purpureaus	Lablab, Hyacinth bean	x	x	x	x	
Leuceana leucocephala	Leucaena	x	x	x		
Macroptilium atropurpureum	Siratro		x	x	x	
Macrotyloma axillare	Axillaris			x	x	
M. uniflorum	Horsegram bean		x	x	x	
Neonotonia wightii	Glycine		x	x		x
Peuraria phaseoloides	Peuro	x	x	x		
Stylosanthes guianensis cv Schofield	Schofiled stylo	x	x	x	x	
S. guianensis cv. Cook	Cook stylo		x	x	x	
S. hamata cv. Verano	Verano stylo		x	x	x	
S. humilis	Townsville stylo		x	x	x	

X - Recommended for the Zone **SDS - South of Derived Savanna** **NGS - Northern Guinea Savanna**
DS - Derived Savanna **SS - Sudan Savanna SGS - Southern Guinea Savanna** **M - Montane**

(a) *Panicum maximum (Guinea grass)*

A dense, erect, variable perennial grass, up to 3m high, forming dense tufts up 1.2m in diameter. It is a native and widely spread grass in tropical Africa and has been widely introduced in the tropics, including India and the New World.

It is very palatable to livestock in all its stages and is one of the best fodder grasses of the tropics. For satisfactory growth it requires soils of reasonable fertility and adequate moisture, especially the cultivar Riversdale performs well under humid tropical conditions (1300mm).

(b) *Adropogon gayanus (Gamba grass)*
A. gayanus is an erect tufted perennial of 2m high, native of tropical Africa. It is adapted to a wide range of soil types, can tolerate a long dry season and has produced good results in the northern regions of Nigeria and Ghana. It can be planted by seed and persists well under grazing, but is only palatable before it flowers. It can also be made into hay and is useful for planting on bonds as an anti-erosion measure.

(c) *Cynodon dactylon (star grass, Bahama grass, Bermuda grass)*
C. dactylon is a long-lived spreading perennial, 6-90 cm high, widely dispersed over the tropical regions and the warm countries of the world flourishing under a wide range of habitats, but not tolerating shade. It is said to be native on sandy shores in South-West England C. dactylon is extremely variable in habit, with long rapidly growing runners and rhizomes, blished, it is difficult to eradicate. Being one of the most drought resistant grasses it remains green longer than any other grass. The response to fertilizer and manure is good especially when the soil pH is high. Propagation is usually done vegetatively. It is very palatable when young and can withstand heavy grazing.

(d) *Cynodon plectostachus (signal star grass)*
C. plectostachyus, which is not very distinguishable from C. dactylon, is more robust and less variable. It occurs in East and West Africa and provides valuable grazing. Particularly during dry weather.

(e) *Brachiria decumbens (signal grass)*
B. decumbens is a trailing perennial, with stolons rooting at the nodes, native of tropical Africa. In Africa, it is one of the best nature pasture grasses, with considerable value as a bottom grass. Several well marked ecotypes occur. It is palatable at all stages and persists well under rotational grazing showing a good recovery. Its seed production is limited. It is usually planted by divisions or stem cuttings. Because of its vigorous growth, it is rather difficult to combine it with a legume. Desmodium heterophylum seems able to persist when well managed.

(f) *Brachiria mutica (para grass)*
B. Mutica is a trailing perennial up to 2m high, with long rooting stolons, native of poorly drained soil in South America and West Africa, and now widespread at low altitudes in the tropics. Drought resistance is low and is propagated vegetatively. As it requires careful management when grazed, it is more commonly used as silage. When grazed, it combines well with Centrosema pubescens.

(g) *Brachiria ruziziensis*

B. ruziziensis is a leafy semi-prostrate rhizomatous species adapted to humid frost free condition. It is less vigorous than B. decumbens and B. mutica and therefore combines well with legumes. Seed yield is high, but they require storage and acid storage and acid scarification to reduce seed coat impermeability for germination.

(h) *Chloris gayana (Rhodes grass)*

C. gayana is a perennial grass, 0.5 -1.5m high, native to East and South Africa between 700 - 1000m, and is the dominant natural grass in considerable areas. A number of ecotypes are recognized, some of which are annuals. Erect tufted forms occur, while other are stoloniferous and turf-forming. It can be growth under a wide range of habitats, is palatable to stock at all stages and produces a satisfactory bulk of grazing, fodder or hay. Propagation can be easily done by seed. It is advisable to keep the seeds for a year before sowing, as fresh seed often gives poor germination. Major attributes of this grass are its ease of establishment, rapid ground cover, tolerance of high soil salinity and heavy grazing. C. gayana (has been reported to combine well with the following legumes). Centrosema pubesccens, Clittoria terneata, Desmodium uncinnatum, Glycine wightii, Macroptilium atropurpureum, Stylosanthes guiane sis, Stylosanthes humilis and Trifolium repens. However, it requires high levels of management to maintain the legume component.

(i) *Cenchrus ciliars (African foxtail butter grass)*

C. *cliliars* a perennial grass is found in the drier areas of tropical Africa between sea level and 2000m. Many exotypes are available, including turfted erect froms suitable for hay and decumbens rhizomatous forms suitable for pastures. It is only palatable when young, but persists well under grazing and can be planted by seed both as permanent crop and in legume mixtures like Stylosanthes humilis and Macroptilium atropurpureum.

(j) *Digitaria decumbens (pangola grass)*

D. decumbens is an outstanding grazing grass in humid parts of Central America and the Carribean, originating from South Africa. It forms a dense leaf seeds, propagation is high, and is vigorously stoloniferous. As it does not produce fertile seeds, propagation is vegetative by the stolons which may be spread on the soil surface and then disked. It is extremely competitive and crowds out nearly all the less valuable grasses and weeds. Under a wide range of climatic and soil conditions, however, it does not tolerate water logging. The palatability to all domestic stock is high and it can stand heavy grazing. It responds well to heavy dressings of nitrogen. (much of which finds its way into the herbage). Pangola grass may combine with Centrosema pubescens, Pueraria phaseoloide, Desmodium heterophyllum and Calopogonium mucunoides. A stunting virus, transmitted by the aphid Sogata fructifera gives reason for concern.

(k) *Hyparrhenia rufa (Jaragua grass, thatchir grass)*

H. rufa a tufted perennial of 1.5m high, occurs commonly throughout tropical Africa. It requires a relatively high rainfall, is palatable when young and recovers quickly from grazing or cutting producing a thick close sward on good land. Propagation can be done by either seed or root divisions.

(l) *Melinis minutriflora (molasses grass)*
M. minutriflora is a various, hairy, strong, smelling, spreading perennila, up to 1.5m high, native to tropical Africa. It grows best on well drained soils in areas of moderate rainfall from sea level to 2000m. It has very distinctive odour, does not appear to taint milk or meat. Molasses grass is easily propagated by seed and forms a close sward under good management. This species is susceptible to fire and can be eradicated by burning. It combines well with legumes as *Glycine wightii*, Desmodium spp and *Macroptilium atropurpureum*.

(m) *Paspalum notatum (Bahia grass)*
P. notatum is a rhizomatous, stoloniferous, deep rooting tufted perennial, 50 - 100cm tall, which is native of tropical America. Bahia grass forms a dense cover and is valued for its productivity, relative ease of establishment and persistence. Being an aggressive species stable mixtures are difficult to maintain.

(n) *Setaria sphacelata*
S. sphacelata is a variable perennial grass, 0.5 - 2m tall, occurring commonly in natural grassland in tropical Africa. Usually compactly tufted but free-tillering forms with long creeping stolons are known. The grass is palatable, with a high nutrient content, but has a tendency to early flowering. It can be used for grazing, hay and silage. Propagation can be easily done by seed.

2.9.9.4 Legumes

Before discussing some of the more relevant species in more detail an attempt has been made to compose a quick review regarding their advisable sowing rates, tolerance to drought and water logging and rainfall and soil preferences as follows:

(a) Calopogonium mucunoides (calopo)
C.mucunoides is a vigorous creeping and twining, hairly herb forming a tangled mass of foliage 30 to 45cm deep. Stems succulent, covered with long brown hairs, creeping in lower part; root at nodes which come in contact with the soil, upper part of stems becomes twining. Leaves are trifoliate; leaflets are hairy on both surfaces, smaller than those of *Pueraria phaseolodies*. Terminal leaflet are is broadly ovate to ovate rhomboid, lateral ones are obliquely broadly ovate, about 4 to 5cm long and a little less wide. Flowers are white with greenish-yellow blotch. Pods linear, compressed 2.5 to 4cm long, yellowish-brown, densely covered with long erect hairs, 4 to 8 seeded. Originating from latin America, it is well adapted to the hotter, wetter tropics and can be found in the tropics up to an altitude of 2000m, however prefers low altitudes. Seeds while have to be scarified, can be broadcast on a roughly prepared seed bed or from the air into the ashes after a burn. Oversown into natural pastures under wet moist conditions it should establish well. It grows with all the tall grasses such as *Panicum maximum, Hyparrhenia, Stetaria Brachiaria and Melinis* and, persists with pangola grass if carefully grazed. Calopo recovers slowly after grazing. Once well established it can be cut or grazzed at 8 -12 weeks interval. It is relatively unpalatable before flowering, after which palatability has been reported to increase.

Table 2.70 Agronomic Characteristics of Legumes

TROPICAL LEGUME	SOWING RATE kg ha^{-1}	TOLERANCE TO DROUGHT	WATER LOGGING	MINIMUM RAINFALL	RHIZOBIUM REQ.	SOIL PREFERENCE
Calopogonium mucunoides	1 - 3	Fair	Fair	1,200	Cowpea	Versatile
Centrosema pubescens	3 - 5	Fair	Good	1,200	Specific	Versatile
Desmodium heterophyllum	1 - 2	Fair	Good	1,500	Specific	Versatile
Desmodium intorturn	1 - 2	Fair	Good	900	Specific	Versatile
Desmodium uncinatum	1 - 3	Fair	Poor	900	Specific	Versatile
Lablab purpureus	10 - 20	Good	Fair	600	Cowpea	Versatile
Macroptillium atropurpureum	1 - 3	Good	Fair	600	Cowpea	Versatile
Macroptillium lathyroides	1 - 3	Fair	Very Good	750	Cowpea	Versatile
Macrotyloma axillaris	3 - 5	Good	Fair	1,000	Cowpea	Well drained
Pueraria phaseoloides	1 - 3	Poor	Good	1,250	Cowpea	Heavy, tolerates acid soil
Stylosanthes Guianensis	2 - 5	Good	Fair	850	Cowpea	Versatile
Stylosanthes humilis	3 - 6	Good	Poor	600	Cowpea	Versatile well drained
Cajanus cajan	1.5 - 4	Good	Poor	625	Cowpea	Versatile
Gliricidia sepium		Fair	Poor	800	Cowpea	Versatile

(b) *Centrosema pubescens (Centro)*

Centrosema pubescens is a vigorous twining and climbing perennials herb, which in pure stands forms a compact dense cover 40 to 45 cm high in 4 to 8 months from sowing. It is very leafy and the slightly hairy stems do not become woody for at least 18 months. Leaves are trifoliate; leaflets are dark green elliptic or ovate elliptic, obtuse or shortly obtusely acuminate, slightly hairy, especially on the lower surface. Flowers are bright or palelilac on either side of a median greenish-yellow band with numerous dark violet stripes or blotches. Pods are linear with prominent margins.

Native to Latin America it is now widely grown in the tropics below 600m. Although it prefers the humid tropics it also grows in areas receiving 750mm rainfall. It can be easily propagated by seed, which have to be scarified and inoculated, and will establish quite well in roughly prepared seed beds provided fertility requirements are met. Under certain conditions it can be oversown in existing pastures.

It grows well with *Panicum maximum, Hyparrhenia rufe, Melinis minutiflora, Chloris gayana, Pennisetum purpureum* and *paspalum notatum*. With *Brachiaria mutica and Digitaria decumbens* it is less successful. Once well established this fairly palatable legume persists quite well under grazing, provided that the grass is kept in check at a height of 37.5 to 45 cm and it is not grazed too low. It provides good quality feed during the dry season; in the rainy season, however, intake is generally low.

(c) *Desnodium heterophyllum*

D. *heterophullum* is a perennial prostrate creeper with reddish - brown, hairy stems which branch freely and root at the nodes. Leaves are trifoliate, the terminal leaflet slightly larger and on a longer stalk than the two lateral leaflets. Flowers are small reddish-pink about 3mm long and the indented pods contain 3 to 6 seeds Native to the eastern hemisplane, it occurs in many countries in Asia. It can be propagated by cuttings or seed which have to be scarified, inoculated and sown in a well prepared seed bed.

It combines well with *Brachiaria decumbens, B. humidicola and digitaria decumbens*. This slightly unpalatable legume is highly tolerant of defoliation and withstands heavy grazing. It is advisable to keep the companion grass short.

(d) *Desmodium intortum*

This large trailing and climbing perennial roots at the nodes and has a deep taproot. The long pubescent stems branch freely and are often reddish brown. Leaves usually have reddish-brown to purple flecking on the upper surface. Leaflets. 2 to 7cm long and 1.5 to 5.5cm broad, with length-width ratio of 1.4 to 1, are shorter and more rounded than in *Desmodium uncinatum*. Flowers are deep lilac to pink and seed pods adhere to animals and clothing.

Originating from Latin America it is now widespread in the tropics where the altitude is not more than 2500m above sea level. It can be propagated by seeds or cuttings, however, it does not spread well from natural seeds. The seeds which require no scarification when harvested mechanically need to be innoculated. They can be sown by drilling broadcasting on land or from the air preferably in a well prepared seed bed. Oversowing in existing pastures is generally not successful because of the low seedling vigour. It grows well with *Setaria sp. Panicum maximum, Pennisetum purpureum and Melinis munitiflora*.

This well grazed legume has high yield potential in frost free areas of good rainfall. Care should be taken not to overgraze it. Unfortunately in some areas, the leaves, flowers and roots have been attacked by various pests.

(e) *Desmodium uncinatum (Jacq. D.C., Silver Leaf)*
D. *uncinatum* is a large rambling perennial with cylindical or angular stems, densely covered with short, hooked hairs which easily make the stems to adhere to hands, clothing etc. Leaves are trifoliate with ovate leaflets, 3 to 6cm long and 1.5 to 3cm wide, dark green on the upper side with an area of white shiny surface near the central vein, often surrounded by dark shiny area. The flowers on long paired racemes are pink when flowering and turn bluish afterwards. The sickle shape segmented pods are densely covered with hooked hairs which easily adhere to clothing. Native to South America it is now wide spread through the tropics and subtropics up to an altitude of 1800 - 2500 meters.

Machine - harvested seeds do not require scarification. Innoculation with special Desmpdium strain and lime pelleting is advisable. Although the best establishment is achieved in a well prepared seed bed, it is planted successfully on roughly cultivated land. Oversowing in existing pastures is generally not successful. The seed can be drilled or broadcast both on the ground and from the air.

This fairly palatable legume combines with *Setaria spp., Panicum ssp., Paspalum spp., Chloris gayana and Pennisetum purpureum*. Once well established D. uncinatum can produce abundant good quality herbage, when it is not grazed or cut too low. As with D. *intortum* some pests have caused severe damage in some areas.

(f) *Lablab purpureus (L) sweet*
L *purpureus* is a rampant and vigorously twining herbaceous annual or short-lived perennial with robust stems (3-6m) and trifoliate leaves. Leaflets are broad, ovate-rhomboid, 7.5 to 15cm long, broadly scimitar shaped, smoothly above and shortly hairy underneath. Flowers are white, blue or purple. Pods are 4 to 5cm long, broadly scimitar shaped, smooth and beaked, containing 2 to 4 seeds. It is widespread throughout the tropics up to an elevation of 2000m. In some places it is grown as a food crop. It can be easily propagated by seed which does not require scarification. Innoculation with a cowpea type strain is advisable. Lablab performs best when drilled into a well prepared seed bed, but it can be planted by broadcasting into roughly ploughed or cultivated land if the seed is covered to some extent. Usually it is not combined with grasses because of its slow early growth and short life. Once animals have become used to it they eat it readily. One should watch for bloat when grazing pure stands. Although Lablab is short lived it can supply abundant quantity of high quality feed.

(g) *Macroptilium atropurpureum (DC) Urb. (Siratro)*
M. atropurpureum is a deep rooting perennial with trailing pubescent stems which may root anywhere along their length, especially in moist clay soils but rarely in drier sandy soils. Leaves are pinnately trifoliate, dark green and slightly hairy on the upper silvery and very hairy on the lower surfaces. Inflorescence is a raceme with 6 to 12 deep purple flowers, with a reddish tinge near the base of the petals. Pods are straight, about 7,5cm long and many seeded. Originating from Latin America it is now widespread in the tropics, up to altitudes of 1,600m.

For propagation it is preferably drilled into a well prepared seed bed, but it can be broadcast from the ground or air into roughly prepared ground or the ashes of a burnt forest. Seed requires scarification, inoculation is not necessary, but advisable. Siratro grows well with *Setaria spp., Chloris gayana, Cenchrus ciliaris and panicum maximum*. This palatable legume does perform well under intensive defoliation, so it should be grazed lightly at all times to make full use of its productivity.

(h) *Macroptilium lathyroides (L) Urb*
M. lathyroides is a herbaceous annual or short-lived perennial, erectly branching 0.5 - 1m high under normal conditions, lower parts becoming some what woody. When grown under shade, in association with taller grasses or sown early, it assumes a twining habit and may attain 1.2m. Leaflets are ovate or lanceolate 3,5 to 7.5cm long. Inflorescence consists of semi erect racemes with red-purple flowers. Pods are subcylindrical, 7.5 to 10cm long and 5mm wide, slightly curved with approximately 20 seeds. Originating in tropical America, it is now widespread in the tropics up to 1,800m. Seed require scarfication, though inoculation is not needed. It can be drilled or broadcast into a preferably well prepared seed bed. With poor cultivation establishment will be less successful. Under swampy conditions, it can be combined successfully with *Brachiaria mutica,* on well drained soil it grows well with *Panicum maximum and Setaria anceps*.

M. lathyroides does not perform well when intensively defoliated, so a moderate growing legume should employed. Young plants appear to be less palatable than seedling plants. This rapid growing legume is especially valued as pioneer species. It is susceptible to bean-fly and nematode attack.

(i) *Macrotyloma axillaris (E mey) Verdc.*
M. axillaris is a trailing and twisting legume with hairy stems and bright green ovate leaflets 3 to 5cm long and 3cm wide, slightly pubescent but glossy. Flowers in racemes with 3 greenish - yellow flowers. Pods are slightly curved, hairy 3 to 5cm long and 6mm wide, 7 to 8 seeded. It is widespread in tropical Africa, but occurs also in other continents up to an elevation of 1,200m. Seeds do not require sacrification or inoculation although the latter is advisable. It can be drilled or broadcast in preferably well prepared seed bed, although the legume establishes also on roughly prepared land

M. axillaris grows well with *Setaria spp., Paspalum spp., Chloria gayana, Desmodium spp* and *Macroptilium atropurpureum*. This productive legume withstands a moderate grazing legume, i.e. rotational grazing to a height of 15cm. It is disease resistant.

(j) *Pueraria phaseoloides (Roxb.) Benth. (Puero tropical Kudzu)*
P. phaseoloides is a vigorous twinning and climbing, slightly woody, hairy, deep rooting perennial legume. It may form a tangled mass of vegetation 60 to 75cm deep within 8 ro 9 months of sowing. The young shoots are densely covered with brown hairs. The leaves are trifoliate and leaflets are thin, triangular-ovate and very shallowly lobed. Small mauve to deep purple flowers are borne in scattered pairs in racemes about 15 to 30cm long. The pods are straight or slighty curved, cylindrical, 7.5 to 8.5cm long, thinly clothed with stiff adpressed hairs. Native to southeast Asia it is now widespread though-out the wet tropics, generally below 600m. Seed requires scarification and inoculation is advisable. As early growth is slow, it is best sown (drilled or broadcast) into a weed free seed bed.

P. phaseoloides grows well with *Melinis minutiflora* and *Panicum maximum,* but cannot persist with Brachiaria and Digitaria decumbens. This very palatable legume tolerates moderate grazing, so it should be leniently grazed at all times.

(k) *Stylosanthes quianensis (Anbl.) Sw c.v. Schofield*

This is an erect growing herbaceous perennial with branching upright stems up to 1m tall, which may become more prostrate under grazing. Stems are hairy and become woody at the base with age. The leaves are pinnately trifoliate with elliptic leaflets 15 to 55mm long 7 to 13mm wide. Inflorescence consists of several spikes of a few yellow flowers. Pods are hairy with one fertile joint and a very small beak. The main taproot extends to 1 meter.

Native to Latin America it is now widespread in the tropics up to 2,000m above sea level. Seeds do not require scarification if harvested mechanically. When sown on new land inoculation is advisable. It can be sown without land preparation or with only one cultivation, when necessary (e.g. on erosion terraces) it can be planted by cuttings. Oversowing into natural pastures is quite successful, particularly on sandy soils in areas of adequate rainfall, as is the case of *Imperata* grasslands. As there are very few growing points left on the mature plant defoliation has to be planned carefully. Stylo should be grazed lightly for instance in a rotation of one week on, four to eight weeks off. Tall grasses should be prevented from shading the stylo. It is relatively unpalatable in the early stages of growth. Although the protein content is relatively low it offers one of the best opportunities to raise the productivity of natural grasslands, when fertilizer prices are high, because of its low phosphorus requirements.

(l) *Stylosanthes humilis (Townsville stylo)*

S. Humilis is a self regenerating, self-fertile summer annual or short-lived perennial legume with trifoliate leaves and branched stems, ascending or prostrate. It can reach a height of 0.7m. Leaflets are lanceolate, narrow and pointed. Six, or more single seeded pods are produced in one seed head. Under heavy grazing or when plant stems rest on moist soil, adventitious roots are formed on the stem several centimeters away from the taproot.

Native in Latin America it is now widespread in the tropics up to 1,500m. The seed does not require treatment to break dormancy as hard seed is an advantage under the irregular climatic conditions in which it is normally sown. No specific inoculation is needed. Seed can be drilled or broadcast in a seed bed, where at least competing tall plants have been removed. Oversowing into a natural pasture can also be successful.

It does not prosper with tall grasses. S. humilis can be heavily grazed to suppress companion grasses, except during the period of seed setting. It is not readily eaten in the young stages but increases in palatability as it matures. It is adapted to poor soils of low fertility due to its efficiency in extracting calcium and phosphorus and its tolerance of manganese and aluminum. The overall productivity is, however, low.

(m) *Cajanus cajan (L) Mill ssp*

C. cajan is an annual, or more usually short-term perennial shrub growing to 4m high, but usually 1 to 2m, woody at the base. Leaves are narrow-lanceolate and hairy. Yellow brown or purple flowers are borne in terminal racemes. Pods are usually short (5 to 6cm) though long podded types occur. It has an extremely deep-rooting tap root.

Originating in India and Africa it is now found in many tropical countries. Essentially, it is a plant of the semi-arid lowlands and should not be planted above 770m. Seeds do not require scarification or inoculation. It is being sown in deeply ploughed seed beds. *C. cajan* does not withstand heavy grazing. The plant should be allowed to develop well and then lightly grazed or cut at about 80cm. This palatable legume is more adapted to high elevation than *Leucaena leucophala*. Its forage usually contains a high proportion of good quality seed.

(n) *Gliricidia sepium*

Gliricidia sepium is a tree growing up to 15m with bipinnate glabrous leaves pinnate. It occurs in 3 to 11 pairs, leaflets are wedge-shaped at the base, acute at the top, 2.25 to 6cm long. They are light green on the surface, pale, underneath with bronze spots. Flowers are pedicellate, isolate glabrous, 1.8cm long. The pods are glabrous 22cm long and 1,5cm broad.

Native to Mexico and the West Indies, it is now widespread in tropical plantation agriculture. It can be propagated by cuttings or seed. Used as a living fence, the early increment of new growth can be lopped for fodder. Planted in hedges between alleys of crops it can also serve as an excellent source of green manure and animal feed. Productivity in the dry season is, however, low as it tends to shed its leaves.

(o) *Leucaena leucocephala (Lam.) de Wit*

L. leucocephala is a small tree with bipinnate leaves. Pinnae occur in 4 to 9 pairs on a rachis 15 to 30cm long. Leaflets are oblong-lanceolate 2 to 3.5mm wide, 7 to 10mm long. The inflorescence consists of many small white flowers. Pods are thin and flat up to 20cm long and 2cm wide, acuminate. It has a very deep root system. Originated in Mexico it has spread through out the tropics. Seeds require scarification and inoculation. Seeds can be drilled in a well prepared seed bed. Once well established Leucaena stand defoliation through grazing or cutting quite well. The toxic component mimosine and its derivate di-hydroxy-pyridine (DHP) limits its use to livestock. Recently, however, a DHP degrading bacteria has been discovered in the rumen of goats in Hawaii, which can be successfully transferred to other ruminants. Leucaena is an outstanding producer of large quantities of fodder of high palatability and high protein content.

A devastating pest of Leucaena has been reported. The psyllid insect, *Heteropsylla cubana,* causes considerable defoliation. Adults and nymphs feed on old and new growth but the nymphs do the most damage by excreting a sticky fluid which prevents the development of the remaining foliage. Infected trees are more susceptible to diseases under drought stress or if they are heavily pruned, may die.

2.9.9.5 Management of Forage Grasses

2.9.9.6 Gamba (Andropogon *gayanus*)

Gamba is a tussocky polymorphic perennial, 2 - 3m tall that is widely distributed through out the savanna zones in Nigeria. Its ease of establishment, good ability to grow on soils of low fertility, draught resistance and fire tolerance make it an ideal grass for re-vegetating over-grazed and eroded grasslands. Southern Gamba *(Andropogon tectorum)* is common in the Southern Guinea Savanna and Rain Forest zones.

(a) *Cultural Practices*

Gamba is commonly established by seed on a well-prepared seed bed. Occasionally, vegetative propagation is used where small areas are involved. Broadcasting seed into burned range land is also common. Seed rates depend on seed purity and germination percentage. On average a seed rate of 20 - 30kg per hectare will give good establishment. It forms good mixtures with centro, sirato, stylo and verano stylo.

(b) *Fertilizer Recommendation*

(i) *Sources and Rates*

Generally, higher nitrogen levels are required under high rainfall regimes of the Southern Guinea and Derived Savannas than in the Northern Guinea and Sudan Savannas. Thus 200kg N ha^{-1} is recommended for the higher rainfall areas compared with 100kg N ha^{-1} for the lower rainfall areas. 200kg N ha^{-1} is equivalent to about 769, 952, 435 and 1,000kg N ha^{-1} of CAN, Ammonium nitrate, urea and 20-20-0 NPK respectively, corresponding to about 15.5, 19, 8.5 and 20 bags. Two bags of single super-phosphate (18kg P_20_5) per hectare are expected to supply adequate phosphorus to the grass for proper nutrition. When grown in mixture with legumes only 25 - 50kg N ha^{-1} are applied at the establishment stage and thereafter no further N application is necessary as the legumes are expected to produce symbiotic N for the system.

(ii) *Time of Application*

A single dose of nitrogen at the onset of heavy rains is recommended. Generally, nitrogen should be applied after each cut of the pasture.

(c) *Yield Expectancy*

Northern gamba *(Andropogon gayanus)* produces 7 - 12 tonnes of dry matter per hectare depending on rainfall pattern and time of cut. Pastures cut once at the end of the growing season produce high dry matter yields with lower crude protein content than pastures cut more frequently. Seed yield is about 200 - 300kg ha^{-1} but seed shedding is high. Shed seeds are better gathered from the ground.

2.9.9.7 Signal grass (Brachiaria *decumbens*)

Signal grass (palisade grass) a coarse, rhizomatous and tussocky perennial is native to tropical Africa, and is indigenous to Nigeria. The stolons root and branch at the nodes forming very dense tufts that reach 1.5 to 2m in height. It is adapted to a range of soil types and weather conditions, growing best in areas receiving 1,200 to 1,800mm rainfall per annum. It is however, highly drought-resistant, remaining green well into the dry season.

(a) *Cultural Practices*

Signal grass is regarded as setting little or no viable seeds, and has been established generally from sprigs or stem cuttings. Rooted stolons establish better than unrooted ones. The best establishment occurs on well-prepared seed bed. Sprigs should be spaced 60 x 60cm or 30 x 90cm. Good establishment is possible from viable seeds that have been stored for 9 months or more after seed harvest. Signal grass is quite vigorous, and out competes with associated legumes, unless the pasture is managed properly to maintain legume balance. Because of its extreme vigour, it is usually grown sole.

(b) *Fertilizer Recommendation*

(i) *Sources and Rates*

Under high rainfall and irrigated conditions (1,500 - 2,000/yr) the recommended nitrogen fertilizer rate is 400kg N ha^{-1}/year but only half (200kg N ha^{-1}/year) is required for lower rainfall areas. The 400kg N ha^{-1} should be applied in two equal doses. The second application should be after the first crop has been grazed or cut. Phosphorus fertilizer is applied at the rate of 18kg $P_2 0_5$ ha^{-1} at establishment and repeated every two years.

(ii) *Time of Application*

Apply N and P at planting. For an existing pasture, apply N and P early in the wet season.

(c) *Yield Expectancy*

Herbage yields tend to vary with nitrogen level, season and frequency of cuts. Yields in excess of 20 tonnes ha^{-1}/year can be obtained when 400kg N ha^{-1} is applied. On the average, 10 - 15 tonnes of dry matter is expected.

2.9.9.8 Buffel Grass (*Cenchrus ciliaris*)

Buffel grass is a tussocky deep-rooted perennial that is native to Africa, India and Indonesia. It is tolerant to drought, fire and heavy grazing, but intolerant of prolonged flooding. It is adapted to a wide range of soil conditions. In Nigeria it grows well in the Savanna and Rain Forest areas producing high yields of herbage and seed.

a) *Cultural Practices*

Buffel grass is established from seed. Where seeds are not available, vegetative propagation can be practiced. Seeds are sown by hand-broadcasting or drilling with a tractor into well-prepared seed bed at the rate of 10kg ha^{-1}. Seeds should be planted as soon as steady rains have been recorded, and planting can be done be up to six weeks to the end of the rains. It grows well under irrigation. It forms good mixtures with legumes such as stylo, verano, centro and siratro.

b) *Fertilizer Recommendation*

i) *Sources and Rates*

Buffel grass is a phosphophylic plant and so requires higher dosage of phosphorus fertilizer than most of the grasses, Studies at NAPRI, Shika have however, shown that Buffel requires up to 400kg N ha^{-1}/year. This is equivalent to about 1538, 1904, 870 and 2,000kg ha^{-1} of CAN, Ammonium nitrate, Urea and 20-10-0 NPK respectively, corresponding to about 31, 38, 17 and 40 bags of 50kg each. However, the recommendation for both herbage and seed production is only 100kg N ha^{-1} for the Northern Guinea and Sudan and 150kg N ha^{-1} for Southern Guinea to Rain Forest areas where annual rainfall is higher.

ii) *Time of Application*

Four bags (36kg $P_2 0_5$) per hectare of single super-phosphate is applied at establishment. At every other two years, an application of two bags (18kg $P_2 0_5$) per hectare is recommended. When grown in mixture with legumes, nitrogen fertilizer application rate of 50kg N ha^{-1} is required but only in the establishment year.

Yield Expectancy

Under rainfed conditions, herbage dry matter yields in the savanna zones of 6 to 8 tonnes ha^{-1} are common. Yields of up to 15 tonnes per hectare are possible under irrigated conditions.

2.9.9.9 Rhodes Grass (*Chloris gayana*)

Rhodes grass is a tufted, stoloniferous perennial. It is a very variable species with innumerable natural varieties differing in vigour, leaf, stem and stolon sizes. It is versatile in soil and climatic requirements, and tolerant to limited water-logging. It tillers profusely and grows up to 1.5m tall. Herbage production is best in areas receiving 1,000 - 1,800mm annual rainfall.

a) *Cultural Practices*

It is normally established from seeds at the seed rate of 10kg ha^{-1}. Lower seed rates can be used if sowing is by drilling. It is used both as a ley and permanent pasture. Its ability to provide rapid ground cover after establishment and stoloniferous nature make it ideal for use in soil erosion control. It combines well with centro, siratro stylo and verano stylo.

(b) *Fertilizer Recommendation*

i) *Sources and Rates*

It responds strongly to fertilizer nitrogen producing up to 12 tonnes of dry matter per hectare with 100kg N/ha application. Under irrigation, 200kg N/ha are recommended for both herbage and seed production. 100kg N/ha is equivalent to about 385, 476, 217 and 500kg of CAN, Ammonium nitrate urea and 20-20.0 NPK respectively, corresponding to 8, 9.5, 4 and 10 bags. An application of 18kg P_20_5 or 100kg single super-phosphate is recommended at the establishment phase, and this should be repeated at two-year intervals. Use only 25 - 50kg N ha^{-1} at establishment if Rhodes grass is grown in mixture with legumes.

ii) *Time of Application*

A single dose at the onset of rains for pasture that is for continuous grazing of hay production. For a cut and carry or rotationally grazed pasture, a top-dressing is advisable three months after the first nitrogen application.

(c) *Yield Expectancy*

Herbage dry matter yields of 3 - 4 tonnes per hectare are possible when unfertilized, and 10 - 15 tonnes ha^{-1} when fertilized. Under irrigation, dry matter yields of 18 tonnes ha^{-1} have been obtained in Northern Guinea Savanna when fertilized at 200kg N ha^{-1}. Seed yields range between 400 - 60kg ha^{-1} at 200kg N ha^{-1} application.

2.9.9.9.1 Woolly Finger Grass (*Digitaria smutsii*)

Woolly finger grass refers also to *Digitaria pentzii*. *Digitaria smutsii* is a densely tufted, and stoloniferous perennial grass that grows up to 60cm tall. It roots readily at the nodes when they touch the ground. Its growth is restricted to the wet season, but it responds well to irrigation during the warmer months (February - May). It responds readily to early rains and will give grazeable material within four weeks of steady rains, say, April to May. Because of its rapid ground cover after establishment, it is used in soil erosion control. It suppresses associated tufted legumes because of its growth habit. It is adapted to a range of soils and weather conditions, and grows best in the rainfall range of 1,000 to 1,500mm per annum.

(a) *Cultural Practices*
It does not produce viable seeds. Establishment is by vegetative propagation rooted nodes are planted t either 60 x 60cm or 60 x 90cm apart. Establishment is rapid giving complete ground cover within six weeks. It combines well with climbing legumes like centro and siratro but poorly with tufted legumes which it suppresses.

(b) *Fertilizer Recommendation*
It responds markedly to nitrogen fertilizer application. No firm recommendations are available. Research data, however, show that 100kg N ha^{-1}/year is adequate. Phosphorus fertilizer applied at 18kg P_20_5 ha^{-1} at establishment enhances rapid establishment and growth.

(c) *Yield Expectancy*
Herbage dry matter yields range from 2.5 tonnes ha^{-1} at zero nitrogen application to 8 tonnes ha^{-1} when 100kg N ha^{-1} is applied.

2.9.9.9.2 Guinea Grass (*Panicum maximum*)
Guinea grass is an erect bunch type perennial which is native of tropical and sub-tropical Africa. In Nigeria it is most common in the riverine areas of Southern guinea savanna and Rain Forest Zones. It grows to height of 4m or more. It is polymorphic the differences being in leaf shape, leaf size and height. It is shade-tolerant forming good combination with legumes under trees and tree crops. It grows best on well-drained sandy-loam and loamy sand soils, tolerating moderate levels of acidity.

(a) *Cultural Practices*
It produces viable seeds which shed easily, and this makes large-scale manual seed harvesting of guinea grass seeds rather tedious. As a result of this difficulty, propagation is usually by vegetative means in Nigeria. The crowns with 15 - 30cm of attached stems are planted at 60 x 60cm spacing. Nitrogen application at establishment promotes early tillering and ground cover. It combines well with stlyo, and centro. It can be successfully grown under irrigation.

(b) *Fertilizer Recommendation*
Nitrogen is the principal nutrient required for rapid growth. Nitrogen fertilizer at the rate of 200kg N ha^{-1} in the presence of 18kg P_20_5 ha^{-1} are recommended for guinea grass. Two doses of nitrogen may be used per year. N doses of 100kg and below are best applied as a single dose.

(c) *Yield Expectancy*
About 15 - 20 tonnes DM/ha/year are common from pastures fertilized at 200kg N/ha. Unfertilized pastures yield 3 - 5 tonnes DM ha^{-1}/year. Flowering in guinea grass is profuse but caryopses content of florets is low. This coupled with a high degree of seed shedding gives seed yields as low as 50 - 100kg ha^{-1}. The seed has post-harvest dormancy period of 6 to 18 months.

2.9.9.9.3 Miscellaneous Forage Grasses
Firm and consistent fertilizer and other agronomic information are not available in respect of the following forage grasses in Nigeria:

i) Bahama grass (*Cynodon dactylon)*
ii) Giant stargrass (*Cynodon nlemfluensis or C. plectostochyus)*

iii) Jaragua grass (*Hyparohenia rufa)*
iv) Elephant grass (*Pennisetum purpurum)*
v) Kikuyu grass (*Pennisetum Clandestinum)*
vi) Kyasuwa grass (*Pennisetum Polystachyon)*

2.9.9.9.4 Management of Forage Legumes

2.9.9.9.5 Common Stylo (*Stylosanthes guianensis*)

Stylosanthes guianensis is a polymorphic species. The three main cultivars being grown in Nigeria are schofield, endeavour and cook. The last two were introduced in early 1970s into Nigeria and Schofied came in 1945. Cook stylo is presently the most widely grown cultivar. Cook stylo grows under rainfed conditions of 600 - 2,500mm per annum, but it performs in areas receiving 1,200 - 1,800mm annual rainfall. It is versatile in soil requirements, but prefers well-drained sandy loam to clay-loam soils. It is tolerant of low acidity but does not withstand prolonged waterlogging.

Cook stylo is a semi-erect plant which may attain a height of 1.5m. The stems are reddish and densely pubescent. It is vigorous and aggressive and competes with weeds more successfully than schofield stylo.

(a) Cultural Practices

Common or perennial stylo is one of the most promising forage legumes in Nigeria. It grows in most vegetation zones in Nigeria. It has been grown successfully even in the tin mine reclamation sites around Jos, Plateau State. It is drought tolerant, remaining green well into the dry season (February, March in the Sudan Zone). It is mostly grown in mixtures with such grasses as gamba (*Andropogon gayanus)*, rhodes grass *(Chloris gayana)*, buffel grass *(Cenchrus ciliairis)* molasses grass *(Melinis minutiflora)* green panic *(Panicum maximum, var trichoglume)* and guinea grass *(Panicum maximum)*. When grown alone, the seeding rate is 10kg ha^{-1}. For seed production, a seed rate of 20 - 25kg ha^{-1} is advisable in order to suppress weed. In mixtures, a seeding rate of 5kg ha^{-1} is recommended. The recommended traditional planting time is between June and July. This is only necessary if the pasture is to be grazed within the same year. Establishing the pasture at 3 - 4 weeks towards the end of the rains has proved more effective since at this time there is less weed problem.

The seed exhibits some level of hard-seededness. Germination of hard seeds can be improved greatly by sand or hot water scarification. Seeds immersed in water at 70^0C for 10 minutes have given 70 - 90% germination within a week. Sulphuric acid, though effective in improving seed germination, is expensive and dangerous to handle.

(b) *Fertilizer sources and rates*

Stylo has been reported to be sensitive to copper deficiency, but the main nutrient required for proper production is phosphorus. The rate of application of 60kg P_20_5 ha^{-1} or 6 - 7 bags is frequently used. For maintenance application, 4 bags of SSP are suggested.

(c) *Yield Expectancy*

Two or three year old stylo pasture produces about 8 - 12 tonnes of dry matter per hectare. Seed yields range between 500 to 900kg ha^{-1}, but commercial harvests hardly exceed 400kg ha^{-1}.

2.9.9.9.6 Lablab (*Lablab purpureus*)

Lablab is widespread in the tropics especially in Africa. It is a highly variable species, having climbing to erect forms. It is an annual or short-term perennial. Lablab is adapted to a wide range of soils and climatic conditions and grows within the rainfall range of 500 to 1,800mm and elevations of 0 - 2,000m above sea level. Soil pH range is from 5 to 7.5.

(a) *Cultural Practices*

It is easily established from seeds on well prepared seed bed. It is drilled in rows 1m apart or planted at 60 x 60cm spacing. It can also be established under sorghum or maize when the crops are about 4 - 6 weeks old. No seed pre-treatment is necessary. Weeding may be necessary at the early stage, but once well established it suppresses weeds. Lablab can be sown as late as 6 weeks to the end of the rains, and it will still produce high quantities of seed.

(b) *Fertilizer Recommendation*

About 4 bags (36kg P_20_5) per hectare of SSP is required on poor soils. In subsequent years only 2 bags (18kg ha^{-1}) per hectare of boronated single super-phosphate is required.

(c) *Yield Expectancy*

A well - grown Lablab produces 6 - 10 tonnes of dry matter per hectare. The average herbage yield on most farms is between 5 tonnes of dry matter per hectare. Seed yields about 1,000 to 1,500kg ha^{-1}. Seed pods do not shatter readily.

2.9.9.9.7 Verano stylo (*Stylosanthes hamata cv verano*)

Verano stylo (Caribbean stylo) was first introduced into Nigeria from Australian in 1974, and today it is the most popular pasture legume in Nigeria. Verano stylo is an erect, smooth - stemmed, herbaceous and facultative perennial, that under favourable conditions grows to a height of 1m. It looks similar to Townsville stylo (*Stylonsanthens humulis)* but differs from it by its lack of long hairs around the stem junction below the growing point and seed head. It is adapted to soil types, ranging from stony or gravelly soils to clay loams. It is drought-tolerant, and flowers throughout the year provided there is some moisture. It grows in the rainfall range of 600 - 1,800mm/year.

(a) *Cultural Practices*

Verano stylo is established from seed at the rate of 10 - 15kg ha^{-1}. Sowing is either by hand or mechanical broadcasting unto disturbed seed bed. The seed bed may be a burned rangeland or a well prepared one.

It combines well with gamba, buffel grass and Rhodes grass. Weeding should be restricted to the removal of broad-leaved herbs and shrubs that tend to shade the young seedlings. The proportion of legume to weed grass can be kept in balance by proper grazing management and fertilizer application.

(b) *Fertilizer Recommendation*

Six bags of single super-phosphate per hectare (54kg P_20_5 ha^{-1}) applied at establishment year, followed by a yearly application of 4 bags per hectare give high herbage and seed yields. About 25 - 30kg N ha^{-1} is suggested for application only at the establishment stage.

(c) *Yield Expectancy*

Well managed two to three year old verano stylo pastures produce 6 - 8 tonnes of dry matter per hectare per year. Yields of 2 - 3 tonnes DM ha^{-1} can be expected from unfertilized crop. Seed yields range from 500 to 1,500kg ha^{-1} with a commercial average of 600kg ha^{-1}.

2.9.9.9.8 Miscellaneous Forage Legumes

Fertilizer and other agronomic information on the following forage legumes are either inadequate or unavailable.

i) Hyacinth bean *(Dolichos lablab)*
ii) Centro *(Centrosema Pubescens)*
iii) Calopo *(Calopogonian mucunoides)*
iv) Desmondium spp
v) Mucuna *(Stizolobium spp)*
vi) Pueraria spp
vii) Alalia spp
viii) Leucuana leucocephala and
ix) Cajanus cajan

CHAPTER THREE

3.0 FERTILIZER PRACTICES FOR MIXED CROPPING

3.1 General Concept

Most local farmers involved in food crop production in the country practice mixed cropping farming systems. Past research investigations were, however, focused on sole cropping. Consequently, most research findings benefit farmers practicing sole cropping.

Recently, some attention has, however, been drawn to the improvement of mixed cropping system which is common among the people. Some works on the improvement of the system have been carried out at the International Institute of Tropical Agriculture (IITA) and some other research establishments particularly the National Root Crop Research Institute (NRCRI), Umudike. A report from the latter institute indicates that growing sole cassava is not as profitable as combining cassava with maize, and melon (egusi) and sweet potato. Because of the long standing practice of mixed cropping by local farmers, the World Bank assisted Agricultural Development Programme (ADP) is focused on the improvement of mixed cropping systems. The following crop mixtures are popular especially in the forest zone.

i. Maize/Cassava
ii. Melon/Maize/Cassava
ii Yam/Maize/Melon
iv. Maize/Cassava/Cowpea
v. Yam/Maize/Cassava/Vegetables.

Despite the recent attention given to mixed cropping, no fertilizer recommendations based on sound research findings have been made for the various crop mixtures. Because of this lack of adequate information, fertilizer recommendations are tentatively based on the knowledge of the fertilizer requirements of individual crops in the mixtures. By classifying crops into three broad categories it is possible to suggest rules for the efficient use of fertilizers in crop mixtures,

3.2 Crop Categories

(i) Crops which are determinate in the sense that once the inflorescence has been produced there is no further production of leaves, and yield is determined by translocation from material already stored. This group is dominated by cereals whose grain yield is heavily responsive to nitrogen and, to a lesser extent, phosphorus and other nutrients.

(ii) Crops, mainly legumes, which are indeterminate in that the growth continues after flowering. Yield in this group is more heavily dependent upon phosphorus, nitrogen generally serving to increase the plant frame.

(iii) Root and tuber crops: which produce yield throughout the season and are variable in their response to fertilizers. They particularly have high requirements of potassium for tuber formation.

(a) Suggested Rules

Based on the above simple criteria, fertilizer may be applied to crop mixtures as follows:

(i) Mixtures Involving Cereals. Apply 125% of the recommendation for eachComponent on a pro-rata basis to each crop. (This suggestion is based on the fact that in such replacement mixtures each crop can be expected to yield some 25% more than if grown sole). Where millet is included in the mixtures, it may, be necessary to make a second application to the 'other' crop, since millet is very aggressive early in growth and will take up, especially, nitrogen at the expense of the 'other crop.'

(ii) *Mixtures Involving Group II Crops* . These are replacement mixtures and, as a general rule, do not respond to nitrogen. Therefore, apply 125% of the combined recommendations for phosphorus to the seedbed as usual.

(iii) *Mixtures Involving Groups I and II:* Apply 125% of the combined recommendation for phosphorus to seedbed. Apply 125% of the recommendation for nitrogen for cereal to the cereal component.. These mixtures are generally superimposed mixtures (total population is greater than either of the individual sole crops) and any excess nitrogen will serve to increase the frame of the non-cereal component, which otherwise would be so suppressed by the cereal.

(iv) Mixtures Involving Group III : Crops in this group are generally widely spaced; 125% of the individual crop recommendations should be applied on a pro-rata basis. This will also apply if crop is of this group are mixed with crops from the other groups.

(b) Additional Suggestions

(i) When in doubt, always apply nitrogen by reference to cereal(s) of the mixture; if nitrogen is in short supply, apply in the following descending order of preference.- maize, rice, sorghum, and millet.

(ii) Always share the phosphorus and other nutrients.

(c) *Recommendations Based on Soil Testing*

The above rules used in estimating the fertilizer needs of the mixtures ignore the original nutrient content in the soil. The recommendations given in Table 3.1 based on soil testing principles are made for yam/maize/cassava inter crop and may also apply to other crop mixtures.

Table 3.1 Fertilizer recommendation for crop mixtures

NITROGEN SOIL FERTILITY	RECOMMENDED RATE ha^{-1}	FERTILIZER MATERIAL ha^{-1}
N		
Low	**120kg**	Urea 261kg or 5.2 bags, CAN 462kg or 9 bags
Medium	**80kg**	Urea 174kg or 3.5 bags, CAN 308kg or 6 bags
High	**40kg**	Urea 87kg or 1.75 bags, CAN 154kg or 3 bags
P_20_5		
Low	**120kg**	SSP 667kg or 13.3 bags
Medium	**60kg**	SSP 333kg or 6.7 bags
High	**-**	-
K_20		
Low	**120kg**	MOP 200kg or 4 bags
Medium	**60kg**	MOP 100kg or 2 bags
High	**-**	-

Where the level of phosphorus is not adequate, a compound fertilizer like 15-15-15 may be used. In this regard, any short fall in nitrogen or potassium could be made up for by applying the appropriate straight fertilizer.

The recommendation based on phosphorus requirement using 15-15-15 is as follows:

Table 3.2 Fertilizer recommendation for crop mixtures based on phosphorus requirement

P_20_5	RECOMMENDED	FERTILIZER MATERIAL ha^{-1}
Low	**120kg**	NPK 20-10-10, 600kg or 12 bags
Medium	**60kg**	NPK 20-10-10, 300kg or 6 bags
High	**23kg**	NPK 20-10-10, 115kg or 2½ bags

(d) *Time and Method of Application*
Apply the fertilizer 3 - 5 WAP. Band 6cm and 10cm away from the crop. Application may also be done by broadcasting:-

(e) *Recommended Varieties*
Maize Western yellow 1, TZMSR-W, TZEMR SR - W(Early maturing) TZPB or TZB (white) in areas where streak is not a problem, and TZSR-W-1, TZSR-Y-1 in streak-prone areas.
Cassava: 30572, 30555 and 4(2)1425 and NR8082, NR80-83
Melon: Bara, Serewe, Sofin.

(f) *Other Cultural Practices*

(1) Land Preparation:
Plough land across the slope, harrow and ridge.

(2) Time of Planting:
Maize/Cassava: Plant maize as soon as the rains become steady in March/April in the rain forest areas, and May in the Southern Guinea Savanna . Plant Cassava as soon as possible after the emergence of maize.

Melon/maize/cassava:- Plant melon with the first rains in March, followed by maize as soon as the rains become steady. Plant cassava as soon as possible after the emergence of maize.
Yam/Maize/Cassava: Plant yam and maize at the same time when the rains become steady and cassava about 56 days after planting yam and maize.

(3) Spacing:

(a) Maize/Cassava

(i) Maize: Plant 1m x 1m with 2 seeds/hole to give a population of 20,000 plants/ ha at a seed rate of 5kg ha^{-1}.

(ii) Cassava: Plant at 1cm x 1cm to give 10,000 plants ha^{-1}. Cuttings should be from mature stems with about 5 nodes (about 20 - 25cm long).

(b) *Melon/maize/Cassava*

i) Melon: Plant at 1m x 1m to give a population of 20,000 plants/ha with 2 seeds/ hole.

(ii *Maize:* Plant 2 seeds/hole at 1m x 41m to give a population 20,000kg/ha. About 25kg grains per he tap is required.

(iii) *Cassava:* Plant at 1m x 1m to give 12,000 plants/ha.

(c) Yam/Maize/Cassava

(i) *Maize:* Plant maize 1m apart at the alternate sides of the ridge at the rate of 2 seeds/hole.

(ii) *Yam/cassava:* Alternate yam and cassava 1m apart on the crest of the, ridge.

4. Chemical Weed Control

(i) Forest Zone: Atrazine + Metolachlor (Primextra) at 3.0 a.i. kg ha^{-1} Pre- emergence

(ii) Guinea Savanna Zone: Atrazine + Metolafhlor at 3.0 a.i. kg ha^{-1} Pre- emergence. Prometryne + Metolachlor at 4.0 a.i. kg ha^{-1} Pre-emergence.

5. Manual Weed Control

(a) *Maize/Cassava:* First weeding should be done 2 - 3 WAP maize, 2nd weeding 8 WAP maize, 3rd weeding 12 WAP

(a) *Melon/Maize/Cassava:* First weeding should be done 3 WAP melon, second weeding after melon has been harvested, and subsequent ones as necessary.

(b) *Yam/Maize/cassava:* First weeding should be done 2-3 WAP maize and subsequent ones as necessary.

(b) *Yield Expectancy*

(a) *MaizelCassava:* *Maize* 1.5 - 2.5t dry grain ha^{-1} Cassava 12 - 18t

(b)	Melon/Malze/Cassava	Melon 100 - 300kg dry unshelled seeds ha^{-1} Maize 1.0 - 2.0t dry grains ha^{-1} Cassava: 10 - 15t fresh tuber ha^{-1}
(c)	*Yam/maize/Cassava*	Yam 4-5t ha^{-1} Maize 2 - 3.5t ha^{-1} Cassava: 11 - 18t ha^{-1}

CHAPTER FOUR

4.0 AREAS FOR FURTHER RESEARCH AND SUGGESTIONS

4.1 General Concept

Emerging from discussions in preceding chapters are areas of information gaps directly or indirectly related to fertilizers and fertilizers use on crops. While some of the gaps could be filled through research undertakings as well as by periodic up-dating and review of this document, others require deliberate formulations and pursuance of appropriately defined policies of both Federal and State Governments.

4.2 Fertilizer Recommendations

The fertilizer recommendations provided in this book are based on the fertilizer classes for each ecological zone. This is an improvement on the recommendations provided in the earlier (1989).

The present recommendations can still be regarded as a semi specific form of the generalized formulation in that the recommended fertilizer rates are based on the mean chemical properties (fertilizer level) of a large area (sub-zone) of which the farm is just a small part. Quite often such large sub-zone consists of several soil types with different physical and chemical properties, and therefore, different fertilizer response potentials.

In the continuing efforts at improving fertilizer use efficiency in Nigeria, therefore, the next logical step is to be able to provide specific recommendations for groups of soil having fairly similar properties and fertilizer response potentials. To achieve this, the following areas of research must now be pursued vigorously.

i) Calibration studies to determine the fertilizer nutrient response characteristics of Benchmark soils across the country. In this connection, the initial concern should be N, P, K, S, Zn and B.

ii) Determination of the critical soil nutrient fertility values in the different soil groups.

iii) Use of modeling to improve decision making on Fertilizer Management

4.3 Characterization of Soil Groups

This is a necessary adjunct to 3.1 above. Inadequacy of soil testing facilities and trained personnel to conduct soil tests for farmers at the beginning of each cropping season, constitutes a major bottle-neck in the efficient use of fertilizers. Since this situation is unlikely to improve appreciably in the very near future, it is necessary to conduct comprehensive physico-chemical characterization of major Nigerian soils and document the fertility status of the soils. This information will be useful in improving upon the existing soil fertility maps and providing a more reliable programme of fertilizer recommendation for farmers.

4.4 Soil Testing Facilities

i) An essential attribute of a soil testing laboratory is the ability to analyze a large number of samples accurately, within a short time otherwise samples accumulate and the rate of release of results become too slow to meet the desire and need of farmers. Thus use of multi-purpose extractants is one of the ways of making routine soil analysis fast, efficient, and economical. So far, soil testing for fertilizer recommendation in Nigeria has relied solely on single - element extractants.

With increasing awareness and demand of farmers to participate in soil testing programme, the need to use multi-purpose extractants to improve efficiency in soil testing laboratories, becomes unavoidable. It is necessary therefore, to evolve, reliable, efficient, multi-purpose extractants for Nigerian soils, through properly planned correlation studies.

ii) The Federal Ministry of Agriculture is currently establishing four soil testing laboratories in four ecological zones of Nigeria. These, plus the existing ones in some Research Institutions and Universities, may be insufficient to meet the need of farmers in the country. There is thus an urgent need to establish more, well-equipped soil testing laboratories in different parts of the country. This can be undertaken by Federal, State and Local Governments as well as private commercial interests. A modest building equipped for analysis of N, P, K, pH, O.M., C.E.C. and particle size, may be all that is required in each local government area, while the more elaborate soil testing laboratories of the Federal Government and Research Institutions serve as referral laboratories for specialized analysis (micro-nutrients, Mg. Al etc) urgent steps should be taken to equip the existing soil-testing laboratories, pending the eventual take off of the four Federal Laboratories.

4.5 Fertilizer Formulations

Fertilizer recommendation to farmers in Nigeria often appears as straight N, P, or K e.g. urea, SSP and muriate of potash. Yet it is much more convenient for the farmers to apply fertilizer-nutrient needs in one single formulation. For this reason, the use of compound fertilizer 15-15-15 has also been very widely adopted by farmers. In fact over 70% of all fertilizer used in Nigeria today is in the form of 15-15-15. The problem with too much reliance on 15-15-15 is that this fertilizer has low N and P content, and it lacks sulphur or zinc. Yet supplementary sulphur and zinc appear to be necessary for optimum crop performance in many parts of the country, particularly, the savanna grasslands. There is indication that B may also be needed in some parts. The underlisted crop and soil fertilizer formulations were developed from Soil Fertility Maps of Nigeria:

Table 4.1 SOIL AND CROP SPECIFIC FERTILIZER FORMULATIONS BASED ON SOIL FERTILITY MAPS OF NIGERIA

STATES	FERTILIZER FORMULATIONS
Anambra	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Abia	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Adamawa	(i) NPK: 20-10-10 + 1S + 1Zn for cereals. (ii) NPK: 10-20-10 + 1S + 1Zn for legumes
Akwa-Ibom	(i) NPK: 20-5-5 + 1Zn + 2Ca for cereals and vegetables (ii) NPK: 15-5-10 + 1Zn + 2MgO + 2Ca for roots, tubers and tree crops.
Abuja	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Bauchi	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops.

STATES	FERTILIZER FORMULATIONS
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Benue	(i) NPK: 20-10-5 + 1ca + 15 + 1Zn for cereals, cotton and vegetables (ii) NPK: 10-20-10 + 1S + 1Zn for legumes. (iii) NPK: 15-10-10 + 1Ca + 2MgO + 1Zn for roots, tubers and tree crops.
Borno	(i) NPK: 20-10-10 + 1S + 1Zn for cereals. (ii) NPK: 10-20-10 + 1S + 1Zn for legumes
Ebonyi	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Edo	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Ekiti	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Enugu	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Cross River	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Delta	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Bayelsa	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Gombe	(i) NPK: 20-10-10 + 1S + 1Zn for cereals. (ii) NPK: 10-20-10 + 1S + 1Zn for legumes
Imo	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Jigawa	(i) NPK: 20-10-10 + 1S + 1Zn for cereals. (ii) NPK: 10-20-10 + 1S + 1Zn for legumes
Kaduna	(i) NPK: 20-5-10 + 1Zn + 1S for cereals and vegetables. (ii) NPK: 15-5-10 + 1Zn + 1S for roots, tubers and tree crops (iii) NPK: 20-5-10 + 1Zn + 1S + 1B for cotton (iv) NPK: 10 -20-10 + 1S + 1Zn for legumes
Kebbi	(i) NPK: 20-5-10 + 1Zn + 1S for cereals and vegetables. (ii) NPK: 15-5-10 + 1Zn + 1S for roots, tubers and tree crops (iii) NPK: 20-5-10 + 1Zn + 1S + 1B for cotton (iv) NPK: 10 -20-10 + 1S + 1Zn for legumes
Kwara	(i) NPK: 20-10-10 + 1S + 1Zn for cereals. (ii) NPK: 10-20-10 + 1S + 1Zn for legumes
Kogi	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Kano	(i) NPK: 20-5-10 + 1Zn + 1S for cereals and vegetables.

STATES	FERTILIZER FORMULATIONS
	(ii) NPK: 15-5-10 + 1Zn + 1S for roots, tubers and tree crops (iii) NPK: 20-5-10 + 1Zn + 1S + 1B for cotton (iv) NPK: 10 -20-10 + 1S + 1Zn for legumes
Katsina	(i) NPK: 20-5-10 + 1Zn + 1S for cereals and vegetables. (ii) NPK: 15-5-10 + 1Zn + 1S for roots, tubers and tree crops (iii) NPK: 20-5-10 + 1Zn + 1S + 1B for cotton (iv) NPK: 10 -20-10 + 1S + 1Zn for legumes
Lagos	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Nasarawa	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Niger	(i) NPK: 20-10-10 + 1S + 1Zn for cereals. (ii) NPK: 10-20-10 + 1S + 1Zn for legumes
Ogun	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Ondo	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Osun	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Oyo	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Plateau	(i) NPK: 20-10-5 + 1ca + 15 + 1Zn for cereals, cotton and vegetables (ii) NPK: 10-20-10 + 1S + 1Zn for legumes. (iii) NPK: 15-10-10 + 1Ca + 2MgO + 1Zn for roots, tubers and tree crops.
Rivers	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables. (ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops. (iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes.
Sokoto	(i) NPK: 20-5-10 + 1Zn + 1S for cereals and vegetables. (ii) NPK: 15-5-10 + 1Zn + 1S for roots, tubers and tree crops (iii) NPK: 20-5-10 + 1Zn + 1S + 1B for cotton (iv) NPK: 10 -20-10 + 1S + 1Zn for legumes
Yobe	(i) NPK: 20-10-10 + 1S + 1Zn for cereals. (ii) NPK: 10-20-10 + 1S + 1Zn for legumes
Taraba	(i) NPK: 20-10-10 + 1S + 1Zn for cereals. (ii) NPK: 10-20-10 + 1S + 1Zn for legumes
Zamfara	(i) NPK: 20-5-10 + 1Zn + 1S for cereals and vegetables. (ii) NPK: 15-5-10 + 1Zn + 1S for roots, tubers and tree crops (iii) NPK: 20-5-10 + 1Zn + 1S + 1B for cotton (iv) NPK: 10 -20-10 + 1S + 1Zn for legumes

Whichever of these is produced, there is need to conduct field studies to determine the optimum rates for different crops under different soil fertility conditions. Certain parts of the country may have specific needs that are different from the recommended formulations. Specific formulations may be recommended for such areas.

4.6 Fertilizer Blending Facilities

With further development of soil testing programme in Nigeria, and farmers' acceptance of the idea of soil testing for fertilizer recommendation, there will be need for fertilizer-mix formulations that correspond accurately with soil test recommendations of individual fields (particularly for medium and large-scale farmers). Therefore, it will become necessary to use bulk blending plants for formulations of fertilizer compounds. It would be desirable to have fertilizer mixing plants in different parts of the country, such that it will be possible to have a blending facility in close proximity of the intended clients. Initially, one bulk - blending plant is suggested for each of the six main ecological zones of the country, which will later be increased to one per State at the minimum.

4.7 Specific Nutritional Problems

Information is required on some specific nutritional aspects in certain crops which have otherwise been fairly intensively studied. For example, studies on the micro-nutrient need of maize, groundnut and cotton need intensifying, especially, in the Savanna and Sudan zones. There is currently inadequate information on the effects of long-term, continuous application of the major nutrients on the soil properties, including the balance of minor elements.

Investigations are needed to test the effectiveness and economics of rock phosphate as a possible source of phosphorus for tree crops in place of single super-phosphate, especially in the southern parts of the country. There is also the need to evaluate the lime requirements of acid soils of Nigeria.

4.8 Nutrition in Crop Mixtures

Intensive work on the agronomy of crop mixtures within Nigeria is new and is concentrated on answering two questions: Whether or not mixtures yield more than equivalent sole crops, and the rationale behind mixtures. Only within the last few years have trials shown whether crops within mixtures respond to fertilizers in the same degree as sole crops. Most serious efforts should be directed towards determining the rate, timing and method of fertilizer application.

4.9 Fertilizers in Forest Production

Probably because of the administrative set up whereby forest management has always been separated from that of field and pasture crops, fertilizers are rarely used in commercial forest production. Accurate statistics about the total fertilizers used annually on forest production are hard to come by, but the amounts are likely to be much less than field crops. However, with the growing importance of forests and forest products in the national economy, it is imperative that attention be given to the role of fertilizers in commercial forest production. Some studies along this line have recently engaged the attention of researchers at the Forestry Research Institute., Ibadan. There is the need to encourage such studies.

4.10 Source of Nitrogen

The bulk of the nitrogen used in Nigeria should preferably be in form of urea, DAP and/or calcium ammonium nitrate. A substantial quantity of ammonium sulphate is however used in many parts of the country especially on crops like oil-palm. It is presently not clear whether its apparent preference is as a result of the sulphur content (23% S) or any other effect. Investigations are, therefore, necessary to determine the possibility of sustaining high yields of these crops using non-acidifying fertilizer sources.

Meanwhile, suitable sulphur containing sources e.g. single super-phosphate or any sulphur-bearing compound fertilizer formation should be used as sulphur sources for areas and crops needing sulphur.

4.11 General Agronomy

There is need for basic agronomic information, including all nutritional aspects, about the following group of crops and crop plants/trees which have so far received little research attention. Indeed, certain crops with asterisks(*) are currently not being worked on, hence there is insufficient information for meaningful recommendations.

i)	Cereals	-	barley, wheat, acha
ii)	Fats and oils seeds	-	benniseed, ginger seed*, sunflower*, castor*, shea (nut) butter*, crambe*, linseed*, neem*, rapessed*, safflower*.
iii)	Grain legumes	-	lima bean*, bambrra nut*, yam bean*, pigeon pea*, gree gram*, forage legume*, chick peas*.
iv)	Fibre crops	-	silk cotton*, roselle*, jute, sisal
v)	Stimulants	-	kola, coffee, tea*, chillies, tobacco
vi)	Other tree and horticultural crops	-	avocado, mango, locust ben*, dates, okra, onion, cashew, bread-fruit*, arvinger, grapes, wallnuts, guava and date palm
vii)	Date palm		

4.12 Crop Varieties and Nutrient Requirement

The primary characteristic of improved crop varieties is that their potential yield is significantly greater than unimproved (local) varieties. Since the various breeding programmes continually introduce new improved varieties, it is imperative to continuously assess the nutritional requirement under different *ecological conditions* as well as the interactions between fertilizers with tillage practices, crop residue management and other agronomic practices.

It is very important to continuously test varieties intended for use under irrigation since the amount, types and application of fertilizers are likely to be influenced by soil and cropping pattern.

4.13 Agronomy of Forage crops

It is evident that research on forage (pasture) crops is scanty, particularly in terms of general agronomy and nutrition. This has come about probably because animal and crop production are separately administered. Until recently, attention has been directed almost exclusively to animal health and care, than to the production of feeds. Crop oriented institutions, on the other hand, have devoted much more attention to the production of field crops that are directly used by man than to the production crops for animal production.

Although there is already a trend towards research in forage crops by Research Institutions, Government should sustain this effort.

4.14 Agricultural Statistics

Lack of accurate records and statistics make it difficult to formulate and effectively implement sound policies. For example, if the land area devoted to a particular crop is known, the total fertilizer needs can be rationally estimated. It is, therefore, imperative that accurate statistics involving all aspects of agricultural development be kept.

4.15 Missing Extension Linkage

A wide gap exists between the resultant research information and what the farmer does. While research institutions succeed in gathering useful data and arriving at practical conclusions, most of such information end up on the pages of learned journals and newsletters. Indeed, crop production could be more than doubled if the farmer had access to all the information and was able to apply them. In order to ensure effective and prompt application of research findings, it is strongly suggested that each research institution should create an extension unit that would form an integral part of each research institute. This would enhance:

a) Translating technical research into simple and practical language and form for use by extension agents and farmers.

b) Liaison, as reference unit, with Ministries of Agriculture in respect of all aspects of extension, including the provision of research information in appropriate forms, the periodic up-dating of such information, and occasional mounting of general or specific training programme

c) Offering direct assistance to farming communities and organizations while ensuring that this does not result in undesirable duplication of effort with those of the Ministries of Agriculture

d) Liaison with purely research staff to ensure that research undertakings are practical oriented and aimed at finding solutions to field problems

e) The existing relationship between the ADPs and the extension units of research institutions should be strengthened.

4.16 Industries and Agricultural Research

To date, government has been the sole supporter of agricultural research in the country. There is need to encourage public involvement in agricultural research. For example, commercial companies who use agricultural products as raw materials should be encouraged to support research on crops that are of interest to them.

4.17 Pesticide Residues

More attention should be devoted to studying the residual effects of herbicides and pesticides on the different crops and soil types.

4.18 Integrated Plants Nutrition

The concept of bio-nutrition whereby plants are induced to effectively utilize the natural nutritional potentials of the soil deserves further study. It is possible that plants growing in their natural habitat may not require added fertilizers until such a time that they begin to exhibit obvious nutrient stress symptoms. In addition, the screening of crop/plant varieties for tolerance or adaptation to the mineral nutrient content of the soil would result in effective and economic use of fertilizer.

Organic products and animal wastes can be converted and recycled to feed the plant and improve soil fertility. Further research is needed in the conversion of organic wastes to fertilizers and the use of the biogas so generated for domestic needs.

A National network on integrated utilization of farm bye-products should be established conform the basis for generating agricultural by products, thus improving and sustaining soil fertility.

Fertilization of trees and crops reduces the adverse effects of desertification, deforestation and erosion on the environment.

4.19 Research on Rock-Phosphate

Nigeria has extensive deposits of phosphates embedded in four sedimentary basins namely Dahomey Basin in Ogun State; Nigerian side of the llulemedor basin in Sokoto State; Anambra - Imo Basin and Benin flank of the Niger Delta Basin in Edo State. The most abundant of these phosphate deposits is located in Sokoto State with an estimated reserve of between 5 - 10 million tons. The phosphatic materials occur within the Dange Formation which has a thickness ranging from 22 - 45 meters.

Phosphorus is one of the most limiting plant nutrients for crop growth in the forest and savanna zones of the sub-humid and humid tropics. Response to P has been most remarkable on cereals and legumes in Nigeria and the response increases northward of the country following the decline in native soil fertility. Phosphate containing fertilizers seem to be the only viable option for augmenting the fertility of the soils. The resent deregulation of the fertilizer sub-sector has increased the cost of chemical fertilizers in Nigeria. The application by the local farmers. The use of cheap sources of phosphate or other alternatives is being advocated as suitable replacement for expensive chemical fertilizers. The occurrence of a large deposit of Rock Phosphate in Sokoto has stimulated agronomic research on the product.

Results of the limited research investigations on the rock show that it has high contents of P_20_5 and CaO while the values of SiO_2, Al_2O_2, Fe_2O_3 and MgO are low. The reactivity falls within the medium range and the rock is well suited for the manufacture of single super-phosphate and phosphoric acid. The relative agronomic efficiency is about 60% of that of single super-phosphate and therefore can be recommended to limited - resource farmers for direct application in ground form (100 mesh) in strongly to moderately acid soils.

There is however a need for further research in the following areas:-

- Comprehensive characterization of SPR to include the mineralogy
- Agronomic field testing of SPR in various agro-ecological zones and on a wide range of crops
- Evaluation of SPR under farmers' constraints to adoption to the production
- Assessment of available management options to improve the efficiency of SPR for crop growth
- Assessment of possible hazardous environmental effects of heavy and radioactive metal content of the phosphate rock.

4.20 Use of synthetic fertilizers and the concept of ecological or organic agriculture

Fertilizers are chemicals often applied to crops to enhance growth in situations where mineral elements required by the crops are in short supply.

Fertilizers are more frequently used in developing nations principally to sustain food sufficiency irrespective of the environmental problems such used could present inhabitants in developing nations need food. They need to improve on their traditional agricultural practices and apply fertilizers.

However, such application of fertilizers should be done with care and through adequate study of the need of the soil and plants. Of recent soil fertility concepts are pointing to the "ecologizing" agriculture by emphasizing ecological, organic or bio dynamic systems of farming both in rural and urban locations. This concept appears to de-emphasize the use of synthetic fertilizers.

Can this apparently new concept of crops nutrition meet the high demand for food by developing nations? Is it not a concept being postulated or pre-maturely pushed down the throat of developing nations by developed countries who appear "overfed" and saturated with excess food production? Should developing nations depend solely on organic farming or bio dynamic agriculture to feed their people? Is it not possible to depend on synthetic fertilizers to achieve the desired goal of food sufficiency pending a thoroughly scientific appraisal of the concept of ecological or organic farming? A critical study is needed, on the desirability of the dependence on this new concept vis-a-vis the conventional philosophy of fertilizer application in Nigeria.

4.21 CONDUCTING A FERTILIZER DEMONSTRATION

Before starting a fertilizer demonstration you should set up a plan and a layout: What do I want to demonstrate to the farmer? With which crop will the demonstration be most convincing (most valuable or most grown in your area or most needed for food)? With which farmers will I cooperate? What will be the best situated place or field for the demonstration? What fertilizer do I have available for use on the selected crop? When and how do I have to apply the fertilizer? What other measures do I need to take into account?

Therefore, in order to carry out a fertilizer demonstration you need to prepare and have ready the following:

1. A plan for the demonstration (two or more plots24, where and with which crop, size of each plot, demonstration on one field only or on several fields).

2. A notebook for the demonstration plan, for plot records (amount of nutrients applied, date of application), location of plots, growth observations, weed and pest control during crop growth and the final yields.

3. One or more interested farmers who will work with you and help you to conduct the demonstration in his/their fields.

4. Fertilizer of the right grade or grades at the right time and a dry place to store the fertilizers before use.

5. A scale or balance to weigh out the fertilizer quantity for each plot.

6. Have ready paper bags, preferably multilayered, in which you put the fertilizer for the different treatments clearly marked.

7. A measuring tape or device to determine the plot size/length and shape; stakes and strings to mark the plot boundaries, particularly the corners.

8. Harvesting equipment, including cutting tools, and scale or balance for measuring crop yields.

9. Information on actual fertilizer and agricultural produce prices, and possibly a pocket calculator to calculate the economic outcome of the demonstration (value/cost-ratio VCR and/or the net profit).

As a general rule: Keep your fertilizer demonstrations simple!

Usually you will start with two plots, i.e. one treated plot and one control plot or farmers practice plot. Thus you will work without replications. However, if you implement the demonstration plots on fields of several farmers, the different locations may be considered as replications of the demonstration and may be evaluated. However, this should be verified with the statistician at your local experimental station.

a) Identify the fertilizer effect against a non-fertilized plot, with all other factors remaining equal. The simple design would be: no fertilizer - recommended fertilizer.

b) If you want to convince farmers to use a higher rate of N and/or P205 and/or K2O you have to adapt the design to compare two rates of nutrients.

The design then would be: no fertilizer - lower rate of nutrient (e.g. 30 kg/ha N) - higher rate of nutrient (e.g. 60 kg/ha N). The same design is used for P205 and K20. The demonstration while testing a higher rate of one nutrient, should always be done in the presence of the other two nutrients (balanced fertilization).

c) If you want to demonstrate to the farmers the importance of balanced fertilization you will have to use a three or four plot-design: no fertilizer - plot only with nitrogen (N) - plot with nitrogen and phosphate (NP) - plot with nitrogen, phosphate and potassium (NPK).

Variations of this design with three plots are:

no fertilizer - NP -NPK
or no fertilizer - P - NP
or no fertilizer - N - NP
or no fertilizer - N - NPK.

d) In addition to proving the benefits of fertilizer use you may also want to demonstrate the benefits of improved agricultural practices, particularly the system of integrated plant nutrition. Then you need a four plot design:

1. plot: no fertilizer with farmer's practice.

2. plot: recommended fertilizer with farmer's practice.

3. plot: no fertilizer with recommended improved practices (conservation tillage, organic matter supply, manure, green manure, improved seed variety, date and method of planting, weed and disease control, etc.).

4. plot: recommended fertilizer with recommended improved practices (conservation tillage, organic matter supply, manure, green manure, improved seed variety, date and method of planting, weed and disease control, etc.).

Because of the gradual inclusion of "other" improved practices, and not only fertilizer use, this last design calls for special emphasis. Therefore, it is recommended to work primarily with simple demonstrations as described under a) and b), and to implement the other demonstrations or simple trials as under c) and d) or with still more, i.e. six to ten treatments25 in cooperation with your local experimental station.

4.22 DETERMINATION OF PLOT SIZE

The size of demonstration plots will depend on the field size of farms. Since farms and fields may often be small in your region, the demonstration plots also have to be small. However, they should be large enough to make convincing demonstrations and to get accurate yield data to determine the effect of the treatments. Thus, the size of plots or strips may vary between

50 to 400 square metres (5 in x 10 in up to 10 in x 40 m).

In general, the plots used for the demonstration should be rectangular and laid out side by side. Paths of 0.5 to 1 in in width should be left between the plots and around the site of the demonstration (see Figure 11). Keep in mind the topography of the field so that all plots look in the same direction.

The former FAO Fertilizer Programme worked with an 8-plot design for simple trials: Control plot = 000, PK plot = 011, NK plot = 101, NP plot = 110, NPK plot = 111, 2N + PK plot = 211,2P + NK plot = 121 and 2K + NP plot = 112.
The FAO database on the results of trials and demonstrations is scheduled to publication on the internet in 2001.

Fig 1.26. Example of the lay-out of a simple demonstration with control plot and two different rate of N

Plot size: 5mx10m
Paths of 0.5 m in width between the plots

It is recommended that the order of treatments should be at random for the trials, not systematic. However, when you are running a demonstration with only three plots the order 0-1N-2N (or other nutrients) should be used. To avoid any confusion to the farmers regarding the plots, this should also be done if you lay out the same demonstration on several farmers' field'.

For row crops you have to adjust the width of the plot so as to include an exact number f rows: ten rows each spaced 1 m apart require a plot 10 m wide, but nine rows 1.20 m apart will need a plot which is 10.80 m wide. If the treated plots are of the larger size it is not necessary to harvest the whole plot, but only 20 to 50 square metres or 10 m of total length of row per plot treatment.

A randomized lay-out is normally used when a trial is carried out with e.g. six different treatments and three replications. The following is an example of the order of treatments for such a trial:

Replication a: (treatments) 6 - 3 - 5 - 2 - 4 - I

Replication b: (treatments) 2 - 4 - 6 - t - 3 - 5

Replication c: (treatments) I - 2 - 3 - 4 - 5 - 6

4.23 CALCULATION OF FERTILIZER RATES PER PLOT

If you wish to apply straight fertilizers to the demonstration plot, e.g. urea, triple superphosphate and muriate of potash, you calculate the quantities for the different treatments according to the formula:

Amount of fertilizer needed per plot = $\frac{nutrient\ rate\left(\frac{kg}{ha}\right) x\ plot\ area\ in\ m2}{Percentage\ nutrient\ in\ fertilizer\ x\ 100}$

Table 4.2 Example: the demonstration design is

Plot treatment (kg/ha)	N	and/orP_20_5	And/or K_20
a)	0	0	0
b)	30	30	30
c)	60	60	60

Please note that high fertilizer application rates should only be used for irrigated crops or in areas with high rainfall. With a nutrient rate of 30 kg/ha N, a plot area of 50 square metres and urea with 45% N as nitrogen fertilizer the calculation is as follows:

Amount of urea needed per plot $\frac{30\ x\ 50}{245\ x\ 100!} = 0.33kg\ of\ urea\ needed\ per\ plot$

Therefore, you would have to weigh out 0.33kg of urea per plot for treatment b) and 0.66 kg for treatment c). For a plot sixe of 400 square metres the necessary quantiy of urea would be 2.64 kg and 5.28 kg, respectively. Rates in pounds and acres can be calculated in a similar way (see Annex).

4.24 BROADCASTING FERTILIZER ON SMALL PLOTS

You should prepare the correct amount of fertilizer for each treatment (plot) in a paper bag, which is clearly labeled and listed in your notebook, to avoid any mistake. The fertilizer can easily be spread by hand. However, it is obvious that it is difficult to spread very small fertilizer quantities uniformly, in this case put some dry soil in a bucket. Pour the weighed fertilizer for the specific plot on top of the soil and mix it thoroughly. This gives a greater volume and will aid in distributing the fertilizer uniformly. The smaller the demonstration plot, the greater will be the effect of errors and mistakes on the overall result. Therefore, the smaller the plot, the more care you have to give to have an absolutely uniform distribution of the fertilizer over the plot.

With small handfuls of fertilizer/fertilizer soil mixture, use a spreading or sowing movement to broadcast the fertilizer as you walk over the plot. This method can be used for basal dressing (before planting) and for top-dressing (on a standing crop) and is applicable to a great number of crops. However, for crops planted in rows such as maize, yams, and groundnuts or for tree crops, side dressing or single plant treatment is recommended. Small amounts (some grams) of fertilizer may be dropped in holes or furrows beside the seed and covered with soil.

4.25 EVALUATION OF FERTILIZER DEMONSTRATIONS

The demonstration sites must be regularly visited throughout the season, wherever possible with the owner of the field. Data on growth development as well as on rainfall/irrigation, weed and disease control, etc. should be written down in your notebook. The harvesting and weighing of the yield can be done in the course of a field day. However, if you have had field days during the growing season to demonstrate the difference in growth development, it may be useful to harvest approximately 20 m'- of the crop a few days before the field day, to weigh the yield, to compare the different treatments and to evaluate the economic outcome. This does not exclude the harvesting again of part of or of the rest of the plot, at a final field day.

The advantage of pre-harvesting part of the plot before the field day is, that with the yield data and with information on fertilizer costs and agricultural produce prices at hand, you can calculate the valuelcost-ratio or the net profit and prepare diagrams and posters to be shown at the field day.

This method will be most persuasive to a farmer, since the best and only argument to him to use fertilizers is the economic benefit he will gain.

When calculating the value/cost-ratio you divide the value of the increase in crop yield by the cost of fertilizer applied to obtain that yield:

$$\frac{\text{Value of yield increase (in terms of money)}}{\text{Fertilizer costs (in terms of money}} = \text{Value/Cost ration (VCR)}$$

A value/cost-ratio of more than I indicates that the fertilizer has been profitable. A VCR of 2 indicates a return of 100 percent: i.e. it means that, e.g. every US$ 1 spent on fertilizers gives a return in additional crop yield of US$ 2. Furthermore, the farmer generally receives this return already after a short period of investment, i.e. usually after a few months. However, the value/cost-ratio should be higher than 2 to secure a profitable return to the farmer.

The net return indicates the income increase in absolute amount of money. It is calculated by subtracting the cost of fertilizer used from the value of the increase in the crop produced through the use of fertilizer:

Value of yield increase (in terms of money); Fertilizer cost (in terms of money) = Net return

A positive net return means that the fertilizer application was profitable. Net return and value/cost-ratio serve different purposes. Depending on the cost of the fertilizer applied, it may be the case that the highest value/cost-ratio is not always giving also the highest net return. In other words, the highest yield per hectare does not necessarily mean the highest return.

Making both the calculations will give you a tool to give to the farmer the most economic recommendation for fertilizer use possible.

4.26 CONDUCTING MEETINGS ON FERTILIZERS

As stated above, you should invite farmers and other community leaders (by postcard, letter, poster, newspaper or radio) to field days of the fertilizer demonstrations or trial plots near their village or farms, during the growing season of the crop on which you have laid out the demonstration.

Your invitation should include the following information:

- Purpose of the meeting: to see and to discuss a fertilizer demonstration on... crop.
- Who is invited: local farmers (with their wives), friends, community leaders, representatives of rural banks, fertilizer retailers, etc.
- Place of the meeting: clear directions where the meeting will take place and how to get there.
- Time of the meeting: month, day and hour.

For the field day you should have samples of fertilizers prepared to show them to the farmers. Demonstrate to them how the fertilizer had been applied. The host farmer should show and explain the growth and yield observations made on the different plots. If possible, harvest part of the plots with the participants and encourage them to estimate the expected yields of the plots treated as well as the plots untreated, and also estimate the resulting economic benefit through the application of fertilizers. Recommend to the farmers to carry out demonstrations on their own farms and fields.

In addition to those special field days, invite together with farmers (and their wives), retailers and village leaders to more general meetings to discuss and inform about fertilizers. Make these meetings a village affair by generating enthusiasm. These meetings work best if you can present photographs, coloured slides, posters or wall charts of trial and demonstration results. These should preferably have been obtained in your region. Make wall charts to explain the nutrient needs of plants and the role that fertilizers play in fulfilling those needs. Diagrams from this booklet may be helpful. Get the village chiefs to sponsor such meetings. As stated before, because conditions change rapidly, the recommendation given for this year may not necessarily also be the optimal `recipe' for the next year. Not only weather conditions change, but also rainfall, soil fertility and crop varieties planted are all subject to changes.

Considering farming in a wide general 'sense, one notes that farming is changing constantly. Therefore it is recommended that farmers, in addition to making proper use of fertilizers, should also aim at gaining the knowledge of all the underlying principles and processes, to enable them to cope with new situations or new and different problems. Farmers are forced to change their farming system or management practices when technical, economic or social conditions change.

APPENDICS

Appendix I - Acronyms

SN	ABBREVIATION	FULL MEANING
1	N	Nitrogen
2	P	Phosphorus
3	P_20_5	Phosphorus pentoxide
4	K	Potassium
5	K_20	Potassium oxide
6	Ca	Calcium
7	Mg	Magnesium
8	S	Sulphur
9	Fe	Iron
10	B	Boron
11	Cu	Copper
12	Zn	Zinc
13	Mo	Molybdenum
14	CAN	Calcium ammonium nitrate (nitrochalk)
15	AS	Ammonium Sulphate
16	SSP	Single super-phosphate
17	TSP	Triple super-phosphate
18	KCI	Potassium chloride (muriate of potash)
19	K_2SO_4	Potassium sulphate
20	$MgSO_4$	Magnesium sulphate (epsom salt)
21	$ZnSO_4$	Zinc sulphate
22	$CuSO_4$	Copper sulphate
23	$MnSO_4$	Manganese sulphate
24	FYM	Farm yard manure
25	CEC	Cation exchange capacity
26	Meq	Milli-equivalent
27	EC	Emulsifiable concentrate
28	FW	Flowable
29	WP	Wettable powder
30	ACC	Accession
31	FARZ	Federal Department of Agricultural Research *Zeamays*
32	FARO	Federal Department of Agricultural Research *Oryza sativa*
33	ULV	Ultra low volume
34	One (1) Bag	Weighs 50kg
35	RRINC	Rubber Research Institute of Nigeria Clone
36	RRIM	Rubber Research Institute of Malaysia
37	WAP	Weeks after planting
37	NFTC	National Fertilizer Technical Committee
39	MOP	Muriate of Potash

Appendix II Nutrient Content of Some Common Fertilizer Materials

SN	FERTILIZER MATERIAL	PLANTS NUTRIENT CONTENT (%)					
		N	P_2O_5	K_2O	S	CaO	Other
1	Urea	46	-	-	-	-	-
2	Calcium ammonium nitrate	26	-	-	-	18	-
3	Ammonium sulphate	20	-	-	23	-	-
4	Sodium nitrate	16	-	-	-	-	-
5	Ammonium sulphate-nitrate	26	-	-	12	-	-
6	Ammonium nitrate-sulphate	30	-	-	5	-	-
7	Mono Ammonium Sulphate (MAP)	11	53	-	-	-	-
8	Potassium nitrate	13	-	44	-	-	-
9	Single super-phosphate	-	18	-	14	27	-
10	Triple super-phosphate	-	45	-	1.5	20	-
11	Phosphate rock	-	27, 41	-	-	46	-
12	Basic slag	-	15	-	0.2	45	5 MgO
13	Potassium chloride	-	-	60	-	-	-
14	Potassium sulphate	-	-	50	17	-	-
15	Gypsum	-	-	-	18	32	-
16	Magnesium sulphate	-	-	-	13	-	16 MgO
17	Manganese sulphate	-	-	-	15	-	26 Mn
18	Ferrous sulphate	-	-	-	18:8	-	32.8 Fe
19	Copper sulphate	-	-	-	13	-	25 Cu
20	Zinc sulphate	-	-	-	17.8	-	36 Zn
21	Gypsum (hydrated)	-	-	-	18.6	32.6	-
22	15-15-15 compound	15	15	15	-	-	-
23	20-20-20	20	20	-	-	-	-
24	0-20-20 compound	-	20	20	-	-	-
25	12-12-17-2 compound	12	12	17	-	-	2 MgO
26	18-18-7 compound	18	18	7	-	-	-
27	Mono Diammonium phosphate: DAP	18	46	0	-	-	-
28	16-12-0	16	12	0	-	-	-
29	20-10-0	20	10	0	-	-	-
30	20-10-10	20	10	10	-	-	-
31	20-0-20	20	0	20	-	-	-
32	27-13-13	27	13	13		10%Ca	
33	25-10-10	25	10	10			
34	20-10-5 + 10% Ca	20	10	5			

Appendix III Glossary of Terms on Fertilizers

SCOPE

This standard shows terminology related to fertilizers.

Acid-Forming Fertilizers: A fertilizer capable of increasing the residual acidity or reducing the residual alkalinity of the soil

Activity of Water insoluble Nitrogen: The water-insoluble nitrogen in mixed fertilizers showing an activity below 50% by the alkaline method and also 80% by the neutral method shall be classed as inferior

Additive: Substance intended to improve the properties of a fertilizer or soil conditioner

Aggregate Sample: A combination of all increments from the sampling unit.

Agricultural Liming Material: Material containing oxides, hydroxides and/or carbonates of calcium and/or magnesium, used for neutralizing the acidity of the soil

Air-Slaked Lime: A product composed of various proportions of the oxide, hydroxide and carbonate of calcium or of calcium and magnesium, and derived from exposure of quicklime to the air in sufficient quality to show physical sign of hydration

Alkaline (Or Basic) Fertilizer: A fertilizer capable of increasing the residual alkalinity or reducing the residual acidity of the soil

Ammonia (Liquid Anhydrous): A material mostly produced by the synthetic process and obtained in the liquid form. It is used in the fertilizer industry for ammoniation of super-phosphate, in making base mixtures, in making mixed fertilizers, or for conversion into salts such as sulphate, phosphate, chloride, nitrate, etc. It is also applied directly into the soil by suitable mechanical means. Fertilizer grade anhydrous ammonia contains about 82 percent of nitrogen.

Ammoniated Super-phosphate: A product obtained from super-phosphate when it is treated with ammonia or solutions containing free ammonia.

Ammoniating Solution (Nitrogen Solution): A solution used for ammoniating super-phosphate or a mixture of super-phosphate with other fertilizers. This solution may be liquor ammonia itself or a solution of ammonium nitrate or urea in liquor ammonia.

Ammoniating Chloride (SAL Ammonia or Muriate of Ammonia) (NA_4Cl): Ammonium salt of hydrochloric acid containing 25 percent of nitrogen in ammoniacal form.

Ammonium Citrate: A term used to express the soluble phosphate content of fertilizers, to describe various extraction ,solutions of given concent rat ions of ammonium citrate and aqueous ammonia.

Ammonium Nitrate (NH_4N0_4): A product obtained by neutralizing nitric acid with gaseous ammonia. it is usually in a granular or prilled form, arid coated with a suitable material to prevent absorption of moisture and caking in storage. Fertilizer grade ammonium nitratre has a total nitrogen content of 33 - 34.5 percent, of which one-half is present as ammoniacal nitrogen arid the other half as nitrate nitrogen.

Ammonium Phosphate: Two important ammonium phosphates are: (a) monoammonium phosphate ($NH_4H_2PO_4$) containing about 11 percent of nitrogen and about 53 percent of P_2O_5 (b) diammonium phosphate [$(NH_4)_2HPO_4$)], fertilizer grade phosphate contains about 18 percent of nitrogen and 46 percent of P_2O_5

Ammonium Phosphate Sulphate: A material produced by neutralizing a mixture of phosphoric acid and sulphuric acid with ammonia.

Ammonium Sulphate (Sulphate of Ammonia) [$(NH_4)_2SO_4$)]: Ammonium salt of sulphuric acid containing 20.6 percent of nitrogen in ammoniacal form.

Ammonium Sulphate Nitrate: A double salt of ammonium sulphate and ammonium nitrate containing 26 percent of nitrogen, of which about one-fourth is in the nitrate form and three-fourths in the ammoniacal form.

Analysis: As applied to fertilizers, it designates the percentage composition of the product expressed in terms which the existitig trade practice and law require and permit.

Application: General term for all processes of administering fertilizers and soil conditioners to a crop or soil or both.

Aqueous Ammonia: A solution containing water and ammonia in any proportion, usually qualified by a reference to ammonia vapour pressure.

Ash: The mineral residue remaining after the destruction of organic mate-rial by burning.

Available Phosphoric Acid: The sum of water-soluble and citrate soluble phosphoric acid as P_2O_5 in a fertilizer, except for bone meal and basic slag in which the amount of phosphoric acid as P_2O_5 soluble in a two percent citric acid solution is considered available.

Bagged Fertilizer: A fertilizer di-tributed in a sealed package or container.

Basic Fertilizer: See "Alkaline Fertilizer".

Basic Slag: A by-product in the manufacture of steel from phosphorus-containing iron ores, containing 8 to 18 percent P_2O_5

Bat Guano: Partially decomposed bat manure. The nitrogen content varies from 0.4 to 9.0 percent and total phosphoric acid (P_2O_5) from 1 - 11 to 216 percent.

Batch: A definite quantity of material manufactured or produced under conditions which are presumed to be uniform.

Blood, Dried Blood, Blood Meal: Blood which has been dried and to which no other material has been added.

Bone: Hard tissue forming the structure of animals and containing salts of calcium, chiefly phosphate and carbonate.

Bone Ash: A product obtained by burning bones to ash. The material contains 30 to 40 percent P_2O_5

Bone Black (Bone Char) : A product obtained by heating bones in closed retorts. This is used for clarifying sugarcane juice and the spent material.used as phosphorus fertilizer. It may contain 1 to 2 percent of nitrogen and 30 tp 35 percent P20.,

Bone Meal, Raw: A by-product of the bone-crushing industry, consisting of ground bones without any of the gelatine or glue removed. It contains at least 3 percent nitrogen, and about 22 percent P_2O_5 of which about 8 percent is citratesoluble.

Bone Meal, Steamed: A product obtainod by subjecting bones to the action of steam under pressure to dissolve part of the gelatine and grinding the residue. It contains about 28 percent of P_2O_5 of which about 16 percent, is citratesoluble.

Bone Tankage: A product obtained by processing bones along with a smaller proportion of meat of carcass, with steam under pressure. It may contain 3 to 10 percent of nitrogen and 7 to 20 percent of phosphoric acid (as P_2O_5) .

Brand: A term design, or trademark use.1 in connection with one or several grades of fertilizer.

Bulk Density (Loose): The mass per unit volume of a material after it has been tipped freely into a container under clearly specified conditions.

Bulk Density (Tamped): The mass per unit volume of a material tipped into a container and then compacted under clearly specified conditions.

Bulk Fertilizer: Commercial fertilizer delivered to the purchaser, in solid or liquid form in a non-packed form (to which a label cannot be attached).

Caking: The formation of a coherent mass from individual particles.

Calcium Ammonium Nitrate: A mixt-ure of ammonium nitrate and finely pulverized limestone or dolomite, granulated together it contains 21 to 26 percent of nitrogen, half of which is in the form of ammoniacal nitrogen the other half in the form of nitrate nitrogen.

Calcium Cyanamide (Cyanamide) ($CaCN_2$): A commercial product consisting principally of calcium cyanamide and carbon. It contains not less than 20 percent of nitrogen which is not immediately, plant available.

Calcium Meta-phosphate [$Ca(PO_3)_2$] : A product obtained by treating phosphate rock with gaseous phosphorus pentoxide (P_2O_5) at high temperature.

Calcium Nitrate [$Ca(NO_3)_2$]: The calcium salt of nitric acid. It is an excellent source of the nitrate form of nitrogen and of water soluble calcium. The commercial product contains about 15 percent nitrogen and 28 percent CaO.

Chilean Nitrate of Soda (Chile Salpetre) : A product obtained by refining the crude nitrate deposits found in Chile and containing about 99 percent. sodium nitrate (See also Nitrate of Soda).

c.i.f: Cost, insurance and freight.

c. & f.: Cost and freight.

Citrate-Soluble P_2O_5: That part of the total particularly in basic slag and bone meal that is insoluble in water but soluble in 2 percent citric acid solution.

CLay: A group of hydrated aluminum Silicates of microcrystalline structure And a constituent of soils.

Coated Fertilizer: Fertilizer the granules of which are covered with a thin layer of a different material in order to improve the behaviour and/or modify the characteristics of the fertilizer.

Complete Fertilizer: A product obtained by mixing different fertilizer stock materials, containing three major plant- nutrients, namely, nitrogen, phosphorus and potassium (see also fertilizer mixture).

Complex Fertlli7er: Fertilizers which contain two or more major made by a, chemical reaction between the nutrient- containing raw materials.

Compost: A product obtained by the controlled decomposition of organic wastes.

Compound Fertilizer: Fertilizer having a declarable content of at least two of the nutrient nitrogen, phosphorus, and potassium, obtained chemically or by mixing, or both.

Conditioning of Fertilizer: The treatment of a fertilizer to reduce hygroscopicity and caking in storage. This usually involves coating the fertilizer particles with a finely divided material such as clay. In the case of the single super-phosphate fertilizer for example, conditioning is by granulation.

Container: A closed receptacle directly in contact with a fertilizer or soil conditioner whereby it may be transported or stored in unit quantities (for example a bag, bottle, tank, barrel)

Crushing Strength: The minimum force required to crush individual particles.

Curing of fertilizers: Like in the conditioning of Fertilizers, curing is done to prevent caking in bags. The caking is as a result of various chemical reactions taking place. It requires weeks and frequently for these reactions to be completed and during this time most of the water combines with materials like gypsum, and crystallized compounds are formed. In order to prevent these reactions from taking place in the fertilizers after bagging the fertilizers are kept in storage heap in the factory where the chemical reactions take place. Then the fertilizer is conditioned and bagged.

Cyanamide: A product consisting principally of calcium cyanamide and carbon with not less than 20 percent nitrogen. It is manufactured from calcium carbide and nitrogen gas, and has herbicidal and insecticidal action. The temperature of calcium cyanamide will increase when it absorbs water during storage. Under such a circumstance inflammable packaging material. may ignite. The hazard of explosion is however not present.

Declarable Content: The content of a nutrient which, according to national legislation, may be given on a label or document associated with a fertilizer or soil conditioner.

Delivery: A quantity of material transferred at one time.

Dicalcium Phosphate ($CaHP0_4$) : A product containing not less than 34 percent of P_2O_5 in citrate-soluble form, which is considered available to plants.

Direct Application of Fertilizer: The application to the soil of a major primary fertilizer such as super-phosphate or ammonia, without first combining it with other fertilizer materials.

Dissolved Bone: Ground bone or bone meal that has been treated with sulphuric acid. It is commonly known as "Bone Super-phosphate" and contains 1 to 2 percent nitrogen and 16 percent total P_2O_5 of which about 8 percent is water-soluble.

Dolomite: A mineral composed chiefly of carbonates of calcium and magnesium in substantially equi-molar proportions.

Dung: The semi-solid excrement of animals used as a manure and soil conditioner.

Equivalent Acidity: The number of parts by weight of calcium carbonate (as $CaCo_4$) required to neutralize the acidity resulting from the use of 100 parts by weight of a fertilizer.

Equivalent Basicity: The number of parts by weight of calcium carbonate (as $CaCO_4$) that corresponds in acid neutralizing capacity to 100 parts by weight of the fertilizer

f.a.s.: Free a long side.

Fertilization: The use of mineral fertilizers for plant nutrition.

Fertilizer Conditioners: The number of parts by weight of calcium carbonate (as $CaCO_4$) that corresponds in acid-neutralizing capacity to 100 parts by weight of the fertilizer.

Fertilizer Conditioners: Materials which are added to fertilizers to control free moisture and keep the fertilizer free flowing by helping to prevent caking.

Fertilizer: A material in which declared nutrients are in the form of inorganic salts obtained by extraction and/or by physical and/or chemical industrial processes (also termed Mineral Fertilizers). It can also be defined as (see 2.22).

Fertilizer: A product containing one or more plant nutrients which is designed for use in promoting plant growth.

Fertilizer Formula: The quantity and grade of the stock materials used in making a fertilizer mixture, for example, 400 kq of ammonium sulphate containing 20.6 percent nitrogen, 400 kg of super-phosphate containing 16) percent soluble P_2O_5 and 200 kg of potassium sulphate containing 48 percent K_2O

Fertilizer Formulation: It expresses the quantity and grade of the stock materials used in making a fertilizer mixture for example 50kg super-phosphate containing 30 per cent water soluble phosphoric acid (as P_2O_5) or 400g of ammonium sulphate containing 20.6 percent of nitrogen.

Fertilizer Grade: The legal guarantee of its available plant food content expressed in terms of N, P_2O_5 and K_2O or in other forms of expression (e.g. elemental) as required by national legislation.

Fertilizer Material: A fertilizer which either (A): contains important quantities of no more than one of the primary plant nutrients (nitrogen, Phosphorous and potassium; (B) Has approximately 85% of its plant nutrient content present in the form of a single chemical compound or (C) is derived from a plant or animal residue or by product or of a material deposit which has been processed in such a way that its content of primary nutrients has not been materially changed except by purification and concentration.

Fertilizer mixture: A product obtained by mixing different fertilizer inter-mediates and containing more than one of the three fertilizer nutrients, nitrogen, phosphorus and potassium (see also complete fertilizer).

Filler: Any material mixed with fertilizers for any purpose other than the addition of available nutrients, such as for conditioning to give anti-caking properties, and for increasing the weight to bring the percentage of nutrients to desired values.

Final Sample, Laboratory Sample: A representative part of the reduced Sample or, where no intermediate reduction is required, of the. aggregate sample.

Fish Guano: A material consisting essentially of fresh by-products of the fishing industry and produced by grinding and composting.

Fish Heal: A product obtained by drying and grinding, or otherwise treating, fish or fish waste and to which no addition has been made.

f.i.o.: Free in and out.

f.o.b.: Free on board.

f.o.r.: Free on rail

Fused Calcium and magnesium Phosphate: A product derived from the fusion of rock phosphate with approximately 30 percent of Magnesium oxide as such or as, a mineral silicate.

Fused Tricalcium Phosphate: A product composed chiefly of the alpha form of the alpha compound represented by the formula $Ca_3(PO_4)_2$. It is obtained when rock phosphate containing 5 to 10 percent silica is fused and the melt quenched.

Garbage Tankaqe: A product obtained by treating waste house-hold food materials with steam under pressure; the resulting material is dried and ground.

Grade: The percentage of total nitrogen, available phosphorus and soluble potassium stated in whole numbers in the same order and percentages as in minimum guarantee.

Granulated Fertilizer: A which has been made into particles of approximately uniform size, ranging in diameter from 1 to 5mm.

Grain Size: The dimension which corresponds to the smallest sieve aperture through which a particle will pass of presented in the most favourable attitude

Granular Fertilizer: Solid material formed into particles of a pre-determined mean size

Granulation: Techniques using a process such as agglomeration, accretion or crushing, to make a granular fertilizer

Ground Phosphate Rock: Material obtained by grinding naturally occurring phosphate rock to a fineness meeting relevant legislation or accepted custom

Growth Medium: Any material such as soil, peat, etc used as a support for plant roots, that has a capacity for water retention and which may contain added or naturally occurring nutrients

Guano: Includes many materials which vary in source, composition and readiness for use. It may be (a) bat guano - found in caves; (b) Peruvian guano - the accumulated excrement of sea birds found in Peru; (c) fish guano, whale guano, sheep guano, goat guano, and (d) phosphatic guano of various kinds. The nitrogen content varies from 0.4 to 9.0 percent and total P_2O_5 from 12 to 26 percent.

Guarantee (Of Composition): Quantitative and/or qualitative characteristics with which a marketed product must comply for contractual or legal requirement

Gypsum: A hydrated calcium sulphate ($CaSO_4$, $2H_20$): The commercial material contains varying amounts of impurities and is used as a soil amendment

High Analysis Fertilizer: A fertilizer containing not less than 25 percent of the major plant nutrients, namely, nitrogen, phosphorus (as P_2O_5) and potassium (as K_2O)

Hoof and Horn Meal: A product resulting from processing, drying and grinding of hooves and horns and containing 13 to 15 percent nitrogen

Humus: Term used in agronomy for defining certain fractions of the soil evolved from organic materials therein.

Increment: A representative quantity of material taken from a sampling unit

Investigational allowance: An allowance for variations inherent in the taking, preparation and analysis of a sample of fertilizer.

Isobutylidene Diurea (IBDU): A condensation product of isobutyraldehyde and urea with not less than 31 percent nitrogen.

Kainit: A potassium salt containing potassium and sodium chloride and sometimes magnesium with not less than 12 percent of potash (as K_2O).

Kainit: A mineral composed of potassium chloride and magnesium sulphate ($KCI.MgSO_4.\ 2H_20$). The crude potash ore sold as kainite has varying contents of sodium chloride, arid contains Hot less than 12 percent K_2O

Kieserite: Magnesium sulphate ($MgSO_4.H_2O$) containing 27 percent MgO and 22 percent S.

Kotka Phosphate: A product obtained by partial acidulation of ground rock phosphate with sulphuric acid and containing not less than 16 percent of available P_2O_5 of which at least 6 percent is water-soluble.

Label: Paper or plastic label or a printed area of a package or container marked withe the information required by national legislation.

Liming Material: A liming material is used to increase the basicity of the soil. Liming materials contain the element Calcium; examples are quicklime (CaO), slaked lime $Ca(0H)_2$, Calcium carbonate ($CaCO_4$) and Calcium silicate ($CaSiO_3$)

Liquid Fertilizer: A fertilizer material or mixed fertilizer that is a solution, suspension or slurry.

Liquid Fertilizer: This term includes anhydrous ammonia, ammoniating solutions, other nitrogenous solutions and liquid fertilizer.9% The principal materials used in making fertilizers are ammonia, urea, phosphoric acid and potassium chloride.

Liquid Manure: Liquid resulting from animal urine and litter juices or from a dung heap.

Liming Material: Product containing one or both of the elements calcium and magnesium, generally in the form of an oxide, hydroxide or carbonate, principally intended to maintain or raise the pH of soil.

Lot: All containers in a single consignment of the material of the same grade and type, drawn final, a single batch of manufacture shall constitute a lot. It a consignment is declared to consist of different batches of manufacture, the batches shall be marked separately and the groups of containers in each batch shall constitute separate lots. In the case of a consignment drawn from a continuous process 2,000 containers (or 100 tonnes) of the material shall constitute a lot.

Magnesia (Magnesium Oxide) : A product consisting chiefly of the oxide of magnesium.

Magnesium Sulphate: Usually the product known as kieserite ($MgSO_4$. H_20) .The highly hydrated form Epsom salts ($(MgS)_4.7H_20$) is suitable for foliar application.

Major Fertilizer Elements: These elements are nitrogen, phosphorus and potassium.

Manures: See Organic Manures.

Micro Nutrients: See "Trace elements"

Mineral Fertilizer: See Fertilizer

Minimum Guarantee: The minimum percentage of primary plant nutrients claimed to be present in a fertilizer in the following order and form: Total Nitrogen (N) .... percent, available phosphorus (P_2O_5) ..... percent, Soluble potassium (K_2O) ..... percent.

Mixed fertilizer: See Fertilizer mixture.

Nitrate of Soda and Potash: Chiefly the sodium and potassium salt of nitric, acid containing not less than 35 percent of nitrate nitrogen and 10 percent of potash (as K_2O) (see also Potassium Nitrate).

Nitrophosphates: Product s, obtained by treatment of phosphate rock with nitric acid alone or in admixture with sulphuric or phosporic acid, with or without subsequent treatment with ammonia.

Non-Acid-Forming Fertilizer: A fertilizer not capable of increasing the acidity or reducing the alkalinity of the soil.

Oil Cake: The residue left after extraction of fatty oil from different oil seeds employed for industrial purpose, chiefly valued for its nitrogen content and also containing phosphorus, potassium and other elements in small proportions.

Order of Term of Plant Nutrients in Fertilizers: The order of plant nutrients in fertilizer shall be nitrogen (N) first phosphoric acid (as P_2O_5) second and potash (as K_2O) third.

Organic Fertilizer: A material whose origin is animal or vegetable.

Organic Manures: Carbonaceous material mainly of vegetable and/or animal origin added to the soil. specifically for the nutrition of plants.

Organic Nitrogen Fertilizer: Fertilizer containing nitrogen associated with carbon in organic combination.

Oversize: That portion of a batch or sample which does not pass through a sieve of specified aperture size.

Partial sample: A quantity of material taken at a point from a sampling unit

Particle Size Analysis (Granulometry) By Sieving: The division of a sample by sieving into size fractions.

Peat: Residual matter from plants grown and decayed in almost permanently waterlogged conditions and which may contain a limited quantity of naturally occurring mineral material.

Phosphate Rock: A natural rock containing one or more calcium phosphate minerals of sufficient purity and quantity to permit its use directly or after concentration in the manufacture of commercial. phosphorus fertilizers.

Plant Food Ratio: The ratio of the numbers of fertilizer units in a given mass of fertilizer expressed in the order N-P-K.

Plant Nutrient: A chemical element essential for plant growth.

Potassium Chloride (Nitrate of Potash) : A mineral with soluble potash content ranging from 48 to 62 percent.

Potassium Meta-phosphate (FP00 : A product composed chiefly of the crystalline compound represented by the formula K_2O

Potassium Nitrate (KNO_2): A nitrogen-potassium fertilizer containing 13 percent N and 44 percent K_20.

Potassium Magnesium Sulphate: A double salt of potassium and magnesium containing about 21 percent K_2O

Potassium Sulphate: The potassium salt of sulphuric-acid with not less than 48 percent of soluble potash (as K_2O) ranging from 34 to 54 percent

Potassium Sulphate (K_2SO_4) : A potassium fertilizer containing 48 percent K_2O and also supplying 17-20 percent of sulphur.

Powder: Solid substance in the form of fine particles.

Precipitated Bone Phosphate: A by-product from the manufacture of glue from hones obtained by neutralizing the hydrochloric acid solution of processed bone with lime. The phosphorus is chiefly present as dicalcium phosphate.

Prill: Particle, obtained by solidification of falling droplets of fertilizers

Processed Tankage: A product made Wider steam pressure from crude inert organic nitrogenous materials, with or without the use of acid for the purpose of increasing the activity of nitrogen.

Reduced Sample: A representative part of the aggregate sample obtained a process of reduction in such a manner that the mass approximates to that of the final (laboratory) sample.

Reverted Phosphoric Acid: The part of the water-soluble P_2O_5 in a fertilizer which as a result of some reaction has become insoluble in water.

Sampling Unit: A defined quantity of material having a boundary which may be physical, for example a container, or hypothetical for sample a particular time or time interval in the case of a flow of material.

Secondary Fertilizer Elements: Calcium, magnesium and sulphur

Secondary Plant, Nutrients: Calcium, Magnesium and Sulphur.

Semi-Organic Fertilizer: Product in which declared nutrients are of both organic and inorganic origin obtained by mixing and/or chemical combination of organic and inorganic (mineral) fertilizers.

Sieving: The process of separating a mixture of particles according to their sizes by one or more sieves.

Slow Release Fertilizer: Fertilizer whose nutrients are present as a chemical compound or in a physical state such that their availability to plants is spread over a period of time.

Slurry: Semi-liquid effluent from livestock, consisting of urine and faeces possibly diluted with water.

Sodium and Potassium Nitrate: The sodium and potassium salts of nitric acid with not less than 15 percent nitrogen.

Sodium Nitrate: The sodium salt of nitric acid with not less than 12 percent nitrogen.

Any substance that is added to the soil for the j:pose of improving its physical or chemical character, enhancing soil productivity or promoting the growth of crops it excluding commercial fertilizers and organic manure.

Soil Conditioner: Material added to soil mainly to improve its physical and, as a consequence, its chemical and biological properties.

Soil Fertility: The ability of a soil to support satisfactory plant growth.

Solubility of a Fertilizer Nutrient: The quantity of a given nutrient which will be extracted in a specific medium under specified conditions, expressed as a percentage by mass of the fertilizer.

Solution Fertilizer: Liquid fertilizer free of solid particles.

Straight Fertilizer: Qualification generally given to a nitrogen, phosphorus or potassium fertilizer having a declarable content of one primary nutrient only.

Sulphate of Potash @'(K_2SO_4): See potassium sulphate.

Sulphur-Coated Urea: This is a recently developed fertilizer. It consists of urea granules coated with a layer of sulphur. The pores in the coating are sealed with wax which contains 0.5 percent coaltars. The coaltar is supposed to reduce the rate at which microorganisms decompose the coating on the fertilizer. As a result the nitrogen is released slowly to plants.

Super-phosphate (Single Super-phosphate): A commercial product obtained by treating phosphate rock with sulphuric acid and containing about 18 percent of P_2O_5 mainly water-soluble, along with calcium sulphate and other products of reaction (contains 16 percent 5).

Suspension Fertilizers: A two-phase fertilizer in which solid particles are maintained in suspension in the aqueous phase.

Test Sample: A representative part of the final sample prepared by an appropriate method for a particular test

Test Sieving: Sieving with one or more test sieves.

Trace Elements (Micro-nutrients): Elements which are essential to plants in very small quantities for completion of their normal life cycle (B, Cl, Cu, Fe, Mn, Mo, Zn).

Triple Super-phosphate: A commercial product obtained by treating phosphate rock with phosphoric acid and containing about 46 percent P_2O_5, mainly water-soluble.

True Density: The mass per unit volume of the particles of a material

Undersize: That portion of the batch or sample which passes through a sieve of specified aperture size

Unit: A unit of plant food is 10kg or 1 percent of a tonne. Thus 0-20-0 contains units of nutrient per ton.

Urea $(CO(NH_2)_3)$ A synthetic, non-protein organic compound, crystalline or made into granules or prills for fertilizer use and containing 46 percent nitrogen.

Urea formaldehyde: Slow release nitrogen fertilizer produced by reaction between urea and formaldehyde.

Waste-Lime (By-Product Lime) : An industrial waste or by-product containing calcium or calcium and magnesium in forms that will neutralize, acids. It may be designated by prefixing the name of the industry or process by which it is produced; for example gas lime, tanners' lime, lime kiln ash.

Appendix IV Conversion Table for Liquid Herbicide Formulations

RATE kg a.i. ha^{-1}	CONCENTRATION OF ACTIVE INGREDIENT IN FORMULATION, g/l ml OF FORMULATION PER 10 SQUARE METERS									
	120	240	250	300	360	480	500	550	600	720
1	8.33	4.17	4	3.33	2.78	2.08	2	1.82	1.67	1.39
2	16.67	8.33	8	6.67	5.56	4.17	4	3.64	3.33	2.78
3	25.00	12.50	12	10.00	8.33	6.25	6	5.45	5.00	4.17
4	13.33	16.67	16	13.33	11.11	8.33	8	7.27	6.67	5.56
5	41.67	20.83	20	16.67	13.89	10.42	10	9.07	8.33	6.94
6	50.00	25.00	24	20.00	16.67	12.50	12	10.91	10.00	8.33
7	58.33	29.17	28	23.33	19.44	14.50	14	12.73	11.67	9.72
8	66.67	33.33	32	26.67	22.22	16.67	16	14.55	13.33	11.11
9	75.00	37.50	36	30.00	25.00	18.75	18	16.36	15.00	12.50
10	83.33	41.67	40	33.33	27.78	20.83	20	18.18	16.67	13.89

Example: To apply a herbicide containing 250g/l at a rate of 4kg/ha^{-1} to a 10 square metre plot use 16ml of the formulation

Appendix V Conversion Table for Wettable Powders, Soluble Salts and Granules

RATE kg a.i. ha^{-1}	CONCENTRATION OF ACTIVE INGREDIENT IN FORMULATION GRAMS OF FORMULATION PER 10 SQUARE METRES										
	20%	50%	55%	60%	65%	72%	74%	75%	80%	85%	95%
1	5	2	1.82	1.67	1.54	1.39	1.35	1.33	1.25	1.18	1.05
2	10	4	3.64	3.33	3.08	2.78	2.70	2.67	2.50	2.35	2.11
3	15	6	5.45	5.00	4.62	4.17	4.05	4.00	3.75	3.53	3.16
4	20	8	7.27	6.67	6.15	5.56	5.41	5.33	5.00	4.71	4.21
5	25	10	9.09	8.33	7.69	6.94	6.76	6.67	6.25	5.88	5.26
6	30	12	10.91	10.00	9.23	8.33	8.11	8.00	7.50	7.06	6.32
7	35	14	12.73	11.67	10.77	9.72	9.46	9.33	8.75	8.24	7.37
8	40	16	14.55	13.33	12.31	11.11	10.81	10.67	10.00	9.41	8.42
9	45	18	16.36	15.00	13.85	12.50	12.16	12.00	11.35	10.59	9.47
10	50	20	18.18	16.67	15.38	13.89	13.51	13.33	12.50	11.76	10.53

Example: To apply a herbicide containing 80% active ingredient at a rate of 3kg/ha_{-1} to a 10 square metre plot use 3.75g of the formulation

Appendix VI Fertilizer Marketing Companies in Nigeria, August 2000

COMPANY	LOCATION
Akkad group of companies	Lagos and Kano
BUA Nigeria Limited	Lagos
Chemmix	Kaduna

Blending Plants in Nigeria, August, 2000

F & C Blending Plant	Kaduna
Morris Blending Plant	Niger
Zungeru Fertilizer Company	Niger
Funtua Blending Plant	Katsina
Bauchi Blending Plant	Bauchi
Gombe Blending Plant	Gombe
Borno Blending plant	Borno
Agro Nutrient and Chemical Company	Kano
KASCO Blending plant	Kano
Edo State Blending plant	Edo
SCENTUM Al fertilizers	Enugu
Gaskia Fertilizer Company	Kano
Sasisa Fertilizer Company	Kano
Zamfara Blending Plant	Zamfara
Sokoto Blending Plant	Sokoto
Kebbi Blending Plant	Kebbi
Adamawa Blending Plant	Adamawa
NAFCON Plant	Rivers
Crystal Fertilizer Blending plant	Niger
FSFC	Kaduna

Source - Federal Fertilizer Department, Abuja.

Appendix VII Methods of Qualitative Identification of Elements Contained in Fertilizer Materials

a) **Apparatus**

250ml conical flasks, Whatman No. 1 filter papers. Test tubes, bunsen buner

b) **Reagents**

i) NaOH pellets
ii) $NACl0_4$ - saturated solution
iii) Diphenylamine - 0.5g diphenylamine + 20ml H20 + 100ml. Conc. H_2S0_4
iv) Vanadomolybdate solution - prepare solution A by dissolving 25g $(NH4)_6 M0_7)0_{24}$ $4H_20$ in 400ml H_20. Prepare solution B by dissolving 1.25g of NH_4-Vanadate in 500ml of water and add 250ml of conc. $NH0_3$ and then cool room temperature. Pour solution A into B, and dilute to 1 litre with water.
v) In HCl - dilute 83ml conc. HCl to 1 with water
vi) 0.1N HCl - dilute 8.3ml conc. HCl to 1 liter with water
vii) 0.1N Na0H - dissolve 4.0g Na0H in water and dilute to 1 liter
viii) Brmocresol green indicator - dissolve 0.1g indicator in 100ml ethanol
ix) 4N HCl - dilute 333ml conc. HCl to 1 liter
x) 0.1N $HN0_3$ - dilute 6.7ml conc. $HN0_3$ to 1 liter
xi) $BaCl_2$ - saturated solution (about 50g/100ml)
xii) $AgN0_3$ - 10g/100ml

c) **Procedures**

i) Preparation of the test solution
ii) Shake 50g of fertilizer with 100ml of water for 5 minutes in a 250ml conical flask. (through Whatman No.1 filter paper)
iii) Filter through Whatman No. 1 filter paper. Save both the filtrate and the material left on the filter paer

d) **Detection of Ammonium and Potassium**

i) Transfer 5ml of filtrate from section A to a test tube
ii) Add 2 pellets of solid Na0H
iii) Soil gently to remove NH_3
iv) Add 2ml of saturated $NaC10_4$. Check for formation of a white precipitate

e) **Detection of Nitrates**

i) Place 10 drops of diphenylamine solution in dry test tube
ii) Add one drop of filtrate section A and note if a blue colour forms

f) **Detection of Phosphate**

i) Place 1ml of vanadomolybdate solution in a test tube
ii) Add one drop of filtrate from section A to the tube and check for development a yellow colour

iii) If the test is negative, add 20ml of 1N HCl to the solid material remaining on the filter paper from section A
iv) Repeat steps 1 and 2 with the acid filtrate

g) **Detection of Calcium**

i) Place 5ml of filtrate from section A into a test tube
ii) Add one drop of bromo - cresol green indicator
iii) Add 0.1N Hcl or 0.1N Na0H as necessary to give a green colour
iv) Add one drop of saturated $(NH_4)_2C_2O_4$ and check for precipitate formation

h) **Detection of Sulphates**

i) Place 2ml of filtrate from section A into a test tube
ii) Add 2ml of 4N Hcl
iii) Add 1 drop of saturated $BaCl_2$ solution check for formation of a white precipitate

i) **Detection of Chlorides**

i) Place 4ml of 0.1N HNO_3 into a test tube
ii) Add 1 drop of filtrate from section A
iii) Add 1 drop of 10% $AgNO_3$ and check for formation of a white precipitate

Appendix VIII Calculating Fertilizer Rates

A number of calculations on fertilizer materials may be necessary. The usual ones needed are (1) nutrient percentage, (2) weight of bulk fertilizer to use, and (3) weights of materials to use in making mixed bulk fertilizer for adding several nutrients. Such a mixture might be based on a fertilizer recommendation from a tested soils sample.

a) **Calculating Nutrient Percentage**

All nutrients should be expressed as the percentage of the element (percent zinc, percent nitrogen, percent phosphorus). Unfortunately, early chemists reported elements as "burned solids" which produced oxides. Thus, we are still using the convention of reporting phosphorus as P_20_5 equivalent and potassium as K_20 equivalent. Efforts are being made to change these conventions to report only N, P and K percentages.

Phosphate fertilizers do not actually contain P205

A close approximation of the percentage of a nutrient can be obtained using the fertilizer formula and chemical atomic weights. Urea has a formula of $(NH_2)_2C0$. The molecular weight (sum of all atomic weights) is 60.056. The percentage nitrogen is calculated as follows:

$$\frac{2N}{H4\,N2\,CO} x(100) = \frac{(28.014g)x^2}{(60.056g)} x^{(100)} = 46.6 \text{ percent}$$

Because the fertilizers are seldom pure, the calculations can be rounded downward to the nearest whole integer: (28 g/60g) (100) = 46 percent.

b) **Calculating Simple Fertilizer Mixtures**

Calculate the amount of Urea, Diammonium Phosphate (DAP) and Muriate of Potash (MOP) needed to produce 1000kg (1 tonne) of blended 20-10-10.

Solution

Given: Urea - 46% N; DAP - 46% P_20_5 and 18% N; MOP - 60% K_20.
The mixture must have: 20 percent of 1000 percent of 1000kg which equals 100kg K_20.
Let us begin our calculations with DAP which supplies N and P_20_5. To get 100kg P_20_5 each 100kg of DAP has 46kg of P_20_5 and 18kg N.

Thus:

46kg P_20_5 is contains in 100kg DAP

100kg P_20_5 will be obtained from:

$$\frac{100}{46} x \frac{100kg}{1} \text{ DAP} = 217\text{kg DPA}$$

Find out the amount of N to be supplies from 217 kg of DAP.

Thus:

100kg DAP contains 18kg of N
217kg DAP contains

$$\frac{217}{100} x \frac{18}{1} = 39.06\text{kg N}$$

Note that 200kg N was calculated as being equal to 20% of 1000kg of 20-10-10.

If DAP would supply 39.0kg N then urea would provide 200 - 39 = 161kg N

Thus:

46kg N in 100kg urea
161 kg N would be obtained from

$$\frac{100}{46} x \frac{161\text{kg of urea}}{1} = 350\text{kg - urea}$$

Potassium

To obtain 100kg of K20

60kg K20 in 100kg MOP
100kg K20 would be obtained from

$$\frac{100}{60} x \frac{100}{1} = 166.6\text{kg – M O P}$$

To produce 1000kg of 20-10-10, you will require:

a)	350kg	Urea
b)	217kg	DAP
c)	166.6kg	MOP
	733.6kg of Urea + DAP + MOP	
+	266.4kg Kaolin or Limestone	
	1000kg	

c) An extension agent is evaluating maize response to various levels of nitrogen and his N - source is urea with 46% N. Each of the experimental plots is 0.25ha. If the N rates are 60, 120 and 150kg N per hectare, calculate the quantities of urea he will apply per plot to meet each of the 3 nitrogen rates.

Working
That urea contains 46% N means that 46kg N is supplied by 100kg urea. Therefore 60 Kg N will be supplied by

$$\frac{100 x 60}{46} = 130 \text{ – Urea}$$

Similarly, 120kg N will be supplied by

$$\frac{100 x 120}{46} = 260\text{kg - Urea}$$

By the same working, 150kg N will be supplied

$$\frac{100 \times 150}{46} = 320\text{kg - urea}$$

The above amounts of urea will meet the needs of one hectare in each case.

Therefore quantities per plot where each plot measures 0.25 of ¼ ha will then be

$$\frac{130}{4} \_\_ \frac{260}{4}$$

and

$$\frac{326}{4}\text{kg - urea / plot}$$

That is 32.5, 65 and 81.5 kg of urea for each of the 3 rates of treatment.