TABLE OF CONTENTS

INTRODUCTION *iii*

TABLE OF CONTENTS *v*

LIST OF FIGURES *x*

HOW TO USE THIS TRAINING PACKAGE *xii*

MODULE 1: NITROGEN AND TROPICAL AGRICULTURE *(10 Pages)*

Summary 1-1
Key Concepts 1-1
Nitrogen in Nature 1-2
The Role of Nitrogen in Human Nutrition 1-4
Nitrogen in Agriculture 1-6
Introduction to Biological Nitrogen Fixation 1-7
The Need for BNF in Agricultural Systems 1-9
Review, Discussion, Case Studies 1-10
Training Aids

MODULE 2: LEGUMES AND THEIR USE *(14 pages)*

Summary 2-1
Key Concepts 2-1
The Leguminosae 2-1
Nodulation in the Leguminosae 2-2
Legume Identification 2-3
Review, Discussion, Case Studies 2-7
Training Aids

MODULE 3: AN INTRODUCTION TO RHIZOBIA *(13 pages)*

Summary 3-1
Key Concepts 3-1
Soil Microorganisms 3-1
Rhizobia are Special Soil Bacteria 3-2
Rhizobia in the Laboratory 3-2
Can One Rhizobial Strain Nodulate All Legumes? Concept of the Cross-Inoculation Groups 3-4
Strains of Rhizobia are Diverse 3-7
Rhizobia are Saprophytes 3-8
The Importance of Native Rhizobia 3-11
Review, Discussion, Case Studies 3-12
Training Aids

MODULE 4: THE LEGUME-RHIZOBIA SYMBIOSIS *(12 pages)*

Summary	4-1
Key Concepts	4-1
Basic Processes of the Symbiosis	4-1
The Amount of Nitrogen Fixed by Leguminous Crops	4-5
The Fate of Fixed Nitrogen	4-7
Cropping Systems to Exploit BNF	4-8
Discussion and Demonstration	4-12
Training Aids	

MODULE 5: INOCULATION OF LEGUMES: PRINCIPLES AND PRACTICES *(32 pages)*

Summary	5-1
Key Concepts	5-1
The Need to Inoculate	5-1
What is Inoculation	5-2
Inoculant Production	5-3
Selecting Good Inoculants	5-8
Inoculant Application	5-11
Summary of Inoculation Methods	5-22
Inoculant Storage and Handling	5-24
Reminders	5-30
Review, Discussion, Case Studies	5-31
Training Aids	

MODULE 6: THE RESPONSE TO LEGUME INOCULATION *(16 pages)*

Summary	6-1
Key Concepts	6-1
What is a Response to Legume Inoculation with Rhizobia?	6-2
Factors Affecting the Response to Legume Inoculation	6-5
The Role of Native Rhizobia on the Response to Legume Inoculation	6-12
Review, Discussion, Case Studies	6-15
Training Aids	

MODULE 7: TESTING AND EVALUATING BNF IN THE FIELD *(24 pages)*

Summary	7-1
Key Concepts	7-1
Identifying the Need for Inoculation and Intrepretation of Data	7-2
The Process of Developing Recommendations to Farmers to Inoculate their Legume Crops	7-2
Diagnoses of BNF Problems and Measuring the Response to Legume Inoculation	7-19

Review, Discussion, and Case Studies 7-24
Training Aids

MODULE 8: COMMUNICATION SKILLS AND TECHNOLOGY TRANSFER *(9 pages)*

Summary 8-1
Key Concepts 8-1
Improving Communication Skills 8-1
Blocks to Communication 8-4
Teaching Adults Requires Special Considerations 8-5
Planning 8-8
Training Aids

GLOSSARY

SLIDES (Explanation and 40-slide set)

DEMONSTRATION SECTION:

Module 1: Demonstration 1 — **Display Of The Amounts Of Cereals And Legumes Required To Provide Equivalent Amounts Of Protein**

Module 1: Demonstration 2 — **Display Of Nodulated Legumes**

Module 3: Demonstration 1 — **The Cross-inoculation Concept: Legumes Require Specific Rhizobia**

Module 3: Demonstration 2 — **Growth Characteristics Of Rhizobia**

Module 4: Demonstration 1 — **Demonstrating Differences In Effectiveness Of Strains Of Rhizobia**

Module 4: Demonstration 2 — **Estimating Nitrogen Inputs Of A Soybean Crop**

Module 5: Demonstration 1 — **Laboratory Scale Inoculant Production**

Module 5: Demonstration 2 — **Quality Control In Inoculant Production: Fermentor Broth**

Module 5: Demonstration 3 — **Influence Of Storage Conditions On Temperature Of Stored Inoculant**

Module 5: Demonstration 4 — **Quality Control In Inoculants**

Module 5: Demonstration 5 — **Seed Inoculation**

Module 5: Demonstration 6 — **Soil Inoculation**

Module 5: Demonstration 7 — **Evaluating The Quality And Effectiveness O Inoculants**

Module 6: Demonstration 1 — **The Effect Of Nitrogen Fertilizer And Manage Ment On Nodulation And Growth Of Legumes**

Module 7: Demonstration 1 — **Effect Of Farm Management Practices On The Yield Response To Legume Inoculation**

Module 7: Demonstration 2 — **A Pot Experiment To Demonstrate The Yield Response To Legume Inoculation**

Module 8: Demonstration 1 — **Taking Control of The Technology Transfer Process**

Module 8: Demonstration 2 — **Communication Skills Practice**

Module 8: Demonstration 3 — **Planning A Comprehensive BNF Transfer Program**

LIST OF FIGURES

Page/Figure		
1-3	1-1	A simple nitrogen cycle highlighting BNF
1-5	1-2	Protein: An important part of human nutrition
1-7	1-3	Energy requirements of synthesized N fertilizer
1-8	1-4	Root nodules of soybean (*Glycine max*)
1-9	1-5	BNF meets a legume's need for nitrogen
2-3	2-1	Subfamily Papilionoideae
2-4	2-2	Subfamily Caesalpinoideae
2-4	2-3	Subfamily Mimosoideae
2-5	2-4	Leaves of legumes and associated structures
2-5	2-5	Legume pods
2-6	2-6	The winged bean, a representative multi-use plant
3-3	3-1	Rhizobia grown on YMA media have a gummy or slimy appearance
3-3	3-2	Rod shaped rhizobia in the nodule of cowpea (*Vigna unguiculata*)
3-6	3-3	Examples of using the cross inoculation groups for selecting proper rhizobial inoculant for legume host
3-7	3-4	Strain TAL 22 as a superior rhizobial strain on rice bean (*Vigna umbellata*)
3-10	3-5	The effect of climate on rhizobial population
4-2	4-1	Stages of infection, nodule development and nodule formation
4-3	4-2	Some representative shapes of leguminous nodules
4-3	4-3	The legume-rhizobia symbiosis
4-5	4-4	Amounts of nitrogen fixed by various legumes
5-3	5-1	Comparing rhizobia in soil and in inoculants

5-6	5-2	Inoculant production using sterile carrier
5-7	5-3	Inoculant production using non-sterile carrier
5-9	5-4	A sample inoculum label
5-12	5-5	Effect of different stickers on the number of viable inoculant rhizobia on soybean seeds at time of planting.
5-12	5-6	Survival of rhizobia on legumes after storage at a high temperature
5-14	5-7	Seed inoculation by the slurry method
5-17	5-8	Seed coating by the two-step method
5-21	5-9	A side view of soil inoculation
5-21	5-10	Inoculant applicator
5-22	5-11	Trees planted in dibble tubes for transplanting
5-24	5-12	The folly of storing inoculant in direct sunlight or a metal roofed building
5-25	5-13	Suggestions for rhizobial inoculant storage
5-26	5-14	Survival of soybean rhizobia at three temperatures
5-26	5-15	Survival of chickpea rhizobia at three temperatures
5-27	5-16	Transporting inoculants to the field
5-27	5-17	Protecting inoculant from the elements
5-28	5-18	Illustration of the dramatic differences between the cost of chemical fertilizers and rhizobial inoculants
6-4	6-1	Farmers may realize increased yields from legume inoculation
6-7	6-2	Environmental factors and nutrient limitations are important considerations the Law of the Minimum
6-8	6-3	Phosphorus deficient soil limits response to inocualtion
6-9	6-4	Good management practices ensure good crops and benefits from inoculum

7-3	7-1	Stages of on-farm research
7-10	7-2	Treatments are repeated and placed in blocks on a slope
7-20	7-3	Situations commonly observed in farmers' fields and their explanations
8-9	8-1	The structure of BNF communication for extension of technology