STRUCTURE ANALYSIS AND SYSTEM DYNAMICS OF AGROFORESTRY HOME GARDENS OF SOUTHERN KERALA

By

JACOB JOHN

THESIS

SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLAYANI
THIRUVANANTHAPURAM

1997

DECLARATION

I hereby declare that this thesis entitled **"Structure analysis and system dynamics of agroforestry home gardens of southern Kerala"**. is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellayani,
7-7 - 1997.

JACOB JOHN

CERTIFICATE

Certified that this thesis entitled **"Structure analysis and system dynamics of agroforestry home gardens of southern Kerala"** is a record of research work done independently by **Sri. Jacob John** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Vellayani,
7-7 - 1997.

Dr. M. Achuthan Nair
(Chairman, Advisory Committee)
Associate Professor,
Department of Agronomy,
College of Agriculture, Vellayani.

Approved by

Chairman :

Dr. M. ACHUTHAN NAIR

Members :

1. **Dr. M. R. CHIDANANDA PILLAI**

2. **Dr. V. L. GEETHA KUMARI**

3. **Dr. (Mrs.) P. SARASWATHI**

4. **Dr. S. REGEENA**

External Examiner :

Dr. S. CHINNAMANI

ACKNOWLEDGEMENT

By the Grace of God I am what I am

I have ebullient and intense pleasure in expressing my heartfelt indebtedness and gratitude to Dr. M. Achuthan Nair, Associate Professor of Agronomy, College of Agriculture and Chairman of the Advisory Committee for not only suggesting the problem but also for instilling in me the confidence to undertake this study. Words fail to express my deep and sincere obligation for the sincerity, dedication, persuasion, guidance, benevolence and affection shown by him. His help in arriving at logical conclusions stood in good stead in the preparation of the manuscript with clarity and precision. The stimulation by his never ending flow of ideas contributed very significantly to my professional development. I recognize a grandeur in the beatings of his heart. He was a source of strength, a beacon light to my faltering steps in challenging work situations.

I avail myself of this opportunity to place on record my heartfelt thanks to Dr. M.R.Chidananda Pillai, Professor and Head of the Department of Agronomy, College of Agriculture, Vellayani for his learned counsel and help throughout.

I wish to express my profound gratitude and obligation to Dr. (Mrs.) P. Saraswathi, Professor and Head, Department of Agricultural Statistics, College of Agriculture, Vellayani for her inestimable co-operation, valuable guidance and periodic suggestions at various stages of this investigation.

I express my utmost gratitude and appreciation to Dr. V.L. Geetha Kumari, Associate Professor of Agronomy, College of Agriculture, Vellayani for her incessant encouragement, blessings, friendly approach, affectionate advice and constructive criticisms throughout the course of this investigation.

I sincerely thank Dr. S. Regeena, Assistant Professor, Farming Systems Research Station, Kottarakkara for her expert comments, advice and critical scrutiny of the manuscript.

I am extremely grateful to Dr. C. Sreedharan, Dean, College of Agriculture, Vellayani, Dr. Mohanakumar, Director of Research, Kerala Agricultural University, Dr. P.D. Vijaya Gopal, Associate Director of Research, NARP (SR), Vellayani and Dr. K.M.Rajan, Professor (Research Co-ordination), for all the guidance and necessary facilities given to me during the entire course of study.

I extend my special thanks to Dr. S.K. Nair (Associate Professor of Plant Pathology), Dr. Vijayaraghavakumar (Assistant Professor of Agrl. Statistics), Dr. P.K.Ashokan (Associate Professor of Forestry), Prof Abdul Hameed (Professor of Agrl. Chemistry and Soil Science), Dr. S. Pushkala (Professor of Agrl. Chemistry and Soil Science), Sri. Anoop. E.V. (Assistant Professor of Forestry), Smt. Elsamma Job (Assistant Professor of Agrl. Economics), Dr. Gokulapalan, C. (Assistant Professor of Plant Pathology) and Smt. Sofie Cherian (Assistant Professor of Food Science and Nutrition) for providing me help everwillingly and expertly during different critical phases of this study.

With ardent gratitude, I remember the inspiration, whole hearted co-operation and goodwill bestowed on me by all the members of the teaching staff, especially my course teachers, of the Department of Agronomy, College of Agriculture, Vellayani in all my endeavors.

Words fail to express my sincere and fervent thanks to my dear friends and co-workers in the ICAR ad hoc project Sri.Sanjeev, V. and Roshni, G.C. for their precious assistance and moral support.

I should specially mention Sri. Moosa, P.P., Sri. Santhosh Mithra, Miss. Rajasree, R., Mrs. Shalini Pillai, Sri. Sreekumar, S., Sri. Suresh Kumar, S.N., Miss. Suneetha, S., Sri. Rajan, S., Sri. Bygu, Sri. Joise Abraham, Miss. Sheeba Rebecca Issac and Sri. Ravindran

C.S. for their unrelenting and indispensable help and company which is always a matter joy to be remembered. My heart goes out in gratitude to them.

It is my great privilege and pleasure to have the best help and co-operation from all staff of the NARP (SR), Vellayani.

The instrument of my acknowledgement would remain incomplete if the farmers of the homesteads Sri. Robert, S. and Sri. Paulose, A. are not thanked for their co-operation and assistance, without which the field investigations would not have materialized.

I owe immense gratitude to the Indian Council of Agricultural Research for permitting me to work as Senior Research Fellow in the ICAR ad hoc project entitled " Homestead Agroforestry Systems of Kerala "and do myPh.D.programme as its part.

I sincerely thank the Kerala Agricultural University for appointing me as Senior Research Fellow in ICAR ad hoc project of which the thesis forms a part.

Adequate justice cannot be done in a few words to the help rendered by Sri. Sreekumar, NARP(SR), Vellayani. His technical ingenuity and services have been incalculable and invaluable.

I owe unmeasurable indebtedness to my wife, daughter and parents for their affection, moral support, blessings and coping with the long periods of negligence and monotony that they might have been inadvertently put to.

Over and above all I gratefully bow before my Lord Almighty for the countless blessings showered upon me all throughout and for giving me the courage, determination and bountiful blessings to complete this research work.

Jacob John

CONTENTS

Page No.

INTRODUCTION 1

REVIEW OF LITERATURE 5

MATERIALS AND METHODS 49

RESULTS AND DISCUSSION 67

SUMMARY 204

REFERENCES i

APPENDIX

ABSTRACT

LIST OF TABLES

Table No.	Title	Page No.
1	Panchayats selected for the agroforestry systems inventory description survey in the district	51
2	Analytical methods adopted for the estimation of nutrient contents of leaf / plant samples	57
3	Analytical methods adopted for the estimation of nutrient contents of throughfall and stemflow	57
4	Analytical methods adopted for the estimation of chemical properties of soil	60
5	Differences in holding size and species diversity of the home gardens in the district and its agroecological zones	69
6	Tree / Crop Species noticed in the home gardens in the district	71-74
7	Relative predominance of different crop categories in the district	76
8	Relative predominance of different crop categories in different agroecological regions in the district	76
9	Relative predominance of different crop categories in relation to holding size	77

Contd...

Table No.	Title	Page No.
10	Average number of plants of different crop categories in the home gardens	79
11	Frequency of occurrence of different tree species in the district and its agroecological regions	82
12	Relative predominance of different tree species in the district and its agroecological regions	83
13	Average number of tree species in the home gardens	84
14	Average number of cattle and poultry in the home gardens	96
15	Marketing channels selected by homestead farmers for the sale of their produce	99
16	Constraints experienced by the homestead farmers	101
17	Economic analysis of home gardens in the district and its agroecological zones	103
18	Correlation analysis of various components and activities in the home gardens	106
19	Correlation between area, total number of trees and individual tree population	107
20	Inventory of the home garden at Location I	109
21	Inventory of the home garden at Location II	111
23	Annual litterfall of different tree species at Location I	114

Contd...

Table No.	Title	Page No.
24	Nutrient addition by different tree/crop components in the homestead at Location I (0.50 ha) in the first year	117
25	Nutrient addition by different tree/crop components in the homestead at Location I (0.50 ha) in the second year	118
26	Nutrient addition by different tree/crop components in the homestead at Location II (0.40 ha) in the first year	119
27	Nutrient addition by different tree/crop components in the homestead at Location II (0.40 ha) in the second year	120
28	Nutrient addition by organic manure at Location I	127
29	Nutrient addition by organic manure at Location II	129
30	Total nutrient addition through various sources in the home garden at Location I	131
31	Total nutrient addition through various sources in the home garden at Location II	133
32	Nutrient removal from the home garden at Location I	135
33	Nutrient removal from the home garden at Location II	136
34	Soil physical properties of Location I	142
35	Soil physical properties of Location II	143
36	Soil moisture content of Location I	144

Contd...

Table No.	Title	Page No.
37	Soil moisture content of Location II	145
38	Soil chemical properties of Location I	148
39	Soil chemical properties of Location II	149
40	Soil microbiology of Location I	152
41	Soil microbiology of Location II	153
42	Microclimate at Location I	156
43	Microclimate at Location II	157
44	Light intensity (Lux) at the floor of major tree species of Location I (First year)	162
45	Light intensity (Lux) at the floor of major tree species of Location I (Second year)	163
46	Light intensity (Lux) at the floor of major tree species of Location II (First year)	164
47	Light intensity (Lux) at the floor of major tree species of Location II (Second year)	165
48	Economic analysis of the home garden at Location I (First year)	168
49	Economic analysis of the home garden at Location I (Second year)	169

Contd...

Table No.	Title	Page No.
50	Economic analysis of the home garden at Location II (First year)	171
51	Economic analysis of the home garden at Location II (Second year)	172
52	Allelopathic effect of leaf extracts of different tree species on rice	178
53	Allelopathic effect of leaf extracts of different tree species on cowpea	181
54	Allelopathic effect of powdered leaf litter of different tree species on rice	183
55	Allelopathic effect of powdered leaf litter of different tree species on cowpea	185
56	Optimisation model for home garden at Location I	193
57	Linear programming analysis of Location I	196
58	Optimisation model for home garden at Location II	199
59	Linear programming analysis of Location II	202

LIST OF FIGURES

Fig. No.	Title	Between Pages
1.	Map showing the panchayats selected for the agroforestry systems inventory description survey in Thiruvananthapuram district	49-50
2.	Holding size of the home gardens in the district	68-69
3.	Species diversity of the home gardens in Thiruvananthapuram district	74-75
4.	Relative predominance of different crop categories in Thiruvananthapuram district	85-86
5a.	Relative predominance of different crop categories in highlands	86-87
5b.	Relative predominance of different crop categories in midlands	86-87
5c.	Relative predominance of different crop categories in lowlands	86-87
5d.	Zonal comparison of the relative predominance of different crop categories	86-87
6.	Relative predominance of different crop categories in relation to holding size	86-87
7.	Tree intensity in relation to holding size	88-89
8.	Percentage of home gardens planted with various tree species in the district	88-89
9a.	Percentage of home gardens planted with different tree species in highlands	88-89
9b.	Percentage of home gardens planted with different tree species in midlands	88-89

Contd...

Fig. No.	Title	Between Pages
9c.	Percentage of home gardens planted with different tree species in lowlands	88-89
10.	Comparison between zones with respect to percentage of home gardens planted with each tree	88-89
11a.	Relative dominance of different tree species in Thiruvananthapuram district	89-90
11b.	Relative dominance of coconut, rubber and arecanut in Thiruvananthapuram district	89-90
12.	Relative predominance of different nitrogen fixing trees in the district	91-92
13.	Relative predominance of different nitrogen fixing trees in different agroecological zones	91-92
14.	Method of recycling of tree parts by the homestead farmers	92-93
15.	Structure of a typical home garden in Thiruvananthapuram district	93-94
16.	Adoption of package of practices recommendations by the farmers	94-95
17.	Nutrient management by farmersin the home gardens	94-95
18.	Cropping / Farming systems adopted in the home gardens	95-96
19.	Feeding pattern of cattle	96-97
20.	Institutions approached by the farmers for credit	97-98
21.	Economic analysis of the home gardens in the district and its agroecological zones	103-104
22.	Structure of the home garden at Location I	109-110
23.	Structure of the home garden at Location II	111-112

Contd...

Fig. No.	Title	Between Pages
24.	Litter fall of different tree species in the home garden at Location I	114-115
25.	Litter fall of different tree species in the home garden at Location II	116-117
26.	Nutrient addition in the home garden at Location I through various avenues	131-132
27.	Nutrient addition in the home garden at Location II through various avenues	133-134
28.	Nutrient removal from the home garden at Location I	135-136
29.	Nutrient removal from the home garden at Location II	136-137
30.	Nutrient dynamics of Location I	139-140
31.	Nutrient dynamics of Location II	139-140
32a.	Moisture content of the soil at Location I during 1994-'95 (I year)	144-145
32b.	Moisture content of the soil at Location I during 1995-'96 (II year)	144-145
33a.	Moisture content of the soil at Location II during 1994-'95 (I year)	145-146
33b.	Moisture content of the soil at Location II during 1994-'95 (II year)	145-146
34a.	Soil microbiology of Location I (Fungi)	152-153
34b.	Soil microbiology of Location I (Bacteria)	152-153
34c.	Soil microbiology of Location I (Actinomycetes)	152-153
34d.	Soil microbiology of Location I (Phosphorus solubilizing bacteria)	152-153

Contd...

Fig. No.	Title	Between Pages
35a.	Soil microbiology of Location II (Fungi)	153-154
35b.	Soil microbiology of Location II (Bacteria)	153-154
35c.	Soil microbiology of Location II (Actinomycetes)	153-154
35d.	Soil microbiology of Location II (Phosphorus solubilizing bacteria)	153-154
36a.	Microclimate of Location I during 1994-'95 (I year)	156-157
36b.	Microclimate of Location I during 1995-'96 (II year)	156-157
37a.	Microclimate of Location II during 1994-'95 (I year)	157-158
37b.	Microclimate of Location II during 1995-'96 (II year)	157-158
38a.	Soil temperature at Location I during 1994-'95 (I year)	159-160
38b.	Soil temperature at Location I during 1995-'96 (II year)	159-160
39a.	Soil temperature at Location II during 1994-'95 (I year)	159-160
39b.	Soil temperature at Location II during 1995-'96 (II year)	159-160
40.	Light transmission by major tree species at Location I	163-164
41.	Light transmission by major tree species at Location II	165-166
42.	Economic analysis of the home garden at Location I	169-170
43.	Economic analysis of the home garden at Location II	172-173
44.	Allelopathic effect of leaf extracts of trees on germination of rice	179-180
45.	Allelopathic effect of leaf extracts of trees on plumule and radicle length of rice	179-180

Contd...

Fig. No.	Title	Between Pages
46.	Allelopathic effect of leaf extracts of trees on germination of cowpea	181-182
47.	Allelopathic effect of leaf extracts of trees on plumule and radicle length of cowpea	181-182
48.	Allelopathic effect of powdered litter of trees on germination of rice	183-184
49.	Allelopathic effect of powdered litter of trees on plumule and radicle length of rice	183-184
50.	Allelopathic effect of powdered litter of trees on germination of cowpea	185-186
51.	Allelopathic effect of powdered litter of trees on plumule and radicle length of cowpea	185-186
52.	Optimisation model for the home garden at Location I	193-194
53.	Optimisation model for the home garden at Location II	199-200

LIST OF PLATES

Plate No.	Title	Between Pages
I & II	General view of the home garden at Location I	52-53
III & IV	General view of the home garden at Location II	53-54

Abbreviations used in this thesis

CD	–	Critical Difference
cm	–	centimetre
g	–	gram
kg	–	kilogram
mm	–	millimetre
t	–	tonne
%	–	per cent
ha	–	hectare
DW	–	Dry weight
sq.km	–	Square kilometer
ICRAF	–	International Centre for Research on Agroforestry
sq.m	–	Square meter
m	–	meter
yr	–	year
c.f.u	–	colony forming units
kg/ha/yr	–	kilograms per hectare per year
t/ha	–	tonnes per hectare
RHS	–	Right hand side
NS	–	Not significant
g/cc	–	grams per cubic centimeter

INTRODUCTION

1. INTRODUCTION

Agroforestry is a land use system in which woody perennials and herbaceous crops are deliberately grown together in mixture, with or without animals, and which provides greater benefit for land use than agriculture or forestry alone. It is a relatively new field of applied science. The advantages of agroforestry include sustained soil fertility, soil conservation, increased yield, diminished risk of crop failure, ease of management, pest and disease control and/or greater fulfilment of the socioeconomic needs of the local population. Agroforestry systems and practices vary considerably from place to place and region to region.

Home gardens present an excellent example of the many systems and practices of agroforestry. The agroforestry home gardens are unique to the State of Kerala, where the average size of the holding is small. The Kerala home gardens are more than a folkloric anachronism. It has been one of the survival strategies of the traditional farmers of Kerala since time immemorial. A homestead is an operational farm unit in which a number of crops (including tree crops) are grown with livestock and/or poultry, mainly for the purpose of satisfying the farmers' basic needs. The farmers of the State undertake intensive cultivation on the limited land area available, without any scientific basis. Selection of crops in the home garden is based on farmers' perception and centuries of experience. In spite of the importance of this system to the economy of the state and its people, practically no research has been undertaken to critically study the structure and functioning of home gardens.

Home gardens, with a number of components, are complex in nature and very much sophisticated in structure. Like any other production system, home gardens do not remain static over time and space. Unless the home garden dynamics are directed in the right path, there is imminent danger to the systems' sustainability.

Qualitative descriptions on the functioning of traditional land use practices around homesteads have been given by several workers. However, quantitative information on the biological interactions between the trees and other components, biomass productivity, nutrient dynamics and beneficial effects of trees on soil and microclimate in the homesteads are lacking. Moreover, the extent to which home gardens simulate the degree of closure in nutrient cycling and soil properties found under natural vegetation still remains uninvestigated. The complexity of the homestead system demands a systems approach for its analysis. Though, several works on individual aspects have been undertaken, a comprehensive study on the system, as a whole, has not been attempted till date.

When many species of trees and herbaceous plants are grown together, interactions involving allelopathy are presumed. The accumulation of tree litter on the soil under agroforestry system of farming could have deleterious effects on the agricultural crops. Consequently, seed germination and establishment of certain crops may be inhibited. While identifying suitable plants for homestead farming, efforts should be made to select the species with the least allelopathic activity. Although, during the last two decades, much work has been conducted in agriculture and forestry, the studies on the allelopathic effect of tree species on associated agricultural crops, in home gardens, are limited. Moreover, little information is available on the allelopathic effect of tropical tree species.

Under the shrinking per capita availability of arable land integrated homestead models hold relevance. A viable production strategy to overcome the disadvantages of land holding size lies in optimising income per unit area per unit time, by crop intensification and mixed farming practices. Very few efforts seems to have been made to optimise the production strategy of the complex homestead farming system or to develop suitable integrated homestead models for resource optimisation and profit maximisation.

Home gardens have been evolved over time under the influence of resource constraints. Moreover, farmers are operating in the home gardens in the absence of expert recommendations. So far, no serious efforts were made to provide institutional and policy support for strengthening research on this traditional system that has exceptional merit (Chinnamani, 1991). Very few investigations were undertaken to study the potential contribution of these systems to agricultural development.

Therefore, the present investigation was undertaken with the following objectives :

1. To undertake a detailed agroforestry systems inventory description survey on the structure and function of homesteads in Thiruvananthapuram district of southern Kerala.

2. To examine the dynamics of the home garden, their management practices, estimate the nutrient dynamics in the system and to monitor the microclimate, soil physical, chemical and biological properties in two homesteads of Thiruvananthapuram district of Kerala State.

3. To assess the allelopathic effects of common multipurpose agroforestry tree species.

4. To develop integrated homestead models, for resource optimization and profit maximization from the selected home gardens, through linear programming.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Agroforestry home gardens have evolved over a long period of time and has a long tradition in many tropical countries. A general interpretation of the home gardens is that it is a system for the production of subsistence crops for the gardener and his family. Lot of literature is available on home gardens and most of the publications are qualitative in nature. Numerous terms have been used by various authors to denote these practices. These include mixed garden horticulture (Terra, 1954), home gardens (Ramsay and Wiersum, 1974), Javanese home garden (Soemarwoto *et al.*, 1976; Soemarwoto, 1987), compound farms (Lagemann, 1977), mixed garden/house garden (Stoler, 1978), kitchen gardens (Brierley, 1985), household garden (Vasey, 1985) and homestead agroforestry (Nair and Sreedharan, 1986; Leuschner and Khalique, 1987). There are several types of home gardens in other geographical locations, each with its characteristic features.

2.1 Homestead : definition

Ninez (1984) considered homestead as a production sub system which aims at the production of household consumption items. Soemarwoto and Soemarwoto (1984) defined home garden as an agroforestry system which ideally combines the ecological functions of forests with those of providing the socio-economic needs of the people. Hanman (1986) referred to homestead as the home and its adjoining land owned and occupied by the household including the immediate area surrounding the dweller's unit and the space used for cultivation of trees and vegetables. According to Nair and Sreedharan (1986) homestead is an operational farm unit in which a number of crops (including tree crops) are grown with livestock, poultry and/or fish production mainly for the purpose of satisfying the farmer's basic needs. Soemarwoto (1987) described homestead as a system for the production of subsistence crops for the farmer and his family, which may or may not have the additional production of cash crops.

2.2 Homestead : structure

The most organized effort to understand the structure of agroforestry systems has been a "Global Inventory of Agroforestry Systems and Practices in Developing Countries", an USAID project undertaken by ICRAF. Based on the information gathered, Fernandes and Nair (1986) undertook an evaluation of the structure and function of ten selected home gardens in different eco-graphic regions of the tropics. They summarized that home gardens are characterized by a mixture of several annual or perennial crops grown in association, and commonly exhibiting a three to five layered vertical structure of trees, shrubs and ground cover plants, which recreates some of the properties of nutrient cycling, soil protection and effective use of space above and below the soil surface. They felt that the structural complexity, species diversity, multiple output nature and tremendous variability in the home gardens make them extremely difficult to work with, according to the currently available research procedures.

The multi-level plantations and home garden systems, common in smaller land holdings, are analogous to a rain forest with a multilayered canopy. The systems and their components vary with location (Swaminathan, 1987). The home gardens that exist in different continents in the tropical humid zone appears to exhibit various structure and function. Homestead agroforestry practices have been described from Java (Karyono, 1981; Michon, 1983; Soemarwoto and Soemarwoto, 1984; Soemarwoto, 1987), Tanzania (Fernandes *et al.*, 1984), India (Nair and Krishnankutty, 1984; Jambulingam and Fernandes, 1986; Nair and Sreedharan, 1986; Sharma *et al.*, 1991; Happy Mathew, 1993; Babu, 1995), Thailand (Boonkird *et al.*, 1984; Kamtuo *et al.*, 1985), Pacific Islands (Thaman, 1985; Vergara and Nair, 1985), Indonesia (Michon *et al.*, 1986), Nigeria (Balasubramanian and Egli, 1986), Malaysia (Tajuddin Ismail, 1986), Sri Lanka (Jacob and Alles, 1987), Bangladesh (Leuschner and Khalique, 1987), West Indies (Okafor and Fernandes, 1987) and Mexico (Rico-Gray *et al.*, 1990).

In an extensive survey from the lowlands to the highlands of West Java, Karyono (1981) recorded that the average size of 351 home gardens sampled was 0.02 ha. The size decreased with altitude. The total number of species found in the survey was 501 in the dry season and 560 in the wet season, with a cumulative number of 602 in the two seasons. The average number of species in the dry season was 19.0 per home garden and 24 in the wet season.

Species density was eight per 100 sq.m. in the wet season. The highest number of species in the home garden, was in the altitude between 500 and 1000 m, species density increasing with increasing altitudes. An analysis of the structure of the pekarangan in the Citarum watershed in West Java (Michon, 1983) revealed a five layered canopy structure. The lowest layer of less than 1 m height; the second layer of 1 - 2 m; the third 2 - 5 m; the fourth 5 - 10 m and the fifth greater than 10 m. Soemarwoto and Soemarwoto (1984) described the Javanese pekarangan, as a clean and carefully tended system surrounding the house, where plants of different heights and arohitectural types, though not planted in an orderly manner, optimally occupy the available space both horizontally and vertically. Soemarwoto (1987) reported a typical Javanese home garden with a multitude of crops presented in a multitier canopy configuration.

The Chagga home gardens of northern Tanzania ranged from 0.20 to 1.20 ha with an average of 0.68 ha is characterized by an intensive integration of numerous multipurpose trees and shrubs with food crops and animals (Fernandes *et al.*, 1984). It was essentially a commercial system based on arabica coffee and banana, so that the coffee/banana layers which constituted the second (1.0 - 1.25 m) and third canopy strata (2.5 - 5.0) from the ground dominated over the others. The lowest zone (0 - 1.0 m) consisted of food crops like taro, fodder herbs and grasses. Above the third layer, there was a diffuse zone (5.0 - 20.0 m) consisting of preferred fuel and fodder species and another zone (15.0 - 30 m +) of the valuable timber trees and other fodder and fuel wood species.

Nair and Krishnankutty (1984) concluded that Kerala had a high density of population, resulting in small sized farm holdings. The size of holdings ranged commonly from 0.02 ha to 1.00 ha. Jambulingam and Fernandes (1986) reported that farmers in Tamil Nadu State integrated numerous species of multi-purpose trees and shrubs in close association with agricultural crops. The woody perennials were found to cope with poor growing conditions and this integration on farm lands represents a strategy to minimize the risk of crop failure. They also observed that the productivity of these traditionally managed systems could be considerably improved by scientific interventions. A unique study on the structure and function of agroforestry home gardens of Kerala by Nair and Sreedharan (1986) revealed that the size of the holdings ranged from 0.02 to 1.00 ha, with an average of 0.22 ha, with coconut as the most dominant and important tree crop. The other perennial crops in the homestead were arecanut, black pepper, cocoa, cashew and various tree species such as teak, jack, wild jack, casuarina, portia, silver oak, erythrina etc. Cattle and poultry rearing was also undertaken in most of the homesteads. Thus a four tier structure was commonly noticed. Sharma *et al.* (1991) recorded that crop cultivation, animal husbandry and forestry constitute the three main closely integrated components of the farming systems in the hills of Himachal Pradesh. Happy Mathew (1993), after an agronomic resource inventory of a homestead of 0.20 ha conducted in southern Kerala, observed various agroforestry components such as jack, mango, bread fruit, portia and coconut intercropped with a multitude of intercrops, including elephant foot yam, cassava, dioscorea, ginger and fodder grass, resulting in a cropping intensity of 156 per cent. Babu (1995) reported that majority of the homesteads surveyed in north Kerala (47.78 %) were with crops and livestock and 51.67 per cent of the home gardens were coconut based.

Boonkird *et al.* (1984) observed that the home gardens in Thailand were dominated by a wide variety of fruit trees. The other main crops in the gardens were legumes, tuber crops, vegetables, spices and medicinal plants. Kamtuo *et al.* (1985) recorded a total of 100 species in kitchen gardens and 77 species in hut gardens in the Knon Kaen province in north-east Thailand.

Thaman (1985) reported from random surveys of home gardens in Papua New Guinea, Fiji, Tonga, Kiribati, Nauru Island and Nauru, at least 85, 114, 79, 61, 33 and 65 different species and distinct varieties of food plants, respectively. In addition, a very wide range of non-food plants was also found in home gardens which were of considerable importance for handicraft, fuel, medicine, fibres, dyes, ornamental purposes, perfumes, livestock feed, and construction materials.

Vergara and Nair (1985) described home gardens in the Pacific islands as a tree-crop-livestock mix around the homesteads. The home garden consisted of various trees such as coconut, casuarina, other plantation crops and a large number of subsistence crops along with cattle, pigs and poultry.

Michon *et al.* (1986) after studying the multistoreyed agroforestry garden system in West Sumatra, Indonesia, observed that home gardens of the villages was a minor component of the farms which consisted of ornamental plants and valuable fruit species.

Balasubramanian and Egli (1986) described the homestead agroforestry system of Rwanda, Nigeria as an intensive system of organic agriculture which involved the combination of food, fodder, tree crops and animals. Banana and tuber crops were the main food crop components. The arrangement of the components was haphazard. A distinct vertical zonation of tall trees (6.0 m and above), banana (3.0 - 4.0 m), cassava and sorghum (2.0 - 3.0 m) and low growing food crops (0 - 1 m) was evident.

Tajuddin Ismail (1986) discussed a unique agroforestry approach of integrating animals (sheep, poultry and bees) in small holder rubber plantations in Malaysia.

The Kandyan gardens in Sri Lanka represented a home garden system practiced in small holdings and their size varied from 0.4 to 2.0 ha, with an average of 1.00 ha. The most important tree crops in the system were arecanut, jack and coconut. The highest number of crops grown on a farm was 18 and the lowest four. Eighty per cent of the farms had 8-15 crops (Jacob and Alles, 1987).

Studies on the home gardens in Bangladesh showed that the size ranged between 0.02 - 1.44 ha, the average being only 0.097 ha. Mango, jack and arecanut trees were noticed in 60 - 90 per cent of the homesteads. The home gardens were dominated by fruit trees, followed by fuel and timber trees.

Grass, rice straw, rice bran, crop residues, leaves and oilcake were the most common feed materials fed to the cattle (Leuschner and Khalique, 1987).

The West Indian compound farms (Okafor and Fernandes, 1987) are a home garden-type of agroforestry system, involving the deliberate management of multipurpose trees and shrubs in a multistoreyed association with agricultural crops and small livestock within the compounds of individual houses. The gardens are characterized by a four-layer canopy dominated by a large number of tall indigenous fruit trees.

In the Mayan home gardens of Mexico (Rico-Gray *et al.*, 1990), specific arrangements of plants were not found in any of the home gardens and they were practically unique with fruit trees like annona, guava, papaya, citrus, mango and banana.

Nair (1993) observed that all home gardens consisted of a herbaceous layer near the ground, a tree in the upper layer, and intermediate layers with different crops in between. The lower layer could be usually partitioned into two, with the lowermost (less than 1 m height) dominated by different vegetable and medicinal plants, and the second layer (1 - 3 m height) being composed of food plants such as cassava, banana, yam, and so on. The upper tree layer, divided into two, consisted of emergent, fully grown timber and fruit trees occupying the uppermost layer of over 25 m height, and medium sized trees of 10 - 20 m occupying the next lower layer. The intermediate layer of 3 - 10 m height was dominated by various fruit trees, some of which would grow taller. This layered structure is never static. Tuber crops such as taro, cassava, yam and sweet potato dominate in the home gardens, in general, because they could be grown with relatively little care as understorey species in partial shade and yet be expected to yield reasonably. A conspicuous trait of the tree-crop component in home gardens was the predominance of fruit trees and other food-producing trees.

From the above review, it is evident that despite the research works conducted, very few results are available to exactly define home gardens under different agroecological zones and to describe the structure and function of home gardens of Kerala.

2.3 Nutrient dynamics

One of the main principles of soil management in agroforestry is to make the best use of its resource-conserving and resource-sharing potentials. The main advantage of trees is the addition of nutrients by organic cycling.

According to Switzer and Nelson (1972), three principal mineral flow pathways affect the nutrition of terrestrial communities. They are geochemical, biogeochemical and biochemical cycling. The major biogeochemical cycling processes are nutrient uptake by plants and its return by litterfall, stemflow and throughfall. Nutrient cycling is an important aspect that has to be considered while deciding the management practices for any agroforestry system. In most tree species, significant quantities of nutrients are accumulated and cycled through litterfall, stemflow and throughfall (Will, 1959).

One of the important advantages of agroforestry is that trees act as nutrient pumps. Transfer of nutrients from plant parts to soil takes place in varying degrees within tree-plant-soil system (Mitchell *et al.*, 1975; Bormann *et al.*, 1977).

2.3.1 Litterfall

The nutrients cycled through the litter is an important component of the input of nutrients. A substantial portion of the accumulated nutrients in the plant biomass is returned to the soil through litterfall and the study of the quantitative aspects of litter production is important as it remains a major pathway for nutrient transfer in agroforestry.

According to Divineau (1976) and Vinha and Pereira (1983) the litter production and nutrient release varies depending on the species. O' Connell and Menage (1982) observed that litter falling annually, increased with stand age. The pattern of litterfall varies greatly with climate. Rowers and Westman (1977) studied the nutrient dynamics of litter in a sub-tropical eucalyptus forest and reported that total litterfall was greatest during summer. Charley and Richards (1983) observed that Eucalyptus forests under warm temperate conditions demonstrated variation in litterfall from year to year. Gill *et al.* (1987) reported that the litter production and cycling of nutrients in an acacia plantation was higher than in an eucalyptus plantation of the same age. Pushp and Surendra (1987) inferred after studying the dynamics of nutrients and leaf mass in Central Himalayan forest trees and shrubs, that the climate, growth form and different ecophysiology of species interact in a complex fashion to influence leaf phenology and nutrient translocation. They further reported that pine growing in low fertile soil had a greater nutrient translocation capacity with greater litterfall. The nutrient concentrations in leaf and non leaf litter was estimated by Singh (1984) and it was found that leaf litter contained a higher percentage of nutrients. A variation in the leaf litter nutrient content in a year was also reported. Pande and Sharma (1988) noticed that nutrient return followed the pattern of litterfall, whereas, nutrient release depended on the litter decomposition rate.

The nutrient status of the site is characterized by the total quantity of litterfall than by the nutrient concentration of the litter (Proctor *et al.*, 1985).

Miller *et al.* (1976) quantified litterfall in differently fertilized plots in corsican pine (*Pinus nigra* var. *maritina*) of 36 years age. They concluded that litterfall accounted for nearly all the nitrogen and phosphorus released by trees. Cole and Rapp (1980) estimated the average annual litterfall for temperate deciduous and coniferous forests as 5400 and 4380 kg/ha/year respectively. Chaubey *et al.* (1988) reported that litter production was greater (1.5 - 2.0 tonnes) in the teak plantations than natural forests. Experiments on a two year old *Leucaena leucocephala* stand showed an annual litterfall of 10 t/ha with the maximum fall in dry summer months (Sandhu and Sinha, 1990). A study on the litterfall pattern of various tree species in an agroforestry system carried out by Shajikumar and Ashokan (1992) revealed that out of the four species *Eucalyptus tereticornis* produced more litter compared to the other tree species viz., *Ailanthus triphysa*, *Gliricidia sepium* and *Leucaena leucocephala*. The quantity of litter produced by *Eucalyptus tereticornis*, *Ailanthus triphysa*, *Gliricidia sepium* and *Leucaena leucocephala* were 4059,1751,3323 and 1593 kg/ha respectively. Banwari *et al.* (1996) recorded that the average leaf fall from the perennial tree canopies dominated by mango, jamun, subabul, arjuna, neem, pipree, sea sam etc. was about 3.8 t/ha/yr. Happy Mathew *et al.* (1996) after an investigation in a 0.20 ha homestead quantified the annual input of litter from the different tree components as 981.35 kg. Korikanthimath *et al.* (1996) determined that in cardamom plantations, an average of 5 - 8 tonnes of dry leaves fell from shade trees annually. Kumar *et al.* (1996) quantified the leaf litter obtained annually from a vastly occupied cashew plantation in coastal Karnataka, as 1.37 and 5.2 t/ha in 10 -15 and 25 - 35 year old plantations respectively. Nagaraja *et al.* (1996) in a study conducted in the southern dry region of Karnataka, under various systems, found that about 5 to 10 t/ha of leaf litter could be generated through mango, sapota and fodder trees. Nair *et al.* (1996) reported that the annual litter addition by the tree components in a 0.48 ha homestead amounted to 384.65 kg. Viswanath *et al.* (1996) reported that the shade trees like jack, champaka, goni, hemmaralu and erythrina commonly found in a cardamom plantation, play a vital role in recycling of nutrients from the lower soil depth to the surface. Jack tree was found to contribute the maximum biomass of 4.71 t/ha/year through fallen leaves, compared to the least (0.97 t/ha) with hemmaralu. The annual biomass from the rest of the trees ranged from 1.39 to 1.77 t/ha.

Rodin and Bazilevich (1967) found that about 50 - 70 kg/ha of N is added by litterfall in coniferous forests and 250 - 325 kg/ha in tropical and subtropical forests. Cole and Rapp (1980) quantified the nutrient return by way of litterfall, as 61.0, 4.0 and 42.0 kg/ha/year of N, P and K for temperate deciduous and 37.0,4.0 and 26.0 kg/ha/year for temperate coniferous forests. Out of the total nutrient return by litterfall, stemflow and canopy wash (throughfall), 83 per cent, 41 per cent and 85 per cent of N, K, and P were by litterfall alone. Charley and Richards (1983) estimated that in eucalyptus forests, leaves accounted for 50-70 per cent of total litterfall and for most of the inputs of Ca, Mg, S, N, P and K that reached the floor in organic debris. Kadeba and Aduayi (1985) quantified the nutrient return in a stand of *Pinus caribaea* as 15.9, 0.6 and 17.3 kg/ha/year of N, P and K respectively. Shajikumar and Ashokan (1992) reported that out of the four species viz., *Eucalyptus tereticornis, Ailanthus tryphysa, Gliricidia sepium, Leucaena leucocephala* and the N, P and K contents in the litter were more in *Gliricidia sepium* and *Leucaena leucocephala*. The quantity of N added to the soil by the above four tree species was 65, 25, 58 and 103 kg/ha respectively, while the corresponding quantities of P cycled were 4.8, 1.8, 1.9 and 5.3 kg/ha. Happy Mathew *et al*. (1996) from an investigation in a 0.20 ha homestead, quantified the annual nutrient input, by way of litter from the different tree components, as 8.50, 2.0 and 6.36 kg N, P and K respectively. Korikanthimath *et al*. (1996) estimated that the litter from shade trees, in cardamom plantation, added 100 - 160 kg N, 5 - 8 kg P, 100 - 160 kg K, 10 - 16 kg Ca and 25 - 40 kg of Mg per hectare. Nair *et al*. (1996) reported that the annual nutrient input through litterfall from various trees in a

0.48 ha homestead was 4.40, 1.20 and 3.00 kg N, P and K respectively. Viswanath *et al.* (1996) found that among the different shade trees found in cardamom plantations, jack was more efficient from the point of recycling of plant nutrients (N - 63 kg, P - 9.6 kg and K - 38 kg/ha/year) followed by champaka and erythrina. Their results indicated that there was an addition of about 180 kg N, 23 kg P and 99 kg K/ha/year to the surface soil by leaf fall from different shade trees.

Rudrappa and Hareesh (1996) suggested forest litter as very good sources of nutrient in organic farming. They found that the nutrient content values of leaf litter from casuarina and acacia was comparable with the values of farmyard manure.

2.3.2 Stemflow

The significance of stemflow, as a component of nutrient cycling in forest ecosystems, has been widely recognized. The water getting leached down as stemflow contacts with the various parts of the tree and contains varying quantities of nutrients.

Helvey and Patric (1965) observed that rain striking plant surfaces is channeled to the ground as stemflow. In most situations, nutrient input by stemflow is less than 10 per cent. Quantification of stemflow was carried out by Miller *et al.* (1976) and it was found that stemflow represented only 1.7 to 3.4 per cent of the gross rainfall and the concentration of elements in stemflow were higher than those for throughfall. Harry *et al.* (1978) found that stemflow accounted for only about two per cent of the water received beneath the canopy and it was positively correlated with tree diameter. Franke and Leopoldo (1982) after undertaking stemflow observations in forest areas of Manuas region (Brazil) estimated that out of the total rainfall only 0.30 per cent reached the soil surface as stemflow. Sanjay and Verma (1987), while measuring the stemflow in chirpine calculated that the stemflow was only 0.66 per cent of the total annual rainfall.

Harry *et al.* (1978) observed that the leaching of phosphorus, potassium and calcium from the trees by stemflow were usually greater on the more productive sites than on poorer ones.

Generally, stemflow water will have higher concentration of elements (George, 1979). According to Carey *et al.* (1981) among the elements, N and K were easily leached down. Escudero (1985) after his experiment on chemical composition of the soil underneath *Quercus rotundifolia*, found that the soil had a higher mineral content due to the flow of water down the trunk. After field observations on interception of precipitation, by six tropical deciduous trees, Yadav and Mishra (1985) found that stemflow samples had a higher nitrogen concentration. Baker and Attiwill (1987) reported that stemflow had the highest concentration of elements.

Happy Mathew *et al.* (1996) estimated that the nutrient input through stemflow from various tree species in a 0.20 ha homestead was 0.01, 0.0 and 0.01 kg/year of N, P and K respectively.

O'Connell (1985) compared the nutrient input by throughfall and stemflow from the understorey and tree layers in stands aged 2,6,9 and 40 years with nutrient inputs through litterfall. He concluded that the major source of N, Ca and P was litterfall and equal amounts of K was contributed by litterfall, throughfall and stemflow.

2.3.3 Throughfall

Throughfall is one of the mechanisms by which nutrients are added to the soil through the rainfall dripping through the canopies of trees.

Helvey and Patric (1965) observed that rain striking plant surfaces drops to the soil as throughfall. In most situations, 85 per cent or more of the input is by throughfall. Quantification of throughfall was carried out by Miller *et al.* (1976) and they found that throughfall accounted for two-third of the gross rainfall. Studies conducted by Franke and Leopoldo (1982) in the forest areas of Manuas region (Brazil) revealed that out of the total rainfall, 77.70 per cent reached the soil surface as throughfall.

The intensity of rainfall has a great influence on the quantity of throughfall. If the rainfall is of small intensity, much of the water will be lost through interception losses. As the size of the shower increases, the amount of throughfall also increases (Yadav and Mishra, 1988). Charley and Richards (1983) reviewed that the annual nutrient load in throughfall varied greatly with tree species. The quantities vary with conifers and broad leaved species, with less addition in the case of conifers. They found that the throughfall nutrients in tropical forests were greater.

Parker (1983) reported that foliar leaching is the major process, which controls the throughfall enhancement for all elements. Carey *et al.* (1981) reported that among the elements, N and K were easily leached down. In another study in a plantation in Japan, it was observed that in throughfall the nutrient concentration was in the order K > Ca > N > Na > Mg (Halibara *et al.*, 1984). After field observations on interception of precipitation by six tropical deciduous trees, Yadav and Mishra (1985) found that, throughfall samples had a lower nitrogen concentration than stemflow. Jasbir Singh (1986) reported that throughfall accounted for the maximum addition of potassium. Several reports indicated that the elements that are returned to the soil by throughfall mechanism would include in it N, P, K and other micronutrients (Leninger and Winner, 1988 ; Santaregina and Gallardo, 1989). In a study, on the effects of rainfall in leaching of nutrients in a plantation in China, Ma (1989) found the relative abundance of nutrients in throughfall as K > N > Ca > Mg > P.

Bernhard - Reversat (1975) estimated an annual elemental input of 64.0, 9.1 and 177.0 kg/ha of N, P and K respectively by throughfall in rain forests of Ivory Coast. Golley *et al.* (1975) recorded an annual return of 50.0 kg/ha of K by throughfall in the rain forests of Panama. Khanna and Nair (1977) found that 151 kg/ha/year of potassium was added by coconut canopy washout in Kerala. The annual addition of nutrients to the soil by way of throughfall and stemflow in a lowland tropical rain forest was 6.7 and 24.6 kg/ha/year N and K respectively (Manokaran, 1980). In a study at the Montane rain forest, Edwards (1982) found that the amount of nutrients leached from the canopy was 29.6, 2.5 and 71.1 kg/ha/year N, P and K. Happy Mathew *et al.* (1996) estimated the nutrient input by way of throughfall from various tree species in a 0.20 ha homestead and found that the annual amount of N, P and K added were 2.10, 0.10 and 3.17 kg respectively.

O'Connell (1985) compared the nutrient input by throughfall and stemflow from the understorey and tree layers in stands aged 2,6,9 and 40 years with nutrient inputs through litterfall. He concluded that the major source of N, Ca and P was litterfall and equal amounts of K was contributed by litterfall, throughfall and stemflow.

From the above, it could be seen that throughfall occurs in ecosystems with trees at varying amounts. However, quantification of this phenomenon occurring in agroforestry home gardens are scanty.

2.3.4 Biomass production, nutrient recycling and nutrient removal

Trees are considered not only as a source of addition of organic matter to the soil but also as a component constituting a significant addition through biomass.

Bavappa *et al.* (1986) estimated that in a coconut-based and arecanut-based cropping system, the biomass production per year was 50 t/ha and 17 t/ha respectively. The biomass production by the other intercrops in both the systems was more or less the same (6 - 7 t/ha). Banwari *et al.* (1996) recorded the annual average biomass under different tree canopies as 2.0 t/ha under orchards, 6.0 t/ha from roadside plantation, 8.0 t/ha from agroforestry and 1.5 t/ha from hedges, kitchen, lawns etc. Nagaraja *et al.* (1996) estimated that about 10.0 t/ha of biomass could be generated from mango, sapota and fodder trees.

Pillai and Davis (1963) suggested that by systematically recycling the coconut by-products it is possible to plough back 20.7 kg N, 10.5 kg P and 30.8 kg K per hectare annually. Hegde *et al.* (1993) observed that in integrated coconut farming, with animals, by recycling of the animal dung and urine, it was possible to meet the full demand of nitrogen and partial demand of P and K of coconut + fodder system. They also estimated that the amount of organic matter added to the soil through fallen leaves and prunings of cocoa ranged from 818 - 1985 kg/ha/year. Intercropping of soybean, in coconut, was found to add 1500 kg of organic matter in the form of recycled leaves and stalks. Intercropping groundnut in coconut and incorporating the haulms in coconut basins supplied about 195 g nitrogen per palm. Shanmugasundaram and Subramanian (1993) recommended the recycling of crop residues and animal wastes to promote the yield of coconut and associated crops in coconut based integrated farming system. Korikanthimath *et al.* (1996) observed that in cardamom plantations the plants provide enough quantity of trash material (dried leaves and pseudostem) during regular trashing operation (three to four times a year). They suggested that these materials could be used as mulch material which eventually decompose and enrich the soil fertility of the plantations. Rangaswamy and Jayanthi (1996) opined that when enterprises like cattle rearing, fishery, poultry, goat rearing, mushroom and sericulture are resorted to, their organic wastes/residues should be properly recycled and utilized for deriving maximum compatibility and benefit. Also, the organic residues of crops could supplement the chemical fertilizers to a certain extent. Reddy *et al.* (1996) suggested that the forestry species are to be pruned regularly to yield good amount of biomass. Venkitaswamy (1996) stated that coconut produces large quantities of waste materials such as leaves, spathes and stipules besides husk which is rich in various plant nutrients. He suggested that recycling of the tree parts could add considerable quantities of organic matter to the field. It was also observed that nutrients to the tune of 25.0, 15.0 and 25.0 kg N, P and K/ha/ year could be added by recycling the wastes. Soemarwoto (1987) observed that the extent and intensity of the recycling systems in home gardens are declining. He opined that this would reduce the efficiency of resource use, which in the long run, affects soil structure and fertility.

One of the major avenues of output or removal of nutrients from a managed system, is the export through harvested produce. Such exports are generally greater for annual agricultural crops in terms of the total quantity removed per unit area per unit time. In the case of woody perennials, it depends on the frequency and intensity of harvesting. Even repeated harvests of fruits, leaves and latex do not amount to destructive or total harvesting in woody perennials and the rates of their export out of the soil-plant system are relatively low as compared to annual agricultural crops (Nair, 1993).

Khanna and Nair (1977) worked out the nutrient output from leaves in a 30 year old pure coconut plantation and the quantity was estimated to be

33.1, 3.80 and 13.4 kg/ha/year of N, P and K respectively. Alvim (1981) pointed out that the products exported from the plantation crops (rubber, vegetable oils, fibres and starch foods) are basically composed of carbon, hydrogen and oxygen with only a small fraction of mineral elements extracted from the soil. The plantation crops export from the field mainly elements extracted from the air and water, so that stress on mineral nutrients of the soil will be relatively low. Araungeran *et al.* (1982) studied the distribution of fluxes of nitrogen in coffee and cacao plantations under shade. The N output (export) from the coffee system by harvest (17 kg/ha/year) was much less than the contribution (input) by the shade trees. In the cacao system, the N output by harvest was about 45 kg/ha/year, with about 20 kg N being returned annually to the field along with cacao pod shells after processing. Happy Mathew (1993) found that coconut leaves weighing 550.56 kg had annually removed from a 0.20 ha homestead, 2.15, 0.75 and 3.13 kg N, P and K respectively. Hegde *et al.* (1993) determined that coconut grown in one hectare annually removed about 74.0, 30.0 and 137.0 kg N, P and K respectively. Nair *et al.* (1996) after an investigation in a 0.48 ha home garden found that coconut leaves (14.4, 2.7 and 9.1 kg), jack (7.3, 2.0 and 3.0 kg) and cassava tuber and top (6.3, 2.4 and 4.1 kg) removed large quantities of N, P and K from the homestead.

2.4 Soil properties

The homestead farming system is very complex due to the involvement of a number of components including multipurpose tree species and animals. Micro-site enrichment by trees is a net effect of several factors and the most important among them can be grouped in two broad categories viz., soil fertility and soil physical conditions (Nair, 1984).

According to Brinson *et al.*, 1980, due to the constant addition of organic matter to the soil by litterfall the chances of changes in the soil physico-chemical properties is great. Swift and Sanchez (1984) summarized the beneficial effects of soil organic matter as being a source of inorganic nutrients for plants, a substrate for micro-organisms, a factor in soil aggregation, root development and soil and water conservation. Young (1986) reported that the fundamental reason why agroforestry systems are perceived to improve soil properties is the protection, a tree cover gives the soil, against surface compaction, runoff and erosion. The cover may be provided by a tree-top canopy, annual crops or pasture and a surface-litter layer produced by the vegetation. Sanchez (1987) opined that growing trees in conjunction with annual crops or pastures provided more thorough plant cover which protected the soil from erosion and a deeper and prolific root system to enhance nutrient cycling.

2.4.1 Physical properties

Pathak (1954) and Salter *et al.* (1965) observed an increase in the water holding capacity of the soil by adding organic matter through farmyard manure in agroforestry systems, while Rajput and Sastry (1987) observed a significant increase in the water retention of soils by addition of farmyard manure. Biswas and Khosla (1971) and Singh *et al.* (1976) found that addition of farmyard manure increased the available water capacity of soil.

A significant decrease in bulk density with increase of organic carbon content of the soil consequent to organic manure application was recorded by Mazurak *et al.* (1975) and Morachan (1978).

Nelliat and Shamabhat (1979) observed that mixed farming caused substantial improvement in the physical properties of the soil.

Bronstein (1984) recorded a higher moisture content in soils under *Erythrina poeppigiana* than in open fields.

Lal (1989) reported a lower soil bulk density, higher soil moisture retention and available plant water capacity under alley cropping practices compared to non-alley cropping practices.

Hegde *et al.* (1993) observed that organic matter addition improved the water holding capacity and decreased the bulk density of the soil in coconut gardens.

An enhancement of soil physical properties such as structure, porosity, moisture retention and erosion resistance was recorded under forest cover by Nair (1993) and he opined that trees helped to maintain organic matter through the provision of litter and root residues.

Happy Mathew *et al.* (1996) reported that the soil in the homestead had a lower bulk density, higher particle density, water holding capacity and moisture content when compared to the open control.

Pushkala and Sumam (1996) found that the porosity and water holding capacity of the soil was more in plots planted with coconut, nutmeg and jack when compared to bare plots.

2.4.2 Chemical properties

Kellman (1979) reported that in addition to translocation of nutrients from soil layers beyond the reach of annual crops and pasture species, enhancement of nutrient status beneath tree canopies was due to the canopy capture of precipitation inputs.

Kass *et al.* (1983) summarized the beneficial effect of trees, as supply of organic matter and nutrients to associated crops.

Atta-Krah *et al.* (1985) reported that soil under alley cropping was higher in organic matter and nitrogen content than soil without trees.

The gradual accumulation of mineral nutrients by perennial, slow growing trees, and the incorporation of these into an enlarged plant-litter-soil nutrient cycle is the mechanism responsible for soil enrichment (Nair, 1984).

Swaminathan (1987) opined that the inclusion of multipurpose, woody, leguminous trees and shrubs in low-input farming systems improve soil fertility.

Lal (1989) observed that over a period of six years, the relative rates of decline in the status of nitrogen, pH, and exchangeable bases were much less under alley cropping than under continuous cropping without trees.

Kang and Wilson (1987) and Kang *et al.* (1990) reported that, with the continuous addition of *Leucaena leucocephala* prunings, higher soil organic matter and nutrient levels were maintained compared to no addition.

The soil in the homestead was found to have a higher organic matter content and available N, P and K content when compared to the open control plot (Happy Mathew *et al.*, 1996).

2.4.3 Microbiological properties

Due to the complex nature of homestead systems, much studies have not been undertaken on the rhizosphere micro-organisms in the system (Fernandes and Nair, 1986).

According to Clark (1949), the nature and activity of microflora in a given soil environment depends upon the crops grown and management practices.

Nair (1973) observed that short term changes in soil environment produced by season and to a small extent by crop species brought about temporary quantitative changes in micro-organisms of soil.

Nair and Balakrishnan (1977) found that crop combination acts as a buffer against drastic changes of ecoclimate and this had considerable effect on the various biological processes occurring in the environment.

Nair and Rao (1977) after a study in the root regions of coconut palm, reported that intensive cropping of coconut plantations enhanced microbial activity in the rhizosphere of coconut. They found an increase in the number of micro-organisms in intensively cropped cacao mixed plantations.

Nelliat and Shamabhat (1979) observed that mixed farming caused substantial improvement in the biological characteristics of the soil.

Gaur and Mukherjee (1980) noticed increase in the population of fungi, actinomycetes and bacteria by mulching of the soil. They found that azotobacter population was stimulated by one and a half to four folds and actinomycetes and fungal populations by three folds with mulching.

Yamoah and Mulongoy (1984) observed higher microbial activity by the addition of organic matter under alley cropping.

Bavappa *et al.* (1986) noted an increase in the total microbial population, especially N fixers and P solubilizers in coconut and arecanut-based high density multi-species cropping systems.

Happy Mathew *et al.* (1996) reported that the population of bacteria, fungi and actinomycetes were higher in the homestead soil when compared to the open control.

Susan and Alice (1996) found that the application of organic materials to the soil stimulated microbial proliferation.

2.5 Microclimate

The microclimate in a homestead system varies widely when compared with a pure crop system or an uncropped land. Moreover, trees act as a buffer against drastic changes in the climate and also play a predominant role in amelioration of the microclimate. Very few studies have been conducted regarding this aspect in homesteads.

2.5.1 Relative humidity

Relative humidity is an important factor indirectly influencing crop yields, by bringing changes in the rates of evapotranspiration and by incidence of pests and diseases.

Nair and Balakrishnan (1977) reported that shading reduced the air temperature in crop communities and the resultant higher relative humidity values caused considerable reduction in the rates of evaporation. They had also found that relative humidity in all cropping systems with coconut had a higher value than the open area. It was further observed that evaporation in the ecoclimate of crop combination was only about 30 per cent of that from open area and the main reason for this was the higher values of relative humidity in crop combinations.

Ramakrishna and Sastri (1977) recorded that the relative humidity under the tree canopy was seven per cent higher than that in the plot without trees.

The relative humidity in the homestead was found to be always higher than that in the open (Happy Mathew *et al.*, 1996).

2.5.2 Soil temperature

Nair and Balakrishnan (1977) concluded that a crop cover on the ground helped to reduce temperature at the soil surface during summer months and the crop combination acted as a buffer against drastic changes in ecoclimate.

Ramakrishna and Sastri (1977) observed that the air and soil temperature were lower under tree canopy. The sub-surface (0.5 cm) temperature under the tree canopy was lowered by 10 - 16° C, while at 30 cm depth the temperature was lowered by 4 - 5°C.

Harrison-Murray and Lal (1979) reported that surface litter cover greatly reduced the high ground-surface temperature of bare soils in the tropics, which sometimes exceed 50°C.

Nair (1983 and 1984) noticed that the homestead system caused less exposure of the bare soil and hence reduced soil temperatures.

Budelman (1989) found that mulching resulted in a lower soil temperature when compared to unmulched soil.

Happy Mathew *et al* (1996) observed that the soil temperature in the homestead was always lower than the open control.

2.5.3 Light intensity

Solar radiation is the ultimate source of energy for all plants. The study of the light penetration by the tree canopies and their shading effect assumes importance in any cropping system. Few reports on the influence of trees on the light penetration characteristics, are reviewed hereunder.

Nelliat *et al.* (1974) studied the apparent coverage of ground by coconut palms of different age groups. They observed that when the palm is about 8 - 10 years of age, the percentage of light transmitted was only about 20 per cent and then the transmission increased progressively as the canopy coverage of the ground decreased.

Nair and Balakrishnan (1976) measured the intensity of light falling at the plantation floors of coconut during different seasons of the year, at different distances from the palms of about 25 years of age. They found that, at a distance of 3.5 m from the base of palms, the interception of solar radiation, by coconut leaves, was only 44 per cent of radiation. They reported that the percentage interception of available light by coconut palms was maximum during the early mornings. Therefore, the time of peak availability of light for other intercrops was during 10.00 to 16.00 hours.

Nair (1979) observed that the leaf canopies of components in a typical homestead are arranged in such a way that they occupy different vertical layers with the tallest component having foliage tolerant to strong light and shorter components having foliage requiring shade and high humidity.

According to Nair (1984) during the initial stages of coconut growth all sun loving crops were grown in the lower tier and from bearing stage (8 years) to about 25 years of coconut, when the shade was rather dense, shade loving crops like yams, turmeric, ginger and so on were grown. Afterwards, the incoming solar radiation in the garden increased and the homestead could be planted with a number of annual and perennial crops.

2.6 Economic analysis

Economic analysis is important to ascertain whether a system is sustainable or not. The main objective of intercropping in a perennial plantation, is to increase the overall return from a unit piece of land without adversely affecting either the current or the long term productivity of the main crop. At the same time, the returns from the additional crop should justify the adoption of intercropping practice and should contribute to the long term productivity of the system (Liyanage *et al.*, 1984).

Wherever input/output data are available, computation may be made to evaluate the system. The computational methods available for such evaluation, are subdivided into optimization and non-optimization ones. While, the first type enables the analyst to find the optimum solution, the second type enables the analyst to determine which of the alternative solution is the better one, not necessarily the optimum one.

Hoekstra (1985) suggested the non-optimization method, also known as cost : benefit analysis, as a better method, for analysing agroforestry systems. In this system, the inputs and outputs are taken into consideration for analysis.

Leaf litter from trees and shrubs may be used to add soil nutrients and organic matter to the soil. So far, there are no recorded instances of leaf litter being sold commercially. Market prices may be derived, on the basis of nutrient contents and prices of commercially available fertilizers (organic and inorganic). Hence, leaf litter should be valued through the agricultural production system. This approach has been reported by Balasubramanian (1983) ; Hoekstra (1985); Ngambeki and Wilson (1984) ; Vergara (1982).

The basic premise of an agroforestry system, is that the total benefit is greater, where joint, rather than singular, production exists. Several workers have studied the use of joint production economics in analysing agroforestry systems (Etherington and Mathews, 1983; Harou, 1983; Hoekstra, 1985 and Raintree, 1982).

Nair (1976) calculated the net income from a multistorey combination of coconut + black pepper + cocoa + pineapple in a coconut garden of about 25 years of age in Kerala under irrigated management as Rs.15430/- per annum.

Nelliat and Krishnaji (1976) estimated a net return of Rs.15661/- from a multistorey cropping system with black pepper, cacao and pineapple in one hectare of coconut. They also estimated a net return of Rs. 11631/- per hectare by mixed cropping with 50 per cent area under coconut and the rest for tuber crops viz., cassava, elephant foot yam, sweet potato and greater yam.

Gonzales-Jacomes (1981) reported that in Central Mexico the average income per square metre of home garden was 2 - 2.5 times that of rice fields and in tourist areas, where home gardeners sold ornamental plants , the average income could reach almost 20 times that of rice fields.

Arnold (1987) reported that tree systems were favoured by farmers when capital was scarce as these systems required less investment than alternative crops. An important factor in the widespread adoption of home gardens was their contribution to risk reduction, by spreading output across several products and over different seasons.

Kandaswamy and Chinnaswamy (1988) found that among different mixed farming practices, dairy-based system was most profitable with an annual net income of Rs.6090/-. The next best system was dairy-cum-poultry based farming system, having an annual net income of Rs.5899/-. Poultry based mixed farming gave only a marginal annual net income of Rs.2287/-.

Nambiar *et al.* (1988) estimated a net return of Rs. 17340/ha/year from a coconut + black pepper + cacao + pineapple multistoreyed cropping system.

The economic analysis of a system with 175 coconuts, 175 black pepper, 400 cacao and 10600 pineapple in one hectare, revealed that, this combination could generate a net return of Rs.30300/ha/year while the net return from an irrigated middle aged coconut mono crop was Rs.23200/ha/year. The benefit-cost ratio in this system was 1.76 (Das, 1989).

Das (1990) worked out the net return of a system (1.04 ha) consisting of coconut palms, hybrid napier, Brasilean lucerne fodder grass, pepper, banana, cassava, vegetables and 4 - 5 milch cattle, to Rs.29500/ha/year as against Rs.17000/- from a coconut mono crop under irrigated condition in Kerala.

Abdul Salam and Sreekumar (1990) after a study in a homestead of 0.272 ha cents with coconut-based mixed farming recorded that the income generated from the home garden was sufficient to meet the home demands as well as the educational requirements of a seven member family, consisting of five children. Besides 60 coconut palms, the system included arecanuts, pepper, jack, tamarind, mango, banana, tapioca, tuber crops, vegetables, fruit plants, guinea grass, gliricidia, a jersey cow, ten chicken and five bee hives. Approximately, Rs.19200 - 21000 was received by sale of coconuts annually and Rs.4500/- by the sale of milk.

Nair *et al.* (1991) estimated that coconut + clove mixed cropping could give a net return of Rs.46800/ha/year against Rs.23200/ha/year in the case of coconut monocrop under irrigation. A high net return of Rs. 95300/ha/year could also be obtained from a coconut + nutmeg mixed cropping system.

Pasha (1991) described animal husbandry as an important source of income for small and marginal farmers, who have adopted their farming technique in order to maximize production and returns to resource utilization.

Babu *et al.* (1992) and Rathinam (1991) opined that diversified homestead farming is a deliberate strategy aimed at producing harvests throughout the year, so that, there is always, some product of economic value, available for household use or sale.

Job *et al.* (1993) conducted an economic analysis of coconut-based cropping systems in Kerala and noticed an increase in farm income in large sized holdings due to the increased occurrence of coconut trees. The mean annual farm income was Rs.2028.58 from holdings with area upto 0.20 ha, Rs.3351.38 for 0.20 to 0.40 ha and Rs. 5978.43 from holdings of more than 0.40 ha. They opined that by identifying the optimum mix of crops scientifically, the income from coconut-based cropping system could be increased substantially.

In an experiment to study the feasibility of growing various intercrops (turmeric, ginger, coriander, grass and sun hemp) in different tiers in coconut plantation, it was found that the income realized from the annual intercrops was Rs. 9477.25/acre (Shanmugasundaram and Subramanian, 1993).

Happy Mathew and Nair (1996) calculated the annual net return from a 0.20 ha homestead and found that the maximum net return was from poultry while the maximum benefit : cost ratio was for coconut cultivation. The benefit : cost ratio of the farming activities of the system as a whole was 1.60.

The optimization methods of economic analysis are based on the technique of linear programming, which have been described by Beneke and Winterboer (1978) and Heady and Candler (1959). Hoekstra (1985) suggested that because of the rather large amount of data required over a long period, these optimization methods are not very popular for analysis of agroforestry systems.

Abdul Salam *et al.* (1991a) developed a model for multipurpose farming systems in south Kerala, for an area of 0.40 ha. They predicted a net return of Rs.17273/- and a benefit : cost ratio of 1.8.

A homestead model suitable for a 0.20 ha holding in the coastal uplands of south Kerala, under rainfed conditions using the technique of linear programming, was developed by Abdul Salam *et al.* (1991b). The coconut-based mixed farming system, involving 14 activities and integrating the crop and livestock systems, provided a net return of Rs.12,628/- with a benefit-cost ratio of 1.64.

Using the technique of linear programming Abdul Salam *et al.* (1992 b) developed a homestead model for 0.20 ha, in the coastal uplands of south Kerala under irrigated agriculture, with coconut that provided a net income of Rs. 17,513/- and ensured a benefit of Rs. 1.84 per rupee invested, for a four member family.

2.7 . Allelopathy

In multistorey cropping, agri-horticultural and agroforestry systems, since many plant species grow together, plant to plant interactions, involving allelopathy, are presumed. The accumulation of tree litter on the soil, under agroforestry system of farming, could have negative effects on the agricultural crops. Consequently, seed germination and establishment of certain crops may be inhibited.

Although, during the last two decades, much work has been conducted in agriculture and forestry (Rice, 1984), the studies on the allelopathic effect of tree species on associated agricultural crops in agroforestry are limited (King, 1979 ; Gaba, 1987 ; Malkania, 1987 ; Narwal, 1994). While identifying suitable plants for agroforestry system of farming, efforts should be made to select the species with the least allelopathic activity (Gaba, 1987).

Practically all plants appear to have the potential to produce chemicals. Allelochemicals may be produced by any part of the plant viz., roots and leaves (Horsley, 1977), pollen (Ortega *et al.*, 1988), seeds or fruits (Friedman *et al.*, 1982) although leaves and roots are the main sources (Horsley, 1977). Quantitatively and qualitatively, production of allelochemicals is regulated by the stage of the plant and is modified by environmental stresses like soil temperature, drought, flooding or poor drainage, ultraviolet light or sunlight, micro-organisms, soil salinity, diseases, herbicides, minerals and even growth regulators or hormones (Chou, 1986 ; Menges, 1987 ; Einhellig, 1989). According to Nandal *et al.* (1994) trees are rich sources of secondary metabolites (allelochemicals) and these chemicals impose certain kind of environmental stress on other plants growing in their vicinity, a phenomenon known as tree allelopathy.

Rice (1979 and 1984) observed that allelopathic interaction by a plant is possible through leaching, volatilization from aerial parts, decay of fallen parts and / or exudation in the rhizosphere. Goss (1973) stated that the secondary metabolites, in which most of the allelochemicals fall, leach out of the plant in their water soluble form - the glycosides. The translocation of the secondary metabolites within or out of the plant is facilitated through such glycosides. Kuiters *et al.* (1986) suggested that the effect of concentration of extracts on germination had management implications as under field conditions the inhibitory effect of litter largely depended on the amount of litter deposited. The increased amount of litter leads to greater release of chemicals. Richardson and Williamson (1988), in a study on the allelopathic effect of shrubs on pines, found inhibition of germination to be highly correlated with precipitation. They suggested that foliar run-off may provide an appropriate conduit mechanism for water soluble inhibitors.

Phytotoxic substances exuded by many tree species allelopathically retard growth of associate weed and crop species (Chou and Yang, 1982 ; Chou and Kuo, 1986 ; Suresh and Rai, 1988). Though many physiological processes are affected by allelochemicals (Rice, 1979 and 1984), retardation of growth is indicated to be the frequent response (Fisher, 1980). Rice (1994) described that the effect of allelochemicals on metabolic changes of receiver plants included effect on cell division, elongation and ultrastructure of cells, hormone induced growth, membrane permeability, mineral uptake, stomatal opening and photosynthesis, respiration, protein synthesis, lipid and organic acid metabolism, porphyrin synthesis, enzyme activity, xylem corking and clogging and internal water relations.

Allelopathic effect has been determined as the reason for the hampered rate of growth, survival and establishment of vegetation below the crown of Eucalyptus in spite of sufficient light intensity, nutrients and space (Bhaskar and Dasappa, 1986; Suresh and Rai, 1987; Sidhu and Hans, 1988). The allelopathic effect of Eucalyptus has been attributed to the production of several volatile terpenes (Del Moral and Muller, 1969 and 1970) and some water soluble inhibitors by Eucalyptus leaves (Al-Mousawi and Al-Naib, 1975) some of which are toxic for seed germination and seedling growth. Singh and Kohli (1992) detected that the eucalyptus rhizosphere was found rich in chemicals (phenolic acids) which were injurious to the vegetation growing nearby and their content varied with the distance from the tree as well as with the depth of the soil. Dhillon *et al.* (1982) studied the harmful effect of 10 - 20 m tall *E. tereticornis* plantation rows on the yield of rice and found that in the crops sown 1, 2, 4 and 5 m away from the trees, the losses in yield were 45.8, 38.6, 38.4 and 25.9 per cent respectively.

Tomer and Srivastava (1986) assessed the inhibitory effect of *E. tereticornis* on yield of rice through field studies. Craig and Saenalo (1988) reported that the deleterious effect of eucalyptus on rice could not be ameliorated even with the application of additional fertilizer. Suresh and Rai (1987) and Bansal (1988) reported the inhibitory effect of *E. tereticornis* on cowpea while Rao and Reddy (1984) reported its stimulatory effect. Kohli (1990) reported that different parts of Eucalyptus yielded different amounts of organic compounds, mainly aglycones. The aqueous leachates derived from the stem, leaves and bark of *E. tereticornis* was found to reduce the germination percentage and length of plumule and radicle of *Phaseolus aureus* and *Vigna unguiculata* when compared to water treated control. They found that the eucalyptus chemicals reduced chlorophyll, protein, RNA and carbohydrate content of the leaves, cellular respiratory ability, hydrological status and enzyme activity. Sunil and Amarjeet (1991) tested the water extracts of leaves of *E. tereticornis* for seed germination and primary root and shoot development of *Phaseolus vulgaris* seeds and reported that leachates from green leaves were found to be most inhibitory in primary root development. The affected seedlings produced a curved blunt ended extension of the root-shoot transition region which was devoid of a root cap and root hairs. Inhibition of root development in affected seedlings was attributed to an unknown water soluble substance present in the leachates.

Germination of the seeds was also affected. Shivanna *et al.* (1992) after conducting *in situ* experiments in Eucalyptus plantations reported a reduction in the germination of finger millet, cowpea and sesamum due to allelopathy.

Bhumibhamon *et al.* (1980) found that the extracts of bark and leaves of *Acacia nilotica* significantly inhibited the seed germination, radicle and plumule growth of sorghum, cotton, egg plant, okra, chillies, tomato and sunflower. They assumed that phytotoxins were mainly present in the extract. Swaminathan *et al.* (1989) tested for the potential inhibitory effects of aqueous extracts of leaves of *A. nilotica* on eight arable crops and found that seed germination of the arables was significantly inhibited and to a greater extent, radicle and plumule growth too were affected. The reduction in radicle growth varied from 4 to 13 per cent and the corresponding figure for plumule growth was 3 to 13 per cent. It was reported that the effective substances were phytoxins, mostly tannins. Jadhav and Gayanar (1992) observed that the leaf leachates of *Acacia auriculiformis* decreased the percentage germination, plumule and radicle length and dry matter in rice and cowpea. Length and dry matter production were more severely affected in rice than cowpea. Sundramoorthy *et al.* (1992) reported that the stem, leaf, litter and soil leachates of *Acacia tortilis* exhibited inhibitory as well as promotory effect on all test legume crops viz., cluster bean, green gram and kidney bean.

Suresh and Rai (1987) tested the allelopathic influence of leucaena on cowpea in top soil and rhizosphere soil from its plantation either mulched with dry leaves or irrigated with aqueous leaf extract. Seed germination, root length and dry matter production were depressed both in leucaena top soil and in aqueous extracts. Koul (1990) found no significant effect of leucaena soil and decomposed leaf extracts on the germination of rice. This finding contradicts the results of laboratory studies by Koul *et al.* (1991) where extracts of fresh leucaena leaves inhibited rice seed germination. Chaturvedi and Jha (1992) reported the stimulatory effect of second and third leaf extracts of *L. leucocephala* on rice radicle growth. Rizvi *et al.* (1990) demonstrated that mimosine (present in leucaena seeds and foliage) concentrations from 0.25 to 1.5 mm inhibited germination, radicle and plumule length of rice and green gram. Maximum inhibition was seen in plumule (81 per cent) and radicle length (71 per cent). Dry weight of plumule and radicle was decreased by 57 and 45 per cent respectively. A reduced cotyledon weight in mimosine treated seeds suggested the possibility of inhibited mobilization of stored food from cotyledon to embryo, because food mobilization efficiency of mimosine treated seeds was significantly low.

Singh and Nandal (1993) found that the leaf extracts and top soil samples of *A. nilotica, E. tereticornis* and *L. leucocephala* inhibited the germination and growth of cowpea, sorghum, cluster bean and pearl millet.

Bhumibhamon *et al.* (1980) demonstrated the stimulatory effect of leaf leachates of *Tectona grandis, Shorea robusta and Mangifera indica*, on the growth of *Costus speciosus*.

The germination and growth of green gram, black gram, cowpea, pigeon pea, cowpea, soybean, sorghum, sunflower, wheat, pea, maize and mustard were inhibited by litter extracts and top soil of *Casuarina equisettifolia* (Suresh and Rai, 1987; Srinivasan *et al.*, 1990; Joshi and Prakash, 1992).

Bhatt and Todaria (1990) noticed that ground cover was reduced significantly under *Albizzia lebbeck*.

The inhibitory effect of root, bark and leaf extracts of *Ailanthus altissima* on the growth of garden cress was reported by Heisey (1990).

The litter extract of *Bombax ceiba* and *Albizzia lebbeck* was found to have a stimulatory effect on germination of wheat, maize, pea and mustard (Joshi and Prakash, 1992).

Rao *et al.* (1994) demonstrated that the leaf extracts of *Azadirachta indica, Terminalia arjuna, Dalbergia sissoo, Albizzia lebbeck, Sesbania grandiflora, A. auriculiformis* and *L. leucocephala* significantly inhibited the germination of test crops (wheat, paddy and gram). The reduction in test crops germination was directly proportional to the increase in concentration of leaf extracts of various tree species. On soaking the seeds at higher concentrations, the germination of test crops rarely exceeded 10 per cent. On increasing the concentration of leaf extract from 1 : 15 to 1 : 5 the increase in response index and hence the inhibition was higher in wheat and paddy.

The major challenges for allelopathic research in agroforestry include, separation of allelopathic effect from the competition effects due to shade, moisture and nutrients; allelopathic effects of trees on germination, growth and development of crops in pot culture and field studies; tolerance of crops to different agroforestry tree species including allelopathic effects; screening of multipurpose trees for their allelopathic effects on soil nutrients, availability and uptake, soil microflora and alley crops, so that the least allelopathic species may be recommended for agroforestry (Nandal *et al.* 1994).

Most agroforestry tree species except a few have an adverse effect on the germination and growth of understorey crops. Compared to forest species, the agroforestry tree species have been less investigated for allelopathic influences. In view of the above, more research is needed on allelopathic potential of the tree species and the sensitivity of crops, while selecting trees and crops for agroforestry systems.

From the above review, it is obvious that despite the numerous research works conducted, very few results are available to exactly define home gardens and describe the structure and function of home gardens of Kerala. Information on species diversity, relative predominance of different crops and trees and their variation with respect to agroecological zones is inadequate.

Most of the information available on nutrient cycling pertain to forest ecosystems and temperate tree species. Reports on changes in soil characters, microclimate and overall economics in homestead systems are meagre. Also, a comprehensive study of the system dynamics covering all these aspects is totally lacking.

Although during the last two decades much work on allelopathy has been conducted in agriculture and forestry, the studies on the allelopathic effect of commonly grown tropical multipurpose tree species are scanty.

Homestead models developed through linear programming for resource optimisation and profit maximisation are wanting.

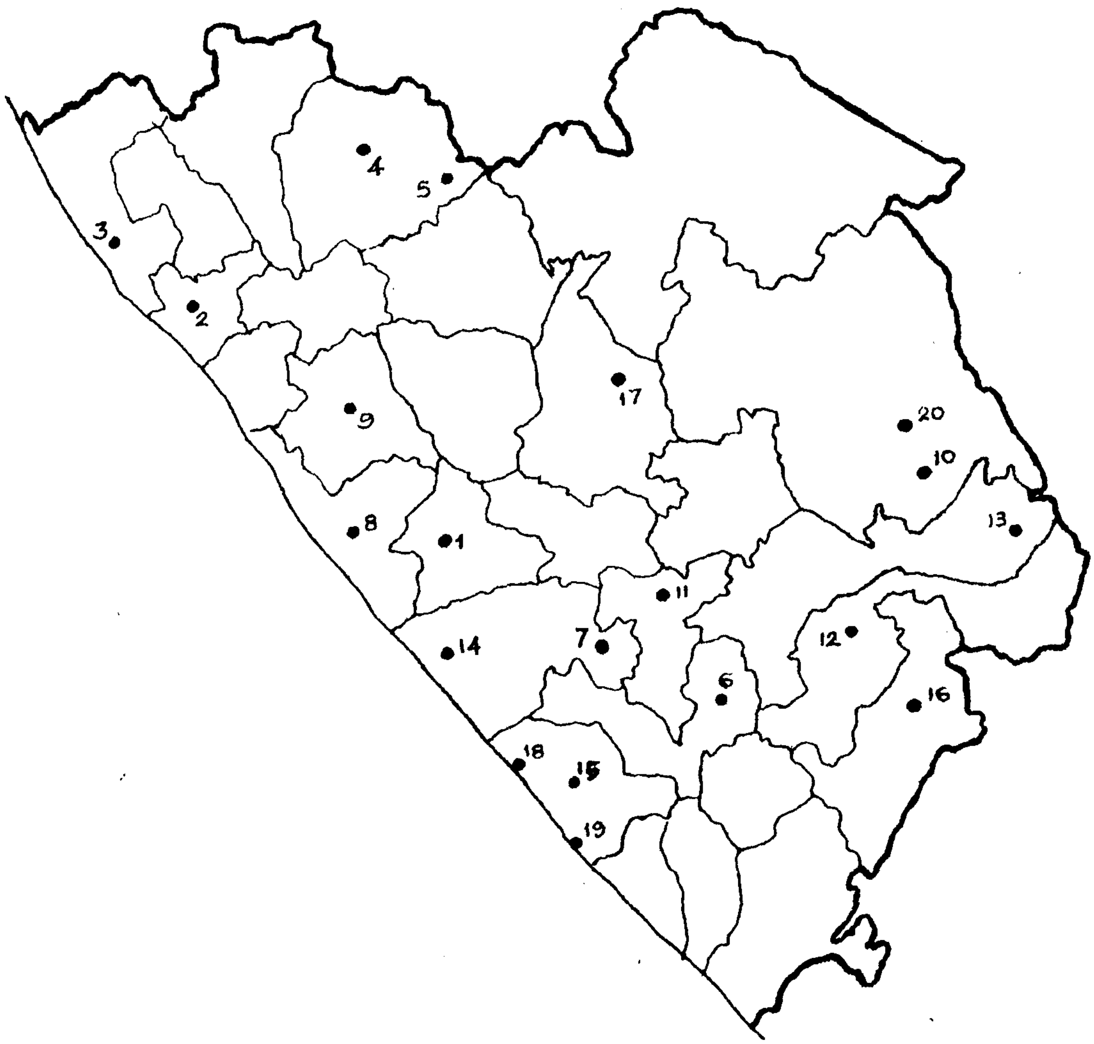
MATERIALS AND METHODS

3. MATERIALS AND METHODS

. The study formed part of an ICAR *ad hoc* project entitled "Homestead agroforestry systems of Kerala - Productivity of extant homestead models and increasing the efficiencies of models" and envisaged a detailed agroforestry systems inventory description survey to critically examine the structure, function and management practices of home gardens in Thiruvananthapuram district of Kerala. Field investigations were undertaken to assess the nutrient cycling, monitor the microclimate, soil physical, chemical and biological properties and to work out the economics of two home gardens of the district. The allelopathic effects of certain commonly grown multipurpose tree species were also investigated through laboratory experiments. The study further aimed to develop integrated homestead models for resource optimization and profit maximization through linear programming for the selected home gardens. The materials used and the methods adopted are described in this chapter.

3.1 Agroforestry systems inventory description survey

Four hundred home gardens from 20 panchayats (Fig. 1) in Thiruvananthapuram district were selected adopting the random sample survey method for the agroforesty systems inventory description survey. These panchayats were selected from the 89 panchayats in the districts. From each



1. Sreekaryam
2. Vakkom
3. Akathumuri
4. Kilimanoor
5. Pulimath
6. Pallichal
7. Vattiyoorkavu
8. Kazhakuttom
9. Mangalapuram
10. Aryanadu
11. Marukil
12. Vilappil
13. Amboori
14. Kadagampally
15. Venganoor
16. Chenkal
17. Anaad
18. Thiruvallam
19. Vizhinjam
20. Vithura

Fig. 1. Map showing the panchayats selected for the agroforestry systems inventory description survey in Thiruvananthapuram district

selected panchayat twenty homesteads were identified randomly. The information needed was collected through personal interview with the farmers and by visual observation based on a questionnaire designed for the purpose (Appendix I).

The twenty panchayats selected for the survey and their description are given in Table 1.

Information on the following aspects were gathered from each of the home gardens surveyed :

3.1.1 Size of the home gardens

3.1.2 Species diversity, their identification and functions

3.1.3 Inventory of crops and trees

3.1.4 Structure of the home gardens

3.1.5 Farming practices adopted by the homestead farmers, source of irrigation, extent of adoption of package of practices recommendations, nutrient management and plant protection measures.

3.1.6 Farming systems followed in home gardens, inventory of cattle/ poultry, their breeds and feeding pattern

3.1.7 Credit and marketing facilities

3.1.8 Difficulties/constraints experienced by the homestead farmers

3.1.9 Economics of farming

Table 1. Panchayats selected for the agroforestry systems inventory description survey in the district

Sl. No	Panchayat	Latitude	Longitude
1.	Sreekaryam	8.32° N	76.55° E
2.	Vakkom	8.41° N	76.46° E
3.	Akathumuri	8.42° N	76.45° E
4.	Kilimanoor	8.41° N	76.52° E
5.	Pulimath	8.44° N	76.53° E
6.	Pallichal	8.26° N	77.00° E
7.	Vattiyoorkavu	8.31° N	76.59° E
8.	Kazhakuttom	8.33° N	76.52° E
9.	Mangalapuram	8.37° N	76.51° E
10.	Aryanadu	8.34° N	77.05° E
11.	Marukil	8.27° N	77.02° E
12.	Vilappil	8.31° N	77.01° E
13.	Amboori	8.30° N	77.11° E
14.	Kadagampally	8.30° N	76.54° E
15.	Venganoor	8.25° N	77.00° E
16.	Chenkal	8.22° N	77.06° E
17.	Anaad	8.32° N	77.00° E
18.	Thiruvallam	8.26° N	76.57° E
19.	Vizhinjam	8.17° N	76.59° E
20.	Vithura	8.00° N	77.00° E

3.2 Field experiments

Two home gardens were selected in Thiruvananthapuram district of southern Kerala (Plates 1-4), for a detailed investigation on the dynamics of the system over a period of two years from October 1994 to September 1996. The study consisted of assessment of the nutrient cycling by different tree species, the influence of different components on the physical, chemical and biological properties of the soil, their role in amelioration of the microclimate in the home garden and overall economics, with a view to maximizing productivity and increasing the income. The results were compared with an adjacent open area taken as the control.

The location details of the home gardens selected for the field investigation are given below.

Location I

Place	: Chenkal, Neyyattinkara
District	: Thiruvananthapuram
State	: Kerala
Latitude	: 8.22°N
Longitude	: 77.06°E
Elevation	: 30 m above MSL

Plate I. General view of the home garden at Location I

Plate II. General view of the home garden at Location I

Soil type	:	Typical red loam soil of Neyyattinkara taluk with good drainage and gentle slope.
Mechanical composition of the soil	:	Coarse sand - 58.60 % Fine sand - 10.06 % Silt - 7.50 % Clay - 22.50 %
Area	:	0.50 ha (5000 m^2)

Location II

Place	:	Njandoorkonam, Sreekaryam
District	:	Thiruvananthapuram
State	:	Kerala
Latitude	:	8.32° N
Longitude	:	76.55° E
Elevation	:	30 m above MSL
Soil type	:	Typical laterite soil with good drainage.
Mechanical composition of the soil	:	Coarse sand - 53.90 % Fine sand - 14.60 % Silt - 10.00 % Clay - 20.00 %
Area	:	0.40 ha (4000 m^2)

Plate III. General view of the home garden at Location II

Plate IV. General view of the home garden at Location II

3.2.1 Structure of the home garden

A detailed inventory of the components, their population and the area occupied by them in the home gardens selected for the study was taken. The structural arrangement of the components was assessed through visual observation.

3.2.2 Dynamics of the home garden

3.2.2.1 Nutrient dynamics

The following considerations guided the study of nutrient dynamics in the homestead.

1. The total nutrient addition by litterfall, stemflow and throughfall by the different tree components in the home garden.

2. Nutrient addition by manure from cattle/poultry or by inorganic fertilizers.

3. Nutrient recycling through incorporation of crop residues.

4. The nutrient removal by way of harvested produce.

3.2.2.1.1 Nutrient addition by litterfall

Litter collection from the different tree species were made with litter traps devised locally and set under the trees. Bamboo baskets of known dimensions were used as litter traps. These baskets were set below the trees on tripods of wooden poles at a height of about 50 cm from the ground. The poles were used to keep the bamboo baskets out of contact with the soil, to prevent termite attack and the possible entry of soil into the baskets during splashing of rain water. Sufficient number of litter traps were set beneath the tree canopy. The position of the traps were interchanged at quarterly intervals to account for the spatial variation encountered beneath the canopy. The quantity of litter collected at monthly intervals per unit area under the tree canopy was quantified separately for each species and the annual litterfall was calculated using the following formula.

Annual litterfall (kg/year) =

$$\frac{\Sigma \text{ Monthly litter collection in the litter trap}}{\text{Area of the litter trap (m}^2\text{)}} \times \text{Canopy area (m}^2\text{)}$$

The quantification of litterfall was made on canopy area basis, as the trees were isolated and wide apart in the homestead. The litter samples from the different traps were pooled for each tree species, dried in a hot air oven and analysed for their nitrogen, phosphorus and potassium contents. The methods adopted for nutrient analysis are given in Table 2. From the total quantity of litter added and the nutrient content of the litter, the nutrient addition by litterfall to the system was calculated and expressed as kg/year for each species.

3.2.2.1.2 Nutrient addition of stemflow

Stemflow was collected using plastic collars devised locally and fitted to each tree at a height of 75 cm above the ground. The plastic collar was fixed to the trees using coal tar. The stemflow was channeled to jerry cans of 35 litres capacity connected with polythene funnels. The coal tar used for fixing the plastic collars was washed a number of times with distilled water to ensure that it was free of any nutrients. The volume of water received by stemflow from each tree species was measured at periodic intervals depending upon the intensity and amount of rainfall. The samples of stemflow thus collected were pooled species wise and analysed for their nitrogen, phosphorus and potassium contents. The methods adopted for the chemical analysis of the water samples obtained by stem flow are given in Table 3. The total quantity of water received by stemflow was multiplied with its nutrient content, so as to compute the nutrient addition by stemflow by each species at monthly intervals. The monthly estimates were added and expressed in kg/year.

3.2.2.1.3 Nutrient addition by throughfall

Throughfall was collected, using gauges designed for the purpose. It consisted of polythene funnels of known dimensions, connected to collecting bottles, placed on the ground under the canopy of different tree species. The gauges were randomly placed. To account for spatial variation encountered beneath the tree canopy, the location of the traps under each tree was changed at monthly intervals. A similar gauge was set up in the open along with a standard rain gauge. The water collected in these gauges were quantified regularly depending on the intensity and amount of rainfall.

Table 2. Analytical methods adopted for the estimation of nutrient contents of leaf / plant samples

Nutrient	Method	
Nitrogen	Modified Microkjeldahl method	(Jackson, 1973)
Phosphorus	Vanadomolybdate phosphoric yellow method	(Jackson, 1973)
Potassium	Flame Photometry method	(Jackson, 1973)

Table 3. Analytical methods adopted for the estimation of nutrient contents of throughfall and stemflow

Nutrient	Method	
Nitrogen	Modified Microkjeldahl method	(Jackson, 1973)
Phosphorus	Bray colorimetric method	(Jackson, 1973)
Potassium	Flame Photometry method	(Jackson, 1973)

The total quantity of throughfall for each species was calculated from the canopy area and total quantity of rain water received. The samples of throughfall collected were pooled and their nitrogen, phosphorus and potassium contents were analysed separately for each tree species at monthly intervals. The methods followed for the analysis of the water samples obtained by throughfall were the same as for stemflow (Table 3). From the value of volume of throughfall and its nutrient content, the total nutrient addition by each tree species was calculated monthly and the estimates were added to quantify the annual addition expressed in kg/year.

3.2.2.1.4 Nutrient addition by cattle / poultry manure and inorganic fertilizers

The manure / litter excreted by the cattle / poultry daily were recorded and the total annual manurial addition to the homestead was quantified. The inorganic fertilizers purchased and added to the system was also recorded. The quantities of the manures / fertilizers were multiplied with their respective nutrient contents for calculating the total nutrient addition to the system and expressed as kg/year.

3.2.2.1.5 Nutrient recycling through crop residues

The total quantity of crop residues recycled back into the system after the harvest of the crops was recorded periodically. Samples of these crop residues were taken, oven dried at 70 °C, powdered and chemically analysed for their N, P and K contents adopting the methods given in Table 2. These values were used to estimate the nutrient addition by crop residues into the system and expressed in kg / year.

3.2.2.1.6 Nutrient removal by way of harvested produce

The biomass harvested from the system was recorded periodically as and when the harvest was done for each tree/crop component. Samples of the harvested produce were taken, oven dried at 70 °C, powdered and subjected to chemical analysis for estimating its N, P and K contents as per analytical procedures given in Table 2. The biomass produced by each crop/tree component was multiplied with their respective nutrient contents and expressed in kg / year in order to assess the nutrient removal by harvested produce.

3.2.2.2 Soil properties

3.2.2.2.1 Physical properties

Soil samples were collected from the homestead at two depths of 15 and 30 cm, at half yearly intervals and analysed for bulk density, particle density, porosity and water holding capacity, using the method suggested by Keen and Raczkowski (1921). A number of samples were collected from different parts of each home garden and composited before analysis. Soil samples were also taken from an adjacent open area, serving as control. Aggregate analysis was carried out by Yoder's wet sieving method (Yoder, 1937). Mean weight diameter was taken as the index of aggregation (Bavel, 1949). Estimation of the soil moisture status at 15 and 30 cm depth in the homestead and open control was also made seperately at monthly intervals.

3.2.2.2.2 Chemical properties

Soil was collected at half yearly intervals from two depths of 15 and 30 cm. These soils were analysed for pH, organic carbon content and available N, P and K. The method of collection of soil samples from the home garden and open control plot was similar to that adopted for the analysis of physical properties. The methods followed for the assessment of various soil chemical parameters are given in Table 4.

Table 4. Analytical methods adopted for the estimation of chemical properties of soil

Parameter	Method	
pH	pH meter with glass electrode	(Jackson, 1973)
Organic carbon	Walkley and Black's rapid titration method	(Jackson, 1973)
Available Nitrogen	Alkaline permanganate method	(Subbiah and Asija, 1956)
Available Phosphorus	Bray colorimetric method	(Jackson, 1973)
Available Potassium	Flame photometer method	(Jackson, 1973)

3.2.2.2.3 Microbiological properties

Soil samples were collected from the rhizosphere of the different trees in the homestead at half yearly intervals. All the samples were composited and analysed for microbial population, within 24 hours of collection of samples. The total number of fungi, bacteria, actinomycetes and phosphorus solubilizing bacteria per gram of soil was estimated by the dilution plate technique (Timonin, 1940). Actinomycetes and phosphorus solubilizing bacteria were estimated at 10^{-6} dilution, fungi at 10^{-4} dilution and total bacteria at 10^{-8} dilution. Composite soil samples from the control plots were also analysed simultaneously. The readings were recorded as colony forming units (c.f.u).

3.2.2.3 Microclimate

A field observatory was set up in both the homesteads to record the soil temperature, relative humidity, maximum and minimum temperature and rainfall. These parameters were recorded daily. Four sets of soil thermometers were installed at two depths of 15 and 30 cm, at four different locations in each homestead. One set was maintained in the open control. Relative humidity in the home garden and open was measured using a hygrometer.

The shading effect of the tree species in the home garden and the light available at their base were determined at monthly intervals, using a lux meter. The measurements were taken at a distance of 2 m from the tree base. The light intensity in the open was also recorded at the same time and interval. From the data, the percentage of light transmitted by the canopy of each tree species was calculated.

3.2.3 Economic analysis

The economics of the selected home gardens was worked out annually. All the enterprises in the homestead were spatially defined and their total costs, gross return and net profit were found out. The total costs incurred in the system and the gross returns were used to calculate the benefit : cost ratio. The method adopted for evaluating the homestead system was the non-optimization method, also known as cost-benefit analysis (Hoekstra, 1985).

3.2.4 Evaluation of the system

Based on the information gathered the merits, demerits and efficiency of both the home gardens were evaluated.

3.3 Allelopathic studies

Four separate laboratory experiments were undertaken to examine the allelopathic effects of the leaf extracts and powdered litter of some commonly grown multi-purpose tree species.

Experiment I : To study the allelopathic effect of leaf extracts of different tree species on rice.

Experiment II : To study the allelopathic effect of leaf extracts of different tree species on cowpea.

Experiment III : To study the allelopathic effect of powdered leaf litter of different tree species on rice.

Experiment IV : To study the allelopathic effect of powdered leaf litter of different tree species on cowpea.

The tree species selected for the study were

T1	Acacia	T6	Jack	T11	Nutmeg
T2	Eucalyptus	T7	Mango	T12	Wild Jack
T3	Casuarina	T8	Ailanthus	T13	Portia
T4	Albizzia	T9	Tamarind	T14	Cashew
T5	Leucaena	T10	Bombax		

Design : C.R.D.

Total treatments : (14 + 1 control) = 15

Replications : 3

In the first two experiments, the fresh leaves of the tree species mentioned above were collected and soaked in distilled water at the weight/ volume ratio of 1:10 for 24 hours. This ratio resulted in low osmolality (Richardson and Williamson, 1988). Extracts were filtered through Whatman No.1 filter paper. Twenty five seeds of rice (var.Jyothi) and cowpea (var.

Kanakamony) was placed in petridishes lined with one sheet of germination paper saturated with 4 ml of the extract. Moisture in the paper was maintained by adding 4 ml of the extract daily. Distilled water served as the control.

The third and fourth experiments were similar to the first one except that the powdered leaf litter of the trees under study were mixed with the planting media (sand) in the ratio 1:10. Litter collected from the base of each tree species was used for the study. Sowing of the seeds in sand served as the control. Moisture in all the treatments were maintained by adding distilled water daily.

The following observations were recorded on the seventh day after sowing.

i. Germination percentage : The number of seeds that germinated were counted and expressed as percentage of the total seeds.

ii. Plumule length : The length of the plumule of all the seeds were measured and expressed as average of twenty five seeds.

iii. Radicle length : The length of the radicle of all the seeds were measured and expressed as average of twenty five seeds.

iv. Response index : The response index with respect to each parameter was calculated using the following formula suggested by Williamson and Richardson (1988).

If $T > C$, $RI = 1 - (C/T)$

$T = C$, $RI = 0$

$T < C$, $RI = (T/C) - 1$

where T = Treatment mean and C = Control mean

3.4 Linear programming

The data on the economics of cultivation obtained from the two selected home gardens throughout the period of study was used to develop optimum models, employing the method of linear programming. The models were developed with the twin objectives of resource optimisation and profit maximisation, taking into account the tastes, preferences and constraints of the farmers. The simplex method of linear programming was adopted for developing the optimum model.

3.5 Statistical analysis

The data collected by the agroforestry systems inventory description survey was subjected to percentage analysis. The percentage distribution in different categories on all variables were worked out by dividing the frequency in each category with the total number and multiplying by 100. The data obtained was classified based on the agroecological regions (highland, midland and lowland) in the district and was statistically analysed by analysis of variance technique, and the significance tested by F test (Snedecor and Cochran, 1967).

To study the relationship between the different desired variables, correlation analysis was done.

The data obtained from the laboratory experiments on allelopathy was analysed by applying the analysis of variance technique for Completely Randomised Design (CRD) and the significance tested by F test at 0.05 and 0.01 levels.

The simplex method of linear programming was adopted for developing optimum models for the selected home gardens.

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

Agroforestry home gardens have stood the test of time. The selection of crops and cropping patterns in home gardens is based on centuries of experience and perception of the farmer. Almost all the home gardens seem to have evolved under the influence of resource constraints or physical limitations, compelling the farmers to produce everything that they can use to satisfy their basic needs. The home garden is perhaps the most complex agroecosystem. With very high species diversity, and complex structural arrangement of the components with apparently strong ecological foundations, the system simulates the structure and function of a natural tropical forest ecosystem. The Kerala home gardens have been considered to be the survival strategy of the farmers of the State for centuries. Thus, the home gardens of Kerala can be perceived as the outcome of socio-economic factors.

4.1 Agroforestry systems inventory description survey

The agroforestry systems inventory description survey was undertaken in 400 home gardens of Thiruvananthapuram district. The data obtained were analysed and presented in Tables 5 to 19 and depicted in Figures 2 to 21. The survey was intended to study the general characteristics of the agroforestry home gardens of the district. The results of the study are presented and discussed below :

4.1.1 Size of the home gardens

The size of home gardens surveyed varied from 0.04 ha to 3.6 ha with an average of 0.33 ha per holding. Ninety five per cent of the home gardens had a size of less than 0.80 ha (Fig 2). Majority (58.25 %) of the holdings were small sized. This was followed by very small holdings which constituted 37 per cent. The large sized holdings (> 2.00 ha) constituted only 1.25 per cent. There was significant difference between the agroecological regions with respect to the holding size (Table 5) with the maximum in highlands (0.55 ha) followed by midlands (0.32 ha).

The size of an overwhelming number of holdings was small. The predominance of smaller holdings was probably due to the high density of population as suggested by Nair and Krishnankutty (1984). The total population of Kerala in 1991 was 29.10 million with an average population density of nearly 749 persons per sq.km, the highest for any Indian state and about three times the all India figure. The high population density has led to a small farm size, which is very small (0.36 ha) even by Indian standards (Kerala State Land Use Board, 1997). In the past, the joint family system kept the size of farms, intact, despite the rise in the number of family members from generation to generation. But, now, this system is breaking up under the influence of modern education and western thought.

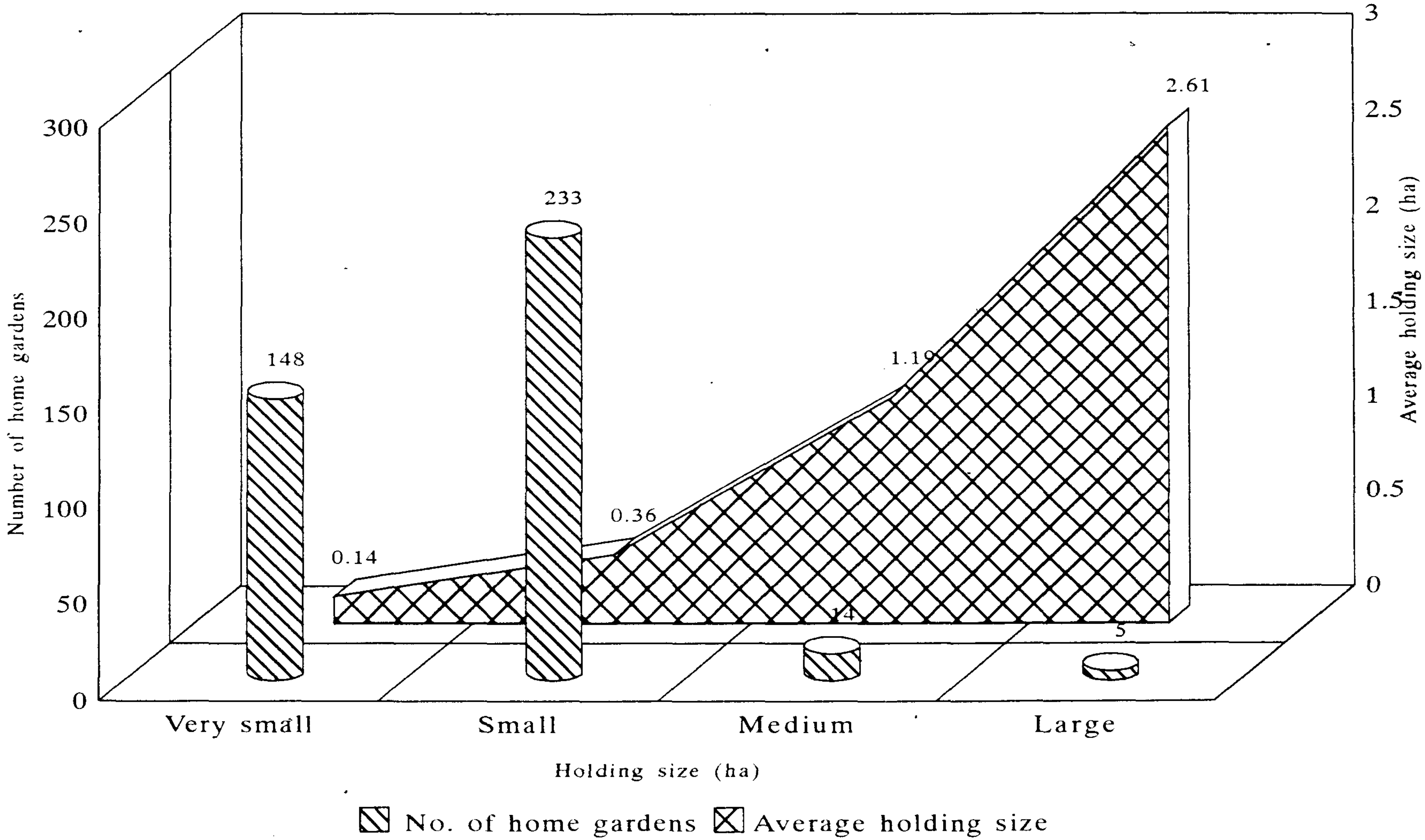


Fig. 2. Holding size of the home gardens in the district

Table 5. Differences in holding size and species diversity of the home gardens in the district and its agroecological zones.

Attribute		Average per home garden			District mean	Critical Difference (0.05)		
		Highland	Lowland	Midland		HL	HM	LM
Area	(cents)	138.27	56.90	78.77	83.32	28.494	23.896	21.331
	(ha)	0.55	0.23	0.32	0.33	...	...	...
Total number of plants		765.07	138.75	385.80	393.28	293.234	245.913	219.520
Number of species		13.77	12.89	15.32	14.60	...	...	1.646

HL - Difference between highland and lowland

HM - Difference between highland and midland

LM - Difference between lowland and midland

As a result, each member of the family, when grown up, wants to set up his separate family, resulting in sub-division and fragmentation of holdings. This calls for a modification of the existing laws of inheritance, in such a manner that holdings of minimum size are not allowed to be sub-divided. The policy of population control or family planning will also help in preventing further break up of holdings.

4.1.2 Species diversity in the home gardens

The farmers deliberately retained and managed numerous species of crops and trees in their home gardens. The survey revealed that as many as 115 species were grown in the home gardens. The nature of growth and the uses / functions of each species are given in Table 6. The number of species (Fig. 3) in each homestead was found to vary from < 5 to > 40. Majority (57.75 %) of the home gardens consisted of 10 - 20 species. An average of 14 - 15 species and 393 plants per homestead was observed, in the district as a whole (Table 5), indicating a very high degree of crop combination and diversification. Moreover, holding size had a significant positive correlation with species diversity ($r = 0.213$).

The species diversity was a deliberate strategy aimed at producing harvests throughout the year, so that there was always some product of economic value available for household use or cash sale. Species diversity is also well planned in terms of pest and disease management, risk aversion and efficient use of natural resources (Babu *et al.*, 1992).

Table 6. Tree / Crop Species noticed in the home gardens in the district

Common name	Scientific name	Nature of growth	Uses
Oilseeds			
Coconut	*Cocos nucifera*	P	1, 3, 4, 5, 8, 11, 12
Pulses			
Cowpea	*Vigna unguiculata*	A	1, 2
Spices and condiments			
Cinnamon	*Cinnamomum zeylanicum*	P	7, 8, 12, 14
Clove	*Eugenia caryophyllum*	P	7, 8, 12, 14
Nutmeg	*Myristica fragrans*	P	7, 8, 12, 14
Tamarind	*Tamarindus indica*	P	1, 3, 7, 12, 14
Ginger	*Zingiber officinale*	A	7, 8, 14
Turmeric	*Curcuma longa*	A	7, 12, 14, 15
Pepper	*Piper nigrum*	P	7, 14
Curry leaf	*Murraya koenigi*	P	7
Cardamom	*Elettaria cardamomum*	P	7, 12, 14
Garcinia	*Garcinia indica*	P	7, 12
Chillies	*Capsicum annuum*	A	7, 14
Pippali	*Piper longum*	P	7, 14
Fruits			
Cashew	*Anacardium occidentale*	P	1, 4, 8, 11, 12
Banana	*Musa spp.*	A	1, 14
Jack fruit	*Artocarpus heterophyllus*	P	1, 2, 3, 4
Breadfruit	*Artocarpus altilis*	P	1, 12
Mango	*Mangifera indica*	P	1, 2
Sapota	*Achras sapota*	P	1
Guava	*Psidium guajava*	P	1, 3, 12
Bullock's heart	*Annona reticulata*	P	1, 8, 12
Seethaphal	*Annona squamosa*	P	1, 8
Egg fruit	*Poutia campechiana*	P	1
Pomegranate	*Punica granatum*	P	1, 14
Lovilovi	*Flacortia inermis*	P	1
Pineapple	*Ananas comosus*	A	1, 5, 12, 14

Contd...

21

Table 6. (Contd.....)

Common name	Scientific name	Nature of growth	Uses
Rose apple	*Euginia jambosa*	P	1, 13
Papaya	*Carica papaya*	P	1, 6, 12, 14
Njaval	*Zizyphus jujuba*	P	1, 2, 14
Cherry	*Malpighia glabra*	P	1, 12
Karakka	*Carisa caronda*	P	1
Lime	*Citrus aurantifolia*	P	1, 8, 12, 14
Bamblimass	*Citrus maxima*	P	1, 8, 12, 14
Fig	*Ficus carica*	P	1, 14
Passion fruit	*Passiflora edulis*	P	1
Aonla	*Emblica officinalis*	P	1, 3, 12, 14
Bilimbi	*Averrhoia bilimbi*	P	1
Mangosteen	*Garcinia mangostana*	P	1, 14
Palmyrah	*Borassus flabellifer*	P	1, 3, 11, 12, 13
Carambola	*Averrhoa carambola*	P	1, 12
Tuber crops			
Taro	*Colocasia esculentus*	A	1, 12
Elephant yam	*Amorphophallus companulatus*	A	1, 14
Tapioca	*Manihot esculenta*	A	1, 12
Arrowroot	*Maranta arundinacea*	A	1, 12
Lesser yam	*Dioscorea spp.*	A	1, 14
Greater yam	*Dioscorea alata*	A	1
Chinese potato	*Coleus parviflorus*	A	1
Sweet potato	*Ipomoea batatus*	A	1, 12, 14
Mango Ginger	*Curcuma amada*	A	7
Timber and fuel trees			
Wild Jack/Ayoni	*Artocarpus hirsuta*	P	3, 4
Ailanthus	*Ailanthus tryphysa*	P	3, 12, 14
Eucalyptus	*Eucalyptus tereticornis*	P	4,8, 9, 12, 14
Mahogany	*Swietania macrophylla*	P	3
Teak	*Tectona grandis*	P	3, 12
Portia	*Thespesia populenea*	P	1,2,3,8,14
Uthimaram	*Lannia coromandelica*	P	1, 3, 6, 12
Red silk cotton	*Bombax ceiba*	P	1, 2, 3, 5, 6, 12

Contd...

Table 6. (Contd.....)

Common name	Scientific name	Nature of growth	Uses
Silk cotton	*Ceiba pentandra*	P	3,5, 8, 12
Bamboo	*Bambusa arundinacea*	P	3, 12
Polyalthia	*Polyalthia longifolia*	P	3, 13
	Polyalthia fragrans	P	3
Acacia	*Acacia auriculiformis*	P	4, 9, 12, 13
Subabul	*Leucaena leucocephala*	P	1, 2, 3, 4, 9, 10, 12
Morinda	*Morinda tinctoria*	P	1, 2, 3, 12
Azhantha	*Pazanelia rheedii*	P	3, 12, 13
Asoka	*Saraca indica*	P	3, 9, 14
Albizzia	*Paraserianthes falcataria*	P	2, 3, 9, 12, 13
Mangium	*Acacia mangium*	P	3
Casuarina	*Casuarina equisettifolia*	P	3, 4, 12, 13
Arjun	*Terminalia arjuna*	P	3, 12, 13, 14
Malay bushbeech	*Gmelina arborea*	P	3, 12
Pezha	*Careya arborea*	P	3, 5, 12
Indian Kinotree	*Pterocarpus marsupium*	P	1, 3, 6, 12, 14
Indian Rosewood	*Dalbergia latifolia*	P	3
Fodder grasses			
Napier grass	*Pennisetum purpureum*	P	2
Guinea grass	*Panicum maximum*	P	2
Vegetables			
Agathi	*Sesbania grandiflora*	P	1, 2, 5, 9, 12, 14
Kuppameni	*Acalypha indica*	P	1, 14
Drumstick tree	*Moringa oleifera*	P	1, 8, 12, 14
Amaranthus	*Amaranthus spp.*	A	1, 2
Bhindi	*Abelmoschus esculentus*	A	1, 5, 8, 12
Brinjal	*Solanum melongena*	A	1
Chekurmanis	*Psoropus androgayanus*	P	1
Bitter gourd	*Momordica charantia*	A	1
Cucumber	*Cucumis sativus*	A	1, 8, 14
Snake gourd	*Trichosanthes anguina*	A	1, 14
Winged bean	*Psophocarpus tetragonolobus*	A	1, 2
Radish	*Raphanus sativa*	A	1, 14

Contd...

Table 6. (Contd.....)

Common name	Scientific name	Nature of growth	Uses
Ash gourd	*Benincasa hispida*	A	1
Bottle gourd	*Lagenaria vulgaris*	A	1, 12, 14
Broad Beans	*Vicia faba*	A	1, 2
Cluster bean	*Cyamopsis tetragonaloba*	A	1, 2, 6, 12
Ivy gourd	*Coccinia cordifolia*	A	1, 14
Pumpkin	*Cucurbita maxima*	A	1, 14
Ridge gourd	*Luffa acutangula*	A	1, 5
Sword beans	*Canavalia gladiata*	A	1
Chundakkai	*Solanum torvum*	A	1, 14
Beverages and masticatories			
Cocoa	*Theobroma cacao*	P	11, 12, 14
Arecanut	*Areca catechu*	P	11, 12, 13, 14, 15
Betel vine	*Piper betel*	P	11
Coffee	*Coffea arabica*	P	11
Miscellaneous			
Neem	*Azadirachta indica*	P	1, 3, 8, 12, 14
Henna	*Lawsonia alba*	P	12, 14
Nuxvomica	*Strychnos nux-vomica*	P	3, 11, 14
Rubber	*Hevea brazilensis*	P	3, 6, 12
Indian almond	*Terminalia catappa*	P	1 ,3, 12
Sugarcane	*Saccharum officinarum*	A	1, 4, 11, 12
Mulberry	*Morus alba*	P	1, 12
Glyricidia	*Glyricidia sepium*	P	10, 13
Ficus/Peepul	*Ficus religiosa*	P	9, 14, 15
Vatta	*Macaranga peltata*	P	6
Erythrina	*Erythrina indica*	P	2, 9, 12, 13
Elenji	*Mimosops elenji*	P	13
Flame of Forest	*Butea monosperma*	P	6, 12, 13, 14

Nature of growth : A - Annual P - Perennial

Uses :
1. Food
2. Fodder
3. Timber
4. Fuel
5. Fibre
6. Latex/Gum
7. Spice
8. Oil
9. Shade
10. Live Fence
11. Beverage/Stimulant
12. Commercial products
13. Ornamental/Avenue
14. Medicine
15. Religous

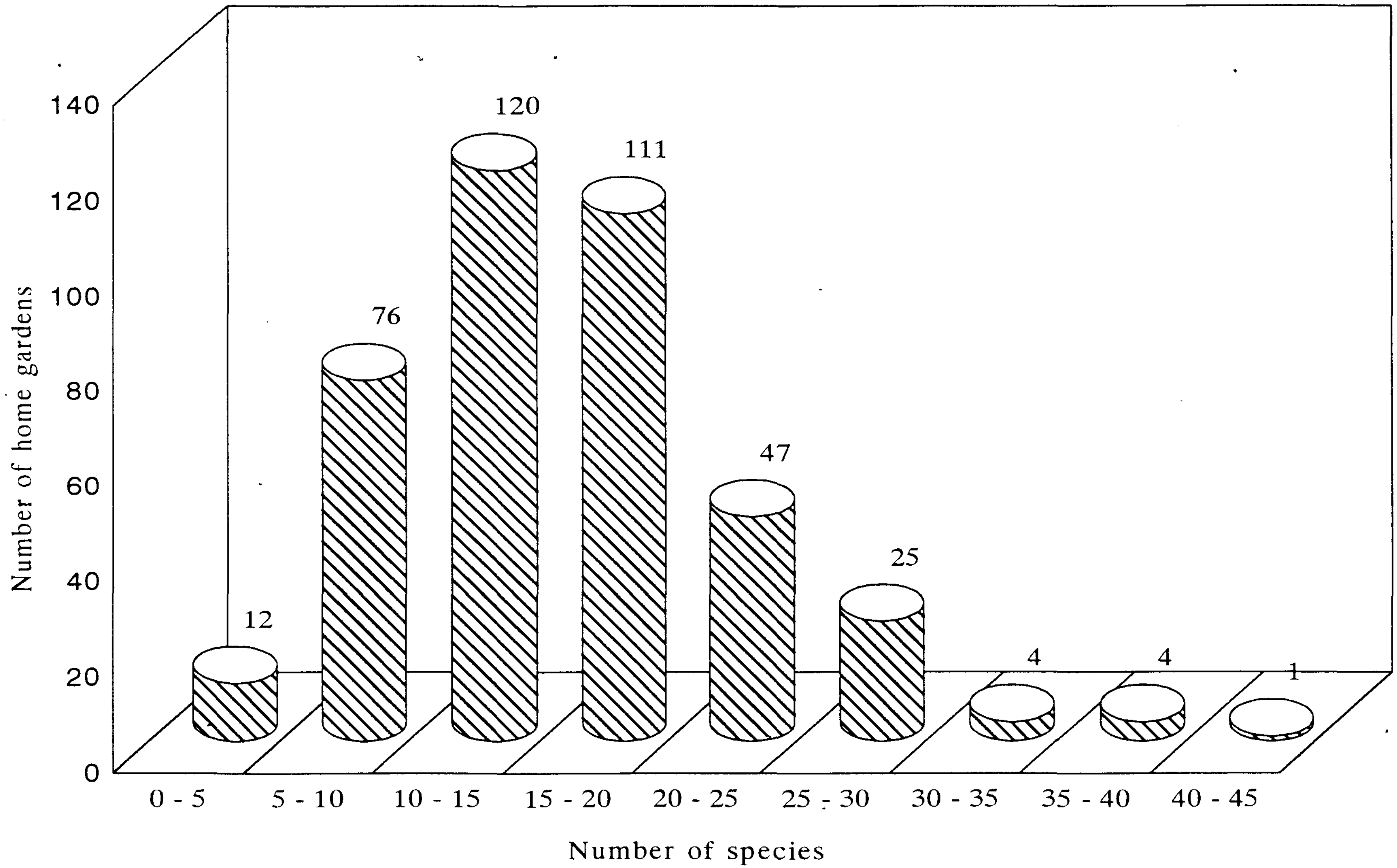


Fig. 3. Species diversity of the home gardens in Thiruvananthapuram district

The occurrence of such a large number of crop/tree species is in accordance with the report of Thaman (1985) who observed that upto 114 different species were grown in the home gardens of New Guinea. The different crop/tree species noticed in the home gardens were similar to those enumerated by Nair and Sreedharan (1986) and satisfied the multifarious needs of the farmer. In addition to food plants, a very wide range of non-food plants were also found in the home gardens which were of considerable importance for fuel, fodder, timber, medicine, fibre, latex, ornamental and religious purposes and in producing items of commercial value (dyes, paints, perfumes, handicrafts, match sticks etc.). Corresponding observations of high species diversity and density have been reported by Kamtuo *et al.* (1985) from Thailand.

4.1.3 Inventory of crops / trees

The system consisted mainly of annual crops, trees and perennial and semi-perennial shrubs. The farmers integrated numerous species of multi-purpose trees and shrubs in close association with agricultural crops. The relative predominance of different crop categories in the district and its different agroecological regions is given in Tables 7 and 8 respectively. The variation in the predominance in relation to the holding size was also examined (Table 9).

Tuber crops were found to be the most dominant category (Table 7). Among the tropical tubers, cassava was the most common and important. Other tuber crops included taro, elephant foot yam, dioscorea, lesser yam, arrow root, sweet potato and chinese potato.

Table 7. Relative predominance of different crop categories in the district

Category	Number of plants	Per cent
Oilseeds	20763	13.20
Fruit crops	31194	19.83
Tuber crops	72830	46.30
Spices	5941	3.78
Vegetables	4900	3.11
Timber and fuel trees	4333	2.75
Fodder crops	2200	1.40
Rubber	12781	8.12
Miscellaneous	2371	1.51
Total	157313	100.00

Table 8. Relative predominance of different crop categories in different agroecological regions in the district

Category	Per cent		
	Highland	Midland	Lowland
Oilseeds	5.50	13.73	40.25
Fruit crops	28.98	15.13	24.40
Tuber crops	38.25	53.21	17.12
Spices	3.20	3.90	5.03
Vegetables	0.67	3.87	6.42
Timber and fuel trees	1.23	3.45	2.73
Fodder crops	0.11	2.04	0.94
Rubber	19.04	4.03	0.00
Miscellaneous	3.02	0.64	3.11

Table 9. Relative predominance of different crop categories in relation to holding size

Category	Per cent			
	Very small (0.02 - 0.2 ha)	Small (0.2 - 0.8 ha)	Medium (0.8 - 2.0 ha)	Large (> 2.0 ha)
Oilseeds	21.70	14.40	47.80	4.40
Fruit crops	19.80	16.60	7.50	54.70
Tuber crops	41.60	47.60	66.80	16.20
Spices	5.20	4.50	1.30	1.70
Vegetables	3.50	4.20	0.60	0.20
Timber and fuel trees	3.20	3.60	0.50	0.40
Fodder crops	0.70	2.00	0.50	0.00
Rubber	1.70	6.20	11.50	21.60
Miscellaneous	2.60	0.90	3.50	0.80

However, in lowlands (Table 8) and large holdings (Table 9) tuber crops ranked third. The average number of tuber crop plants per homestead varied significantly between agroecological regions (Table 10) with the highest being observed in highlands (292.60 plants per home garden).

Fruit crops ranked second in predominance (Table 7). A number of fruit crops like banana, jack, mango, guava, annona, pineapple, rose apple, papaya, lovilovi, sapota and bamblimass were grown in most homesteads. The number of fruit crops were comparatively higher in large holdings (Table 9). The average number of fruit plants per homestead was significantly higher in highlands (221.73 per garden) compared to lowlands and midlands (Table 10).

Among the oilseeds, which ranked third in the district, coconut was the most dominant and important. However, in highlands (Table 8) and in large holdings (Table 9) oilseeds ranked fourth. In lowlands, oilseeds ranked first. In the district as a whole, the average yield of coconut in majority (48.75 %) of the holdings was found to be between 40 - 60 nuts per palm per annum. However, the average yield of coconut in 50.36 per cent of homesteads in the laterite soils, was found to be between 30-50 nuts per palm per annum, while in sandy and red loam soils it was between 50-60. There was no significant difference in the average number of oilseed plants per homestead between different agroecological regions (Table 10).

Table 10. Average number of plants of different crop categories in the home gardens

Attribute	Average number per home garden				Critical Difference (0.05)		
	Highland	Lowland	Midland	District	HL	HM	LM
Number of oilseed crops	42.12	55.85	52.95	51.91	...	...	...
Number of fruit crops	221.73	33.85	58.39	77.99	154.044	129.184	...
Number of tuber crops	292.60	23.75	205.29	182.08	99.217	83.207	74.276
Number of spice crops	24.48	6.98	15.05	14.85	10.806	9.062	...
Number of vegetable crops	5.10	8.91	14.93	12.25	...	...	...
Number of timber/fuel trees	9.42	3.79	13.33	10.83	...	...	5.279
Number of fodder crops	0.83	1.31	7.87	5.50	...	...	...
Number of rubber trees	145.67	0.00	15.54	31.95	35.083	29.421	...
Miscellaneous crops	23.12	4.31	2.46	5.93	12.941	10.230	...

HL - Difference between highland and lowland
HM - Difference between highland and midland
LM - Difference between lowland and midland

Rubber was grown in several homesteads of the district and it is fast becoming a home garden tree crop, especially in the highlands (Table 8) and medium to large holdings (Table 9). However, in the lowlands rubber was not planted in the home gardens (Table 8). The average number of rubber trees per home garden was significantly higher in highlands (Table 10).

Spice crops ranked fifth, among the crop categories in the district and its regions (Tables 7 and 8), irrespective of the size of holdings (Table 9). Cultivation of spices like pepper, clove, ginger, turmeric and cinnamon were very popular. Pepper was grown mostly using other trees (erythrina, arecanut, wild jack, coconut, ailanthus, cashew, portia etc.) as live standards. The average number of spice plants per home garden was significantly higher in highlands (Table 10).

The commonly grown vegetables (rank six) included amaranthus, chilli, moringa, bread fruit, bhindi and brinjal, which were grown mainly for home consumption. However, in highlands, the predominance of vegetables was comparatively low (Table 8). Vegetable cultivation in large holdings was very low (Table 9). There was no significant variation between regions with respect to the average number of plants per homestead (Table 10).

The miscellaneous category mainly consisted of trees / crops like mulberry, arecanut, neem etc. which were found in several homesteads. Fodder crops occupied the last position among the different crop categories in the district (Table 7) and its different regions (except lowlands).

The most commonly cultivated fodder grasses included guinea grass and hybrid napier.

The tree intensity was found to increase as the size of the holding decreased. In large holdings (> 2.00 ha) the tree intensity was 368.55 per hectare while in very small holdings (0.02-0.20 ha) it was 403.32 per hectare. The percentage of home gardens planted with each tree is given in Table 11. In the district as a whole the frequency of occurrence was highest for coconut (100 %) followed by jack (94.5 %), mango (88 %), moringa (61.25 %), guava (58.75 %), wild jack (46.5 %) and tamarind (44.5 %) and lowest for the nitrogen fixing trees viz., mangium, subabul, acacia, and albizzia (3-4.5 %). A similar pattern was noticed in the different agroecological regions (Table 11) with respect to coconut, jack, mango and nitrogen fixing trees. However, the frequency of occurrence of rubber was comparatively higher (75 %) in the highlands and nil in lowlands.

The relative predominance of different tree species in the district and its agroecological zones is given in Table 12 and it was found to be highest for coconut followed by rubber, arecanut, jack, ailanthus, mango, wild jack, moringa, teak and cashew. However, in highlands rubber was found to dominate among the different trees. Region wise analysis of the data on the average number of different tree species per home garden (Table 13) revealed that there was significant difference with respect to jack, mango, annona, papaya, ailanthus, cashew, tamarind, arecanut, rubber, portia, morinda and erythrina.

Table 11. Frequency of occurrence of different tree species in the district and its agroecological regions

Tree species	Percentage of the home gardens planted with the tree			
	Whole district	Highland	Midland	Lowland
Jack	94.50	85.00	95.38	98.75
Mango	88.00	78.33	89.62	90.00
Guava	58.75	40.00	62.31	61.25
Annona	36.75	26.67	40.77	31.25
Rose apple	33.00	25.00	36.54	27.50
Lovilovi	26.75	35.00	21.54	37.50
Papaya	42.25	28.33	44.23	46.25
Moringa	61.25	55.00	59.62	71.25
Wild jack	46.50	51.67	47.69	38.25
Ailanthus	34.25	28.33	38.46	25.00
Cashew	26.25	23.33	30.77	13.75
Tamarind	44.50	35.00	50.77	31.25
Teak	35.00	20.00	37.31	38.75
Arecanut	42.25	43.33	38.46	53.75
Bombax	16.75	20.00	15.77	17.50
Acacia	4.25	3.33	4.23	5.00
Mangium	3.50	1.67	5.00	0.00
Subabul	4.00	0.00	5.38	2.50
Albizzia	4.50	11.67	4.23	2.50
Bread fruit	33.50	36.67	34.23	28.75
Coconut	100.00	100.00	100.00	100.00
Rubber	15.75	75.00	6.92	0.00
Portia	23.75	1.67	26.54	31.25
Mahogany	19.50	16.67	21.54	15.00
Eucalyptus	4.50	1.67	3.46	10.00
Cinnamon	9.00	6.67	11.92	1.25
Clove	16.75	16.67	18.08	12.50
Morinda	17.25	15.00	22.31	2.50
Erythrina	10.00	20.00	10.38	1.25

Table 12. Relative predominance of different tree species in the district and its agroecological regions

Tree	Highland		Midland		Lowland		Whole district	
	Frequency	Per cent	Frequency	Per cent	Frequency	Per cent	Frequency	Per cent
Jack	**170**	**1.23**	**987**	**3.66**	**175**	**2.94**	**1332**	**2.85**
Mango	**115**	**0.83**	**825**	**3.06**	**139**	**2.33**	**1079**	**2.31**
Guava	39	0.28	246	0.91	60	1.01	245	0.74
Annona	**38**	**0.28**	**262**	**0.97**	**30**	**0.50**	**330**	**0.71**
Rose apple	16	0.12	112	0.42	29	0.49	157	0.34
Lovilovi	13	0.09	71	0.26	34	0.57	118	0.25
Papaya	**24**	**0.17**	**238**	**0.88**	**63**	**1.06**	**325**	**0.70**
Moringa	89	0.64	469	1.74	128	2.15	686	1.47
Wild Jack	91	0.66	710	2.64	45	0.76	846	1.81
Ailanthus	**47**	**0.34**	**1073**	**3.98**	**32**	**0.54**	**1152**	**2.47**
Cashew	**126**	**0.91**	**383**	**1.42**	**14**	**0.23**	**523**	**1.12**
Tamarind	**30**	**0.22**	**237**	**0.88**	**29**	**0.49**	**296**	**0.63**
Teak	72	0.52	525	1.95	79	1.33	676	1.45
Arecanut	**1022**	7.40	**690**	**2.56**	**368**	**6.18**	**2080**	**4.45**
Bombax	30	0.22	99	0.37	15	0.25	144	0.31
Acacia	5	0.04	33	0.12	5	0.08	43	0.09
Mangium	5	0.04	28	0.10	0	0.00	33	0.07
Subabul	0	0.00	133	0.49	5	0.08	138	0.29
Albizzia	31	0.22	71	0.26	2	0.03	104	0.22
Bread fruit	26	0.19	117	0.43	31	0.52	174	0.37
Coconut	2527	18.29	13768	51.10	4468	74.98	20763	44.45
Rubber	**8740**	**63.27**	**4041**	**15.00**	**0**	**0.00**	**12781**	**27.36**
Portia	**1**	**0.01**	**291**	**1.08**	**65**	**1.09**	**357**	**0.76**
Mahogany	23	0.17	268	1.00	21	0.35	312	0.67
Eucalyptus	2	0.01	13	0.05	8	0.13	23	0.05
Cinnamon	15	0.11	42	0.16	1	0.02	58	0.12
Clove	51	0.37	100	0.37	21	0.35	172	0.37
Morinda	**16**	**0.12**	**135**	**0.50**	**2**	**0.03**	**153**	**0.33**
Erythrina	**162**	**1.17**	**173**	**0.64**	**1**	**0.02**	**336**	**0.72**
Miscell.	288	2.08	801	2.97	89	1.49	1178	2.52
Total trees	**13814**	**29.57**	**26941**	**57.67**	**5959**	**12.76**	**46714**	**100.00**

Items in **bold** indicate that there is significant difference between regions.

Table 13. Average number of tree species in the home gardens

Attribute	Average number per home garden				Critical Difference (0.05)		
	Highland	Midland	Lowland	District	HM	HL	LM
Jack	2.83	3.79	2.18	3.33	...	...	1.054
Mango	1.91	3.17	1.73	2.69	...	...	1.266
Guava	0.65	0.94	0.75	0.86	...	...	...
Annona	0.63	1.00	0.37	0.82	...	...	0.401
Rose apple	0.26	0.43	0.36	0.39	...	...	...
Lovilovi	0.21	0.27	0.42	0.29	...	...	...
Papaya	0.40	0.91	0.78	0.81	0.388	...	...
Moringa	1.48	1.80	1.60	1.71	...	...	...
Wild Jack	1.51	2.73	0.56	2.11	...	...	...
Ailanthus	0.78	4.12	0.40	2.88	2.764	...	2.468
Cashew	2.10	1.47	0.17	1.30	...	1.407	1.053
Tamarind	0.50	0.91	0.36	0.74	0.382	...	0.341
Teak	1.20	2.01	0.98	1.69	...	...	...
Arecanut	17.03	2.65	4.60	5.20	8.828	10.527	...
Bombax	0.50	0.38	0.18	0.36	...	...	...
Acacia	0.08	0.12	0.06	0.10	...	...	...
Mangium	0.08	0.10	0.00	0.08	...	...	...
Subabul	0.00	0.51	0.06	0.34	...	...	...
Albizzia	0.51	0.27	0.02	0.26	...	...	...
Bread fruit	0.43	0.45	0.38	0.43	...	...	...
Coconut	42.11	52.95	55.85	51.90	...	...	...
Rubber	145.66	15.54	0.00	31.95	29.421	35.083	...
Portia	0.01	1.11	0.81	0.89	0.853	...	...
Mahogany	0.38	1.03	0.26	0.78	...	...	...
Eucalyptus	0.03	0.05	0.10	0.05	...	...	...
Cinnamon	0.25	0.16	0.01	0.14	...	...	...
Clove	0.85	0.38	0.26	0.43	...	...	...
Morinda	0.26	0.51	0.02	0.38	...	...	0.284
Erythrina	2.70	0.66	0.01	0.84	1.356	1.617	...
Total trees	230.23	103.61	74.48	116.78	38.826	46.295	...

HM - Difference between highland and midland
HL - Difference between highland and lowland
LM - Difference between lowland and midland

The average number of arecanut, rubber and erythrina was significantly higher in highlands. The average number of ailanthus and tamarind were higher in midlands.

The tree parts (leaves, twigs, branches) were recycled by the farmers in various ways. In general, about 93 per cent of the respondents had a positive attitude towards the planting of trees and believed that there was room for additional trees in their gardens.

The inventory of the different crop categories revealed that in the district as a whole tuber crops ranked first, followed by fruits, oilseeds, rubber, spices, vegetables, timber / fuel trees and fodder (Fig. 4). In the highlands of the district, tuber crops dominated followed by fruits, rubber, oilseeds, spices, timber / fuel trees, vegetables and fodder (Fig. 5a). Tuber crops predominated in the midlands. This was followed by fruits, oilseeds, rubber, spices, vegetables, timber / fuel trees and fodder (Fig. 5b). In lowlands the predominance was in the order of oilseeds, fruits, tubers, vegetables, spices, timber / fuel trees, fodder and rubber (Fig. 5c). The comparison of the predominance of crop categories between the agroecological zones in the district and among different sized holdings is shown in Figures 5d and 6 respectively.

The predominance of tuber crops in the home gardens may be due to the fact that they can be grown with relatively little care as understorey species in partial shade and yet be expected to yield reasonably as suggested by Nair (1993).

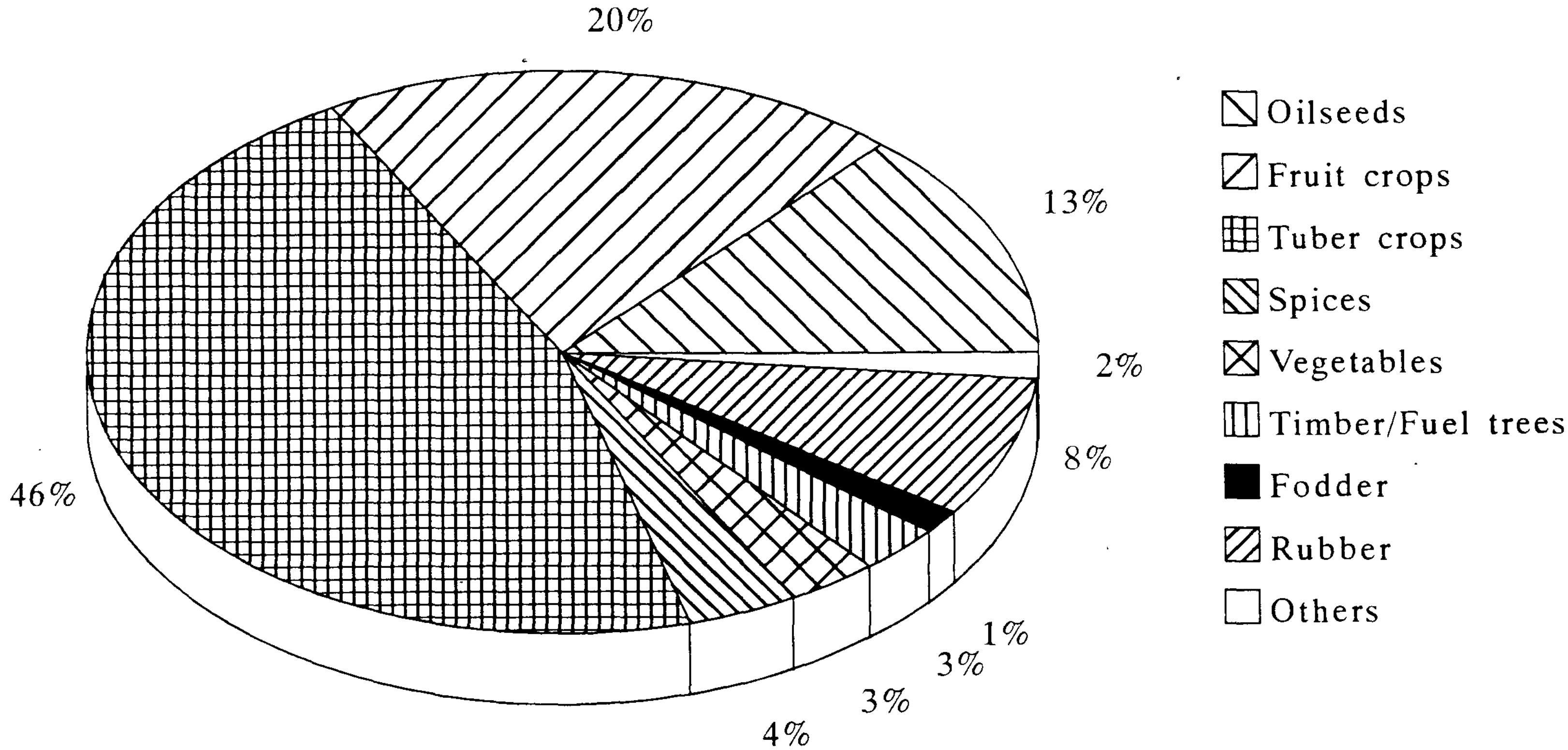


Fig. 4. Relative predominance of different crop categories in Thiruvananthapuram district

The practice of planting of home gardens with a wide variety of fruit trees has been reported by Michon *et al.* (1986) from Indonesia, Nair and Sreedharan (1986) from Kerala and Rico-Gray *et al.* (1990) from Mexico. In certain home gardens dominance of fruit trees has also been recorded (Boonkird *et al.*, 1984; Leuschner and Khalique, 1987; Okafor and Fernandes, 1987). Further, Nair (1993) concluded that a conspicuous trait of home gardens was the predominance of fruit trees.

The observation on the dominance of coconut is in accordance with the findings of Nair and Sreedharan (1986) who suggested that the growth characteristics and planting pattern of coconut palms facilitate successful growing of other crops in between or under them. Also, the labour input required for managing coconut is comparatively less than that for many other crops, which makes it ideal for people engaged in other occupations. The ranking of coconut being pushed down to fourth in highlands (Fig. 5a) and large holdings (Fig. 6) was due to the increased population of rubber which substituted coconut to a certain extent. In the lowlands, (Fig. 5c) oilseeds ranked first due to the complete absence of rubber. Several reasons may be attributed for the low productivity of coconut, such as traditional methods of cultivation, lack of manuring and irrigation practices and high incidence of pests and diseases as suggested by Santha *et al.* (1993).

The increased cultivation of rubber (Fig. 4) may be due to the higher gross return ($r = 0.54$) and net profit ($r = 0.55$) received from it. An increase in the value of the marketed produce was also observed with increase in rubber

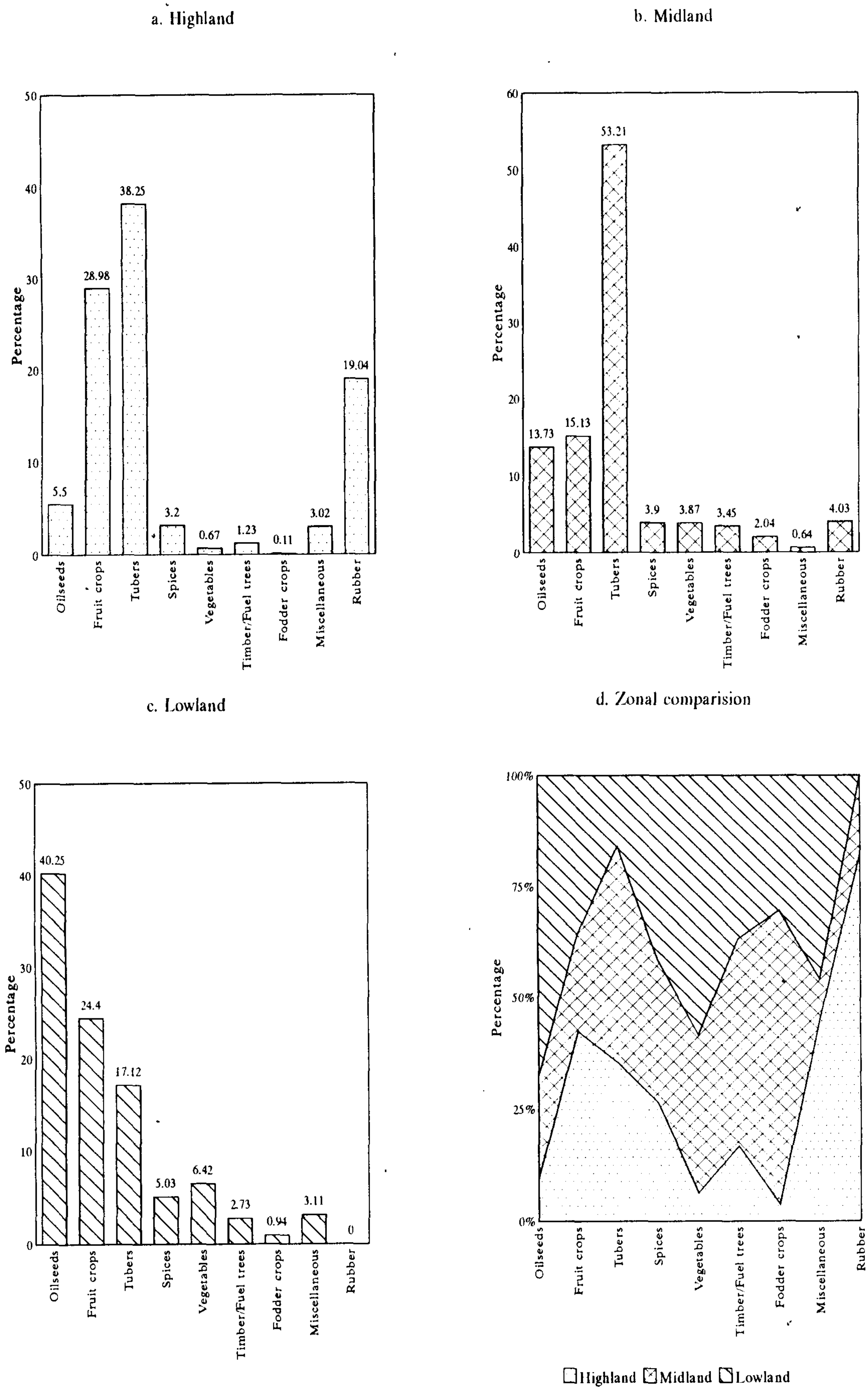


Fig. 5. Relative predominance of different crop categories

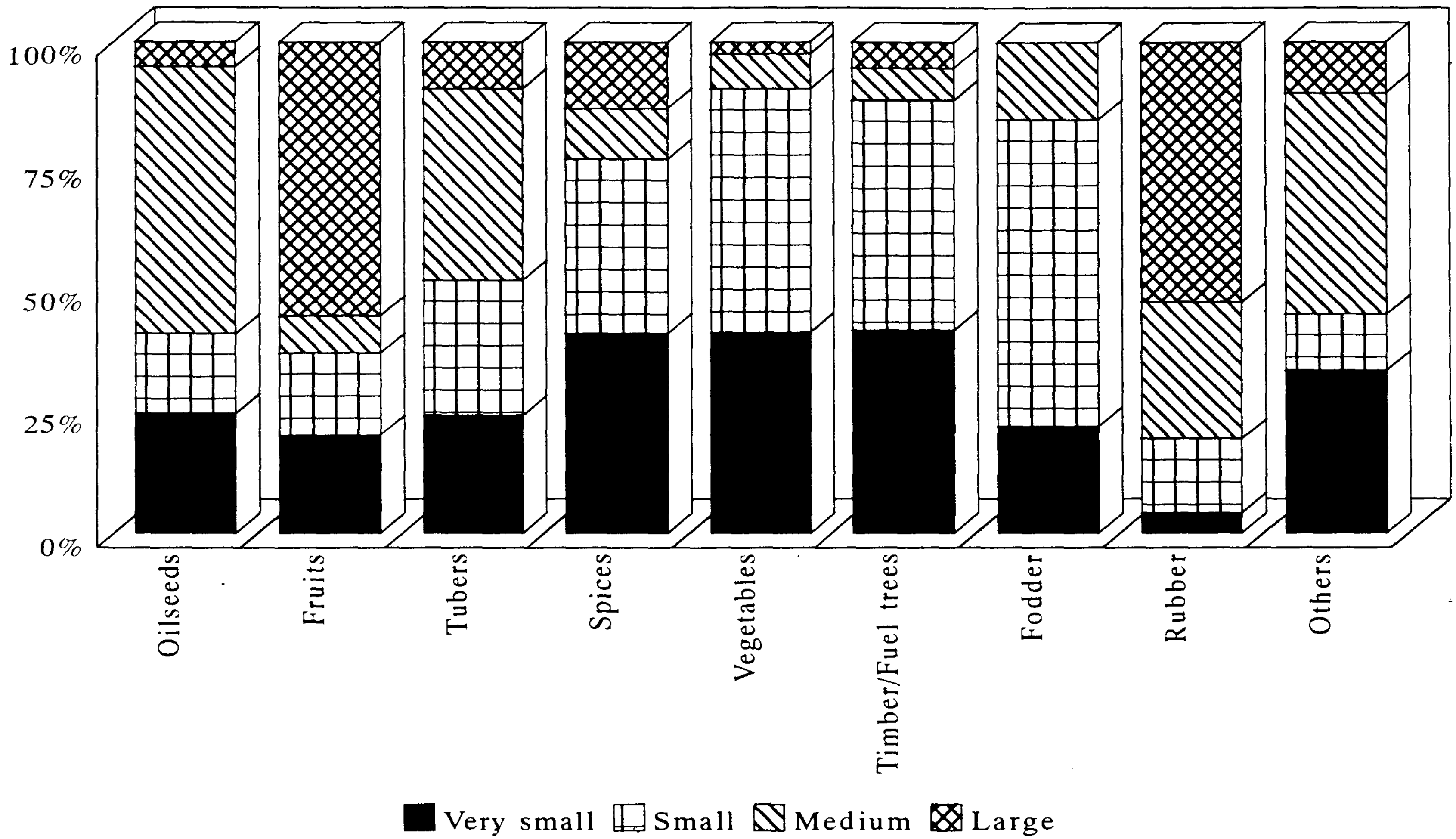


Fig. 6. Relative predominance of different crop categories in relation to holding size

cultivation (r = 0.58). This is in accordance with the findings of Soemarwoto (1987) who stated that when market demand and price offered for a certain plant product becomes high, the cultivation of that species spreads. A unique agroforestry practice of integrating animals in small holder rubber plantations in Malaysia was discussed by Tajuddin Ismail (1986). Considering the high frequency of rubber noticed in the district, especially in the highlands (Fig. 5a) and medium to large holdings (Fig. 6), the above practice could be considered as a viable option.

The occurrence of spices as components of home gardens has been reported by Boonkird *et al.* (1984) and Nair and Sreedharan (1986). The positive correlation (r = 0.30) between the number of spice crops and timber / fuel trees are indicative of the cultivation of spices as intercrops and the utilization of these trees as support. The practice of intercropping spices in rubber plantations was also noticed (r = 0.22). This may be the reason for the higher average number of spices observed in the highlands where rubber trees dominate.

The cultivation of vegetables in home gardens has been reported by Boonkird *et al.* (1984) from Thailand, Nair and Sreedharan (1986) from Kerala and Okafor and Fernandes (1987) from West Indies. The low predominance of vegetables in highlands (Fig. 5a) and in large holdings (Fig. 6) may be due to the increased cultivation of rubber in highlands and large holdings. The less valuable local vegetables are the first to be replaced for rubber cultivation as suggested by Soemarwoto (1987).

Comparatively poor cultivation of fodder crops by the farmers in their home gardens may be due to the high dependence on non-conventional feeds and oilcakes for feeding the cattle.

The inverse relation between the intensity of trees and the size of the home gardens in the district (Fig. 7) is in conformity with the results of Nair and Krishnankutty (1984) who found that the intensity of trees increased as the size of the holding decreased.

Among the different trees planted in the home gardens, multi-purpose trees like coconut, jack and mango had the highest frequency of occurrence (Fig. 8). A similar pattern was noticed in the different agroecological zones also (Fig. 9a,b,c). However, the frequency of rubber was highest in the highlands (75 %) and nil in lowlands (Fig. 10).

Coconut, known as "Tree of heaven" (*Kalpa Vrikshà*) and "Tree of a Hundred uses", plays a vital role in the economy of the State. The leaves are plaited and used for thatching and making baskets. Toddy is obtained by cutting the flower stalk and allowing the sap to drop into small pots tied below them. The fluid in the young nuts is a very refreshing drink. The kernels of the nuts are consumed daily in curries by all classes and oil is extracted from them which is used locally for cooking, lighting and anointing the body. The fibrous rind of the nut known as coir is worked up into ropes and mats. The shell is made into cups and spoons. The petioles, spathe, husk, shells and leaves are also used as fuel. The wood is used for house-building, especially rafts, and when kept dry lasts for a long time.

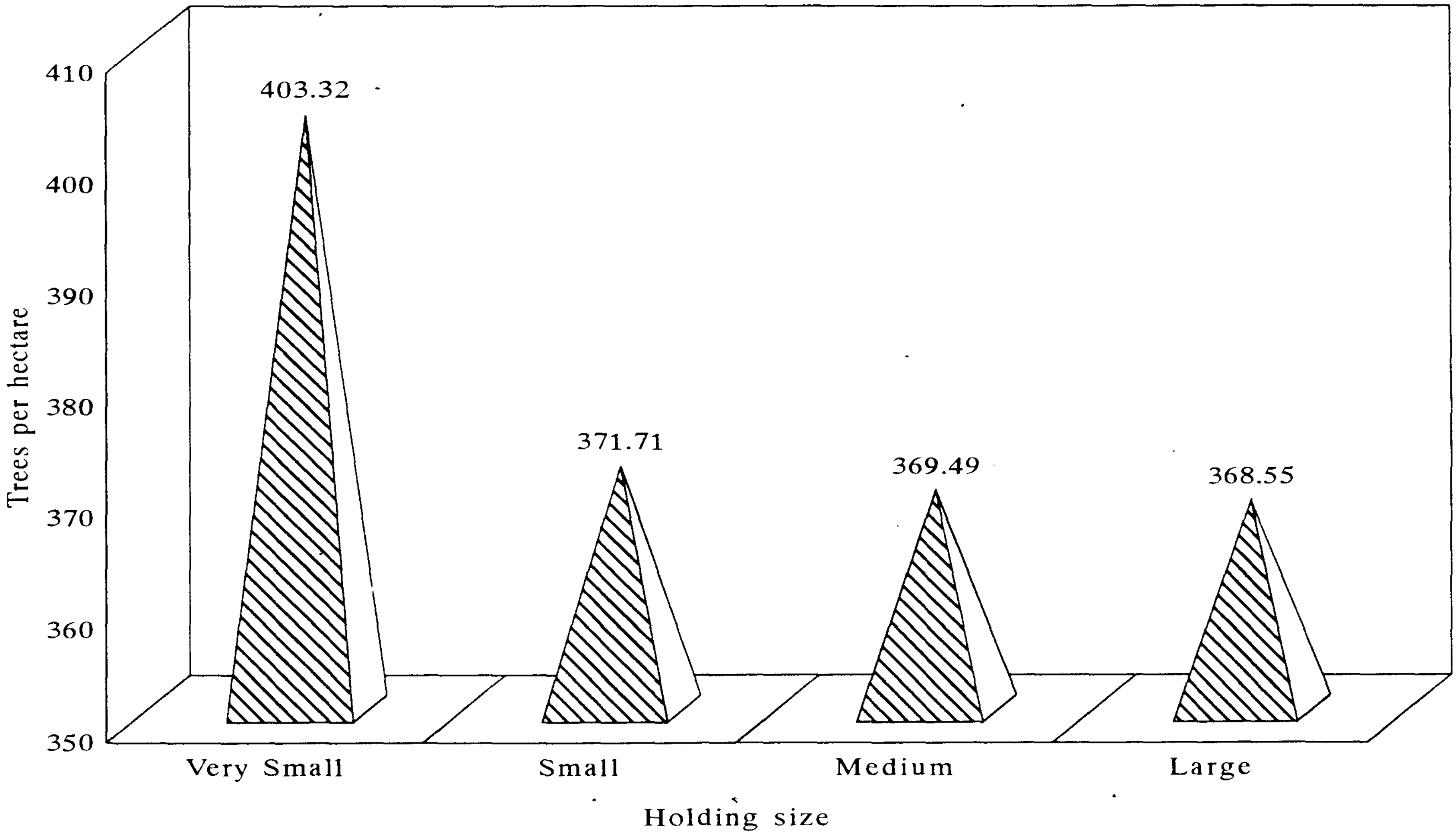


Fig 7. Tree intensity in relation to holding size

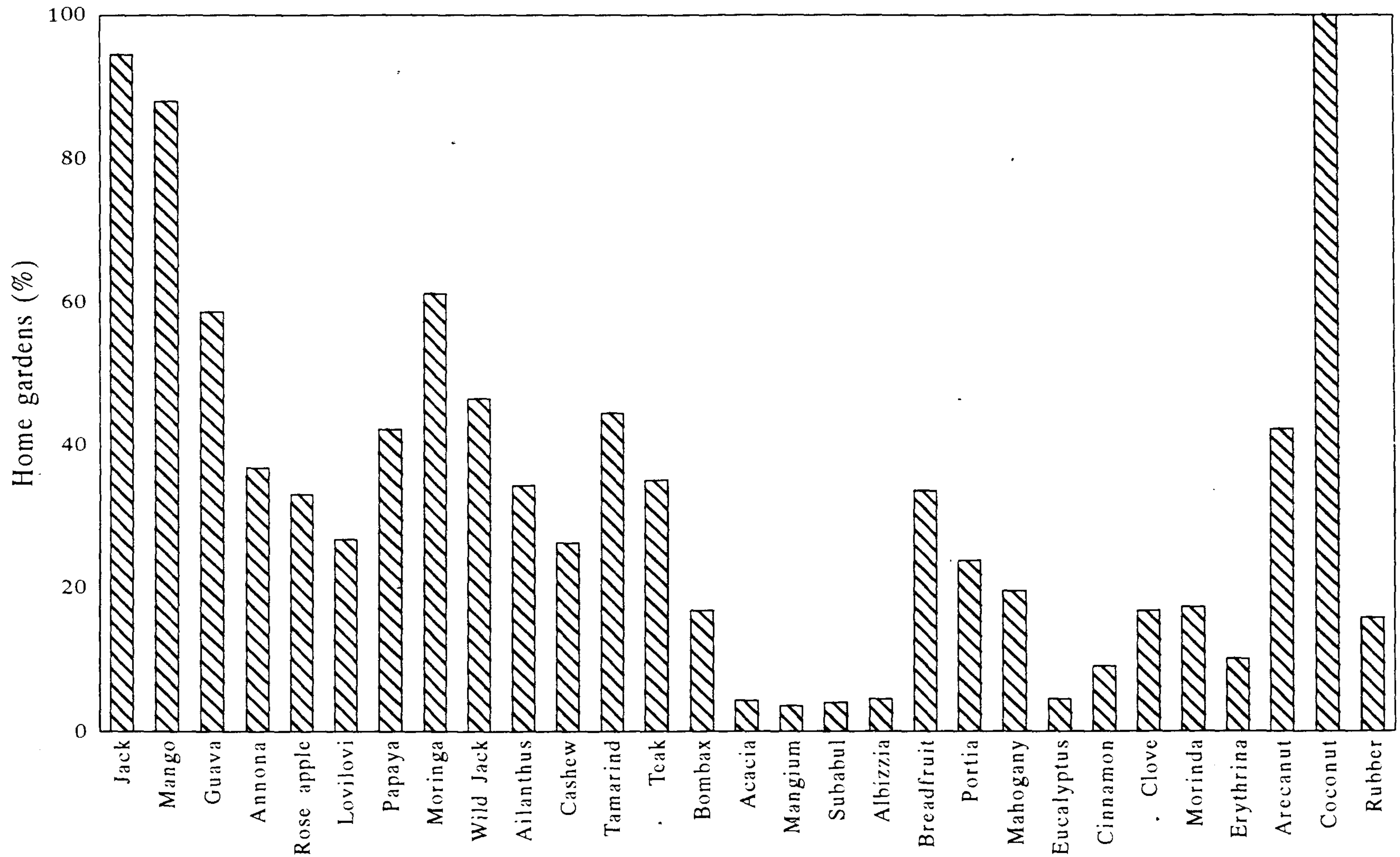


Fig 8. Percentage of home gardens planted with various tree species in the district

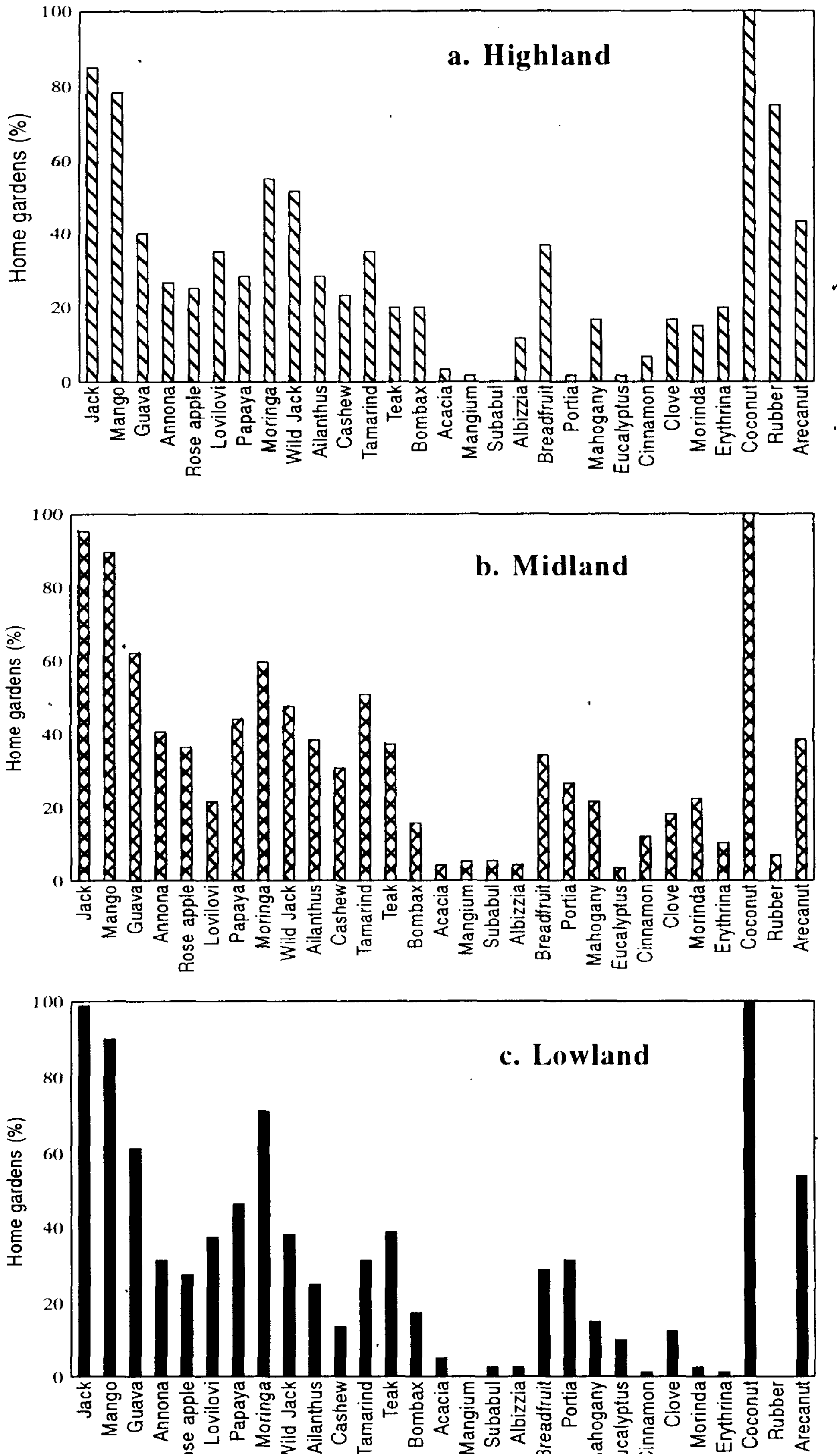


Fig. 9. Percentage of home gardens planted with different tree species in different agroecological zones

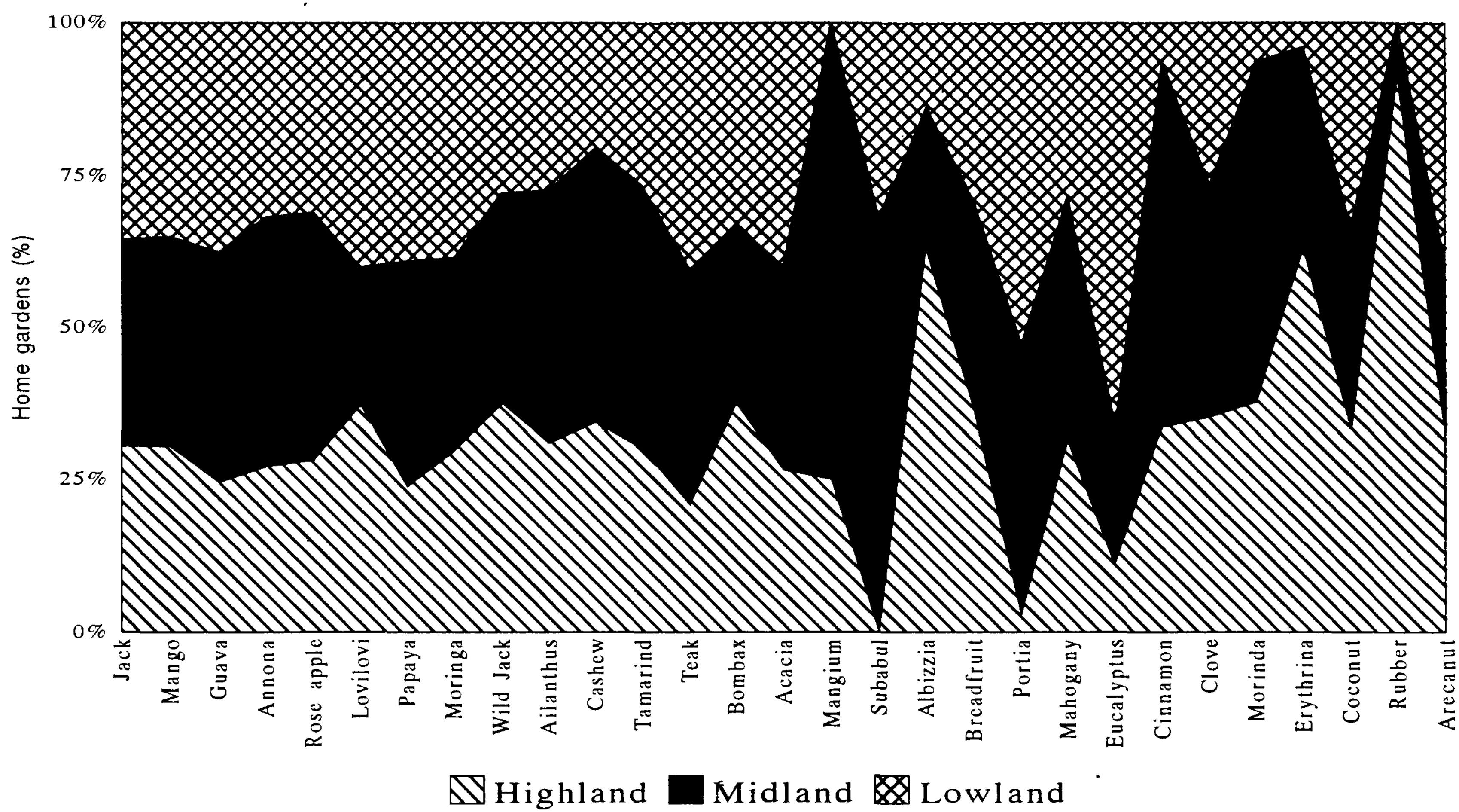


Fig. 10. Comparision between zones with respect to percentage of home gardens planted with each tree

The jack tree bears shade and grows on almost all soils. The wood does not split and is easy to work. The wood obtained from the tree often attains an immense girth and is largely used for making furniture. The fruit is the most valuable part of the tree, as it supplies food to all classes of people, when it ripens. The large seeds are highly starchy and nutritious. The leaves and ripe fruits are occasionally fed to cattle, especially goats. The tree also serves as standard for trailing pepper.

The mango tree grows slowly initially, but once it has established itself the growth is faster. It appears to thrive on almost all soils. The tree is grown chiefly for its fruit which is, next to plantain, the most important of the fruits of the State. Besides being eaten raw, the fruit is made into confections and pickles. The kernel, leaves, flowers and bark are used in native medicine. The timber is largely used for rough-planking, doors and window frames.

Of all the trees, in the home gardens, coconut was found to dominate, followed by rubber, arecanut, jack, ailanthus, mango, wild jack, moringa, teak and cashew (Figs. 11a and 11b).

Rubber was found to dominate in the highlands, where the average size of the holdings are relatively greater (0.55 ha). Rubber is mainly grown for its latex, which when processed into rubber sheets fetches high price in the market.

The arecanut palm is the main source of the common masticatory nut, popularly known as betel nut or *supari*. It is extensively used by all sections of people as a masticatory along with betel leaves and for several religious and

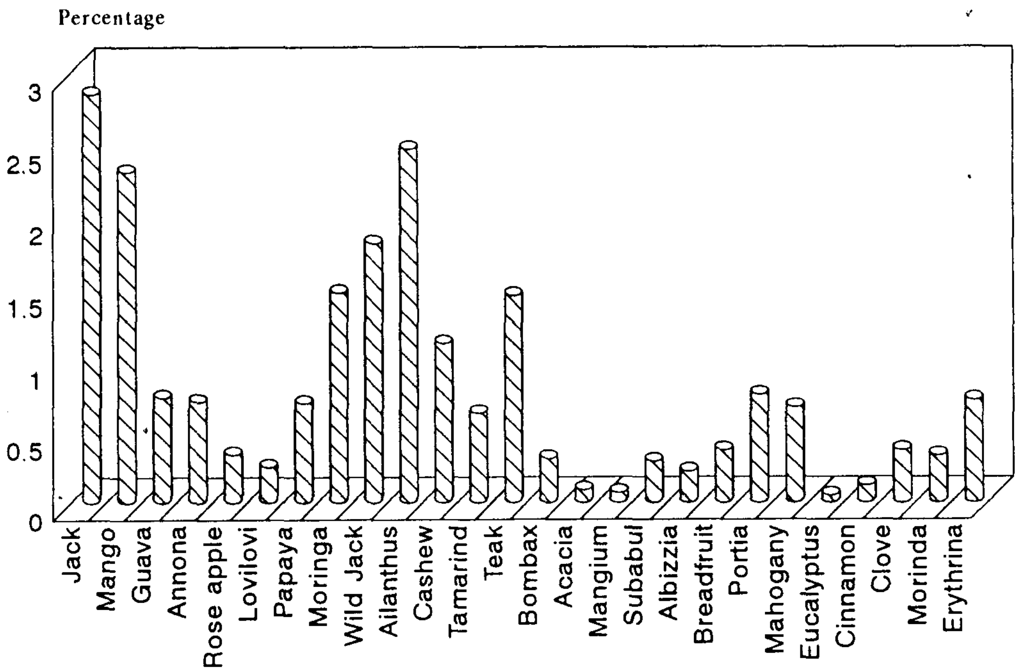


Fig. 11a. Relative dominance of different tree species in Thiuvananthapuram district

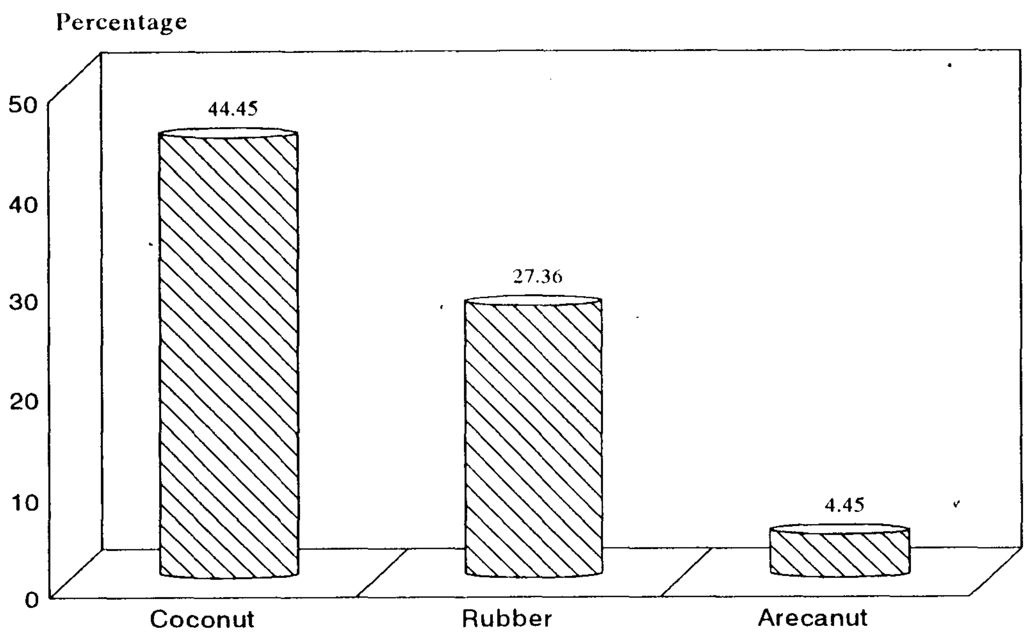


Fig. 11b. Relative dominance of coconut, rubber and arecanut in Thiruvananthapuram district

social ceremonies. The nuts are also used in medicinal preparations. The husks can be converted into boards and insulation material.

Ailanthus (*matty* or *perumaram*), growing on a wide variety of soils, is raised mainly for its wood which is used in match factories. Its' leaves are rated as highly palatable and nutritious fodder for sheep and goats.

Wild jack (*ayoni* or *anjili*), is one of the most valuable trees and is comparable to teak. It is a strong shade bearer and fast growing. The tree produces large sized timber which is straight-grained, durable and easily worked. The wood does not crack and is extensively used, locally, for the paneling and flooring of houses. However, its chief use is for boat building. In homesteads, it is also used as support for trailing pepper vines.

Moringa (drumstick tree) is largely grown for its fruit and leaves which is consumed as vegetable. Moreover, the leaves have medicinal value.

Cashew is yet another export oriented crop, grown in the homesteads. This tree crop is fairly drought-resistant and thrives well even on very poor soil. It is planted for its nut which has a high market value. The cashew apple is juicy and edible. Shell oil is removed while roasting the nut. The wood is used for packing cases, boat building and charcoal.

Trees are considered suitable for homestead agroforestry, if they complement and support rather than compete with the interplanted food crops. Many of the nitrogen fixing, fast growing multiple-use tree species fall in this category. The relative predominance of the different nitrogen fixing trees in the district and its agroecological regions are depicted in Figures 12 and 13 respectively. Unfortunately, only a handful have been planted in the home gardens. The most common nitrogen fixing trees observed were leucaena, albizzia, acacia, mangium and erythrina. Other nitrogen fixing trees remain untried in the home gardens and therefore their potential is unrealized. Similar observations were made by Vergara and Nair (1985) in the home gardens of the South Pacific region. Among the different nitrogen fixing trees planted, erythrina was found to dominate in the district (Fig. 12). Being a tree ideally suited as a standard for trailing pepper vines in most home gardens, the farmer raises them in their homesteads. Similar trends were noticed in the highlands and midlands also (Fig. 13). However, in lowlands the low predominance of erythrina was probably due to the reduction in pepper cultivation as evident from the low average number of spices per home garden in lowlands (6.98) when compared highlands (24.48) and midlands (15.05).

Significant positive correlations (Table 19) were observed between size of the holding and total number of trees (r = 0.85), jack (0.22), mango (0.24), cashew (0.25), arecanut (0.19), coconut (0.54), rubber (0.75), clove (0.39) and morinda (0.19). As the total number of trees in the home garden increased, the population of jack (r = 0.28), mango (0.23), moringa (0.19), cashew (0.27), arecanut (0.42), coconut (0.51), rubber (0.85), cinnamon (0.26) and clove (0.35) was also found to increase.

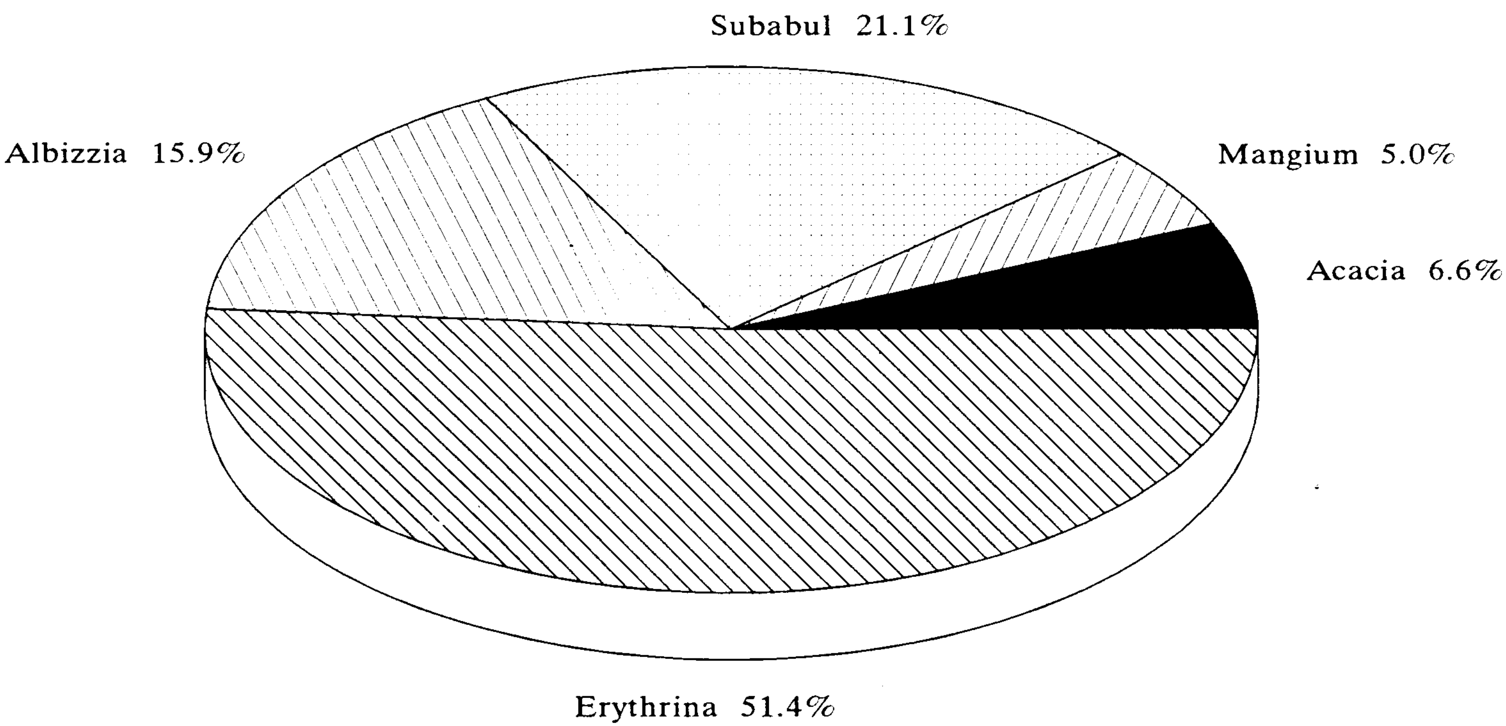


Fig 12. Relative predominance of different nitrogen fixing trees in the district

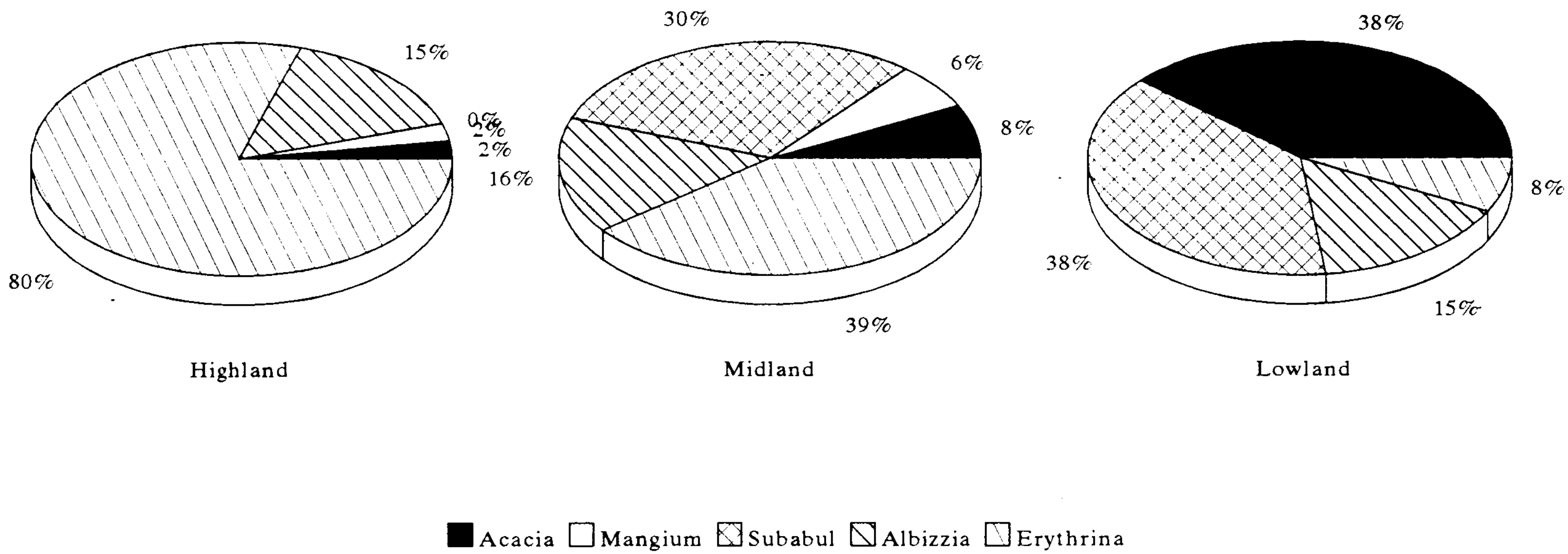


Fig 13. Relative predominance of nitrogen fixing trees in different agroecological zones

An analysis of the method of recycling of tree parts followed by the farmers in their homesteads (Fig. 14) revealed that in majority of the households, the leaves of the trees were used as manure only (31.75 %), followed by their use as manure + mulch (19.5 %). Other recycling methods include, animal feed, fuel and their combinations. The leaves and loppings of several trees were incorporated into the soil as manure. Some farmers use leaves to mulch the base of the annual / seasonal crops especially during summer. Leaves of trees like jack, ailanthus, morinda etc. were fed to cattle, the manure of which was applied to various crops. The ash obtained after utilisation of the leaves, twigs and branches of trees as fuel in households was also applied to different crops as manure.

The stable demand and high prices for wood (fuel, timber) unlike the poor, unstable prices for agricultural crops, are a major incentive for farmers to plant more trees in association with their crops. The high cost of labour and inputs required for annual crops, coupled with the uncertainty of monsoon, would have tempted the farmers to integrate trees in their homesteads, to enable him to minimize the risk of poor crop harvests.

4.1.4 Structure of the home gardens

With respect to the structural arrangement of the tree / crop components, it was found that plants of different heights and architecture, though not planted in an orderly manner, occupy the available space both horizontally and vertically. The home gardens with a multitude of crops presented a multi-tier canopy

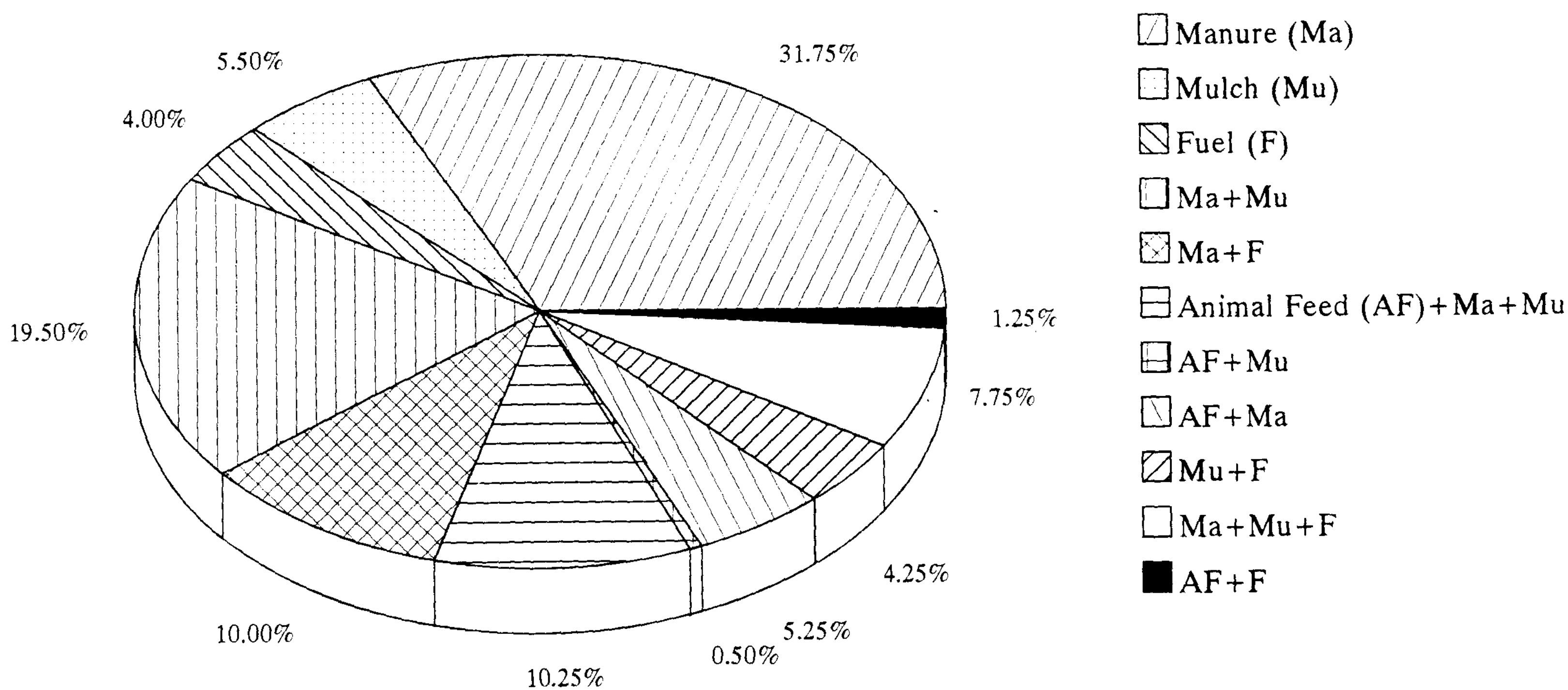


Fig 14. Method of recycling of tree parts by the homestead farmers

configuration (Fig. 15). The major portion of the upper canopy (> 25 m) went to coconut, arecanut, certain fruit and timber / fuel trees. This was followed by certain medium sized fruit, spice and timber / fuel trees (10 - 20 m). The third layer (3 - 10 m) comprised of crops like pepper, tree spices and certain fruit trees. The lower storey (1 - 3 m) of the harvesting plane was occupied by banana, cassava and other tuber crops. At the floor level, pineapple, vegetables and other herbaceous crops were grown.

Reports of crops not being grown according to any specific pattern or planting arrangement was made by Jacob and Alles (1987). The canopy architecture and pattern of component interaction observed in the home gardens of the present study are similar to those of the tropical gardens described by Fernandes *et al.* (1984), Soemarwoto and Soemarwoto (1984), Fernandes and Nair (1986) and Nair and Sreedharan (1986). It could be surmised that, in a practical way, the farmers are aware as to what and where to plant and how to manage the plants, indicating clearly their perception of the specific site conditions and requirements of the crops.

4.1.5 Farming practices adopted in the home gardens

Rain and wells formed the main source of water for cultivation to most of the farmers (63 %), whereas 34.25 per cent of the farmers depended on rain alone. Few farmers (2.75 %) depended on canal irrigation in addition to rain. None of the farmers had modern methods of irrigation, such as drip or sprinkler system, in the homesteads.

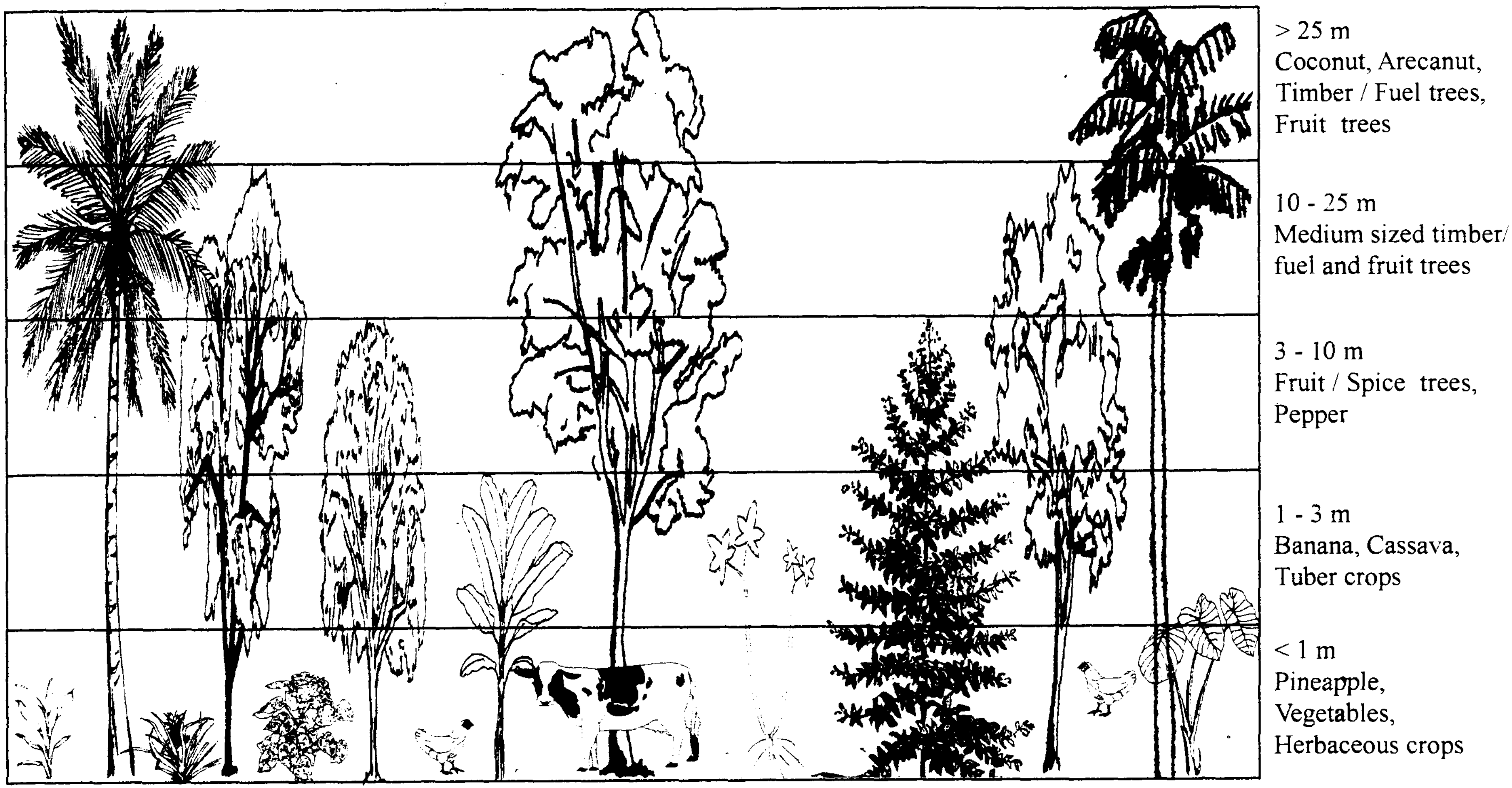


Fig. 15. Structure of a typical home garden in Thiruvananthapuram district

With respect to the adoption of varieties of various crops used in the home garden by farmers, it was observed that 84.25 per cent of the farmers used local varieties, whereas, 15.75 per cent used a combination of improved and local varieties cultivation.

The adoption of package of practices recommendations for various crops were undertaken by only 8.5 per cent of the farmers fully and partially by 38.5 per cent, whereas, majority of the farmers were unaware of the same (Fig. 16).

The practice of using organic manures for various crops was undertaken by 52.75 per cent farmers and 46.50 per cent farmers used both organic and inorganic materials (Fig. 17).

With respect to plant protection measures, 82.25 per cent of the farmers did not adopt any of the practices to control pests.

The high dependence on rain and wells for meeting the water requirements for the different crops and the non adoption of improved methods of irrigation may be due to the low investment capacity of the farmers.

With respect to the manurial practices, the results are in conformity with the reports of Balasubramanian and Egli (1986), who reported that majority of the homestead farmers in Nigeria used organic manures and none used chemical fertilizers. Non adoption of scientific fertilizer application practices might be attributed to lack of knowledge of technical aspects of balanced use of fertilisers and the lack of optimum fertilizer schedules for different regions as identified by KAU (1989).

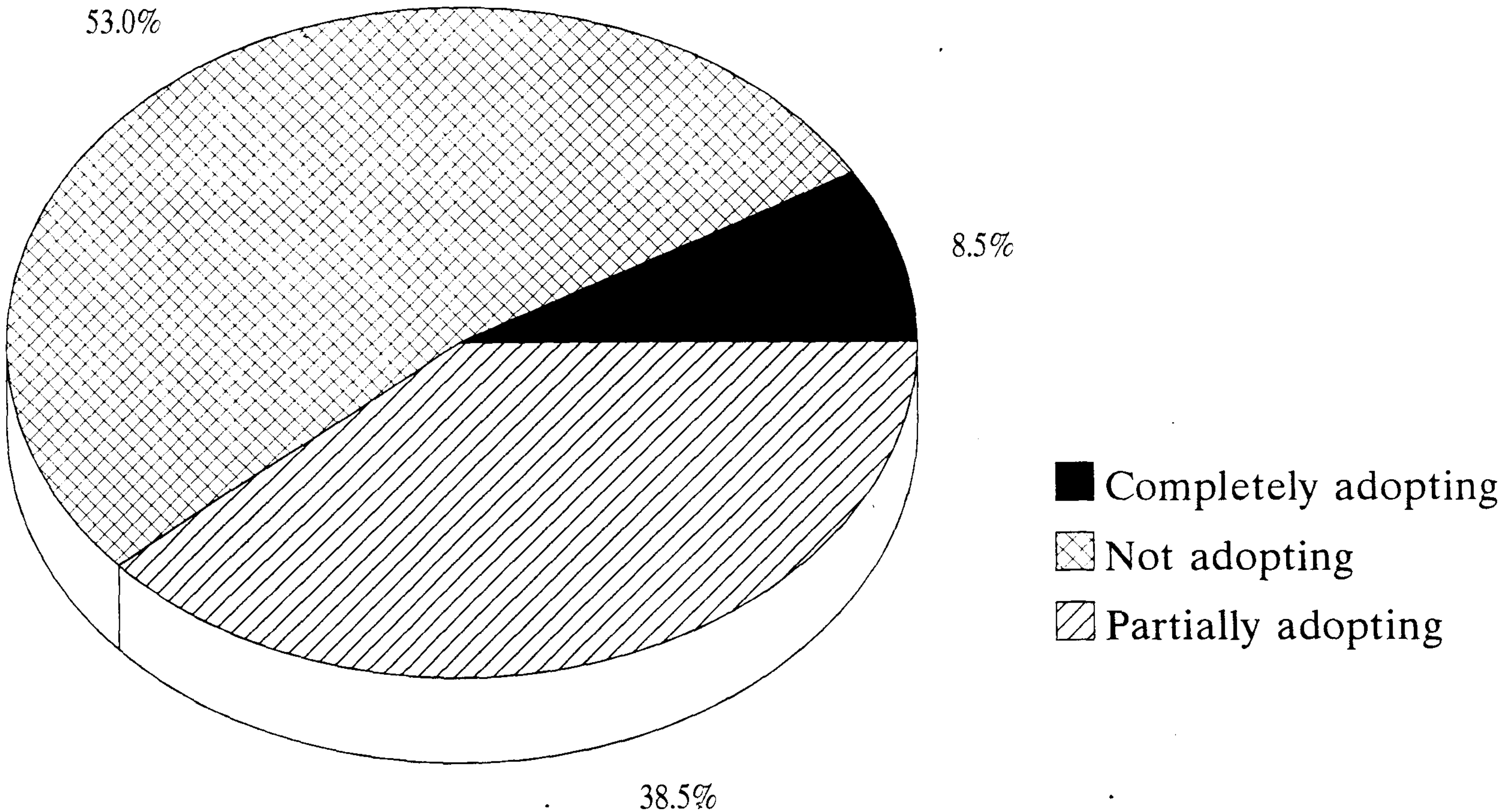


Fig. 16. Adoption of package of practices recommendations by farmers

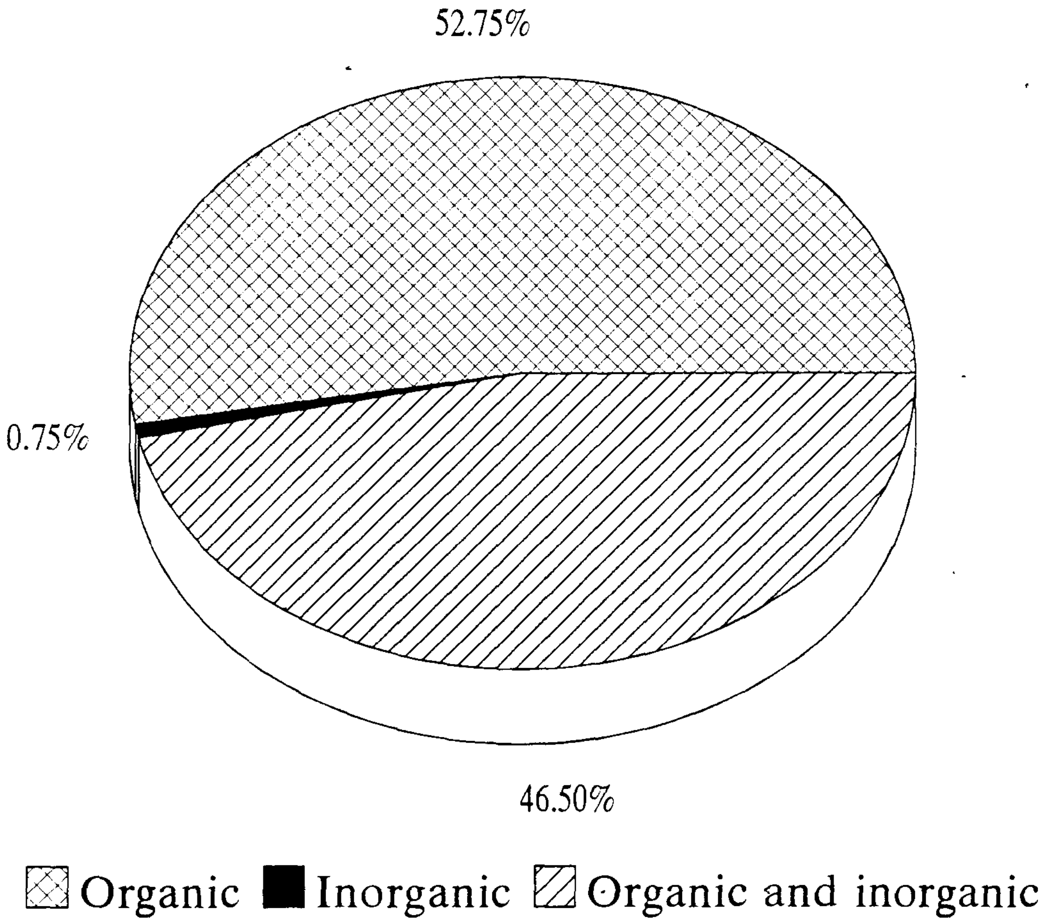


Fig. 17. Nutrient management by farmers in the home gardens

Low adoption of plant protection measures might be due to lack of proper awareness, lack of sufficient capital and high cost as suggested by Santha *et al.* (1993). However, it was observed that the pest and disease incidence in the home gardens was relatively low or even nil. Moreover, the diversity in home gardens is a well planned strategy in terms of pest and disease management.

4.1.6 Farming systems followed in the home gardens

An assessment of the farming systems adopted by the farmers in their home gardens in the district revealed that, in 17.5 per cent of the homesteads, cattle rearing was undertaken as a complimentary enterprise (Fig. 18) whereas 30.25 per cent raised poultry, along with other crops. Most of the farm families (30.50 per cent) had animals like cow, bullock, goat, sheep, buffaloes and birds like chicken, duck, quail and turkey. The home gardens in the district recorded an average of one animal, with 3 - 4 birds (Table 14). Many farmers have started keeping improved cattle. The more popular breeds are Fresian, Jersey and crosses involving these and local breeds.

Assessment of the feeding pattern of cattle (Fig. 19) revealed that non-conventional feeds such as jack, tapioca and rice bran were the main items fed to cattle (18 %) followed by the combination of oilcakes + hay + non-conventional feeds (17 %), oilcakes + grasses (15 %) and oilcakes + hay (12 %). The waste materials from crops and house were also used as feed for animals/birds. The poultry,grown mainly in the backyards, utilize the waste materials from the kitchen for their feed.

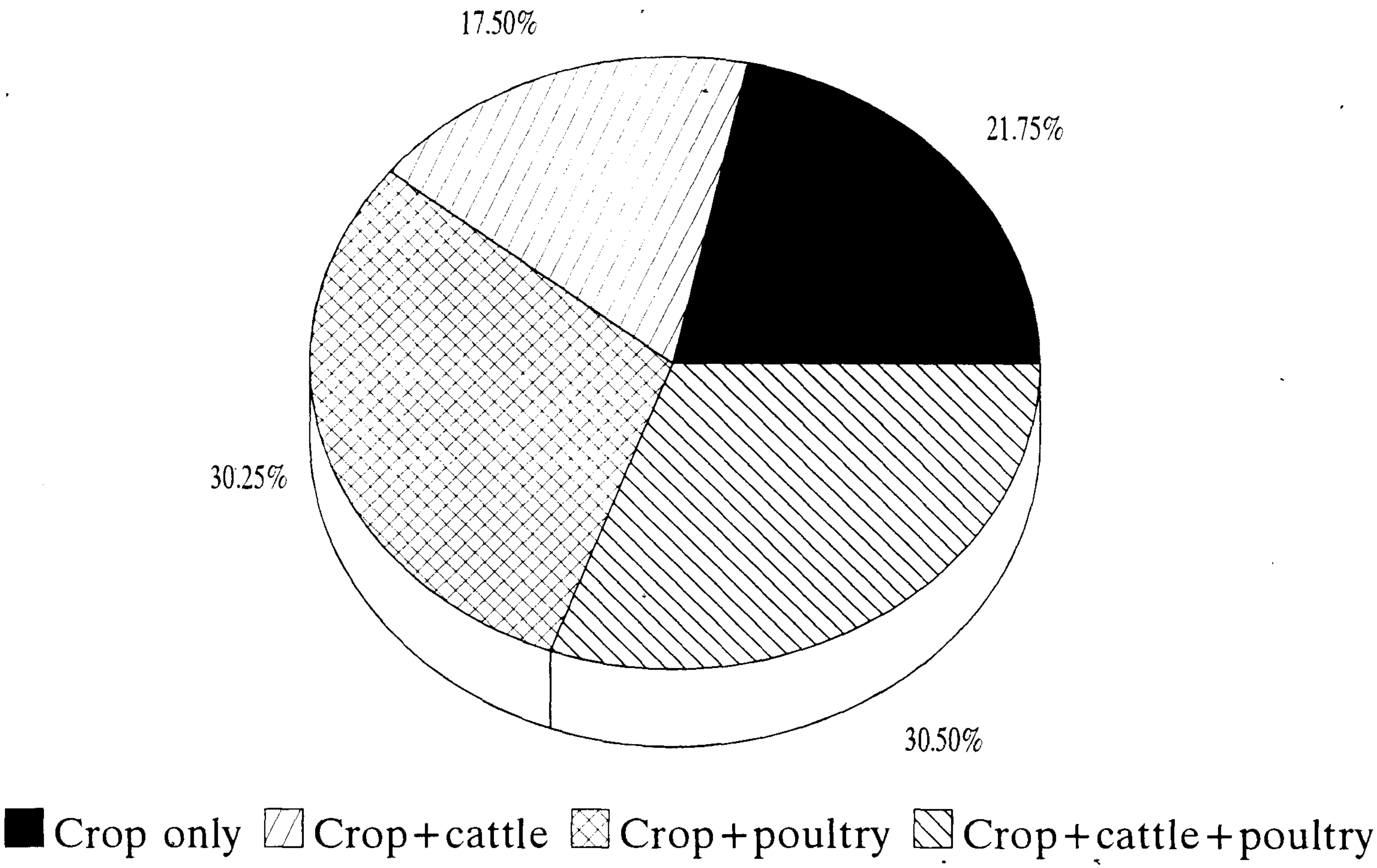


Fig. 18. Cropping/Farming systems adopted in the home gardens

Table 14. Average number of cattle and poultry in the home gardens

Attribute	Average number per home garden				Critical Difference (0.05)		
	Highland	Lowland	Midland	District	HL	HM	LM
Number of cattle	0.68	0.75	0.87	0.82	...	...	...
Number of poultry	4.25	1.93	4.08	3.68	1.694	...	0.647

HL - Difference between highland and lowland

HM - Difference between highland and midland

LM - Difference between lowland and midland

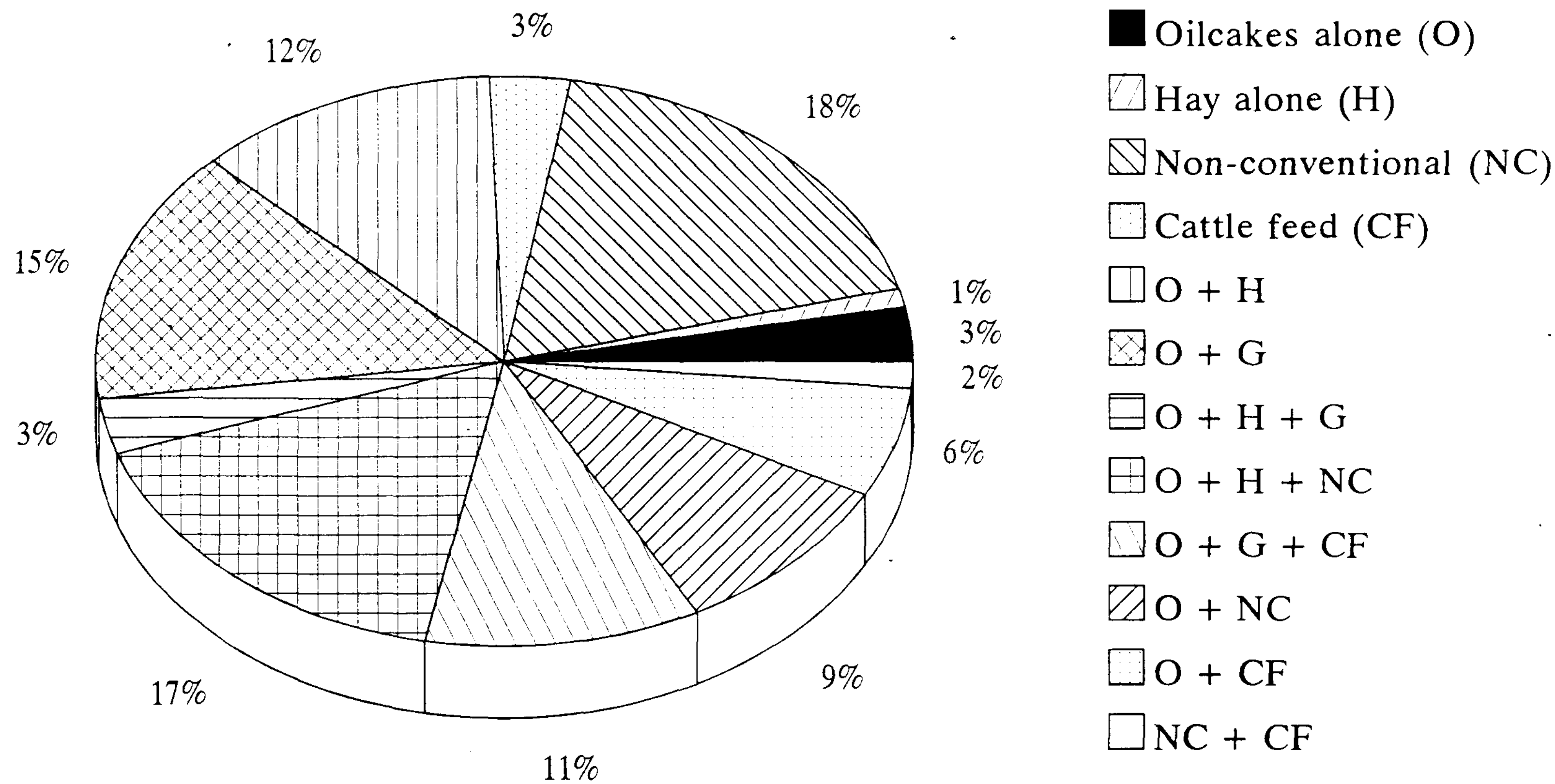


Fig. 19. Feeding pattern of cattle

The practice of maintaining livestock and poultry components in the home gardens has been reported by Boonkird *et al.* (1984) from Thailand, Vergara and Nair (1985) from Pacific Islands and Nair and Sreedharan (1986) from Kerala. Thus combining of cropping with livestock activities have positive influence by effective utilization of crop residues as fodder, efficient production of milk, meat and manure, and, wherever feasible, use of cattle for draught power. Moreover, livestock represents an important capital asset and a source of income to the farmer. Similar views on crop and livestock combinatio were expressed by Balasubramanian and Egli (1986) and Von Maydell (1987).

4.1.7 Credit and marketing facilities

Rural credit for agricultural purposes were available in the form of short term, medium term and long term agricultural loans (Fig. 20). It was observed that the farmers (43.50 %) mainly approached co-operative societies for their requirement of credit for various purposes. Agricultural credits were being arranged through co-operative banks (4.5 %) and milk marketing societies (5.5 %) also. However, the inadequacy of credit was particularly large for the small farmers. The unit of cultivation, in the case of an overwhelming number of farmers, was small. The farmers' need for credit is all the more urgent and important. But, these farmers do not have adequate assets which would be acceptable to financial institutions as security for loans. As a result, farmers do not get loans from modern institutions.

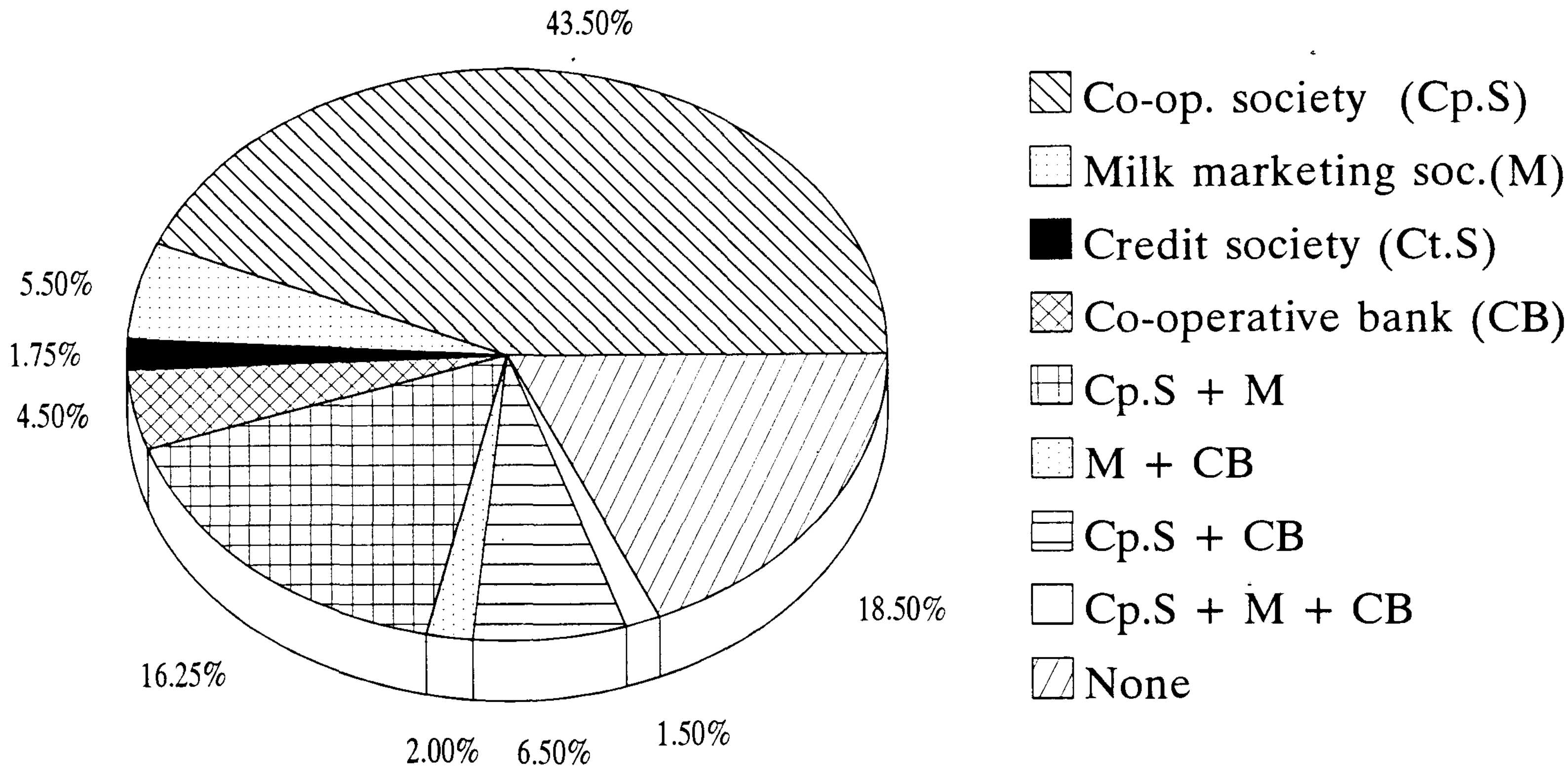


Fig 20. Institutions approached by the farmers for credit

The marketing and sale of produce (Table 15) from the home gardens, invariably took place through middlemen or intermediaries (42.25 %). However, 27.50 per cent of the farmers sold part of their produce to middlemen and part of it in the open market. Milk marketing societies undertook collection and distribution of dairy and poultry products. These agencies also arranged the supply of cattle / poultry feed. The marketing of perishable seasonal crops (vegetables, papaya, pineapple) and crops that were produced in bulk (ginger, turmeric) poses a serious problem. The problem could be aggravated, if, intercropping extends to large areas without simultaneously developing processing facilities at the producing centre and / or transportation infrastructure to consuming / processing centers as pointed out by Liyanage *et al.* (1984).

The existence of a large number of intermediaries makes marketing defective. As a result of the large number of intermediaries, the cost of marketing goes up and the sale of produce is not properly conducted. Many middlemen secretly settle prices among themselves and play fraud on farmers with regard to the payments for their produce. In general, farmers sell their produce separately or individually. The basic reason is that arrangements for institutional marketing are grossly inadequate. The major evil consequences, due to the involvement of middlemen, include the low receipts from the sale of agricultural produce and sale of superior and inferior quality produce at the same price. This keeps the income of the farmer low. Co-operative markets, regulated markets, stabilization of prices, storage facilities, arrangement for effective transport and market information could be suggested as measures to improve the defective marketing system.

Table 15. Marketing channels selected by homestead farmers for the sale of their produce

Marketing channel	Frequency	Percentage
Open market (O.M.)	91	22.75
Regulated market	0	0.00
Contract (C)	1	0.25
Middlemen (M.M.)	169	42.25
Co-operative society (C.S.)	5	1.25
O.M. + M.M.	110	27.50
O.M. + C.S.	5	1.25
O.M. + M.M. + C.S.	12	3.00
M.M. + C.S.	3	0.75
O.M. + C + M.M.	3	0.75
C + M.M. + C.S.	1	0.25

4.1.8 Constraints faced by the farmers

The study of the constraints faced by the farmers in the district showed labour scarcity as the major issue in spite of the increased family labour utilization (Table 16). The farmers were of the opinion that acute labour scarcity was experienced during the periods of peak agricultural operations (77.25 per cent). Moreover, the high labour cost resulted in increased cultivation cost (97.75 per cent).

The farmers faced problems relating to absence or lack of grading, lack of storage and transport facilities. Marketing facilities were poor to fair; the farmers sold their produce to intermediaries for lower prices. Moreover, the home gardens provided significant quantities of perishable food. Because of the poorly developed marketing infrastructure, this is likely to pose problems for large growers. The facilities for proper storage of agriculture produce in the area were comparatively inadequate and the few available ones were unscientific. Quite a significant part of the produce was lost because of dampness, decay and attack of rats and ants. Besides, the quality deterioration of the produce also results in fetching very low price. Because of the inadequacy of storage facilities, the farmer's capacity to hold stock get reduced. Hence, normally, farmers were very keen on disposing off their farm produce in the shortest possible time. This results in fetching low prices for their commodities.

Table 16. Constraints experienced by the homestead farmers

Constraint	High		Medium		Low	
	Frequency	Per cent	Frequency	Per cent	Frequency	Per cent
Labour availability	45	11.25	46	11.50	309	77.25
Cultivation cost	391	97.75	9	2.25	0	0.00
Credit availability	180	45.00	141	35.25	79	19.75
Technical information availability	187	46.75	63	15.75	150	37.50
Availability of manures and fertilizers	291	72.75	74	18.50	35	8.75
Availability of plant protection chemicals	292	73.00	70	17.50	38	9.50
Marketing facilities	130	32.50	191	47.75	79	19.75
Storage facilities	102	25.50	131	32.75	167	41.75

4.1.9 Economic analysis of the home gardens

The economic analysis of the home gardens in the district and its different agroecological regions is given in Table 17 (average per home garden) and depicted in Figure 21 (per hectare basis). It was found that the average total investment for the district was Rs. 21077 per hectare and the total returns was Rs. 49609.33 per hectare, resulting in a net profit of Rs. 28532.36 per hectare (Fig. 21). The value of the marketed produce formed 76 per cent of the total returns, the remaining being the value of consumed produce. The average benefit : cost ratio of the home gardens in the district was worked out as 2.35. Though the gross returns was higher from home gardens in lowlands (Rs.57540.48), the net profit was less (Rs.31416.87 per hectare) when compared to highlands (Rs.33605.45 per hectare).

The average total returns, net profit and value of marketed produce obtained annually from the home gardens were significantly superior in highlands, when compared to the lowlands and midlands (Table 17).

The economic analysis of the home gardens further revealed that the income provided by home gardens is comparable to that provided by rice fields. These estimates are found to be in concurrence with that of Michon *et al.* (1986). The high benefit : cost ratio could be justified by the positive correlation observed between the total investment and total returns. With respect to the economics of cultivation, the system, in general, was found to be profitable.

Table 17. Economic analysis of home gardens in the district and its agroecological zones

Attribute	Average per home garden				Critical Difference (0.05)		
	Highland	Lowland	Midland	District	HL	HM	LM
Area (cents)	138.27	56.90	78.77	83.32	28.494	23.896	21.331
Total investment	7778.68	6008.44	7056.80	6955.41	...	...	...
Total returns	26261.68	13234.31	15053.80	16371.08	5953.923	4993.119	...
Net profit	18483.00	7225.88	7997.00	9415.68	4524.079	3794.016	...
Value of marketed produce	22310.77	9787.44	10899.79	12388.96	5445.368	4566.631	....
Value of consumed produce	3950.92	3446.88	4154.02	3982.12	...	...	...
Benefit : Cost ratio	3.37	2.20	2.13	2.35	...	...	...

HL - Difference between highland and lowland

HM - Difference between highland and midland

LM - Difference between lowland and midland

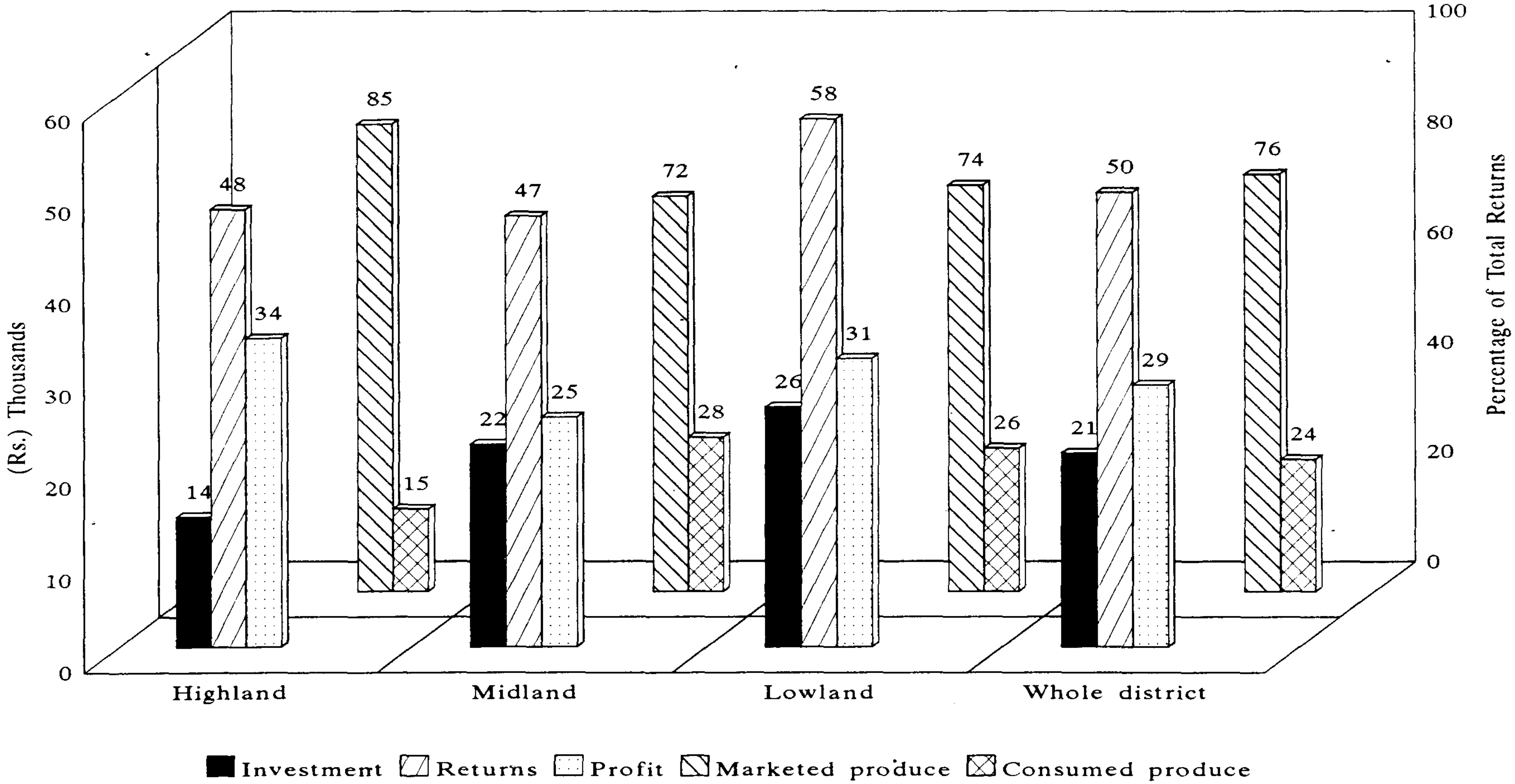


Fig. 21. Economic analysis of the home gardens in the district and its agroecological zones

This integrated production system enabled the farmer to meet many necessities of daily life from his own homestead and also obtained cash income. The diversity of products, as well as production possibilities allowed the farmers to reduce their economic risks.

The study further revealed that the total investment increased, with increase in area (r = 0.345), number of oilseed crops (r = 0.511), number of rubber trees (r = 0.236) and cattle number (r = 0.476). This was probably due to the fact that the larger the farm, the greater is the use of labour. The harvesting of crops such as coconut and rubber is considered as skilled work, which is usually not done by family labour, and such operations constitute the major labour requirement in the system. In the case of cattle, the high input cost tend to increase the investment. These findings are concurrent with those of Jacob and Alles (1987).

The total returns increased with increase in area (r = 0.637), oilseed crops (r = 0.441), tuber crops (r = 0.327), rubber (r = 0.538) and cattle (r = 0.336). A similar trend was noticed in the case of the net profit obtained from each holding.

The value of the marketed produce accounted for 76 per cent of the total returns, the remaining being value of the consumed produce.

The value of the marketed produce was positively correlated with oilseeds (r = 0.400), fruits (r = 0.313), tubers (r = 0.314), rubber (r = 0.579) and cattle (r = 0.292). However, the value of the consumed produce increased with increase in tuber crops and woody perennials only.

The above mentioned correlations may be the reason for the significantly higher net profit and value of marketed produce in home gardens of highlands (Fig. 21), where the holdings are large and mainly planted with rubber.

4.1.10 Correlation studies

Correlation analysis of the data generated from the survey was done and is presented in Tables 18 and 19. The significant correlations have been included in the above discussion of the survey.

4.2 Field experiments

As part of a detailed investigation on the system dynamics and functioning, two home gardens were selected in Thiruvananthapuram district of the southern zone of Kerala. The study was carried out for a period of two years from October 1994 to September 1996. The results obtained on various aspects of the study are presented and discussed hereunder.

Table 18. Correlation analysis of various components and activities in the home gardens

Attribute	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Area (1)	–	0.604	0.213	0.549	0.513	0.294	0.199	NS	NS	NS	0.226	0.755	0.345	0.637	0.616	0.651	0.254	NS	NS
Total number of plants (2)	–	–	0.234	0.398	0.671	0.800	0.213	NS	0.245	NS	0.579	0.469	0.237	0.496	0.488	0.499	0.252	NS	NS
Number of species (3)	–	–	–	0.206	NS	NS	0.308	NS	0.307	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
No. of oilseed crops (4)	–	–	–	–	NS	0.351	NS	NS	NS	NS	NS	0.353	0.511	0.441	0.494	0.400	NS	NS	NS
No. of fruit trees (5)	–	–	–	–	–	NS	NS	NS	NS	NS	NS	0.390	NS	0.294	0.311	0.313	NS	NS	NS
No. of tuber crops (6)	–	–	–	–	–	–	NS	NS	0.203	NS	0.631	NS	NS	0.327	0.308	0.314	0.264	NS	NS
No. of spice crops (7)	–	–	–	–	–	–	–	NS	0.299	NS	NS	0.217	NS	NS	NS	NS	NS	NS	NS
No. of vegetable crops (8)	–	–	–	–	–	–	–	–	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
No. of timber / fuel trees (9)	–	–	–	–	–	–	–	–	–	NS	0.236	NS	NS	NS	NS	NS	0.240	NS	NS
No. of fodder crops (10)	–	–	–	–	–	–	–	–	–	–	NS	NS	NS	NS	NS	NS	NS	NS	NS
Miscellaneous crops (11)	–	–	–	–	–	–	–	–	–	–	–	NS	NS	0.291	0.275	0.292	NS	NS	NS
No. of rubber trees (12)	–	–	–	–	–	–	–	–	–	–	–	–	0.236	0.538	0.546	0.579	NS	NS	NS
Total investment (13)	–	–	–	–	–	–	–	–	–	–	–	–	–	0.591	0.376	0.561	0.520	0.476	NS
Total returns (14)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.944	0.989	0.556	0.336	NS
Net profit (15)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.949	0.436	NS	NS
Value of marketed produce (16)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.447	0.292	NS
Value of consumed produce (17)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.474	NS
Number of cattle (18)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.265
Number of poultry (19)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Table value of "r" (0.05) = 0.198
Table value of "r" (0.01) = 0.250

Table 19. Correlation between area, total number of trees and individual tree population

	Area	Total number of trees
Total number of trees	0.854	-
Jack	0.224	0.283
Mango	0.242	0.233
Guava	NS	NS
Annona	NS	NS
Rose apple	NS	NS
Lovilovi	NS	NS
Papaya	NS	NS
Moringa	NS	0.193
Wild Jack	NS	NS
Ailanthus	NS	NS
Cashew	0.255	0.276
Tamarind	NS	NS
Teak	NS	NS
Arecanut	0.195	0.423
Bombax	NS	NS
Acacia	NS	NS
Mangium	NS	NS
Subabul	NS	NS
Albizzia	NS	NS
Bread fruit	NS	NS
Coconut	0.549	0.517
Rubber	0.755	0.858
Portia	NS	NS
Mahogany	NS	NS
Eucalyptus	NS	NS
Cinnamon	NS	0.269
Clove	0.392	0.352
Morinda	0.197	NS
Erythrina	NS	NS

r (0.05) = 0.19

r (0.01) = 0.25

4.2.1 Structure of the home garden

Detailed inventory of the various components in the home gardens at Location I and II is given in Tables 20 and 21.

At Location I, the net area of the homestead was 5000 m^2. The house, roads and other permanent structures together occupied an area of 912.50 m^2. The net area available for crop cultivation was 4087.50 m^2. The gross cropped area occupied by the 24 tree / crop components was 4400.48 m^2 and resulted in a cropping intensity of 107.66 per cent during the first year and in the second year with 23 enterprises the gross cropped area was 4678.44 m^2 and resulted in a cropping intensity of 114.46. The crops were planted in the homestead based on the space available and as per the needs of the farmer. The major perennial tree crop in the home garden was coconut (adult and young) which constituted 38 per cent of the gross cropped area. This was followed by borassus which accounted for 23 per cent of the gross cropped area. Perennials like coconut, jack, wild jack, gmelina, albizzia and borassus occupied the upper most layer (> 25 m) of the canopy (Fig. 22). Mango, nutmeg and mahogany formed the second layer (10 - 25 m). Breadfruit, coffee, cinnamon, bilimbi, clove, pepper, moringa, papaya and bamblimass constituted the third layer (3 - 10 m). Components like teak, banana, colocasia and curry leaf occupied the fourth layer (1 - 3 m). The lowermost layer (< 1 m) comprised of vegetables. Young coconut was found to occupy both, the second and third layers.

Table 20. Inventory of the home garden at Location I

Sl. No.	Enterprise	Population	Space used (m^2)
1.	Adult coconut	19 nos.	1155.58
2.	Young coconut	40 nos.	502.40 (785.00)
3.	Jack	4 nos.	93.96
4.	Wild Jack	4 nos.	303.52
5.	Nutmeg	13 nos.	483.94
6.	Mango	5 nos.	97.10
7.	Breadfruit	3 nos.	143.23
8.	Gmelina	1 no.	16.61
9.	Albizzia	2 nos.	113.76
10.	Mahogany	2 nos.	60.28
11.	Coffee	4 nos.	62.53
12.	Teak	3 nos.	41.03
13.	Cinnamon	2 nos.	30.02
14.	Bilimbi	1 no.	20.16
15.	Clove	3 nos.	9.42
16.	Banana	9 nos.	28.26 (47.10)
17.	Pepper	10 nos.	10.00
18.	Moringa	4 nos.	50.24
19.	Borassus	20 nos.	1004.80
20.	Colocasia	30 nos.	40.00 (56.52)
21.	Papaya	2 nos.	8.00
22.	Curry leaf	3 nos.	5.00
23.	Vegetables	1 unit	40.00*
24.	Bamblimass	1 no.	80.64
25.	House & permanent structures	-	912.50
			5312.98 (5590.94)

* Enterprise absent in the II year

Figures in parenthesis represents area in the II year

Fig. 22. Structure of the home garden at Location I

At Location II (Table 21), the net area of the homestead was 4000 m^2. The house, roads and other permanent structures (cattle shed, poultry bin etc.) together occupied an area of 300 and 305 m^2 in the first and second years respectively. Hence, the net cropped area was 3700 m^2 (I year) and 3695 m^2 (II year). In the first year, the gross cropped area occupied by the 32 tree/ crop components was 5369.49 m^2, resulting in a cropping intensity of 145.13 per cent while in the second year the gross cropped area and resultant cropping intensity were 5616.49 m^2 and 152.00 respectively. The crops were planted in the homestead based on the space available and according to the needs and convenience of the farmer. The major perennial tree crop in the home garden was coconut (adult and young) which constituted 30 per cent (average of both years) of the gross cropped area. This was followed by cashew which accounted for 28 per cent of the gross cropped area. In addition to the tree / crops the farmer maintained one cow, four goats and 15 chicken in the first year. In the second year the number of goats and poultry were reduced to two and ten respectively, and apiculture was started as a new enterprise. Tree crops like coconut, jack, wild jack and arecanut occupied the top most layer (> 25 m) of the canopy (Fig. 23). Tamarind, mango, cashew, mahogany, Indian gooseberry and ailanthus formed the second layer (10 - 25 m). Trees/crops like bread fruit, bilimbi, annona, pepper, cinnamon, sapota, moringa, neem, bamblimass, guava and morinda constituted the third layer (3 - 10 m). The fourth layer (1 - 3 m) comprised of tapioca, dioscorea, amorphophallus, colocasia, teak, banana and curry leaf. Turmeric, arrowroot and pineapple formed the ground layer (< 1 m). Young coconut occupied both the second and third layers.

Table 21. Inventory of the home garden at Location II

Sl. No.	Enterprise	Population	Space used (m^2)
1.	Adult coconut	40 nos.	1038.60
2.	Young coconut	35 nos.	440.00 (687.00)
3.	Jack	2 nos.	78.94
4.	Tamarind	1 no.	50.24
5.	Wild Jack	2 nos.	61.11
6.	Mango	4 nos.	89.38
7.	Cashew	5 nos.	1524.45
8.	Mahogany	2 nos.	74.55
9.	Breadfruit	1 no.	12.56
10.	Bilimbi	5 nos.	60.73
11.	Annona	6 nos.	129.43
12.	Tapioca	500 nos.	500.00
13.	Dioscorea	25 nos.	25.00
14.	Amorphophallus	25 nos.	37.50
15.	Colocasia	10 nos.	17.66
16.	Turmeric	25 nos.	12.50
17.	Pepper	15 nos.	15.00
18.	Arrowroot	1000 nos.	500.00
19.	Pineapple	50 nos.	50.00
20.	Arecanut	4 nos.	28.26
21.	Indian Gooseberry	1 no.	26.42
22.	Cinnamon	1 no.	29.22
23.	Sapota	1 no.	47.48
24.	Ailanthus	4 nos.	28.84
25.	Moringa	10 nos.	70.65
26.	Neem	1 no.	19.62
27.	Teak seedlings	10 nos.	17.66
28.	Bamblimass	1 no.	45.36
29.	Guava	5 nos.	141.30
30.	Morinda	15 nos.	105.97
31.	Banana	25 nos.	78.50
32.	Curry leaf	4 nos.	12.56
33.	Cow	1 no.	40.00
34.	Goat	4 nos.	40.00
35.	Poultry	15 birds	20.00
36.	Apiculture	5 hives	5.00*
36.	House & permanent structures	-	200.00
			5669.49 (5921.49)

* Enterprise absent in the II year

Figures in parenthesis represents area in the II year

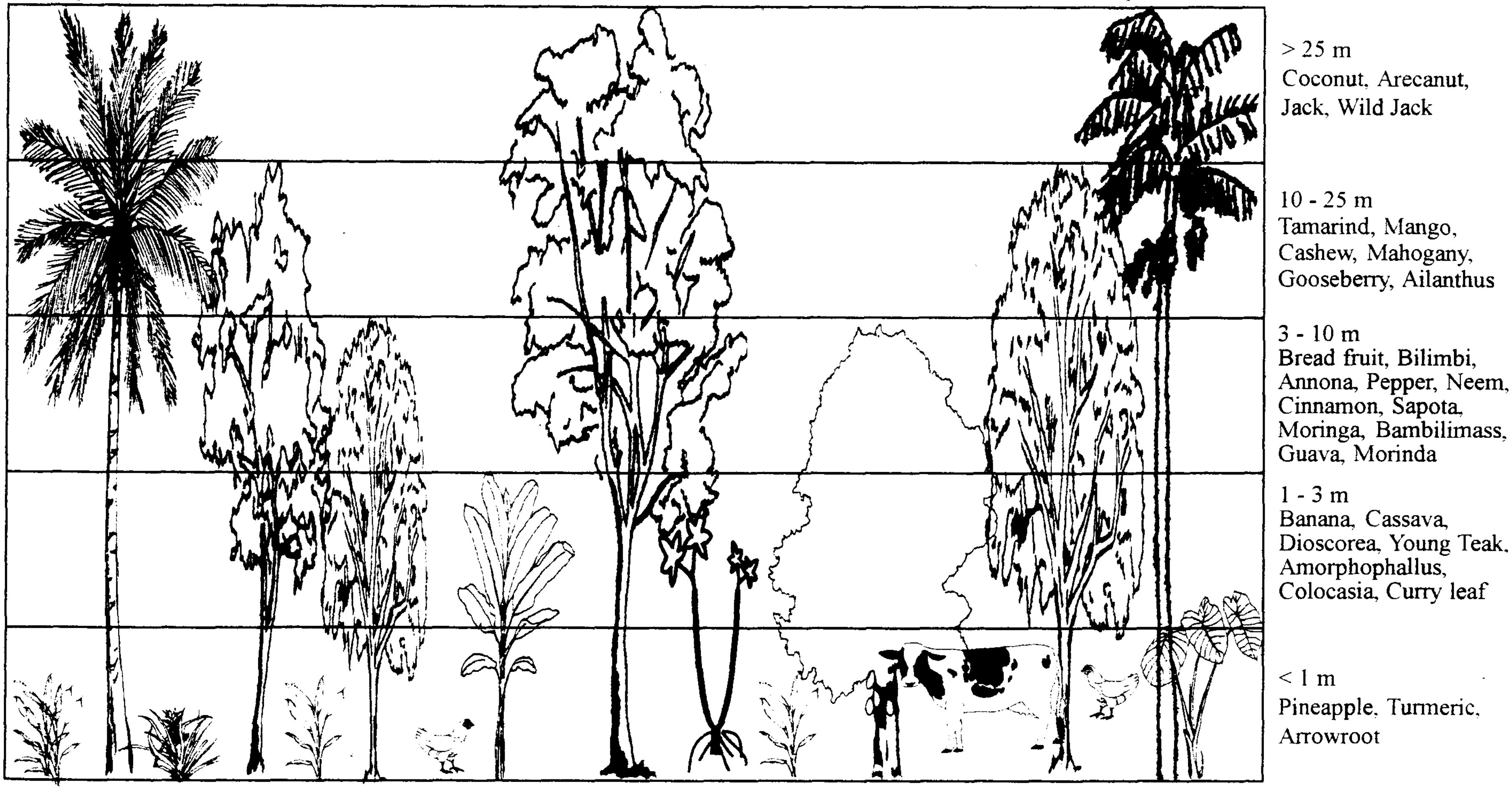


Fig. 23. Structure of the home garden at Location II

The cropping pattern adopted by the farmer and the cropping intensity values in the two home gardens clearly shows that the farmers undertook intensive cultivation in their home gardens. The intensive cropping nature of homesteads in Kerala has been reported by Nair and Sreedharan (1986) and Abdul Salam *et al.* (1992a). However, at Location II, the cropping intensity was comparatively higher. This is in accordance with the findings of Nair and Krishnankutty (1984) who reported that a reduction in the size of holding led to high intensity of cropping. It could be observed that the distribution of trees in the arborescent canopy is layered as in a natural forest. The predominance of borassus in the home garden at Location I was probably due to the proximity of the area to the Tamil Nadu border where it is grown on a large scale. They are found to thrive on a wide range of soils and the effects of shading are negligible due to the small-sized crowns composed of the fan-like leaves. Moreover, the farmer had a regular cash income from the palm throughout the year by way of jaggery making. Similar observations of borassus being grown on a large scale on farmlands in Tamil Nadu were made by Jambulingam and Fernandes (1986). At Location II, the predominance of tuber crops and cashew was observed. The proximity of the home garden to the Central Tuber Crops Research Institute, Sreekaryam, which has a very effective extension wing for transfer of technology, might be the reason for the increased cultivation of tuber crops like tapioca, arrowroot, colocasia and amorphophallus. In the case of cashew, the farmer received fertilizers free of cost from a co-operative society in the locality, which also helped to procure and sell the produce, thus ensuring a reasonable return to the farmer. Human interference obviously had a marked influence on the garden architecture. The components though arranged in a haphazard manner, had their own special niches within the system. The structural complexity and species diversity of the home gardens is similar to that of the tropical home gardens elaborated by several authors (Soemarwoto *et al.*, 1976; Stoler, 1978; Fernandes and Nair, 1986; Nair and Sreedharan, 1986; Jacob and Alles, 1987; Soemarwoto, 1987; Abdul Salam *et al.*, 1990; Happy Mathew, 1993).

4.2.2 Dynamics of the home garden

4.2.2.1 Nutrient dynamics

4.2.2.1.1 Nutrient addition by litterfall

The litter addition by different tree species in the home gardens at Location I and II are given in Tables 22 and 23 respectively.

At Location I, the total annual litter addition was 426.55 and 482.10 kg in the first and second year respectively from 12 tree components in the system. The maximum amount of litter was obtained from nutmeg (192.80 kg in the first year and 218.70 kg in the second year) which accounted for 45 per cent of the total litterfall in both the years (Fig. 24).

Table 22. Annual litterfall of different tree species at Location 1

Tree	Litter (kg)	
	I Year	II Year
Teak	8.73	8.85
Mahogany	11.67	11.99
Jack	30.93	35.10
Wild Jack	110.63	129.23
Bamblimass	12.73	15.15
Nutmeg	192.80	218.70
Bilimbi	3.54	4.92
Mango	23.27	23.96
Breadfruit	12.69	10.80
Gmelina	4.81	6.06
Cinnamon	3.19	4.36
Coffee	11.56	12.98
Total	426.55	482.10

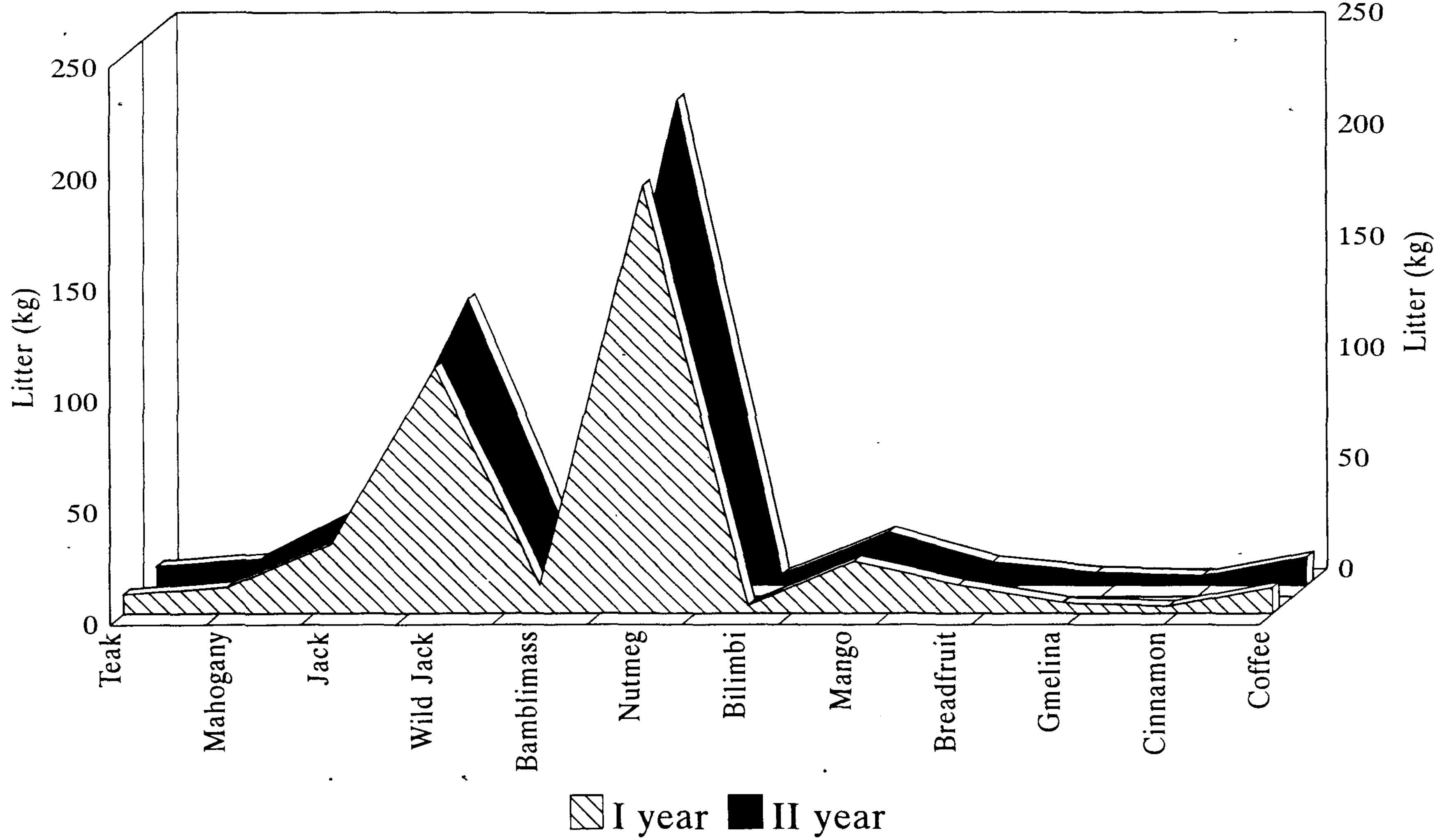


Fig. 24. Litterfall of different tree species in the home garden at Location I

Table 23. Annual litterfall of different tree species at Location II

Tree	Litter (kg)	
	I Year	II Year
Bilimbi	10.86	14.55
Bamblimass	24.23	24.59
Wild Jack	23.57	24.78
Jack	26.15	27.11
Mango	21.39	22.03
Annona	29.61	27.89
Mahogany	14.22	13.97
Cinnamon	2.87	3.58
Guava	15.23	12.67
Cashew	158.79	142.81
Breadfruit	6.70	5.91
Total	333.62	319.89

This was followed by wild jack which produced 110.63 and 129.23 kg in the first and second year respectively. The total nutrient addition (Tables 24 and 25) by way of litterfall was 4.25, 0.32, 1.76 kg NPK (first year) and 5.58, 0.52, 2.55 kg NPK (second year). Among the different components maximum nutrients was added by nutmeg (1.61, 0.13, 1.02 kg NPK in the first year and 2.21, 0.28, 1.55 kg NPK in the second year) followed by wild jack (1.12, 0.06, 0.20 kg NPK in the first year and 1.49, 0.07, 0.27 kg NPK in the second year).

At Location II, out of the total litter addition of 333.62 kg (I year) and 319.89 (II year) by 11 tree components the maximum litter was obtained from cashew (158.79 and 142.81 kg in the first and second year respectively) which accounted for 45 - 47 per cent of the total addition (Fig. 25). This was followed by annona (29.61 in the first year and 27.89 kg in the second year). The annual nutrient addition (Tables 26 and 27) in the system by way of litterfall amounted to 3.82, 0.38, 1.71 kg NPK (I year) and 3.72, 0.39, 1.67 kg NPK (II year). Among the different components, cashew (1.53, 0.18, 0.64 kg NPK and 1.39, 0.17, 0.56 kg NPK in the first and second years respectively) contributed maximum nutrients followed by bamblimass.

The data showed that among the nutrients added by litterfall, nitrogen was the predominant fraction. At Location I, litterfall accounted for 56, 88 and 23 per cent of the total N, P and K added by the tree nutrient cycling processes (litterfall, stemflow and throughfall) in the first year while in the second year it accounted for 75, 96 and 38 per cent of N, P and K respectively.

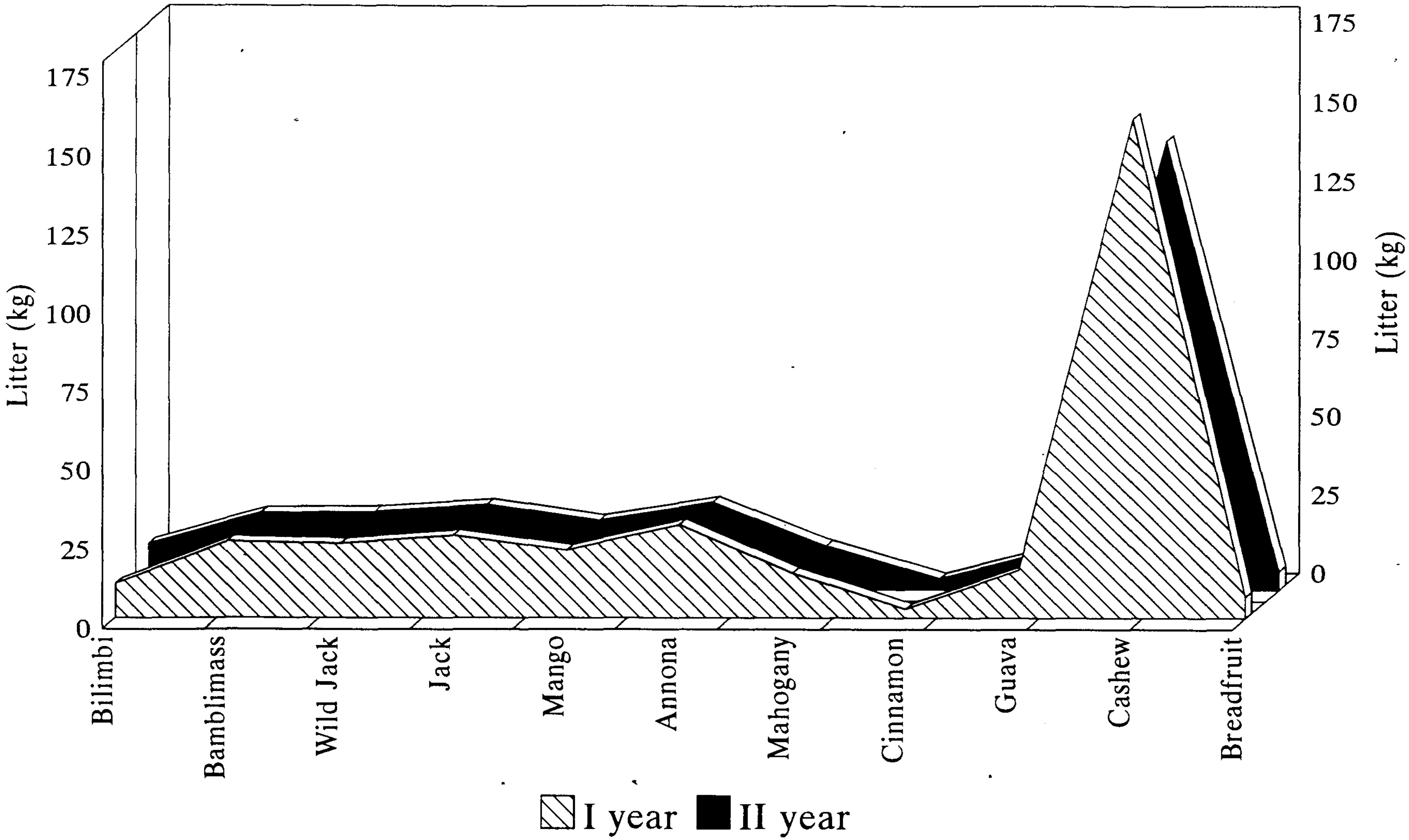


Fig. 25. Litterfall of different tree species in the home garden at Location II

Table 24. Nutrient addition by different tree/crop components in the homestead at Location I (0.50 ha) in the first year

Tree / Crop	Nutrients added (kg)								
	Litterfall			Stemflow			Throughfall		
	N	P	K	N	P	K	N	P	K
Bilimbi	0.0408	0.0093	0.0178	–	–	–	0.0194	0.0003	0.0520
Bamblimass	0.1638	0.0167	0.0751	0.0016	0.0001	0.0040	0.0755	0.0007	0.1854
Wild Jack	1.1171	0.0600	0.1974	0.0187	0.0001	0.0328	0.4000	0.0039	0.5142
Jack	0.3527	0.0174	0.0867	0.0139	0.0001	0.0210	0.1024	0.0009	0.2115
Mango	0.2715	0.0185	0.0866	0.0066	0.0002	0.0090	0.1679	0.0025	0.2550
Mahogany	0.1360	0.0065	0.0366	0.0066	0.0001	0.0092	0.0374	0.0018	0.1533
Cinnamon	0.0409	0.0054	0.0135	–	–	–	0.0282	0.0009	0.0838
Breadfruit	0.2026	0.0271	0.1034	0.0050	0.0002	0.0107	0.0577	0.0032	0.3185
Coconut	–	–	–	0.0286	0.0007	0.0494	1.2669	0.0157	2.0289
Gmelina	0.0752	0.0087	0.0296	0.0050	0.0000	0.0080	0.0200	0.0001	0.0311
Coffee	0.1359	0.0142	0.0803	–	–	–	0.0529	0.0013	0.2149
Nutmeg	1.6144	0.1260	1.0177	0.0357	0.0006	0.0585	0.7733	0.0047	1.3103
Albizzia	–	–	–	0.0055	0.0001	0.0098	0.2140	0.0029	0.2794
Teak	0.0972	0.0052	0.0180	–	–	–	0.0266	0.0013	0.1237
Total	4.2481	0.3150	1.7627	0.1272	0.0022	0.2124	3.2422	0.0402	5.7620

Table 25. Nutrient addition by different tree/crop components in the homestead at Location I (0.50 ha) in the second year

Tree / Crop	Nutrients added (kg)								
	Litterfall			Stemflow			Throughfall		
	N	P	K	N	P	K	N	P	K
Bilimbi	0.0582	0.0193	0.0289	–	–	–	0.0101	0.0002	0.0315
Bamblimass	0.2951	0.0521	0.1544	0.0011	0.0000	0.0027	0.0450	0.0004	0.1100
Wild Jack	1.4861	0.0726	0.2715	0.0130	0.0001	0.0198	0.2235	0.0022	0.3628
Jack	0.4377	0.0203	0.1179	0.0099	0.0000	0.0148	0.0580	0.0007	0.1280
Mango	0.2738	0.0243	0.1270	0.0043	0.0001	0.0065	0.0882	0.0014	0.1808
Mahogany	0.1805	0.0072	0.0624	0.0049	0.0001	0.0063	0.0223	0.0010	0.1031
Cinnamon	0.0674	0.0037	0.0199	–	–	–	0.0146	0.0004	0.0491
Breadfruit	0.1550	0.0109	0.0432	0.0034	0.0001	0.0078	0.0347	0.0018	0.2196
Coconut	–	–	–	0.0197	0.0004	0.0393	0.6642	0.0091	1.6051
Gmelina	0.1021	0.0137	0.0425	0.0029	0.0000	0.0053	0.0113	0.0001	0.0219
Coffee	0.1931	0.0139	0.1189	–	–	–	0.0267	0.0005	0.1252
Nutmeg	2.2103	0.2811	1.5493	0.0189	0.0004	0.0395	0.4350	0.0035	0.7825
Albizzia	–	–	–	0.0044	0.0001	0.0078	0.1150	0.0013	0.1783
Teak	0.1161	0.0053	0.0183	–	–	–	0.0125	0.0006	0.0714
Total	5.5754	0.5244	2.5542	0.0825	0.0013	0.1498	1.7611	0.0232	3.9693

Table 26. Nutrient addition by different tree/crop components in the homestead at Location II (0.40 ha) in the first year

Tree / Crop	Nutrients added (kg)								
	Litterfall			Stemflow			Throughfall		
	N	P	K	N	P	K	N	P	K
Bilimbi	0.1169	0.0229	0.0670	–	–	–	0.0465	0.0029	0.0728
Bamblimass	0.4677	0.0311	0.2523	–	–	–	0.0445	0.0021	0.0565
Wild Jack	0.2534	0.0226	0.1152	0.0024	0.0003	0.0082	0.0175	0.0033	0.1071
Jack	0.3290	0.0179	0.1404	0.0024	0.0003	0.0048	0.0382	0.0022	0.1016
Mango	0.2168	0.0386	0.1144	0.0086	0.0004	0.0093	0.0263	0.0029	0.1155
Annona	0.3856	0.0343	0.1612	–	–	–	0.1478	0.0069	0.1798
Mahogany	0.1881	0.0173	0.0598	0.0027	0.0002	0.0096	0.0232	0.0031	0.1468
Cinnamon	0.0419	0.0029	0.0106	–	–	–	0.0137	0.0013	0.0276
Guava	0.1987	0.0140	0.1032	–	–	–	0.0430	0.0035	0.1307
Cashew	1.5318	0.1765	0.6391	0.0039	0.0008	0.0238	0.4199	0.0651	1.4570
Breadfruit	0.0855	0.0064	0.0452	–	–	–	0.0042	0.0003	0.0137
Tamarind	–	–	–	0.0017	0.0001	0.0029	0.0218	0.0024	0.0469
Gooseberry	–	–	–	0.0033	0.0001	0.0093	0.0090	0.0002	0.0266
Coconut	–	–	–	0.0752	0.0043	0.1163	2.0013	0.0648	3.5132
Total	3.8154	0.3845	1.7084	0.1002	0.0065	0.1842	2.8569	0.1610	5.9958

Table 27. Nutrient addition by different tree/crop components in the homestead at Location II (0.40 ha) in the second year

Tree / Crop	Nutrients added (kg)								
	Litterfall			Stemflow			Throughfall		
	N	P	K	N	P	K	N	P	K
Bilimbi	0.1590	0.0291	0.0896	–	–	–	0.0629	0.0040	0.1113
Bamblimass	0.4761	0.0376	0.2784	–	–	–	0.0642	0.0027	0.0857
Wild Jack	0.2733	0.0238	0.1287	0.0026	0.0003	0.0095	0.0220	0.0038	0.1564
Jack	0.3532	0.0187	0.1467	0.0025	0.0003	0.0049	0.0477	0.0033	0.1431
Mango	0.2279	0.0410	0.1143	0.0093	0.0006	0.0118	0.0334	0.0033	0.1625
Annona	0.3568	0.0325	0.1439	–	–	–	0.1875	0.0088	0.2679
Mahogany	0.1788	0.0184	0.0607	0.0034	0.0002	0.0124	0.0323	0.0040	0.2173
Cinnamon	0.0518	0.0035	0.0128	–	–	–	0.0168	0.0017	0.0528
Guava	0.1701	0.0124	0.0908	–	–	–	0.0566	0.0042	0.2011
Cashew	1.3940	0.1670	0.5645	0.0046	0.0010	0.0354	0.6004	0.0827	1.8470
Breadfruit	0.0791	0.0059	0.0412	–	–	–	0.0055	0.0004	0.0214
Tamarind	–	–	–	0.0018	0.0002	0.0035	0.0282	0.0030	0.0701
Gooseberry	–	–	–	0.0040	0.0001	0.0105	0.0123	0.0002	0.0426
Coconut	–	–	–	0.0871	0.0050	0.1236	2.7565	0.0768	5.2405
Total	3.7201	0.3899	1.6716	0.1153	0.0077	0.2116	3.9263	0.1989	8.6197

The maximum litter production by nutmeg was due to its higher population (13 numbers) and total canopy area (483.94 m^2) when compared to the other trees. It was observed that the total litter produced in the second year was more (Fig. 24). This was probably due to the relatively higher mean atmospheric temperature (28.19°C) and low rainfall (107.90 cm) of the second year when compared to the first year (25.36°C and 130.40 cm).

At Location II, litterfall accounted for 56, 69 and 22 per cent of the N, P, K added through tree nutrient cycling in the first year while in the second the corresponding percentages were 48, 65 and 16. The lower contribution of nitrogen by litter in the second year was due to the reduced litterfall. Cashew accounted for the maximum litter production due to its higher population (5 numbers) and large canopy spread (1524.45 m^2). The total litter produced by the trees was higher in the first year (Fig. 25). This may be due to the comparatively lower rainfall received in the first year (89.90 cm) when compared to the second (118.80 cm).

It can be seen that among the different tree nutrient cycling processes (litterfall, stemflow and throughfall), litterfall was the major avenue for the addition of nutrients, especially N and P (Figs. 26 and 27). Similar observations were made by Cole and Rapp (1980). A major portion of the accumulated nutrients in the tree biomass is returned to the soil through litterfall. It is logical to expect that the crops / plants in the system would derive most of its nutrient needs from the established external litter decay as suggested by Switzer and Nelson (1972).

The differential litter production and nutrient addition exhibited by the trees is in accordance with the reports of Divineau (1976) and Vinha and Pereira (1983) who found that the phenology and quantity of litter production and nutrient release varied with species. Also the total nutrient return depended on total litterfall than by the contents of nutrients in the litter (Proctor *et al.*, 1985). The total litter produced and its nutrient input in both the home gardens is comparable with the results of Happy Mathew *et al.* (1996) and Nair *et al.* (1996). Thus, it could be concluded that the litterfall is likely to act as an input-output system for nutrients as suggested by Das and Ramakrishnan (1985).

4.2.2.1.2 Nutrient addition by stemflow

The amount of nutrients added by way of stemflow by the different tree components at Location I and II is given in Tables 24, 25, 26 and 27.

At Location I, the annual nutrient input (Tables 24 and 25) by stemflow was estimated as 0.13, 0.002, 0.21 kg NPK (I year) and 0.08, 0.001, 0.15 kg NPK (II year). Nutmeg (0.04, 0.001, 0.06 kg NPK and 0.02, 0.00, 0.04 kg NPK in the first and second year respectively) and coconut accounted for maximum nutrient input in both years.

At Location II, the annual addition of nutrients (Tables 26 and 27) by stemflow was 0.10, 0.01, 0.18 kg NPK and 0.12, 0.01, 0.21 kg NPK in the first and second years respectively. Among the different tree components coconut (0.07, 0.004, 0.12 kg NPK and 0.09, 0.005, 0.12 kg NPK in the first and second year respectively) accounted for maximum nutrient input.

In general, it was found that among the nutrients added by stemflow, potassium was the most important followed by nitrogen. This may be due to the greater leachability of K as proved by experiments in forest species (Wells *et al.*, 1975; Henderson *et al.*, 1977 and Carey *et al.*, 1981). In the present study, variations in nutrient addition by stemflow in tree species were observed at both locations. Cole and Rapp (1980) reported that the variation in cycling rates between species is largely because of inherent differences between species relative to nutrient requirement and cycling strategies. Also, the greater nutrient input by nutmeg (13 nos.) and coconut (19 nos.) at Location I and by coconut (40 nos.) at Location II was probably due to its higher population when compared to the other trees.

The higher addition of nutrients in the first year at Location I and in the second year at Location II may be due to the greater rainfall received in the respective years at the respective locations.

Among the different nutrient cycling processes (litterfall, stemflow and throughfall) stemflow accounted for the least addition of nutrients. This was probably due to the lesser quantity of precipitation that is channeled to the ground as stemflow (Helvey and Patric, 1965; Miller *et al.*, 1976; Sanjay and Verma, 1987).

The estimates of nutrient input through stemflow are comparable with the results of Happy Mathew *et al.* (1996).

4.2.2.1.3. Nutrient addition by throughfall

The nutrient addition by way of throughfall by the different tree components at Location I and II are given in Tables 24, 25, 26 and 27.

At Location I, the annual input of nutrients (Tables 24 and 25) by throughfall was 3.24, 0.04, 5.76 kg NPK (I year) and 1.76, 0.02, 3.97 kg NPK (II year). Among the different trees, coconut (1.27, 0.02, 2.03 kg NPK and 0.66, 0.01, 1.61 kg NPK in the first and second year respectively) contributed the maximum nutrients followed by nutmeg during both the years.

At Location II, the annual nutrient addition by throughfall (Tables 26 and 27) was 2.86, 0.16, 6.00 kg NPK (I year) and 3.93, 0.20, 8.62 kg NPK (II year). Coconut (2.00, 0.006, 3.51 kg and 2.76, 0.08, 5.24 kg NPK in the first and second year respectively) accounted for the maximum nutrient addition during both the years, followed by cashew.

Foliar leaching is the major process which controls the enrichment of throughfall with nutrients as suggested by Parker (1983).

At Location I, throughfall accounted for 43, 11 and 75 per cent of the total N, P and K respectively added by tree nutrient cycling (litterfall, stemflow and throughfall) in the first year while in the II year it accounted for 24, 4 and 60 per cent.

At Location II, throughfall accounted for 42, 29 and 76 per cent of the total N, P and K added through nutrient cycling in the first year while in the second year the corresponding percentages were 51, 33 and 82.

In general, it was observed that among the nutrients added by throughfall, potassium was the most important followed by nitrogen (Figs. 26 and 27). This might be due to the greater leachability of K and N as suggested by Wells *et al.*, 1975; Henderson *et al.*, 1977 and Carey *et al.*, 1981. Among the different nutrient cycling processes (litterfall, stemflow, throughfall), throughfall accounted for the largest addition of potassium. This result is concurrent with the findings of Jasbir Singh (1986).

The greater addition of nutrients by throughfall might be due to the greater volume of precipitation being channeled as throughfall (Miller *et al.*, 1976). Also, Helvey and Patric (1965) observed that in most situations, 85 per cent or more of input is by throughfall when compared with stemflow. The yearly variation in the nutrient input by throughfall at both locations might be due to the difference in the quantity of rainfall received in each year.

Variation in the amount of nutrients added by different tree species could be due to the differences in age, canopy area and inherent differences between species relative to nutrient requirement and cycling strategies. Cole and Rapp (1980) and Charley and Richards (1983) attributed similar reasons for differences in the nutrient load in throughfall among tree species. The larger canopy area of adult coconut at Location I (1155.58 m^2) and

Location II (1038.60 m^2) might be the reason for its higher contribution of nutrients by throughfall. The higher addition of nutrients by coconut, especially potassium, is also accordance with the findings of Khanna and Nair (1977).

4.2.2.1.4 Nutrient addition by manures from cattle / poultry and inorganic fertilizers

At Location I (Table 28), the nutrients added by way of organic manures were 3.60, 5.50 and 11.80 kg NPK (I year) and 8.23, 7.51 and 12.98 kg NPK (II year). The organic manures added included cowdung (800 kg and 2425 kg in the first and second year respectively) which was purchased and ash (300 kg and 190 kg) obtained from the homestead. Cowdung and ash were added to coconut. Organic manures accounted for 24, 67 and 57 per cent of the total N, P and K respectively added in the home garden through various avenues in the first year (Table 30 and Fig. 26). In the second year, the corresponding figures were 34, 53 and 35 per cent. The amount of nutrients supplied through inorganic fertilizers (Table 30) were 3.69, 2.31, 0.00 kg NPK and 8.15, 5.90, 15.60 kg NPK in the first and second years respectively. The fertilizers used were urea (5 kg) and bonemeal (11 kg) in the first year and coconut mixture (78 kg) and bonemeal (10 kg) in the second year. The inorganic fertilizers were applied to nutmeg only in the first year while in the second year it was applied to nutmeg and coconut. Out of the total nutrients added through different avenues, fertilizers accounted for 24, 28 and 0 per cent of the total N, P and K respectively in the first year, while in the second year the corresponding values were 34, 42 and 42 per cent (Fig. 26).

Table 28. Nutrient addition by organic manure at Location I

Manure	Quantity added (kg)		Nutrient addition (kg)					
			I Yr.			II Yr		
	I Yr	II Yr	N	P	K	N	P	K
Cowdung	800	2425	2.40	1.60	1.60	7.28	4.85	7.28
Ash	300	190	1.20	3.90	10.20	0.95	2.66	5.70
Total			3.60	5.50	11.80	8.23	7.51	12.98

At Location II (Table 29), the total nutrients added through organic manures were 25.93, 22.97 and 34.02 kg of N, P and K (I year) and 21.80, 20.06 and 26.93 kg of N, P and K (II year). Cowdung from one cow during both the years (4380 kg), goat dung from four goats in the first (730 kg) and two goats in the second year (365 kg) and poultry manure from 15 birds in the first (380 kg) and 10 birds (256 kg) in the second year were the main organic manures added in the system. Cowdung alone contributed to 51, 38 and 39 per cent of the total N, P and K added by organic manures in the first year while in the second year it accounted for 60, 44 and 33 per cent. Out of the total nutrients added through different avenues in the home garden, organic manures accounted for 57, 69 and 56 per cent of the N, P and K respectively in the first year, while in the second year the corresponding values were 47, 62 and 42 per cent (Table 31 and Fig. 27). Nutrients added by inorganic fertilizers were 11.30, 9.40, 15.10 (I year) and 15.00, 11.25 and 22.50 II year) kg N, P and K respectively (Table 31). Fertilizer mixtures were applied to coconut (38 kg and 75 kg in the first and second year respectively), tapioca (25 kg each year) and cashew (50 kg each year) as inorganic sources used during both the years. Fertilizers accounted for 25, 28, 25 per cent of the total N, P and K added through different avenues in the first year, while in the second year the corresponding values were 32, 35, and 35 per cent (Fig. 27).

Thus, it is evident that the main organic manure added in the home gardens was cowdung. In the home garden at Location II, the livestock and poultry manures obtained were used in the homestead itself, for various crops, thus reducing the cost towards inorganic fertilizers.

Table 29. Nutrient addition by organic manure at Location II

Manure	Quantity added (kg)		Nutrient addition (kg)					
			I Yr.			II Yr		
	I Yr	II Yr	N	P	K	N	P	K
Cowdung	4380	4380	13.14	8.76	13.14	13.14	8.76	8.76
Goat dung	730	365	5.11	3.65	5.84	2.56	1.83	2.92
Poultry manure	380	256	6.08	4.56	3.04	4.10	3.07	2.05
Ash	400	400	1.60	6.00	12.00	2.00	6.40	13.20
Total			25.93	22.97	34.02	21.80	20.06	26.93

Such recycling resulted in efficient use of the available resources by the farmer. At both Locations, it was observed that organic manures were the main source of nutrient supply (Figs. 26 and 27). As compared to the local practices, the farmers in the two home gardens used comparatively low amounts of inorganic fertilizers, which is a clear indication of the considerable interest shown by the farmers towards organic farming. The added use of organic manures attributes to the improvement and maintenance of the soil physico-chemical and biological properties in the home gardens. It may be highlighted in this context that the attitude of the farmers for the use of considerable quantities of organic manures in a judicious way results in sustainability in the home gardens.

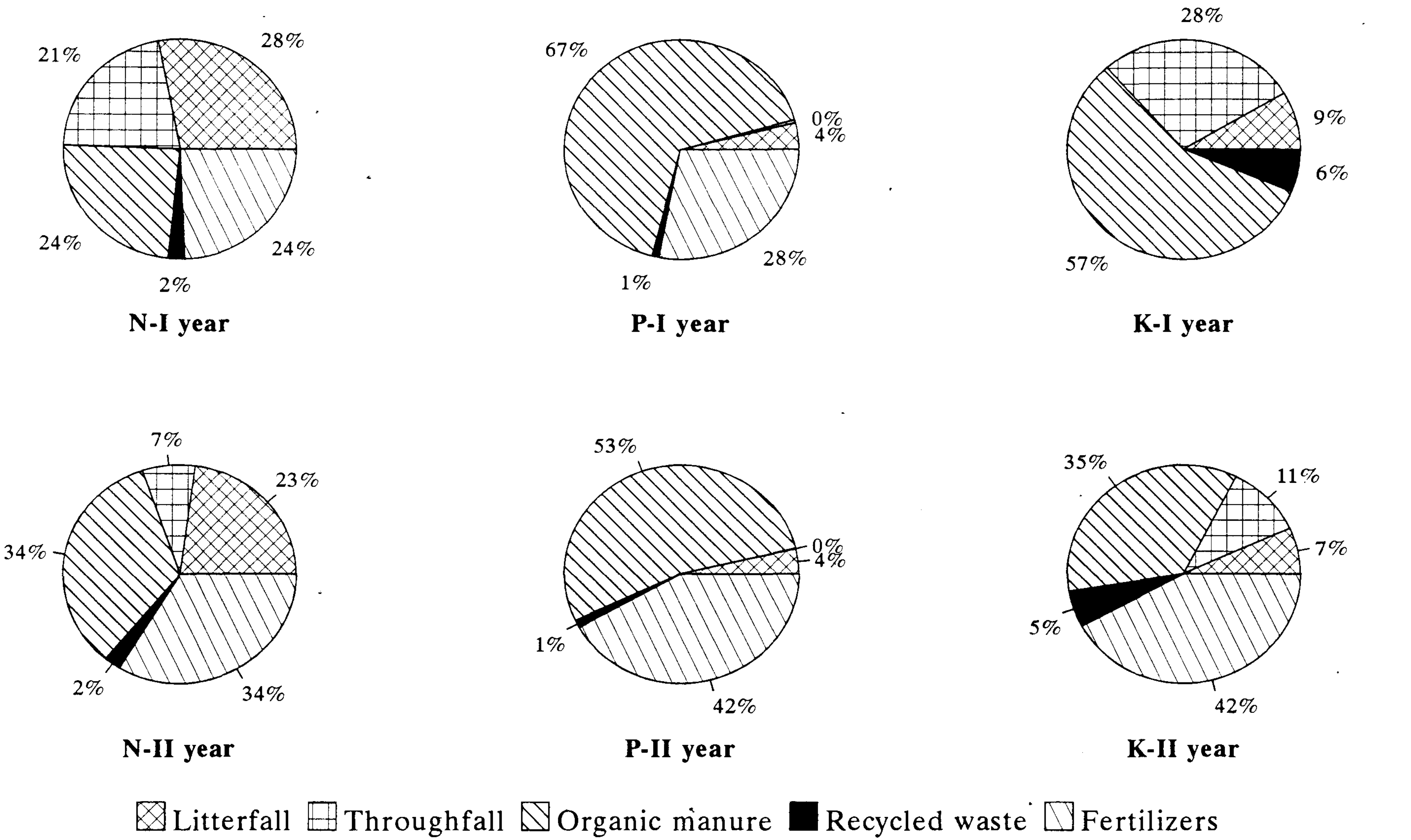
4.2.2.1.5 Nutrient recycling through incorporation of crop residues

The amount of nutrients recycled through incorporation of crop residues at Location I and II is furnished in Tables 30 and 31 respectively.

At Location I, the nutrients added through recycling was 0.35, 0.08 and 1.28 kg N, P and K respectively in the first year while in the second year the corresponding values were 0.58, 0.17 and 2.02 kg (Table 30). Recycled crop wastes accounted for 2, 1 and 6 per cent of the total N, P and K added to the system in the first year and 2, 1 and 5 per cent of N, P and K respectively in the second year (Fig. 26).

Table 30. Total nutrient addition through various sources in the home garden at Location I

Sl. No.	Source	Nutrients added (kg)					
		I Year			II Year		
		N	P	K	N	P	K
1.	Litterfall	4.25	0.320	1.76	5.58	0.520	2.55
2.	Stemflow	0.13	0.002	0.21	0.08	0.001	0.15
3.	Throughfall	3.24	0.040	5.76	1.76	0.020	3.97
4.	Organic manure	3.60	5.500	11.80	8.23	7.510	12.98
5.	Recycled waste	0.35	0.080	1.28	0.58	0.170	2.02
6.	Fertilizers	3.69	2.310	0.00	8.15	5.900	15.60
	Total	15.26	8.252	20.81	24.38	14.121	37.27



* Stemflow values have not been included as they add only trace quantities

Fig. 26. Nutrient addition in the home garden at Location I through various avenues

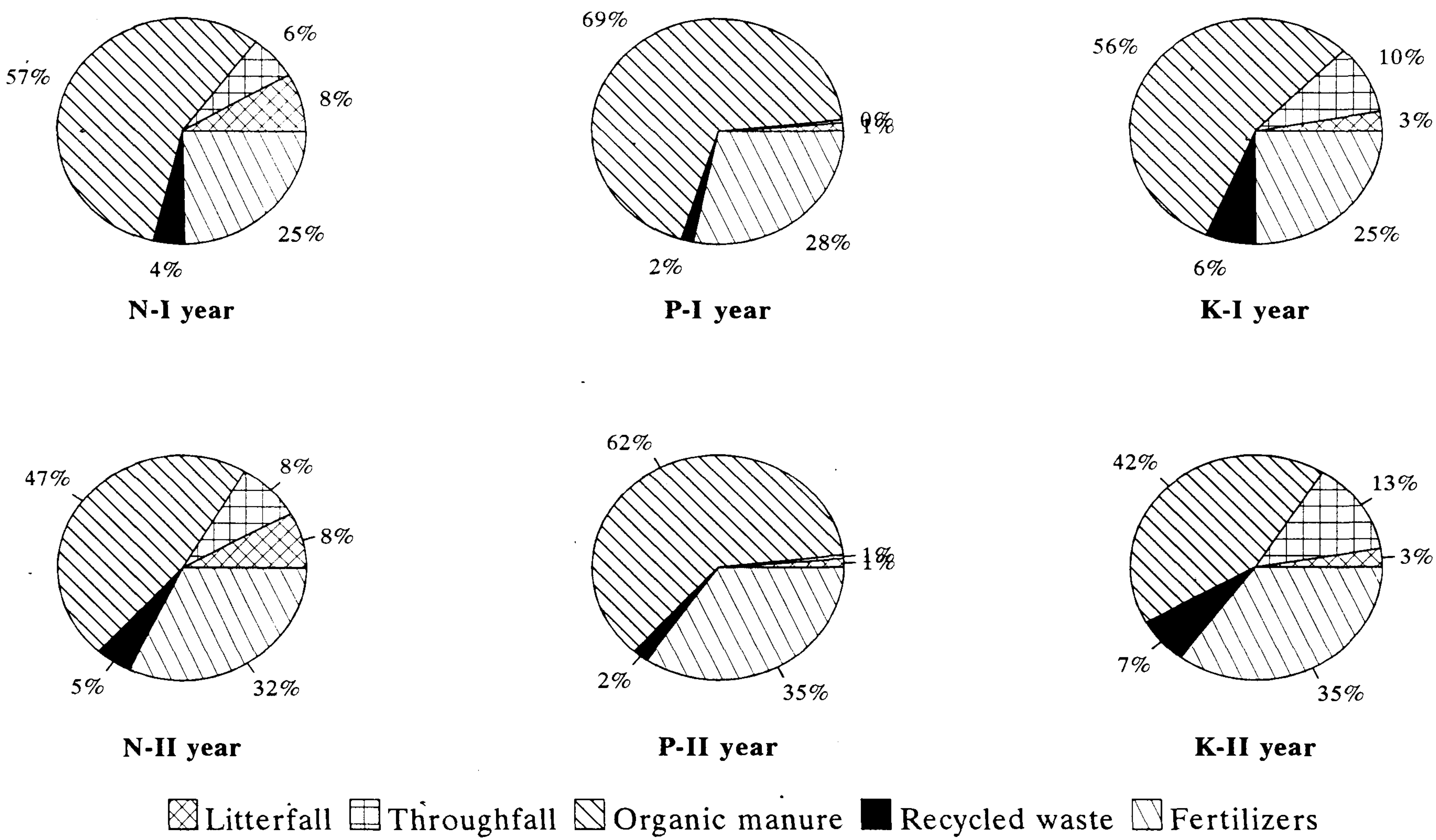
The crop residues of colocasia [4.5 kg and 7.0 kg dry weight (DW) in the first and second year respectively] and the pseudostem of banana (18 kg and 30 kg DW) were the main items recycled, of which the latter was the major contributor for nutrients. Banana pseudostem had a high nutrient content (1.8 % N, 0.5 % P and 6.6 % K).

At Location II, the nutrients added through recycling was 1.92, 0.52 and 3.95 kg N, P and K respectively in the first year while in the second year the corresponding quantities were 2.13, 0.65 and 4.25 kg (Table 31). Recycled crop wastes accounted for 4, 2 and 6 per cent of the total N, P and K added to the system in the first year and 5, 2 and 7 per cent of N, P and K respectively in the second year (Fig. 27). The crop residues of dioscorea (3.75 kg DW each year), amorphophallus (4.50 kg DW each year), colocasia (2.10 kg DW each year), turmeric (2.25 kg DW each year) and arrowroot (87.5 kg and 92.50 kg DW in the first and second year respectively) and the pseudostem of banana (50 kg DW each year) were the main items recycled. Banana pseudostem (0.90, 0.20, 3.4 kg and 0.98, 0.22, 3.6 kg NPK in the first and second year respectively) was the major contributor of nutrients followed by arrowroot.

The extent and intensity of the recycling systems in home gardens are declining. This would reduce the efficiency of resource use, which in the long run affects soil structure and fertility. By systematic recycling, it is possible to plough back into the soil substantial amounts of nutrients, which would otherwise be permanently lost from the system. From the above results, it is evident that the farmers are aware and have a positive attitude about recycling of crop residues.

Table 31. Total nutrient addition through various sources in the home garden at Location II

Sl. No.	Source	Nutrients added (kg)					
		I Year			II Year		
		N	P	K	N	P	K
1.	Litterfall	3.82	0.38	1.71	3.72	0.39	1.67
2.	Stemflow	0.10	0.01	0.18	0.12	0.01	0.21
3.	Throughfall	2.86	0.16	6.00	3.93	0.20	8.62
4.	Organic manure	25.93	22.97	34.02	21.80	20.06	26.93
5.	Recycled waste	1.92	0.52	3.95	2.13	0.65	4.25
6.	Fertilizers	11.30	9.40	15.10	15.00	11.25	22.50
	Total	45.93	33.44	60.96	46.70	32.56	64.18



* Stemflow values have not been included as they add only trace quantities

Fig. 27. Nutrient addition in the home garden at Location II through various avenues

4.2.2.1.6 Nutrient removal through harvested biomass

The major avenue of output or removal of nutrients from the homesteads is through harvested produce. At Location I (Table 32) the total biomass production in the first and second years was 1457.50 and 1657.63 kg DW respectively. The corresponding nutrient removal was 14.27, 2.35, 15.65 kg N, P and K and 15.54, 2.21, 18.01 kg N, P and K. Among the different components, coconut which produced a biomass of 789.00 kg DW (I year) and 1109 kg DW (II year) removed the largest amount of nutrients both in the first (7.11, 1.30, 10.10 kg N, P and K) and second (9.66, 1.32, 13.12 kg N, P and K) years. This was followed by jack which yielded 346 kg DW (I year) and 182 kg DW (II year) biomass and removed 4.32, 0.58, 2.88 kg N, P and K and 2.28, 0.30, 1.52 kg N, P and K in the first and second years respectively. Coconut alone accounted for 50, 55 and 65 per cent of the total N, P and K removed from the homestead in the first year, while in the second year the corresponding values were 62, 60 and 73 per cent (Fig. 28).

At Location II (Table 33), the total biomass production was 2677.70 kg DW and 3688.00 kg DW in the first and second years respectively. The corresponding nutrient removal was 26.71, 4.38, 34.19 kg N, P and K and 34.33, 6.06, 50.22 kg N, P and K. Coconut with a biomass production of 1820 kg DW and 2600 kg DW removed the largest amount of nutrients both in the first (15.86, 2.89, 22.75 kg N, P and K) and second (23.40, 4.29, 33.28 kg N, P and K) year respectively.

Table 32. Nutrient removal from the home garden at Location I

Sl. No.	Crop	First year: Harvested produce dry weight (kg)	First year: Nutrient removal (kg) on dry weight basis: N	P	K	Second year: Harvested produce dry weight (kg)	Second year: Nutrient removal (kg) on dry weight basis: N	P	K
1.	Coconut (nut)	394.00	2.76	0.83	4.29	433.00	2.90	0.65	4.33
2.	Coconut (leaves)	395.00	4.35	0.47	5.81	676.00	6.76	0.67	8.79
3.	Jack	346.00	4.32	0.58	2.88	182.00	2.28	0.30	1.52
4.	Nutmeg mace	4.80	0.05	0.01	0.03	6.00	0.06	0.01	0.04
5.	Nutmeg nut	16.50	0.20	0.04	0.11	18.00	0.22	0.05	0.12
6.	Mango	30.40	0.18	0.03	0.16	27.40	0.16	0.03	0.14
7.	Breadfruit	49.20	0.58	0.07	0.26	41.00	0.48	0.06	0.22
8.	Coffee	4.00	0.10	0.01	0.09	6.00	0.15	0.02	0.13
9.	Bilimbi	2.50	0.03	0.01	0.06	2.10	0.03	0.01	0.05
10.	Clove	4.00	0.03	0.01	0.03	4.00	0.03	0.01	0.02
11.	Banana fruit	23.30	0.23	0.04	0.45	30.40	0.30	0.04	0.60
12.	Banana leaves	20.00	0.36	0.02	0.70	25.00	0.50	0.01	1.00
13.	Pepper	8.00	0.14	0.02	0.14	8.50	0.16	0.02	0.15
14.	Moringa	2.50	0.04	0.01	0.03	3.20	0.05	0.01	0.04
15.	Borassus	141.00	0.64	0.13	0.32	180.00	1.23	0.25	0.57
16.	Colocasia	5.40	0.10	0.03	0.11	6.75	0.13	0.04	0.14
17.	Papaya	5.20	0.06	0.02	0.11	5.00	0.06	0.02	0.11
18.	Vegetables	2.60	0.06	0.01	0.03	-	-	-	-
19.	Curry leaf	0.60	0.02	0.00	0.00	0.78	0.02	0.00	0.00
20.	Bamblimass	2.50	0.02	0.01	0.04	2.50	0.02	0.01	0.04
	Total	1457.50	14.27	2.35	15.65	1657.63	15.54	2.21	18.01

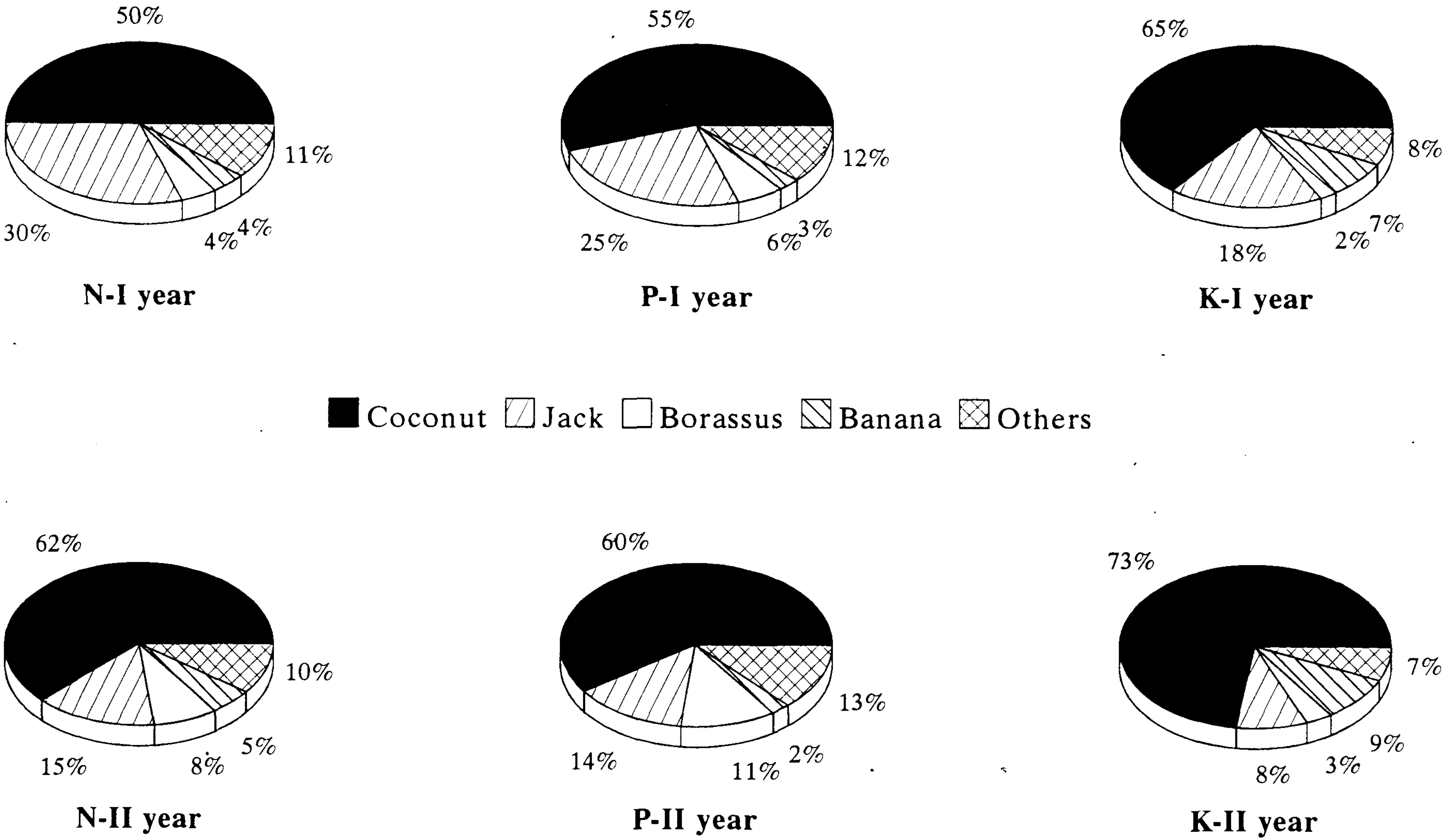


Fig. 28. Nutrient removal from the home garden at Location I

Table 33. Nutrient removal from the home garden at Location II

Sl. No.	Crop	First year: Harvested produce dry weight (kg)	First year: Nutrient removal (kg) on dry weight basis N	First year: P	First year: K	Second year: Harvested produce dry weight (kg)	Second year: Nutrient removal (kg) on dry weight basis N	Second year: P	Second year: K
1.	Coconut (nut)	780.00	5.46	1.64	8.50	1300.00	9.10	2.73	14.17
2.	Coconut leaves	1040.00	10.40	1.25	14.25	1300.00	14.30	1.56	19.11
3.	Jack	114.00	1.80	0.24	1.20	114.00	1.80	0.24	1.20
4.	Mango	18.00	0.11	0.02	0.10	11.00	0.07	0.01	0.06
5.	Cashew	47.00	1.20	0.23	0.27	47.00	1.20	0.23	0.27
6.	Bread fruit	20.50	0.24	0.03	0.11	20.50	0.24	0.03	0.11
7.	Bilimbi	3.00	0.04	0.01	0.07	3.00	0.04	0.01	0.07
8.	Annona	1.50	0.01	0.00	0.01	4.00	0.03	0.00	0.01
9.	Tapioca	100.00	0.28	0.10	1.90	400.00	1.10	0.40	7.60
10.	Dioscorea	20.50	0.21	0.03	0.24	26.00	0.26	0.04	0.30
11.	Amorphophallus	27.00	0.25	0.04	0.56	32.00	0.30	0.05	0.68
12.	Colocasia	3.00	0.05	0.01	0.06	1.50	0.03	0.01	0.03
13.	Turmeric	13.00	0.15	0.04	0.50	11.50	0.13	0.04	0.43
14.	Pepper	6.00	0.15	0.01	0.16	9.00	0.23	0.02	0.23
15.	Arrowroot	35.00	0.25	0.05	0.56	70.00	0.40	0.12	1.28
16.	Pineapple	12.20	0.06	0.01	0.08	12.20	0.06	0.01	0.08
17.	Arecanut	5.00	0.04	0.01	0.02	5.00	0.04	0.01	0.02
18.	Indian Gooseberry	2.00	0.01	0.00	0.02	1.00	0.01	0.00	0.01
19.	Sapota	2.00	0.01	0.00	0.03	2.00	0.01	0.00	0.03
20.	Moringa	10.00	0.24	0.07	0.22	8.00	0.20	0.06	0.18
21.	Bamblimass	4.00	0.03	0.01	0.06	2.50	0.02	0.00	0.04
22.	Guava	3.00	0.02	0.01	0.20	2.80	0.02	0.01	0.01
23.	Banana fruit	60.00	0.44	0.06	0.92	68.00	0.55	0.08	1.15
24.	Banana leaves	50.00	1.04	0.03	2.05	50.00	1.04	0.03	2.05
25.	Curry leaves	1.00	0.02	0.00	0.00	2.00	0.05	0.00	0.00
26.	Morinda leaves	300.00	4.20	0.48	2.10	185.00	3.10	0.37	1.10
	Total	2677.70	26.71	4.38	34.19	3688.00	34.33	6.06	50.22

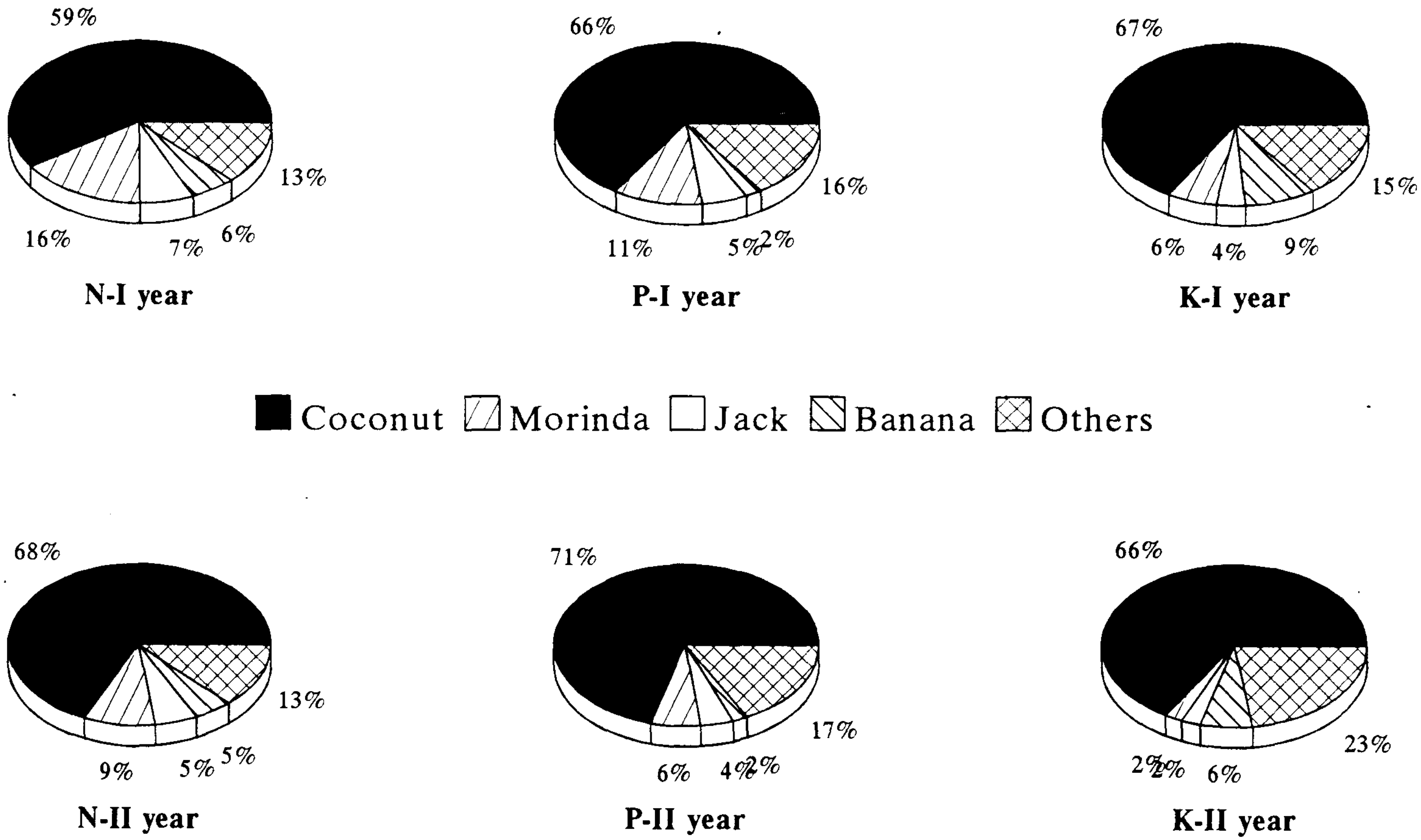


Fig. 29. Nutrient removal from the home garden at Location II

This was followed by morinda leaves (300 kg and 185 kg DW) which removed 4.20, 0.48, 2.10 kg N, P and K and 3.10, 0.37, 1.10 kg N, P and K in the first and second years respectively (Fig. 29). However, with respect to potassium removal in the second year, tapioca (400 kg biomass) removed 7.60 kg. Coconut alone accounted for 59, 66 and 67 per cent of the total N, P and K removed in the first year while in the second year the corresponding values were 68, 71 and 66 per cent.

From the results of the study, it could be seen that large quantities of nutrients were removed from the system through harvested produce (Figs. 28 and 29). These findings are in accordance with the results of Nair *et al.* (1996) on biomass production and nutrient removal from home gardens. The export of nutrients is generally more for annual agricultural crops in terms of total quantity removed per unit area and unit time. In the case of woody perennials, removal depends on the frequency and intensity of harvesting. This was evident in the case of coconut, where harvesting was done once in 45-50 days. The greater removal of nutrients by way of harvested produce of coconut, as can be seen in both locations, was due to the greater biomass produced by this crop and also as a result of frequent harvests. Moreover, the coconut leaf is a product of importance for domestic use. The plaited leaves are used for thatching houses, fencing and for making baskets. Unplaited coconut leaves are also used for fencing, mulching and for shading nursery. The midrib of the leaves are used for making stiff brooms, bird cages and fishing traps. Hence, the leaves of coconut are either used in the above manner or sold locally and were therefore permanently removed from the system. Similar estimates of such high nutrient removal by coconut have been reported by Khanna and Nair (1977), Happy Mathew (1993), Hegde *et al.* (1993), Nair *et al.* (1996) and Venkitaswamy (1996).

One of the main principles in agroforestry is to make best use of its resources-conserving and resource-sharing potentials. Therefore, it is extremely useful to have a proper nutrient budget for the whole system based on nutrient dynamics within the system. Nutrient cycling processes that take place to varying degrees in all land-use systems, become particularly relevant in the agroforestry context because of the likely effect of trees on such processes.

Nutrient cycling processes that takes place in varying degrees, in all land-use systems, become particularly relevant in the homestead agroforestry context because of the likely effects of trees on such processes. Closed nutrient cycles are known to operate in mixed evergreen natural forests. The crown surface forms the boundary of the system, where input of bioelements occurs through precipitation. The soil surface is the entry point for inputs into the soil compartment, occurring through fertilizers and manures. Nutrients taken up by the plant are either stored in an increment (storage) compartment or are used for the production of non-storage organs. Part of the nutrients that are taken up by the plants are also returned through two avenues. First, litterfall and, secondly, through the process of plant cycling. The latter represents that part of the total uptake of the nutrients which is again leached out from the vegetative parts through crown washout, occurring as throughfall (canopy drip) and stemflow. The major avenue of output from the total system is export through harvested produce. Plant nutrients are, therefore, involved in a constant and somewhat closed cycling within the soil and plant compartments of tree-based ecosystems, with minimal output (loss) from the system. The extent to which the system is closed or open will depend upon various factors, the decisive one being the tree / crop proportion (Nair, 1984).

Strictly speaking, from the results of studies on nutrient dynamics at both locations, it may be pointed out that the nutrient addition by various sources (litterfall, plant cycling, organic manure and fertilizer addition) compensated for the nutrient loss from the system through harvested biomass (Figs. 30 and 31). Nutrient addition at Location II was comparatively higher. This was mainly due to the presence of cattle and poultry components in the system which supplied considerable amounts of organic manure. The nutrient addition through litterfall and plant cycling (stemflow and throughfall) was also substantial. Plant nutrients were, therefore, involved in a constant cycling within the soil and plant compartments of the system. Also, the tree root systems may intercept, absorb, and recycle nutrients in the soil that would otherwise be lost through leaching. In a closed nutrient cycle, there is minimum loss of nutrients from the system. At Location II, the nutrient removal was much higher than at Location I. This was due to the presence of more annual crops (tapioca, dioscorea, amorphophallus, colocasia, turmeric, arrowroot and pineapple) the harvests of which resulted in greater export of nutrients from the system. The presence of coconut at both locations also resulted in

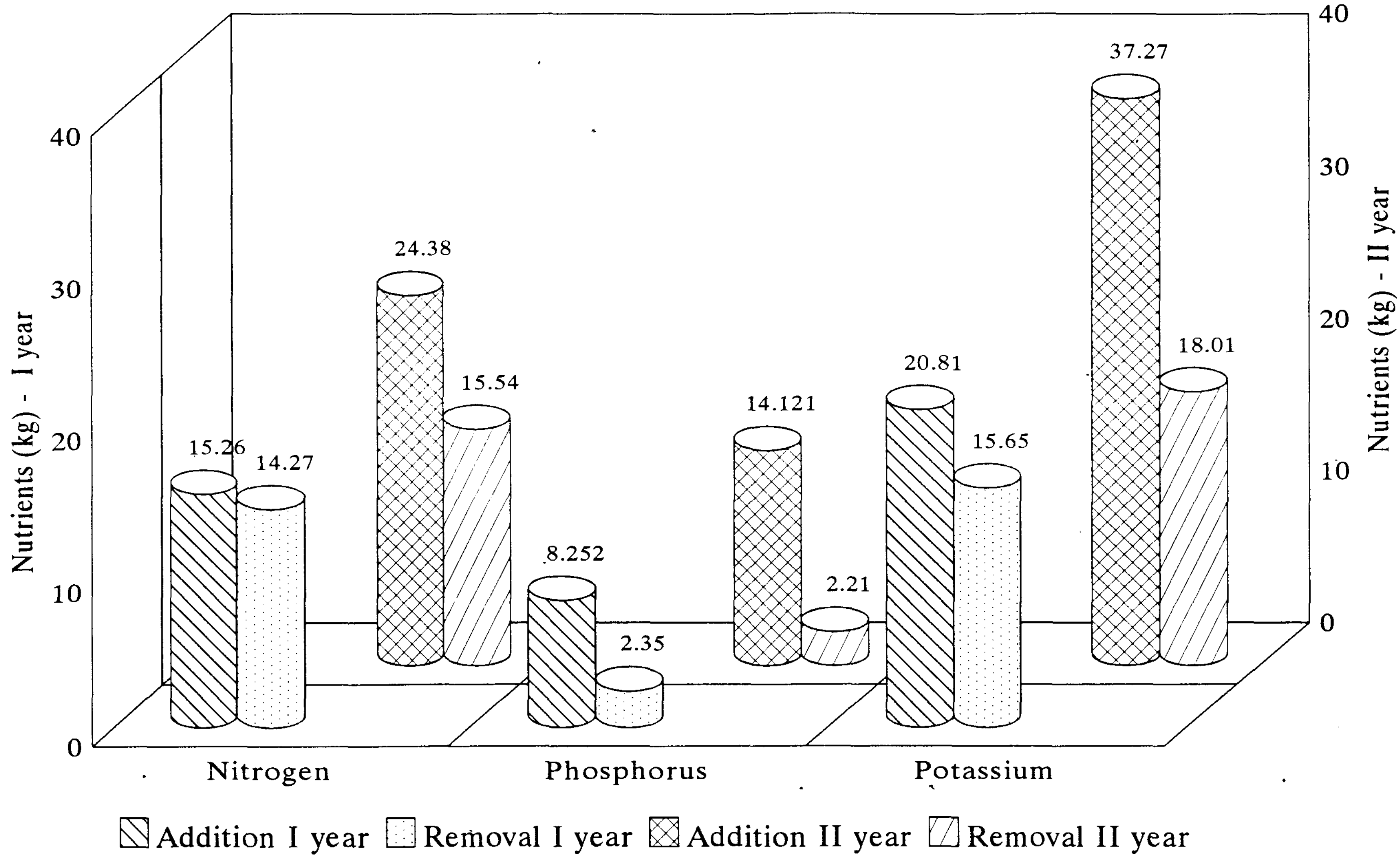


Fig. 30. Nutrient dynamics of Location I

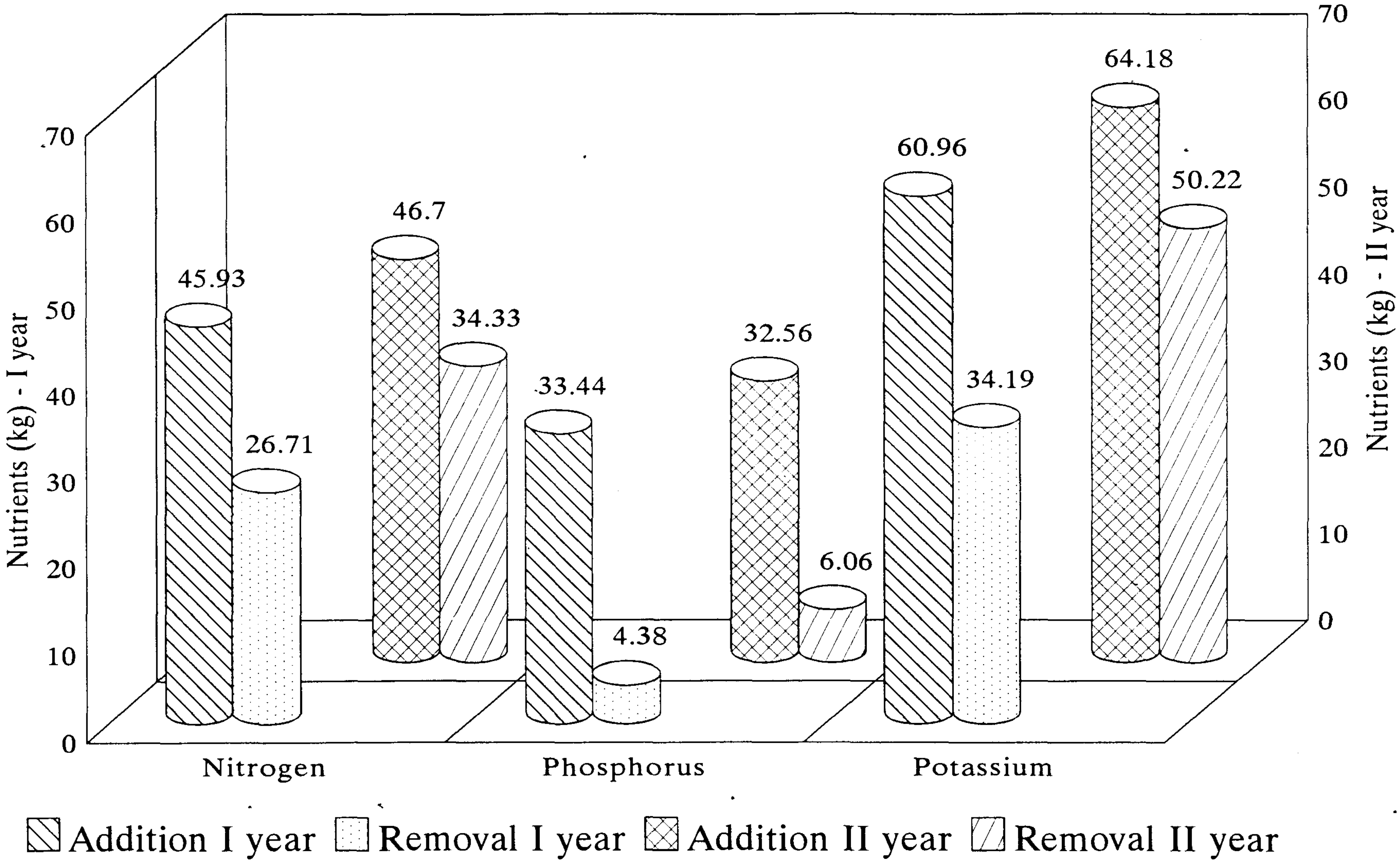


Fig. 31. Nutrient dynamics of Location II

considerable removal of nutrients because of higher frequency of harvesting. In the case of other woody perennials, at both locations, even after repeated harvests, the rate of export of nutrients out of the system were relatively low. Thus, it could be concluded that the closed nutrient cycle known to operate in mixed evergreen forest ecosystems were not strictly operative in the home gardens studied. However, the compensation of the nutrients lost through harvested biomass by addition of manures and fertilizers which is absent under forest ecosystems made the nutrient cycle in home gardens somewhat closed. It could be further concluded that in home gardens dominated by annuals and coconut palms (yielding) judicious application of manures is necessary to sustain its productivity. Also, the inclusion of multipurpose trees, especially nitrogen fixing species, would result in lower rates of export of nutrients from the system and at the same time enrich the soil.

4.2.2.2 Soil properties

4.2.2.2.1 Physical properties

The data on the physical properties (estimated at half yearly intervals) of the homestead soil and its comparison with that in the control for Location I and II are furnished in Tables 34 to 37 respectively. The maximum water holding capacity, porosity and mean weight diameter in the top and bottom soil layers were always higher in the homestead soil when compared to the control.

However, the value of these parameters were comparatively higher at 15 cm depth than at 30 cm, both in the homestead and control. The data on bulk density revealed that the homestead soil was always found to have a lower value than control irrespective of the depth of sampling. The particle density of the soil was more or less same in homestead and open.

At Location I (Table 34), the average maximum water holding capacity (%), porosity (%), bulk density (g/cc) and mean weight diameter (mm) values were 47.35, 51.83, 1.2, 0.82 (15 cm depth) and 33.89, 41.43, 1.5, 0.62 (30 cm depth) respectively in the homestead soil. The corresponding values in the control were 40.94, 44.53, 1.40, 0.65 (15 cm depth) and 35.66, 38.24, 1.58, 0.54 (30 cm depth).

At Location II (Table 35), the homestead soil had an average maximum water holding capacity, porosity, bulk density and mean weight diameter of 46.28, 54.61, 1.22, 0.70 (15 cm depth) and 40.50, 44.91, 1.53, 0.61 (30 cm depth) respectively. The corresponding values in the control were 31.30, 45.91, 1.45, 0.61 (15 cm depth) and 27.89, 40.88, 1.64, 0.57 (30 cm depth).

At both locations (Tables 36 and 37), the moisture content in the homestead soil was always greater than the control at both 15 and 30 cm depths (Figs. 32 and 33). The variation in moisture content between homestead and control was much more pronounced during the months of little or no rainfall. The moisture content was always higher in the bottom layers (30 cm depth) in both homestead and control.

Table 34. Soil physical properties of Location I

	Depth (cm)	Water Holding Capacity (%)	Porosity (%)	Bulk Density (g/cc)	Particle Density (g/cc)	Mean Weight Diameter (mm)
October 1994						
Control	15	42.49	45.23	1.38	2.52	0.72
	30	35.31	38.28	1.58	2.56	0.54
Homestead	15	46.96	51.66	1.16	2.40	0.79
	30	39.50	41.96	1.48	2.55	0.58
April 1995						
Control	15	40.15	42.50	1.41	2.48	0.64
	30	36.95	37.59	1.61	2.58	0.56
Homestead	15	47.10	52.30	1.21	2.38	0.80
	30	38.85	40.39	1.52	2.55	0.65
October 1995						
Control	15	39.95	46.35	1.36	2.53	0.57
	30	34.35	37.59	1.61	2.58	0.55
Homestead	15	46.50	52.15	1.23	2.43	0.86
	30	38.10	40.85	1.52	2.57	0.58
April 1996						
Control	15	41.25	44.62	1.39	2.51	0.62
	30	36.50	38.25	1.58	2.58	0.55
Homestead	15	48.10	49.79	1.20	2.38	0.82
	30	39.50	41.65	1.49	2.55	0.64
October 1996						
Control	15	40.85	43.95	1.39	2.48	0.68
	30	35.20	39.50	1.53	2.60	0.52
Homestead	15	48.10	53.25	1.18	2.37	0.84
	30	38.50	42.30	1.47	2.56	0.65
Average						
Control	15	40.94	44.53	1.40	2.50	0.65
	30	35.66	38.24	1.58	2.58	0.54
Homestead	15	47.35	51.83	1.20	2.39	0.82
	30	38.89	41.43	1.50	2.56	0.62

Table 35. Soil physical properties of Location II

	Depth (cm)	Water Holding Capacity (%)	Porosity (%)	Bulk Density (g/cc)	Particle Density (g/cc)	Mean Weight Diameter (mm)
October 1994						
Control	15	30.73	45.31	1.49	2.72	0.62
	30	28.88	40.50	1.66	2.79	0.56
Homestead	15	46.30	55.30	1.22	2.73	0.68
	30	40.52	44.70	1.52	2.75	0.58
April 1995						
Control	15	29.60	46.41	1.46	2.72	0.60
	30	27.10	41.75	1.59	2.73	0.58
Homestead	15	45.80	53.65	1.21	2.61	0.70
	30	40.30	43.80	1.55	2.76	0.61
October 1995						
Control	15	31.81	44.85	1.39	2.72	0.62
	30	26.02	40.00	1.65	2.75	0.60
Homestead	15	45.92	55.00	1.24	2.74	0.72
	30	40.26	46.00	1.51	2.79	0.61
April 1996						
Control	15	32.41	46.66	1.44	2.70	0.60
	30	29.00	40.65	1.63	2.76	0.56
Homestead	15	47.10	53.43	1.22	2.62	0.66
	30	41.10	44.50	1.53	2.73	0.62
October 1996						
Control	15	31.95	46.30	1.46	2.71	0.59
	30	28.45	41.50	1.65	2.75	0.56
Homestead	15	46.30	55.65	1.23	2.63	0.72
	30	40.30	45.55	1.53	2.71	0.63
Average						
Control	15	31.30	45.91	1.45	2.71	0.61
	30	27.89	40.88	1.64	2.76	0.57
Homestead	15	46.28	54.61	1.22	2.67	0.70
	30	40.50	44.91	1.53	2.75	0.61

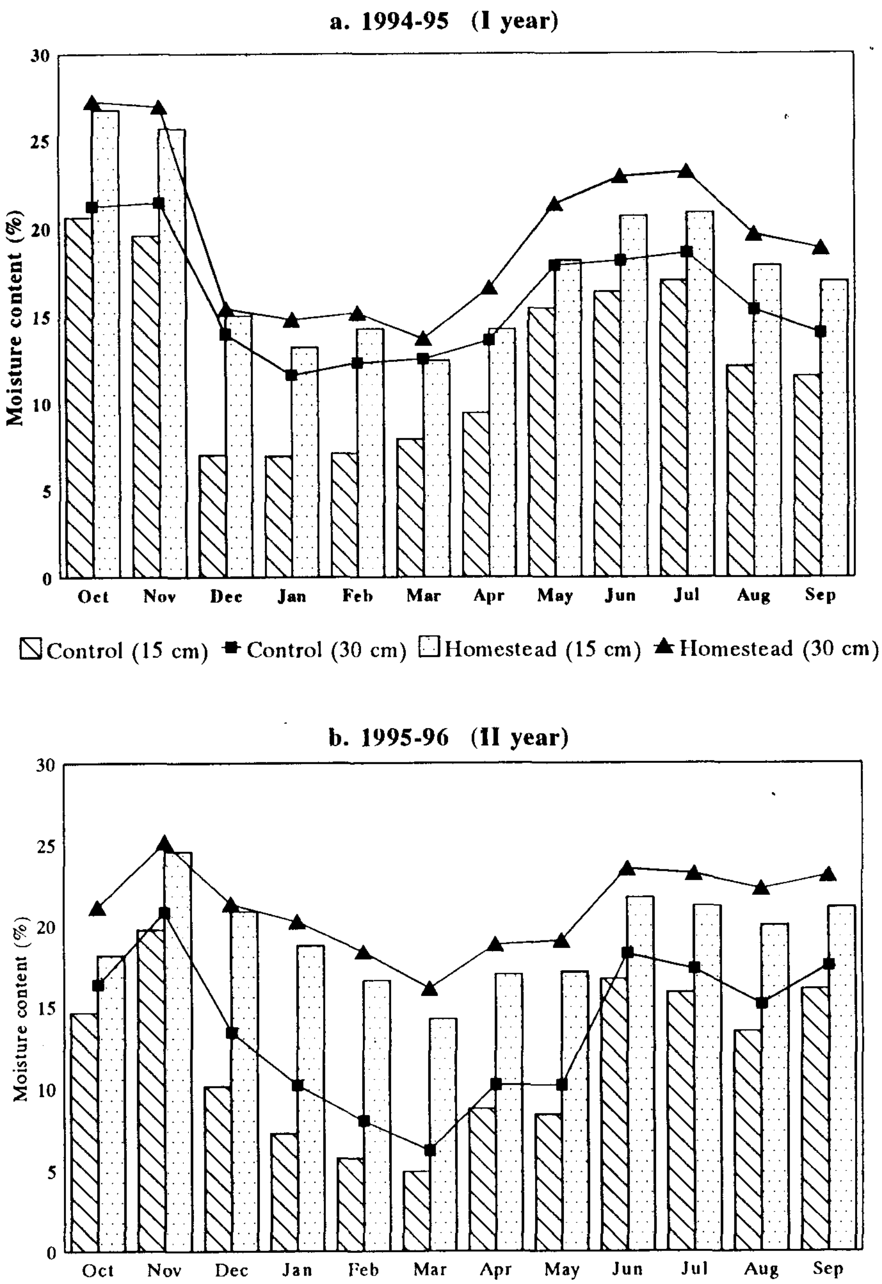


Fig. 32. Moisture content of the soil at Location I

Table 36. Soil moisture content of Location I

Month	Depth (cm)	Moisture content (%)			
		I year (1994-95)		II year (1995-96)	
		Control	Homestead	Control	Homestead
October	15	20.62	26.72	14.62	18.17
	30	21.23	27.21	16.35	21.14
November	15	19.58	25.64	19.73	24.55
	30	21.46	26.91	20.81	25.12
December	15	7.00	15.00	10.13	20.84
	30	13.97	15.40	13.38	21.31
January	15	6.92	13.23	7.26	18.76
	30	11.62	14.79	10.17	20.22
February	15	7.08	14.28	5.74	16.58
	30	12.32	15.16	8.03	18.36
March	15	7.92	12.46	4.93	14.22
	30	12.55	13.71	6.20	16.08
April	15	9.44	14.23	8.76	16.97
	30	13.61	16.57	10.20	18.82
May	15	15.41	18.14	8.40	17.11
	30	17.82	21.33	10.18	19.06
June	15	16.32	20.65	16.70	21.71
	30	18.13	22.91	18.25	23.48
July	15	16.97	20.84	15.84	21.20
	30	18.56	23.16	17.30	23.18
August	15	12.12	17.85	13.48	20.00
	30	15.33	19.64	15.14	22.26
September	15	11.56	16.92	16.06	21.10
	30	14.03	18.83	17.53	23.08

Table 37. Soil moisture content of Location II

Month	Depth (cm)	Moisture content (%)			
		I year (1994-95)		II year (1995-96)	
		Control	Homestead	Control	Homestead
October	15	12.80	15.24	13.71	15.35
	30	13.09	17.82	14.67	16.81
November	15	11.63	14.69	14.80	16.94
	30	13.29	16.28	14.81	17.07
December	15	5.29	11.32	8.14	14.95
	30	7.50	12.04	9.13	16.16
January	15	1.56	6.46	3.83	10.75
	30	3.13	8.77	5.67	12.60
February	15	1.23	3.16	1.48	6.30
	30	2.65	5.01	3.90	8.52
March	15	1.18	4.10	1.15	4.24
	30	2.09	5.06	2.95	7.14
April	15	2.02	3.62	11.08	12.90
	30	2.92	4.29	12.40	14.00
May	15	7.86	9.32	7.86	11.38
	30	9.05	11.56	9.02	13.18
June	15	12.54	14.93	14.26	16.32
	30	13.26	16.15	14.78	17.14
July	15	10.97	14.57	12.84	16.10
	30	11.82	16.00	13.32	17.00
August	15	8.41	13.56	10.46	15.14
	30	9.32	14.11	12.06	16.28
September	15	12.15	14.26	12.92	15.98
	30	13.33	16.19	13.24	16.52

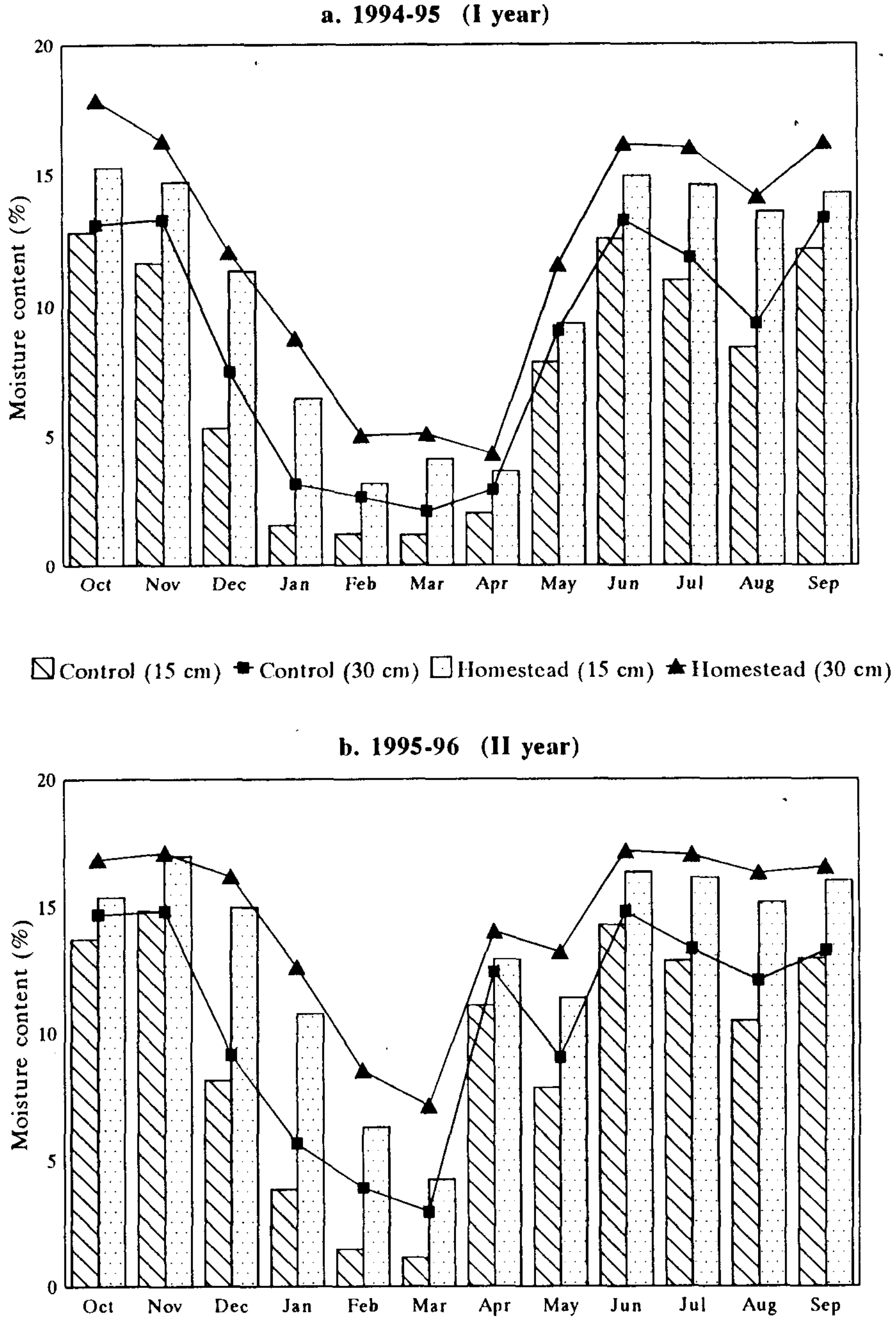


Fig. 33. Moisture content of the soil at Location II

The study revealed that the physical properties of the homestead soil were always better than that of the control. The higher values of maximum water holding capacity and porosity indicate that the homestead soil was capable of holding and supplying increased quantities of moisture to the crops. The higher mean weight diameter values of the soil in the homestead indicates its greater aggregate stability. The lower bulk density in the homestead soil might be due to its higher organic carbon content (Tables 38 and 39). The addition of significant litter and organic manures, recycling of plant wastes, all of which aids in improving the organic matter content of the soil, might be the reason for the enhanced soil physical properties in the homesteads and its maintenance. The effect of organic manures in increasing the water holding capacity of the soil has been reported by Biswas and Khosla (1971); Rajput and Sastry (1987) and Pushkala and Sumam (1996). Enhancement of soil physical properties like porosity and moisture retention through organic matter and litter addition by trees has been reported by Nair (1993) and Hegde *et al.* (1993). Similar results of lower bulk density, higher water holding capacity and moisture status in homestead soil consequent to litter and organic manure addition when compared to control was obtained by Happy Mathew *et al.* (1996).

The higher soil moisture status in the home gardens might also be attributed to the reduction in evaporation losses as a result of the higher humidity maintained by the intense tree / crop canopy cover as suggested by Nair and Balakrishnan (1977). Also, the litter layer under trees acts as a one-way barrier to moisture flow since it increases the infiltration of rain water, simultaneously reducing evaporation from soil (Muller-Samaan, 1986).

4.2.2.2.2 Chemical properties

Comparison of soil chemical properties of the homestead with that of control (estimated at half yearly intervals) for Location I and II are presented in Tables 38 and 39 respectively.

At Location I (Table 38), the average values of pH, organic carbon (%), available N, P and K contents (kg/ha) of the homestead soil were 5.65, 1.13, 544.43, 66.78, 442.72 (15 cm depth) and 5.76, 0.54, 386.06, 47.18, 400.78 (30 cm depth) respectively. The corresponding values in the control were 5.79, 0.57, 238.60, 50.10, 173.66 (15 cm depth) and 5.88, 0.41, 193.40, 38.01, 151.06 (30 cm depth).

At Location II (Table 39), the average pH, organic carbon (%), available N, P and K contents (kg/ha) of the homestead soil were 5.55, 0.85, 479.83, 76.89, 393.52 (15 cm depth) and 5.79, 0.68, 331.39, 63.03, 356.37 (30 cm depth) respectively. The corresponding values in the control were 5.90, 0.72, 224.34, 37.40, 340.12 (15 cm depth) and 5.98, 0.47, 190.31, 31.98, 281.74 (30 cm depth).

The data revealed that the organic carbon content and available N, P and K status were higher in the homestead soil as compared to that in the control, irrespective of the depth of sampling. The value of these parameters were higher at 15 cm depth. However, the pH of the homestead soil was lower than the control.

Table 38. Soil chemical properties of Location I

	Depth (cm)	pH	Organic carbon (%)	Available Nitrogen (kg/ha)	Available Phosphorus (kg/ha)	Available Potassium (kg/ha)
October 1994						
Control	15	5.86	0.60	235.20	51.29	168.00
	30	5.91	0.38	181.20	39.50	151.50
Homestead	15	5.61	1.02	564.47	66.68	432.00
	30	5.75	0.51	385.50	44.50	395.50
April 1995						
Control	15	5.72	0.58	245.30	48.50	172.30
	30	5.82	0.41	195.30	32.50	148.50
Homestead	15	5.68	1.12	522.80	64.95	451.50
	30	5.72	0.53	377.50	45.35	410.50
October 1995						
Control	15	5.81	0.53	240.30	52.50	170.50
	30	5.95	0.43	198.50	41.30	159.30
Homestead	15	5.58	1.20	575.80	67.40	442.50
	30	5.73	0.52	391.50	48.70	401.70
April 1996						
Control	15	5.76	0.56	232.00	47.20	179.20
	30	5.88	0.42	194.40	34.02	141.31
Homestead	15	5.71	1.14	518.80	66.68	438.80
	30	5.86	0.56	388.30	47.83	396.70
October 1996						
Control	15	5.78	0.58	240.20	51.00	178.31
	30	5.86	0.39	197.50	42.75	154.70
Homestead	15	5.68	1.18	540.30	68.20	448.80
	30	5.74	0.56	387.50	49.50	399.50
Average						
Control	15	5.79	0.57	238.60	50.10	173.66
	30	5.88	0.41	193.40	38.01	151.06
Homestead	15	5.65	1.13	544.43	66.78	442.72
	30	5.76	0.54	386.06	47.18	400.78

Table 39. Soil chemical properties of Location II

	Depth (cm)	pH	Organic carbon (%)	Available Nitrogen (kg/ha)	Available Phosphorus (kg/ha)	Available Potassium (kg/ha)
October 1994						
Control	15	5.94	0.75	219.52	35.90	336.00
	30	6.10	0.44	183.54	31.36	288.21
Homestead	15	5.66	0.83	470.40	76.94	384.00
	30	5.85	0.68	329.82	62.31	361.45
April 1995						
Control	15	5.86	0.68	223.50	38.50	341.50
	30	5.95	0.46	195.20	30.65	270.40
Homestead	15	5.55	0.85	475.50	74.35	391.50
	30	5.75	0.67	330.62	63.25	340.50
October 1995						
Control	15	5.87	0.71	224.50	37.41	340.50
	30	5.91	0.48	195.60	32.50	310.50
Homestead	15	5.45	0.85	490.85	77.41	401.30
	30	5.70	0.67	330.50	63.51	360.40
April 1996						
Control	15	5.89	0.73	226.20	36.10	339.86
	30	5.96	0.46	189.70	32.80	288.30
Homestead	15	5.51	0.86	482.91	78.10	393.31
	30	5.81	0.69	333.40	63.30	348.40
October 1996						
Control	15	5.92	0.74	228.00	39.10	342.74
	30	5.97	0.50	187.50	32.60	251.30
Homestead	15	5.57	0.87	479.50	77.65	397.50
	30	5.82	0.69	332.60	62.80	371.10
Average						
Control	15	5.90	0.72	224.34	37.40	340.12
	30	5.98	0.47	190.31	31.98	281.74
Homestead	15	5.55	0.85	479.83	76.89	393.52
	30	5.79	0.68	331.39	63.03	356.37

The fertility status of the soil of both the homesteads was much higher than that of their respective controls. The higher organic carbon and nutrient status in the homesteads soil might be due to the combined addition of organic manures and recycled waste. Though the harvested biomass removed substantial quantities of nutrients, still the higher values might be due to the return of nutrients back to the soil through the various nutrient cycling processes. The plant nutrients taken up by trees from lower horizons are returned to the soil through leaf shedding, stemflow and throughfall and thus helped in maintaining a fairly high soil fertility status. These findings corroborate with the reports of Mitchell *et al.* (1975); Ovington (1962); Switzer and Nelson (1972) and Happy Mathew *et al.* (1996). The role of trees in soil enrichment has also been reported by Nair (1993) and Korikanthimath *et al.* (1996).

It could be seen from the present study that the nutrient status of the top soil (15 cm depth) was always higher than that in the bottom layers (30 cm depth). This might be due to the fact that nutrient addition enriches the top soil as compared to sub soil layers. The enhancement of nutrient status beneath tree canopies due to canopy capture of precipitation input and addition of litter was reported by Kellman (1979).

The lower pH values in the homestead was probably due to the release of organic acids following decomposition of organic matter in the soil and subsequent increased microbial activity.

4.2.2.2.3 Microbiological properties

The population of different micro-organisms in the homestead soil and that in the control at Location I and II are given in Tables 40 and 41 respectively.

At Location I (Table 40), the fungal population was found to vary from 4.00 x 10^4 - 14.00 x 10^4 in the homestead and 0.66 x 10^4 - 5.33 x 10^4 in the control (Fig. 34a). The bacterial count attained a value as high as 42.33 x 10^8 in the homestead, whereas, in the control the maximum count reached was 25.00 x 10^8 (Fig. 34b). The actinomycete (Fig. 34c) and phosphorous solubilising bacteria population (Fig. 34d) was found to vary from 1.33 x 10^6 - 3.00 x 10^6 and 2.66 x 10^6 - 6.00 x 10^6 respectively in the homestead, while in the control, the corresponding ranges were 0.66 x 10^6 - 1.33 x 10^6 and 1.33 x 10^6 - 2.33 x 10^6.

At Location II (Table 41), the fungal population was found to vary from 11.00 x 10^4 - 16 x 10^4 in the homestead and 3.66 x 10^4 - 9.00 x 10^4 in the control (Fig. 35a). The bacterial count attained a value as high as 38.00 x 10^8 in the homestead and that in the control was 17.00 x 10^8 (Fig. 35b). The actinomycete (Fig. 35c) and phosphorous solubilising bacteria population (Fig. 35d) was found to vary from 2.00 x 10^6 - 4.00 x 10^6 and 4.00 x 10^6 - 8.33 x 10^6 respectively in the homestead, while in the control the corresponding ranges were 0.33 x 10^6 - 1.33 x 10^6 and 1.66 x 10^6 - 4.00 x 10^6.

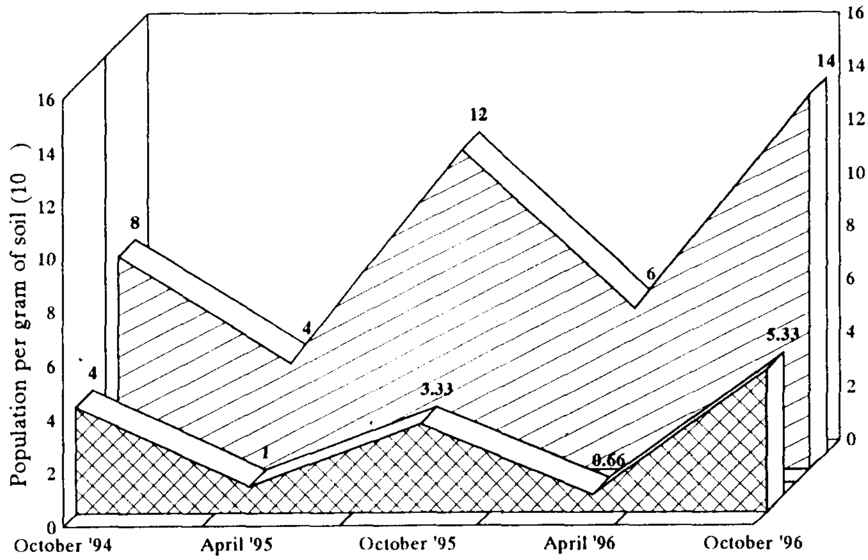
Table 40. Soil microbiology of Location I

Micro-organism	October 1994		April 1995		October 1995	
	Homestead	Control	Homestead	Control	Homestead	Control
Fungus (10^4)	8.00	4.00	4.00	1.00	12.00	3.33
Bacteria (10^8)	32.00	25.00	26.00	13.00	35.00	18.00
Actinomycetes (10^6)	2.00	1.00	2.00	1.00	2.33	1.00
Phosphorus solubilising bacteria (10^6)	3.00	2.00	3.00	2.00	5.33	2.33

Micro-organism	April 1996		October 1996	
	Homestead	Control	Homestead	Control
Fungus (10^4)	6.00	0.66	14.00	5.33
Bacteria (10^8)	18.66	10.00	42.33	16.00
Actinomycetes (10^6)	1.33	0.66	3.00	1.33
Phosphorus solubilising bacteria (10^6)	2.66	1.33	6.00	2.00

Figures indicate the population per gram of soil

a. Population of Fungi



b. Population of Bacteria

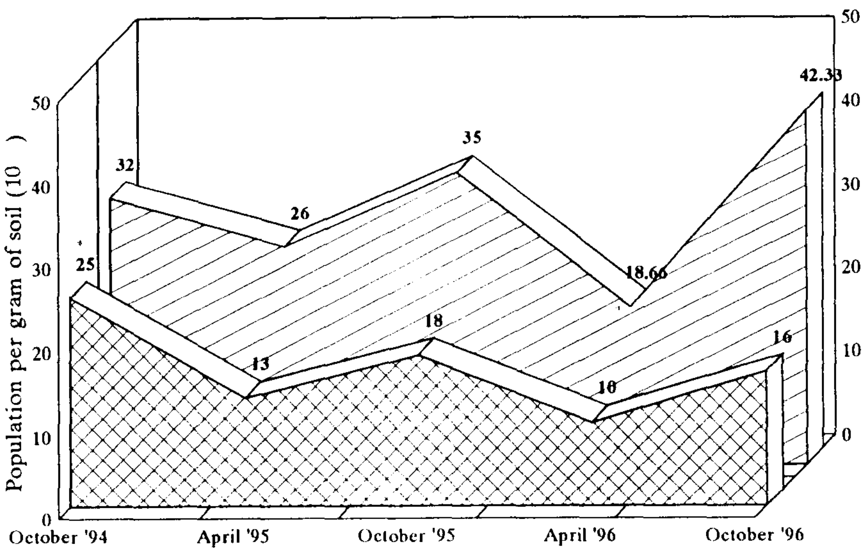
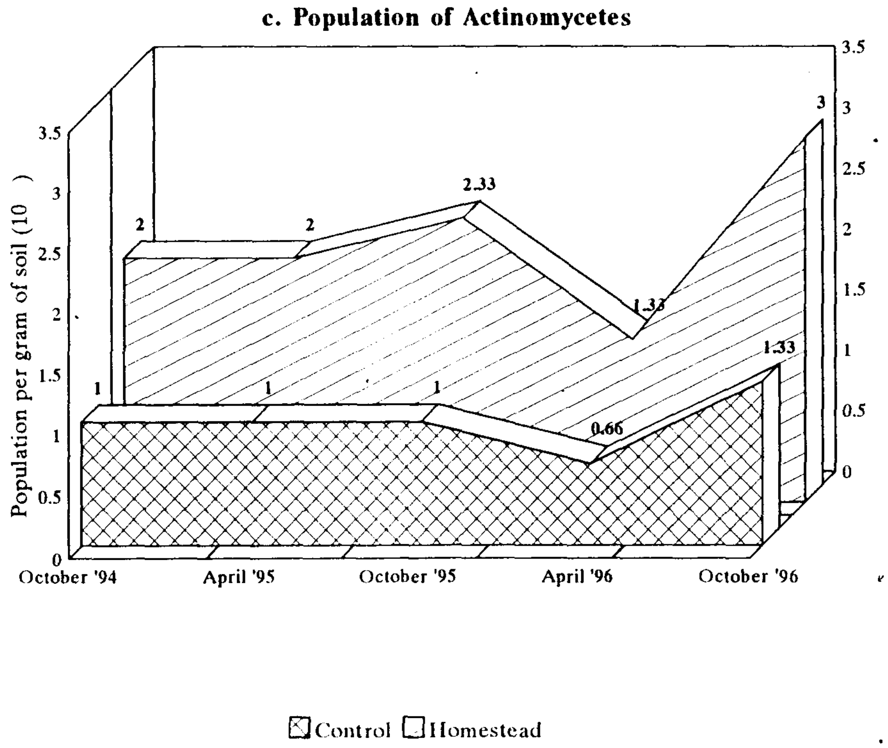


Fig. 34. Soil microbiology of Location I



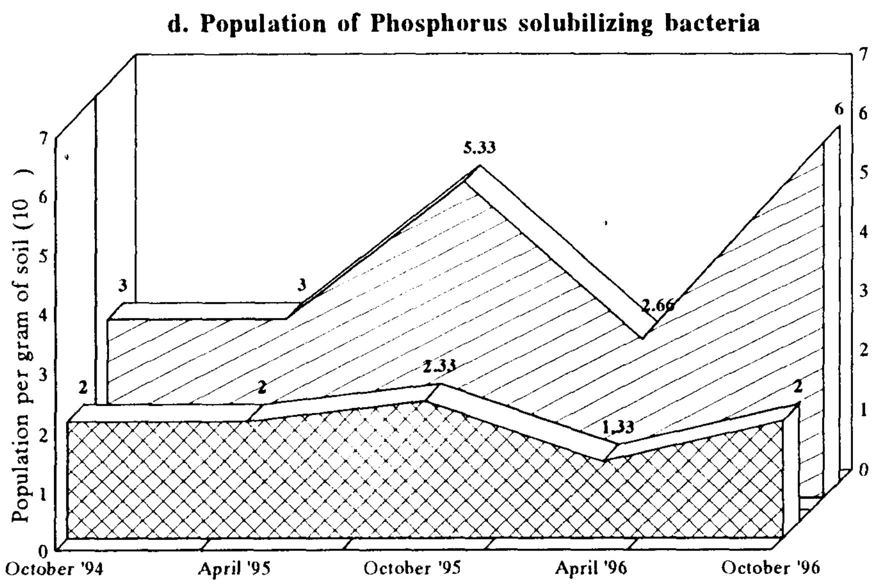


Fig. 34. Soil microbiology of Location I

Table 41. Soil microbiology of Location II

Micro-organism	October 1994		April 1995		October 1995	
	Homestead	Control	Homested	Control	Homestead	Control
Fungus (10^4)	12.00	9.00	11.00	9.00	14.00	6.00
Bacteria (10^8)	30.00	17.00	22.00	15.00	32.00	16.00
Actinomycetes (10^6)	2.00	1.00	2.00	1.00	3.33	1.33
Phosphorus solubilising bacteria (10^6)	4.00	3.00	4.00	3.00	6.66	3.66

Micro-organism	April 1996		October 1996	
	Homestead	Control	Homestead	Control
Fungus (10^4)	11.33	3.66	16.00	5.33
Bacteria (10^8)	17.33	11.33	38.00	14.00
Actinomycetes (10^6)	2.33	0.33	4.00	1.00
Phosphorus solubilising bacteria (10^6)	4.66	1.66	8.33	4.00

Figures indicate the population per gram of soil

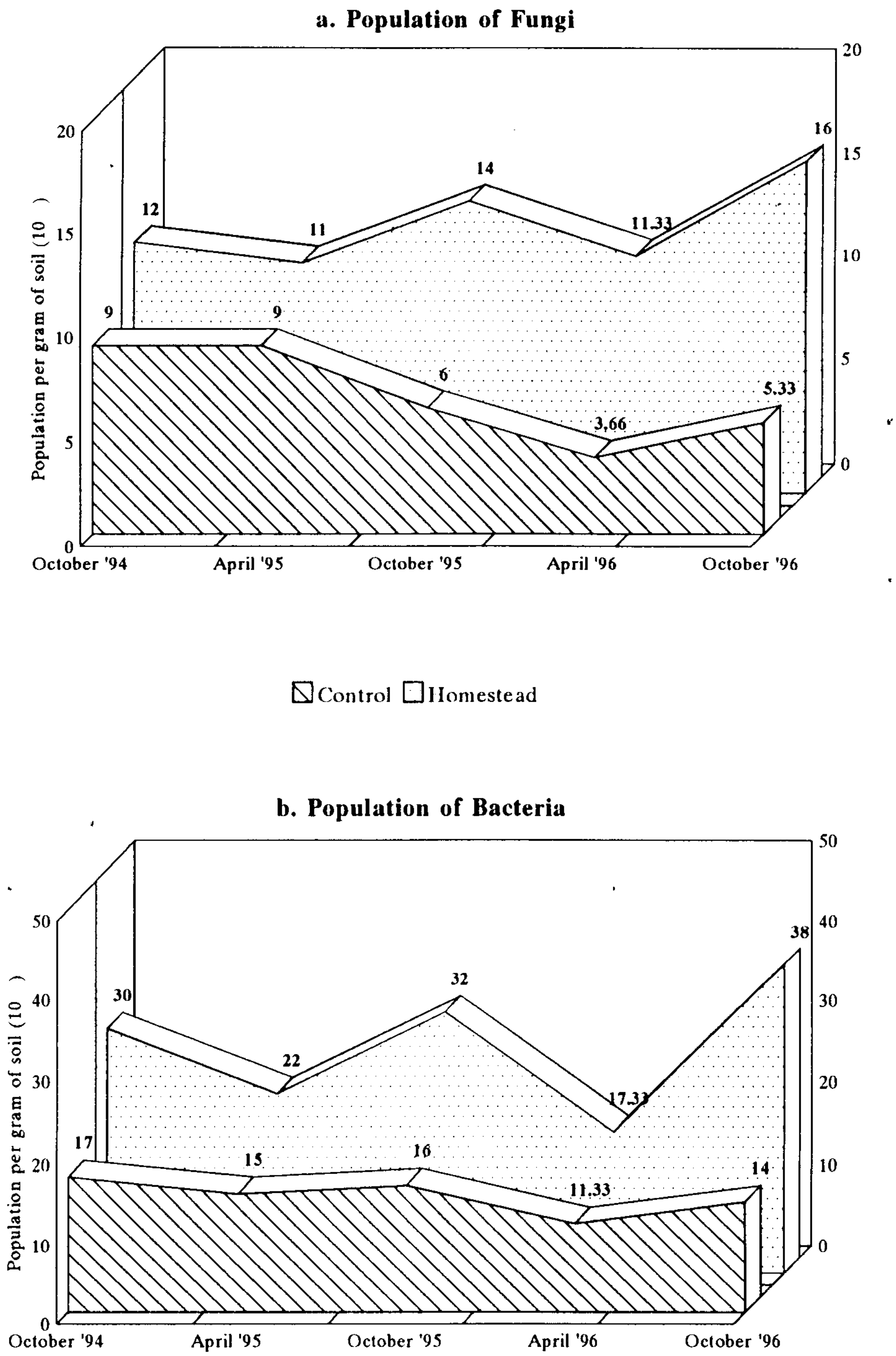
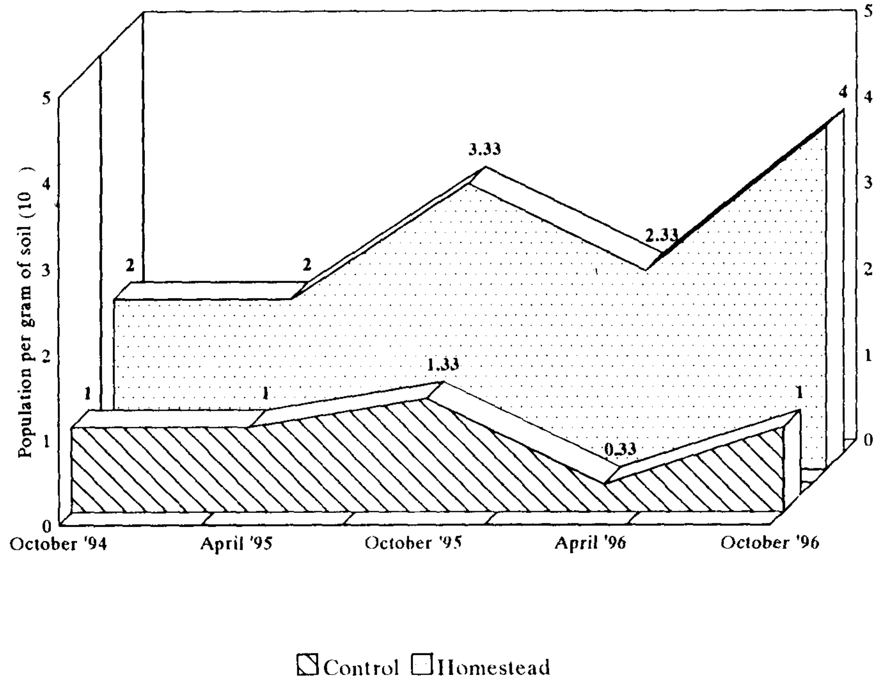


Fig. 35. Soil microbiology of Location II

c. Population of Actinomycetes



d. Population of Phosphorus solubilizing bacteria

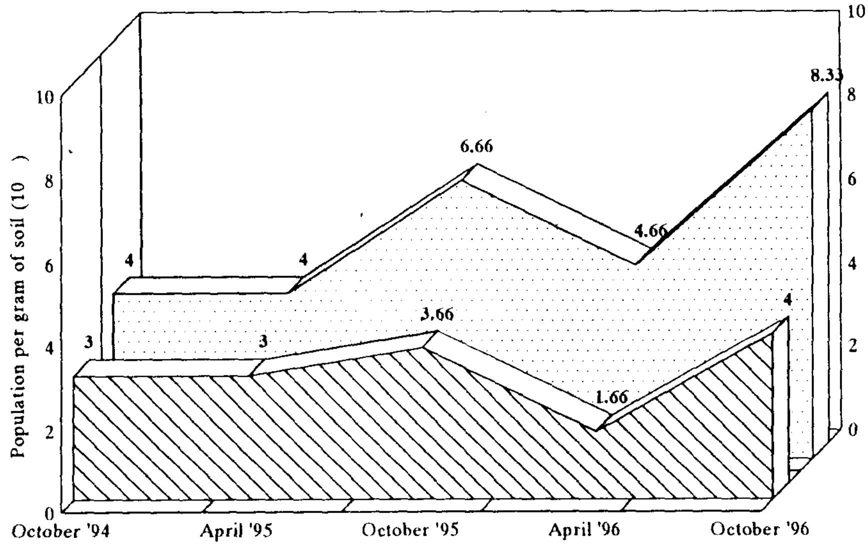


Fig. 35. Soil microbiology of Location II

It is evident from the study, in both locations, that the population of all the micro-organisms in the homestead soil recorded a very high value during the period under study as compared to the control, which is an indication of the intense microbial activity in the homestead (Figs. 34 and 35). The higher microbial population recorded in the home garden could be attributed to the addition of large quantities of organic matter. The subsequent high organic carbon status of the soil might have also helped in the proliferation of these micro-organisms. The effect of litterfall in increasing the number of micro-organisms was reported by Nair and Rao (1977) in an intensively cropped coconut - cocoa mixed plantation. The effect of organic matter in increasing the microbial population has also been reported by Gaur and Mukherjee (1980). The favourable soil temperature, soil moisture and relative humidity in the home gardens might also have aided in the multiplication of the micro-organisms when compared to open control.

There was also seasonal variation in the soil micro-organisms. As a matter of fact, the logical reason for the variation in microflora might be the high intensity of cropping, crop diversity, planting pattern of crops and the varied management practices adopted by the farmer during the different periods. The variation in microbial population with the type of crops has been reported by Clark (1949) and Nair (1973).

4.2.2.3 Microclimate

4.2.2.3.1 Temperature and rainfall

The microclimatic conditions at Location I and II during the period under study is presented in Tables 42 and 43 respectively. At Location I, the monthly mean maximum and minimum temperature were found to range from 25.60 - 31.00°C and 17.73 - 24.60°C in the first year respectively, while in the second year the corresponding values were 29.20 - 33.98°C and 20.8 - 26.62°C (Fig. 36a and b). The total rainfall received in the first and second years was 130.40 and 107.90 cm respectively. At Location II, the monthly mean maximum and minimum temperature was found to range from 28.60 - 32.19°C and 23.60 - 27.76°C respectively in the first year, while in the second year it ranged from 28.90 - 33.51°C and 20.12 - 26.11°C (Fig. 37 a and b). The total rainfall received was 89.90 (I year) and 118.80 cm (II year).

4.2.2.3.2 Relative humidity

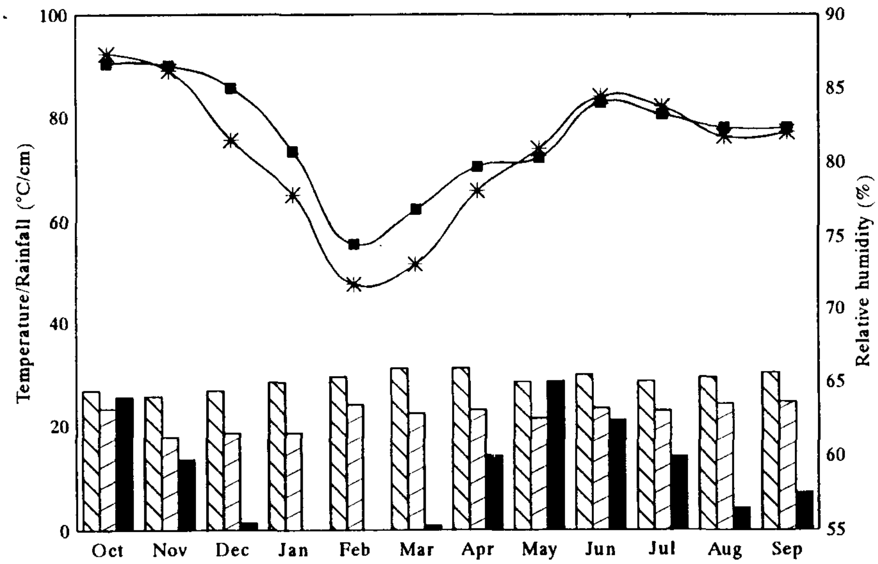
The monthly mean relative humidity in the homestead and open, at Location I and II are given in Tables 42 and 43 respectively.

At Location I (Table 42), the relative humidity in the open ranged from 71.65 - 87.30 per cent (I year) and 65.23 - 84.50 per cent (II year) while in the homestead it ranged from 74.45 - 86.65 per cent (I year) and 69.12 - 83.60 per cent (II year). The relative humidity in the home garden was always greater than open (Figs 36a and 36b), except in the months of very high rainfall (October '94; May, June, July, October and November '95; June, July and September '96).

Table 42. Microclimate at Location I

Month	Average air temperature		Total rainfall	Relative humidity		Soil temperature (°C)			
	Maximum (°C)	Minimum (°C)	(cm)	Open (%)	Homestead (%)	Open 15 (cm)	Open 30 (cm)	Homestead 15 (cm)	Homestead 30 (cm)
October 1994	26.70	23.23	25.4	87.30	86.65	25.20	26.00	24.09	24.28
November	25.60	17.73	13.5	86.15	86.50	26.00	27.00	24.79	25.08
December	26.68	18.46	1.4	81.45	85.00	26.50	27.50	24.64	25.32
Jan.1995	28.33	18.50	0.0	77.80	80.70	28.00	29.00	26.00	27.00
February	29.35	24.00	0.0	71.65	74.45	30.30	31.00	27.60	28.80
March	31.00	22.40	0.8	73.05	76.80	30.20	31.00	27.40	28.80
April	31.00	23.00	14.2	78.05	79.65	28.20	29.50	25.80	27.30
May	28.43	21.37	28.5	80.87	80.27	26.70	27.90	24.32	26.01
June	29.80	23.40	21.1	84.40	84.00	27.70	29.60	26.40	27.60
July	28.60	22.90	14.1	83.70	83.20	28.20	30.00	27.50	29.10
August	29.30	24.20	4.2	81.70	82.30	29.70	30.80	27.30	28.00
September	30.20	24.60	7.2	82.00	82.30	30.30	31.20	27.00	28.00
October 1995	30.70	24.10	12.5	82.80	82.40	30.00	31.80	28.80	29.20
November	30.50	23.50	24.6	84.50	83.60	29.10	30.60	27.50	28.30
December	29.20	20.80	0.0	79.80	81.20	30.00	31.90	28.10	29.70
Jan.1996	32.22	25.44	0.0	69.67	72.48	32.00	32.80	28.60	29.90
February	32.32	26.44	0.0	68.55	70.89	32.60	33.20	29.10	30.30
March	33.98	26.62	0.0	65.23	69.12	33.40	33.80	29.70	30.80
April	32.17	26.02	8.0	71.07	72.00	30.50	31.30	27.90	28.50
May	33.00	26.22	3.2	67.32	70.90	31.60	32.20	27.80	28.30
June	30.75	25.60	18.1	80.00	79.70	28.20	29.10	25.40	26.00
July	30.20	25.66	15.4	81.48	81.20	28.80	29.40	26.00	26.70
August	30.88	25.43	9.8	79.80	80.76	29.50	30.30	26.30	27.00
September	29.53	25.20	16.3	82.74	82.00	27.80	28.30	25.00	25.90

a. 1994-95 (I year)



Max. Temp Min. Temp RH Open RH Homestead Rainfall

b. 1995-96 (II year)

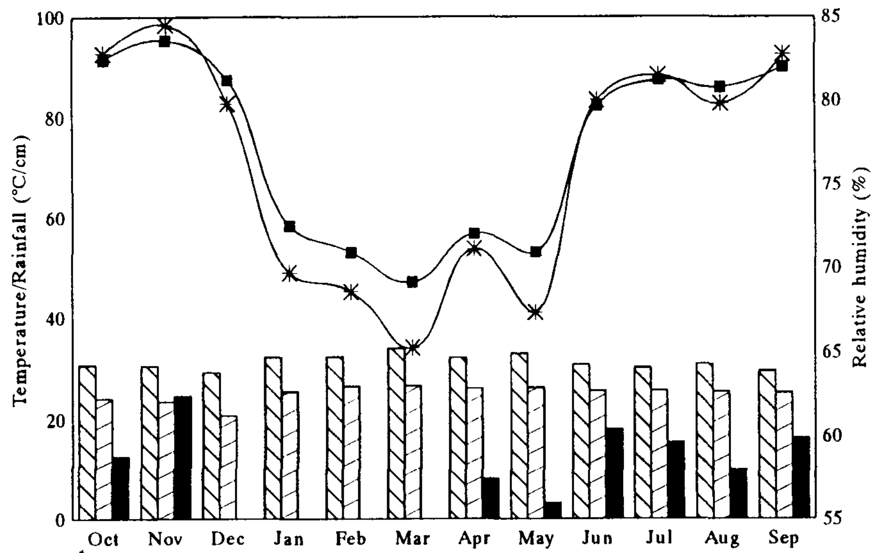


Fig. 36. Microclimate of Location I

Table 43. Microclimate at Location II

Month	Average air temperature		Total rainfall	Relative humidity		Soil temperature (°C)			
						Open		Homestead	
	Maximum (°C)	Minimum (°C)	(cm)	Open (%)	Homestead (%)	15 (cm)	30 (cm)	15 (cm)	30 (cm)
October 1994	28.70	23.60	6.3	81.41	80.17	24.92	25.63	23.13	23.80
November	28.60	25.20	15.0	83.52	81.79	24.68	24.91	23.00	23.18
December	30.00	25.00	0.0	77.35	78.62	28.08	30.38	25.00	26.07
Jan.1995	32.19	26.77	0.0	75.71	76.94	30.06	31.02	27.44	28.08
February	30.92	26.05	0.0	72.04	74.11	31.45	31.62	28.32	28.86
March	31.87	26.16	0.7	72.77	72.80	30.04	31.04	27.58	28.14
April	29.48	27.76	13.0	79.84	78.21	25.63	26.73	24.32	25.69
May	28.86	26.24	11.2	79.41	78.36	25.01	26.49	23.91	24.75
June	28.90	24.69	17.9	83.40	83.00	26.90	27.30	25.40	26.30
July	30.74	24.13	13.3	83.00	82.70	28.70	29.90	26.20	27.40
August	29.90	26.94	3.7	81.30	81.80	29.70	30.30	26.50	27.80
September	28.97	24.40	8.8	81.70	81.40	27.90	28.70	25.60	26.70
October 1995	30.48	22.81	14.5	83.60	82.80	28.30	29.20	24.00	25.20
November	29.80	21.70	20.2	84.20	83.00	25.10	26.00	22.20	23.40
December	28.90	20.12	0.0	79.60	81.10	29.70	30.80	25.40	26.70
Jan.1996	31.63	24.19	0.0	70.67	73.12	31.80	32.50	26.80	28.00
February	32.01	25.60	0.0	68.89	71.55	32.40	32.90	27.60	29.50
March	33.51	26.11	0.0	66.48	68.48	33.10	33.70	28.70	30.80
April	32.04	25.94	25.4	74.15	73.07	30.00	31.10	25.80	27.30
May	32.85	26.05	4.7	70.15	72.60	31.60	32.20	26.70	28.00
June	30.25	25.15	21.0	80.60	80.15	27.10	28.30	25.00	26.20
July	30.21	24.30	12.9	81.82	81.44	28.30	29.00	25.80	26.60
August	29.33	24.25	7.4	79.46	80.63	29.10	29.80	26.00	27.10
September	29.87	24.55	12.7	81.62	80.80	28.10	29.20	25.10	26.00

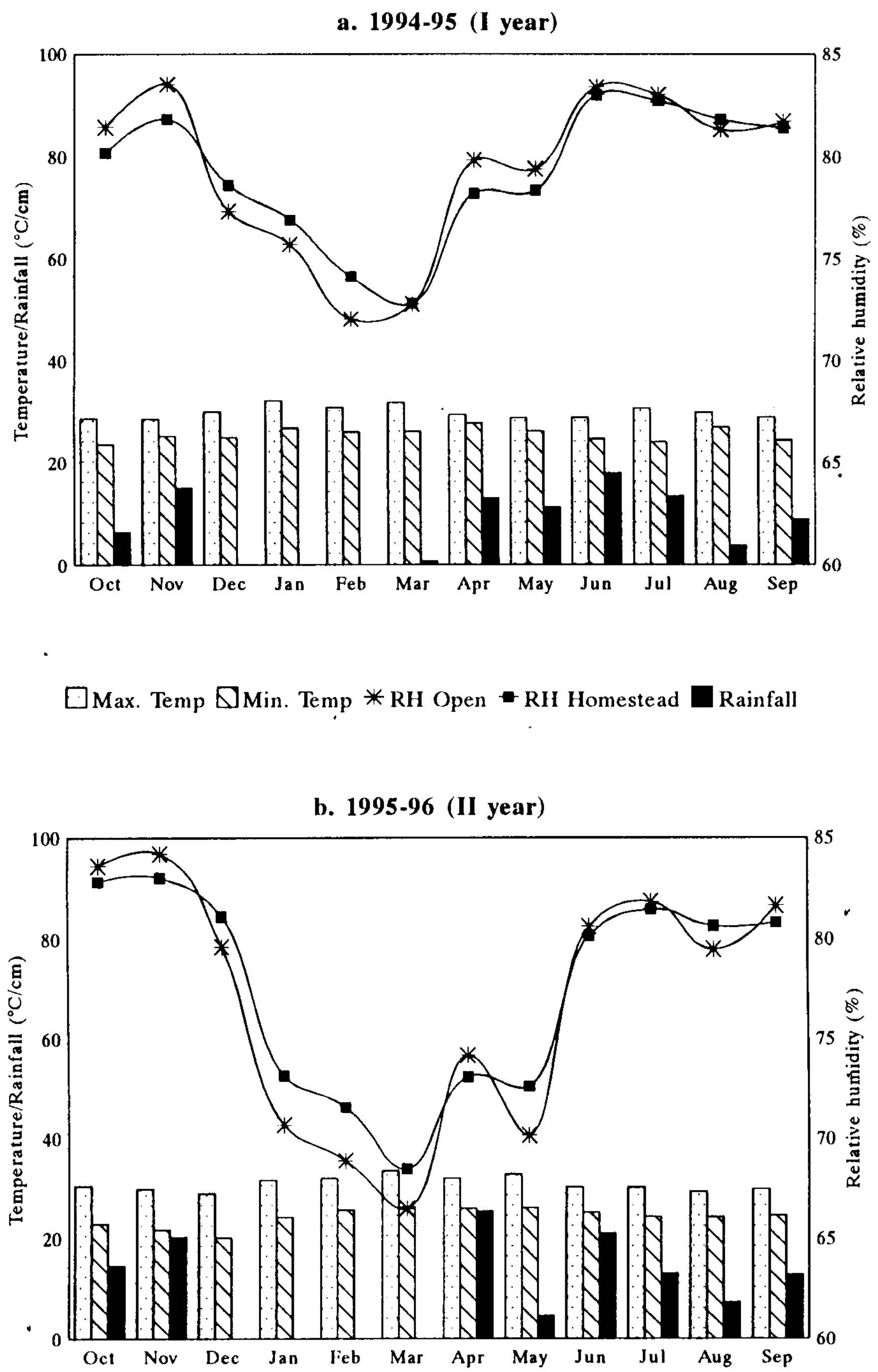


Fig. 37. Microclimate of Location II

At Location II (Table 43), the humidity in the open ranged from 72.04 - 83.52 per cent (I year) and 66.48 - 84.20 per cent (II year) while in the home garden it ranged from 72.80 - 83.00 per cent (I year) and 68.48 - 83.00 per cent (II year). The relative humidity in the open was greater than in the home garden (Figs. 37a and b) during the months of heavy rainfall (October and November '94; April, May, June, July, September, October and November '95; April, June, July and September '96). However, during the months of little or no rain, relative humidity was higher in the home garden.

From the results, it is presumed that the tree canopy helped to maintain the relative humidity in the home gardens at an optimum level (Figures 36 and 37). The relative humidity was prevented from exceeding a critical level (as evident during the months of heavy rain) and also from falling below a critical level (during months of little or no rain). Thus, it could be inferred that the tree / crop combination acted as a buffer against drastic changes in ecoclimate. Similar conclusions were made by Nair and Balakrishnan (1977).

The higher relative humidity in the home garden during periods of little or no rain might have a beneficial effect such as reduction in air temperature and evaporation. The reduction in evaporation losses as a result of high humidity has been recorded by Nair and Balakrishnan (1977).

4.2.2.3.3 Soil temperature

The data on the monthly mean soil temperature (at two depths) in the home garden and open control at Location I and II are given in Tables 42 and 43.

At Location I (Table 42), the soil temperature in the homestead was found to range from 24.09 - 27.60°C (I year) and 25.00 - 29.70°C (II year) at 15 cm depth and 24.28 - 29.10°C (I year) and 25.90 - 30.80°C (II year) at 30 cm depth. In the open control at 15 cm depth the soil temperature ranged from 25.20 - 30.30°C (I year) and 27.80 - 33.40°C (II year) while at 30 cm depth it ranged from 26.00 - 31.20°C (I year) and 28.30 - 33.80°C (II year). The soil temperature in the home garden was always at least one degree less than that in the open, irrespective of the depth of measurement (Figs. 38a and b).

At Location II (Table 43), the soil temperature in the home garden ranged from 23.00 - 28.32°C (I year) and 22.20 - 28.70°C (II year) at 15 cm depth, while at 30 cm it ranged from 23.18 - 28.86°C (I year) and 23.40 - 30.80°C (II year). However, in the open the values were much higher and ranged from 24.68 - 31.45°C (I year) and 25.10 - 33.10°C (II year) at 15 cm depth (Figs. 39 a and b), while at 30 cm depth it ranged from 24.91 - 31.62°C (I year) and 26.00 - 33.70°C (II year).

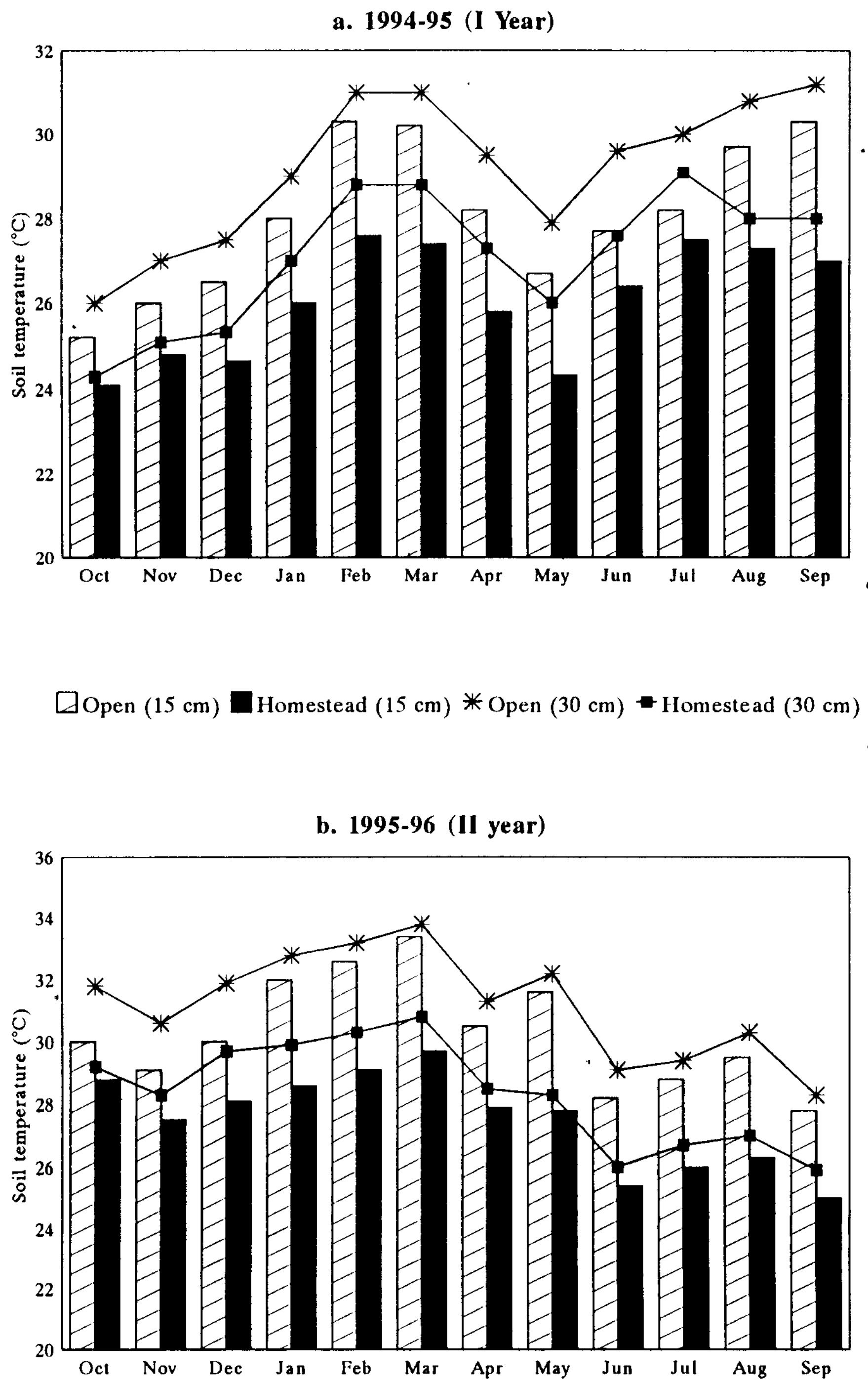


Fig. 38. Soil temperature at Location I

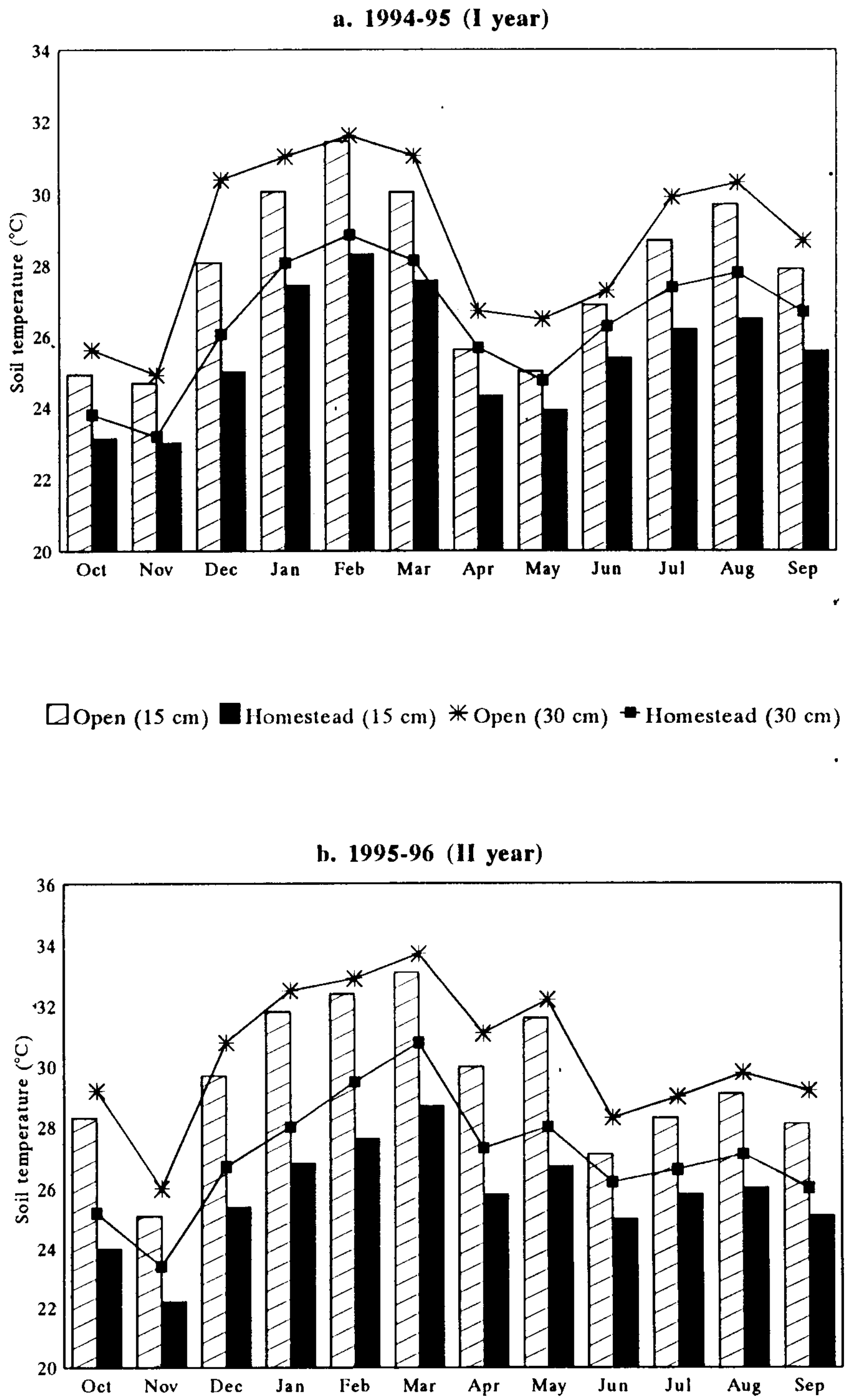


Fig. 39. Soil temperature at Location II

The results revealed that the soil temperature in the home garden was always lower than that in the open, irrespective of the depth and interval of measurement (Figs. 38 and 39). Also, the soil temperature was found to increase with depth both in the homestead and open. The soil temperature, in general, was found to be lesser than the maximum atmospheric temperature. However, the temperature differential was narrow during the months with little or no rain.

The lower soil temperatures experienced in the home gardens might be due to the intense canopy cover provided by the tree / crop components, planted at high cropping intensities. Consequently the reduced exposure of the soil to incident solar radiation results in reduced soil temperatures. Nair (1983 and 1984), Nair and Balakrishnan (1977) and Happy Mathew *et al* (1996) under various situations in home gardens reported similar findings. According to Harrison-Murray and Lal (1979) the surface litter cover provided by the tree components reduces the ground surface temperature.

4.2.2.3.4 Light intensity

The monthly variation in light intensity at the floor of the different trees in the homestead and the percentage transmission of light by their canopies at Location I (Tables 44 and 45) and II (Tables 46 and 47) revealed that the light intensities at the floor of all trees studied were always less than that in the open.

At Location I (Tables 44 and 45), the maximum light intensity in the open during the period of study was in March (98000 lux) in the first year and January (102000 lux) in the second year. The minimum light intensities were during November (64000 lux) in the first year and June (64500 lux) in the second year. During the first year the annual average percentage transmission of light was maximum in the case of coconut (25.37 %) followed by mango (20.56%), teak (14.16 %) and mahogany (8.84 %). Light transmission by nutmeg (0.24 %) was the lowest (Fig. 40). In the second year a similar trend was noticed with only very slight variation in the percentage light transmission. Average transmission by coconut, mango, teak, mahogany and nutmeg was 25.74, 22.67, 14.38, 9.20 and 1.69 per cent respectively.

At Location II (Tables 46 and 47), the maximum light intensity in the open during the period of study was in April (109000 lux) in the first year and January (104000 lux) in the second year. The minimum light intensities were during July (81600 lux) in the first year and June (66100 lux) in the second year. During the first year the annual average percentage transmission of light was maximum in the case of coconut (32.99 %) followed by mango (22.80%), cashew (9.13 %) and wild jack (6.53 %). Light transmission by cinnamon (2.39 %) was the lowest (Fig. 41). In the second year a similar trend was noticed with only very slight variation in the percentage light transmission. Average transmission by coconut, mango, cashew, wild jack and cinnamon was 32.23, 21.51, 8.74, 5.80 and 2.30 per cent respectively.

Table 44. Light intensity (Lux) at the floor of major tree species of Location I (First year)

Crop	Oct. 1994	Nov.	Dec.	Jan. 1995	Feb.	March	April	May	June	July	August	Sept.
Teak	9380 (13.4)	9100 (14.2)	11200 (15.5)	11900 (14.7)	14300 (15.7)	14100 (14.4)	10900 (14.2)	8900 (12.9)	9080 (13.4)	10100 (13.6)	11400 (14.2)	10900 (13.7)
Mahogany	6050 (8.60)	5900 (9.20)	7010 (9.60)	7500 (9.20)	8020 (8.80)	8500 (8.70)	7050 (9.20)	6200 (8.90)	4900 (7.20)	6460 (8.70)	7200 (8.90)	7220 (9.10)
Jack	415 (0.50)	375 (0.50)	461 (0.60)	512 (0.60)	560 (0.60)	551 (0.50)	465 (0.60)	480 (0.70)	610 (0.90)	890 (1.20)	740 (0.90)	630 (0.80)
Wild Jack	1430 (2.00)	1380 (2.10)	1420 (1.90)	1150 (1.40)	4320 (4.70)	6700 (6.80)	1190 (1.50)	2000 (2.90)	1830 (2.70)	1780 (2.40)	2170 (2.70)	1820 (2.30)
Bamblimass	3040 (4.34)	2030 (3.20)	2430 (3.40)	3300 (4.00)	2510 (2.80)	3140 (3.20)	1850 (2.40)	1870 (2.70)	2000 (2.90)	2750 (3.70)	2730 (3.40)	2380 (3.00)
Nutmeg	171 (0.20)	153 (0.20)	161 (0.20)	170 (0.20)	177 (0.19)	186 (0.19)	144 (0.19)	180 (0.26)	135 (0.20)	220 (0.30)	320 (0.40)	310 (0.40)
Bilimbi	532 (0.76)	647 (1.00)	989 (1.30)	1060 (1.30)	1020 (1.10)	1520 (1.60)	920 (1.20)	1310 (1.90)	1300 (1.90)	1040 (1.40)	1280 (1.60)	1510 (1.90)
Mango	13700 (19.5)	10100 (15.8)	11700 (16.2)	18000 (22.2)	19200 (21.1)	17500 (17.9)	17400 (22.6)	16500 (23.9)	13700 (20.2)	15900 (21.4)	18600 (23.1)	18100 (22.8)
Breadfruit	1680 (2.40)	1720 (2.70)	1840 (2.50)	1780 (2.20)	1980 (2.20)	2100 (2.10)	2100 (2.70)	1750 (2.50)	1200 (1.80)	1560 (2.10)	1850 (2.30)	1660 (2.10)
Gmelina	3520 (5.00)	3450 (5.40)	2180 (3.00)	3320 (4.10)	4230 (4.60)	4580 (4.70)	2840 (3.70)	1670 (2.40)	1900 (2.80)	1780 (2.40)	2090 (2.60)	2140 (2.70)
Cinnamon	1520 (2.20)	1430 (2.20)	1600 (2.20)	1660 (2.00)	1680 (1.80)	1420 (1.40)	1230 (1.60)	2010 (2.90)	1600 (2.40)	1700 (2.30)	2090 (2.60)	1980 (2.50)
Coffee	2750 (3.90)	2200 (3.40)	975 (1.30)	1300 (1.60)	1500 (1.70)	1570 (1.60)	1440 (1.80)	1310 (1.90)	1080 (1.60)	1330 (1.80)	1580 (2.00)	1660 (2.10)
Coconut	17700 (25.3)	15800 (24.7)	17700 (24.5)	19800 (24.4)	23000 (25.2)	25600 (26.1)	19500 (25.4)	17300 (25.1)	17800 (26.3)	19100 (25.7)	20900 (26.0)	20500 (25.8)
Open	70000 (100)	64000 (100)	72300 (100)	81100 (100)	91200 (100)	98000 (100)	76900 (100)	69000 (100)	67800 (100)	74300 (100)	80400 (100)	79400 (100)

Figures in parenthesis indicate the percentage of light transmitted.

Table 45. Light intensity (Lux) at the floor of major tree species of Location I (Second year)

Crop	Oct.1995	Nov.	Dec.	Jan.1995	Feb.	March	April	May	June	July	August	Sept.
Teak	9970 (13.2)	9880 (13.4)	12300 (15.2)	15600 (15.3)	15400 (15.3)	14400 (15.3)	13000 (15.1)	11000 (14.9)	9060 (14.1)	10100 (14.0)	10700 (13.5)	10100 (13.2)
Mahogany	6720 (8.90)	6780 (9.20)	7600 (9.40)	9710 (9.52)	9660 (9.56)	9020 (9.60)	8230 (9.57)	6970 (9.42)	5780 (8.96)	6400 (8.84)	6890 (8.70)	6660 (8.67)
Jack	529 (0.70)	480 (0.70)	730 (0.90)	1050 (1.03)	1060 (1.05)	1000 (1.06)	877 (1.02)	740 (1.00)	567 (0.88)	620 (0.86)	665 (0.84)	614 (0.80)
Wild Jack	1660 (2.20)	1920 (2.60)	2270 (2.80)	3060 (3.00)	3180 (3.15)	3080 (3.28)	2790 (3.24)	2190 (2.96)	1690 (2.62)	1840 (2.54)	1820 (2.30)	1690 (2.20)
Bamblimass	2110 (2.80)	1990 (2.70)	2430 (3.00)	3140 (3.08)	3300 (3.27)	3130 (3.33)	2700 (3.14)	2200 (2.97)	1800 (2.79)	2000 (2.76)	2130 (2.69)	2100 (2.73)
Nutmeg	220 (0.30)	140 (0.20)	320 (0.40)	490 (0.48)	505 (0.50)	480 (0.51)	438 (0.51)	340 (0.46)	250 (0.39)	300 (0.41)	303 (0.38)	268 (0.35)
Bilimbi	1130 (1.50)	960 (1.30)	1370 (1.70)	1820 (1.78)	1850 (1.83)	1770 (1.88)	1600 (1.86)	1330 (1.80)	1120 (1.74)	1230 (1.70)	1300 (1.64)	1220 (1.59)
Mango	14100 (18.7)	14600 (19.8)	18700 (23.1)	24500 (24.0)	24800 (24.6)	23600 (25.1)	21300 (24.8)	17700 (23.9)	14700 (22.8)	16000 (22.1)	17400 (22.0)	16200 (21.1)
Breadfruit	1810 (2.40)	1620 (2.20)	2030 (2.50)	2620 (2.57)	2660 (2.63)	2530 (2.69)	2240 (2.61)	1930 (2.61)	1620 (2.51)	1770 (2.44)	1900 (2.40)	1860 (2.42)
Gmelina	1890 (2.50)	1770 (2.40)	2180 (2.70)	2840 (2.78)	2860 (2.83)	2710 (2.88)	2430 (2.83)	2020 (2.73)	1680 (2.60)	1820 (2.51)	1960 (2.47)	1890 (2.46)
Cinnamon	1660 (2.20)	1400 (1.90)	1940 (2.40)	2500 (2.45)	2510 (2.49)	2830 (3.01)	2420 (2.81)	1960 (2.65)	1580 (2.45)	1760 (2.43)	1940 (2.45)	1760 (2.29)
Coffee	1890 (2.50)	1550 (2.10)	2190 (2.70)	2840 (2.78)	2860 (2.83)	2690 (2.86)	2400 (2.79)	2050 (2.77)	1710 (2.65)	1880 (2.60)	2000 (2.53)	1920 (2.50)
Coconut	19300 (25.5)	19000 (25.7)	21100 (26.0)	26700 (26.2)	26100 (25.8)	24500 (26.1)	22200 (25.8)	19200 (26.0)	16600 (25.7)	18500 (25.6)	20200 (25.5)	19200 (25.0)
Open	75600 (100)	73800 (100)	81000 (100)	102000 (100)	101000 (100)	94000 (100)	86000 (100)	74000 (100)	64500 (100)	72400 (100)	79200 (100)	76800 (100)

Figures in parenthesis indicate the percentage of light transmitted.

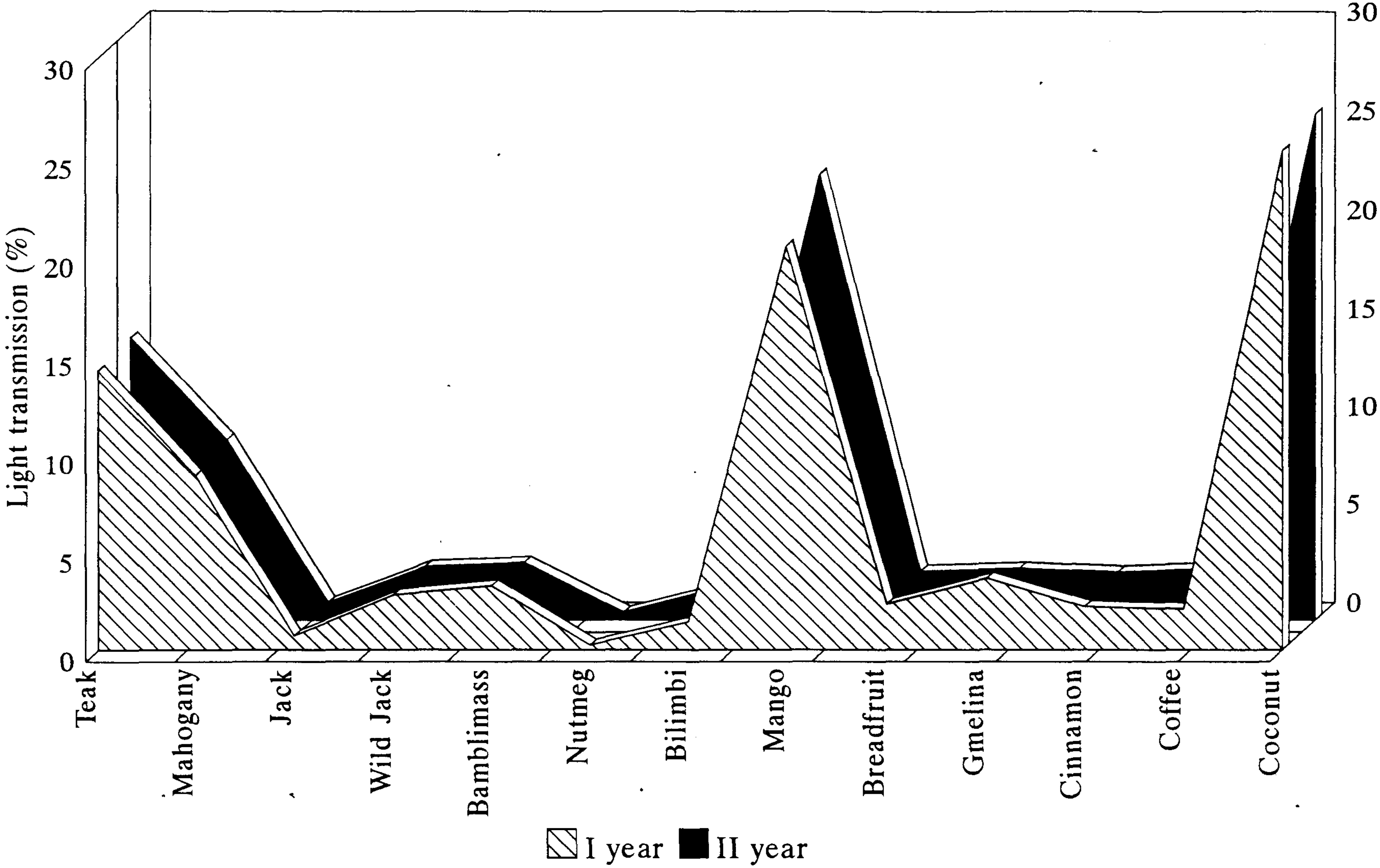


Fig. 40. Light transmission by major tree species at Location I

Table 46. Light intensity (Lux) at the floor of major tree species of Location II (First year)

Crop	Oct.1994	Nov.	Dec.	Jan.1995	Feb.	March	April	May	June	July	August	Sept.
Mahogany	4880 (5.10)	2950 (3.40)	3830 (3.70)	5290 (5.60)	8470 (7.80)	6250 (6.30)	7240 (6.60)	4300 (7.20)	6270 (5.90)	4760 (5.80)	5810 (5.90)	5390 (5.70)
Jack	1980 (2.10)	2880 (3.30)	1960 (1.90)	3220 (3.40)	3240 (3.00)	5650 (5.70)	8080 (7.40)	2900 (4.80)	3940 (3.70)	2860 (3.50)	3680 (3.70)	3880 (4.10)
Wild Jack	2870 (3.00)	3920 (4.50)	3960 (3.80)	7250 (7.60)	9680 (9.00)	10200 (10.2)	14030 (12.9)	3300 (5.50)	5980 (5.60)	4360 (5.30)	5390 (5.50)	5110 (5.40)
Bamblimass	2220 (2.30)	1750 (2.00)	2290 (2.20)	1890 (2.00)	2670 (2.50)	3250 (3.20)	4800 (4.40)	2900 (4.80)	3300 (3.10)	2610 (3.20)	3140 (3.20)	3020 (3.20)
Bilimbi	3290 (3.40)	2920 (3.40)	2540 (2.50)	3960 (4.20)	2020 (1.90)	2960 (2.90)	3860 (3.50)	1920 (3.20)	4140 (3.90)	2940 (3.60)	3810 (3.90)	3600 (3.80)
Mango	21030 (21.8)	21200 (24.5)	20600 (20.6)	19600 (19.6)	28900 (26.8)	22500 (22.5)	27300 (25.0)	16500 (27.5)	23300 (21.8)	16800 (20.6)	20500 (21.0)	20400 (21.5)
Breadfruit	1920 (2.00)	6960 (8.00)	7310 (7.10)	5220 (5.50)	4820 (4.80)	3210 (3.20)	2430 (2.20)	1090 (1.80)	1800 (1.70)	1550 (1.90)	2080 (2.13)	1920 (2.02)
Cinnamon	2620 (2.70)	3320 (3.80)	1200 (1.20)	2880 (3.00)	3850 (3.60)	3950 (3.90)	1340 (1.20)	1100 (1.80)	1700 (1.60)	1590 (1.90)	1970 (2.00)	1850 (2.00)
Coconut	31200 (32.3)	27300 (31.6)	33300 (32.3)	31300 (32.9)	36800 (34.1)	34500 (34.5)	36200 (33.2)	19200 (32.0)	35600 (33.6)	26900 (33.0)	32400 (33.2)	31400 (33.2)
Annona	4110 (4.30)	5110 (5.90)	5700 (5.50)	6210 (6.50)	6460 (6.00)	5210 (5.20)	6200 (5.70)	3600 (6.00)	4580 (4.32)	4160 (5.10)	5120 (5.30)	5000 (5.30)
Guava	2230 (2.30)	2850 (3.30)	3890 (3.80)	2500 (2.60)	5080 (4.70)	1950 (1.90)	2300 (2.10)	2800 (4.70)	3700 (3.50)	2710 (3.30)	3370 (3.50)	3030 (3.20)
Cashew	8650 (8.90)	7250 (8.40)	12180 (11.8)	8260 (8.70)	12100 (11.2)	10200 (10.2)	10570 (9.70)	4700 (7.80)	8710 (8.20)	6580 (8.10)	8070 (8.30)	7720 (8.20)
Open	96500 (100)	86500 (100)	103000 (100)	95000 (100)	108000 (100)	100000 (100)	109000 (100)	60000 (100)	106000 (100)	81600 (100)	97500 (100)	94700 (100)

Figures in parenthesis indicate the percentage of light transmitted

Table 47. Light intensity (Lux) at the floor of major tree species of Location II (Second year)

Crop	Oct.1995	Nov.	Dec.	Jan.1995	Feb.	March	April	May	June	July	August	Sept.
Mahogany	5010 (5.60)	5010 (6.00)	6470 (6.34)	7280 (7.00)	7150 (7.15)	6490 (7.13)	5740 (7.00)	5130 (6.75)	3830 (6.28)	4890 (6.11)	5460 (5.93)	4500 (5.77)
Jack	2990 (3.40)	2730 (3.10)	4350 (4.26)	4990 (4.80)	4820 (4.82)	4390 (4.82)	3920 (4.78)	3360 (4.42)	2450 (4.02)	3070 (3.84)	3580 (3.89)	2660 (3.41)
Wild Jack	4580 (5.10)	4400 (5.30)	6100 (5.98)	6550 (6.30)	6350 (6.35)	5800 (6.37)	5190 (6.33)	4560 (6.00)	3430 (5.62)	4410 (5.51)	5020 (5.46)	4100 (5.26)
Bamblimass	2750 (3.10)	2590 (3.10)	3720 (3.64)	3950 (3.80)	3830 (3.83)	3500 (3.85)	3130 (3.82)	2660 (3.50)	1990 (3.26)	2520 (3.15)	2990 (3.25)	2450 (3.14)
Bilimbi	2990 (3.40)	3220 (3.80)	4190 (4.10)	4780 (4.60)	4650 (4.65)	4210 (4.63)	3770 (4.60)	3200 (4.21)	2370 (3.89)	2990 (3.74)	3350 (3.64)	2670 (3.42)
Mango	17800 (20.0)	16800 (20.1)	22500 (22.1)	23900 (23.0)	23000 (23.0)	21000 (23.1)	18800 (22.9)	17000 (22.4)	12600 (20.7)	16200 (20.3)	18900 (20.5)	15600 (20.0)
Breadfruit	1690 (1.90)	1800 (2.20)	2460 (2.41)	2800 (2.69)	2700 (2.70)	2440 (2.68)	2170 (2.65)	1770 (2.33)	1330 (2.18)	1640 (2.05)	1930 (2.10)	1520 (1.95)
Cinnamon	1620 (1.80)	1780 (2.10)	2370 (2.32)	2910 (2.80)	2820 (2.82)	2580 (2.84)	2290 (2.79)	1730 (2.28)	1250 (2.05)	1520 (1.90)	1840 (2.00)	1460 (1.87)
Coconut	29400 (33.0)	27500 (32.9)	34400 (33.7)	35300 (33.9)	33800 (33.8)	30200 (33.2)	27000 (32.9)	25000 (32.9)	20000 (32.8)	26400 (33.0)	30800 (33.5)	25800 (33.1)
Annona	4440 (5.00)	4280 (5.10)	5610 (5.50)	6340 (6.10)	6150 (6.15)	5610 (6.16)	4980 (6.07)	4160 (5.47)	3100 (5.08)	3970 (4.96)	4700 (5.11)	3870 (4.96)
Guava	2580 (2.90)	2950 (3.50)	4040 (3.96)	4580 (4.40)	4440 (4.44)	4000 (4.40)	3570 (4.35)	2960 (3.89)	2150 (3.52)	2610 (3.26)	3040 (3.30)	2410 (3.09)
Cashew	7100 (8.00)	6910 (8.30)	9350 (9.16)	9880 (9.50)	9520 (9.52)	8600 (9.45)	7680 (9.37)	6770 (8.91)	5140 (8.43)	6520 (8.15)	7450 (8.10)	6200 (7.95)
Open	89200 (100)	83700 (100)	102000 (100)	104000 (100)	100000 (100)	91000 (100)	82000 (100)	76000 (100)	61000 (100)	80000 (100)	92000 (100)	78000 (100)

Figures in parenthesis indicate the percentage of light transmitted

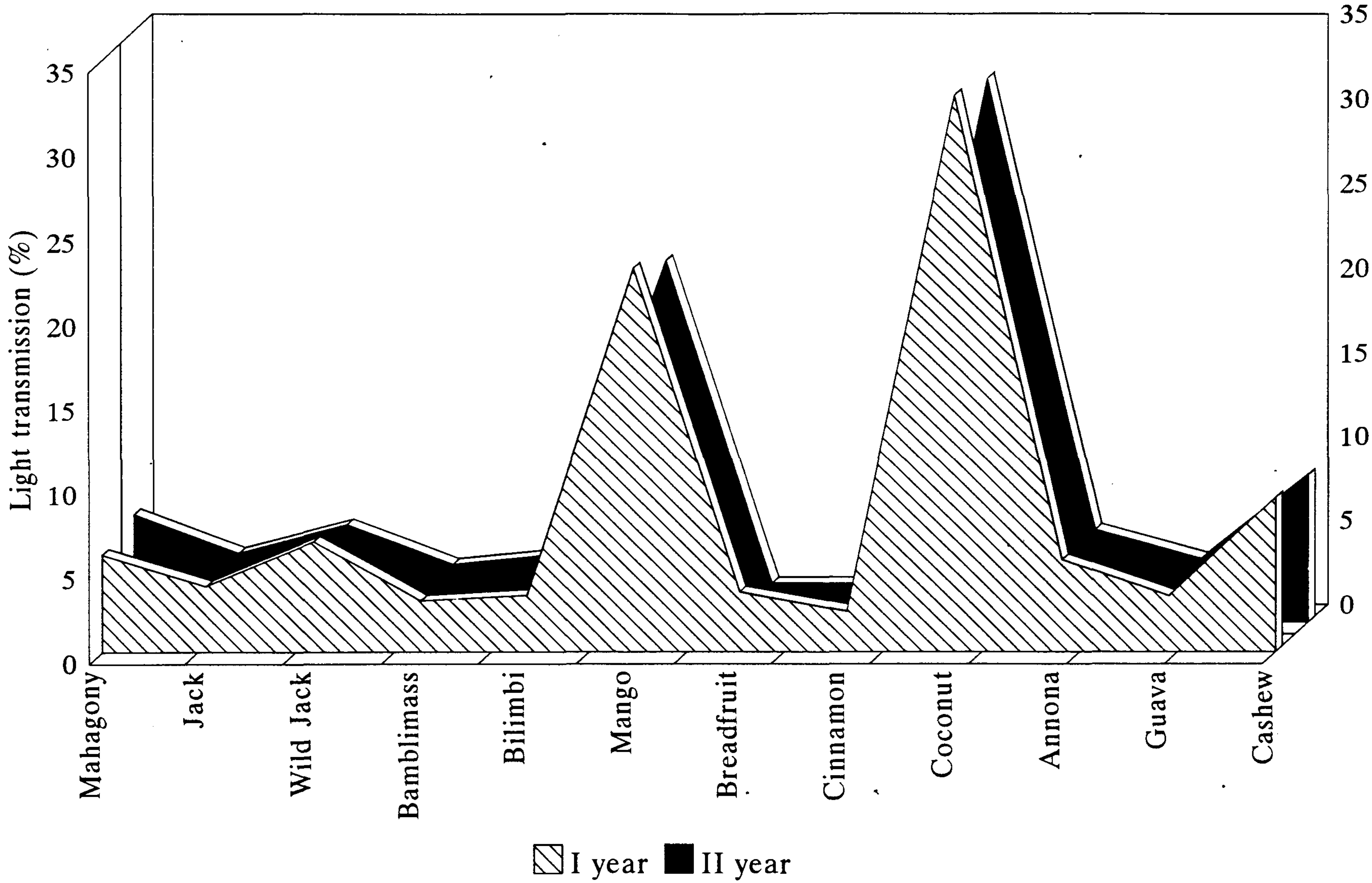


Fig. 41. Light transmission by major tree species at Location II

At both locations, the light intensity received at the floor of the trees showed monthly variation with the maximum and minimum values corresponding to the maximum and minimum light intensity values in the open. However, the percentage transmission of light by each tree species during the different months remained almost constant.

From the above studies, it could be inferred that the light intensity available at the floor of the different tree species in the home gardens was very low (Figs. 40 and 41). Thus, the light available for the crops grown in the interspaces under the canopy of trees was much less of what is required for its potential photosynthesis. One of the main reasons for the low productivity of most of the seasonal and annual intercrops grown in home gardens might be the lower availability of solar radiation. The results of the study highlights the need for the scientific selection of shade loving crops and shade tolerant varieties of different crops by the farmers. Further, it was noticed that percentage infiltration of light beneath the canopy of coconut was comparatively high. Coconut, being the major crop in both the home gardens and occupying the largest area, facilitated much more infiltration of light, thus, making it possible for the growth of annual intercrops requiring more light. Similar observations in coconut based cropping systems have been made by Nelliat *et al.* (1974); Nair and Balakrishnan (1977); Nair and Sreedharan (1986) and Happy Mathew *et al.* (1996).

4.2.3 Economic analysis of the home gardens

The economic analysis of the home gardens with all its farming activities is presented in Tables 48 to 51.

At Location I (Tables 48 and 49), which was a coconut-based system, the net area available for cropping was 4087.50 m^2, after excluding the area occupied by the house, roads and other permanent structures. The gross cropped area in the first and second year was 4400.48 and 4678.44 m^2 respectively and the corresponding cropping intensities were worked out as 107.66 and 114.46 per cent. In the first year (Table 48), the total investment was Rs.1616/- out of which input and labour cost constituted 28 and 72 per cent respectively. The gross and net return from the 24 enterprises was worked out to Rs.8166/- and Rs.6550/-, resulting in a benefit : cost ratio of 5.05 (Fig. 42). Among the different enterprises, the maximum net return (Rs.1713) was obtained from nutmeg followed by coconut (Rs.1377), while the benefit : cost ratio was highest for pepper and clove (24.00). In the second year (Table 49), the farmer invested an amount of Rs.3157/-, of which input cost alone constituted 51 per cent. The gross and net return from 23 enterprises of the home garden were Rs.9263/- and Rs.6106/- respectively with a benefit : cost ratio of 2.93. The maximum net return was obtained from nutmeg (Rs.1920) followed by coconut (Rs.1131) while the benefit : cost ratio was highest for pepper.

Table 48. Economic analysis of the home garden at Location I (First year)

Sl. No.	Enterprise	Population	Space used (m^2)	Input cost (Rs.)	Labour cost (Rs.)	Total expenditure (Rs.)	Gross return (Rs.)	Net return (Rs.)	B:C ratio
1.	Adult coconut	19 nos.	1155.58	200	390	590	1967	1377	3.33
2.	Young coconut	40 nos.	502.40	150	225	375	0000	-375	--
3.	Jack	4 nos.	93.96	00	20	20	370	350	18.50
4.	Wild Jack	4 nos.	303.52	00	000	000	0000	000	-
5.	Nutmeg	13 nos.	483.94	86	280	366	2079	1713	5.68
6.	Mango	5 nos.	97.10	00	30	30	400	370	13.33
7.	Breadfruit	3 nos.	143.23	00	10	10	600	590	60.00
8.	Gmelina	1 no.	16.61	00	00	00	000	000	--
9.	Albizzia	2 nos.	113.76	00	00	000	000	000	–
10.	Mahogany	2 nos.	60.28	00	00	00	000	000	--
11.	Coffee	4 nos.	62.53	00	20	20	220	200	11.00
12.	Teak	3 nos.	41.03	00	00	00	000	000	-
13.	Cinnamon	2 nos.	30.02	00	.00	00	000	000	–
14.	Bilimbi	1 no.	20.16	00	00	00	80	80	–
15.	Clove	3 nos.	9.42	00	20	20	480	460	24.00
16.	Banana	9 nos.	28.26	10	20	30	550	520	18.33
17.	Pepper	10 nos.	10.00	00	20	20	480	460	24.00
18.	Moringa	4 nos.	50.24	00	00	00	20	20	--
19.	Borassus	20 nos.	1004.80	00	80	80	480	400	6.00
20.	Colocasia	30 nos.	40.00	00	10	10	60	50	6.00
21.	Papaya	2 nos.	8.00	00	00	00	70	70	--
22.	Curry leaf	3 nos.	5.00	00	00	00	20	20	--
23.	Vegetables	1 unit	40.00	10	15	25	50	25	2.00
24.	Bamblimass	1 no.	80.64	00	20	20	240	220	12.00
25.	House & permanent structures	-	912.50	--	--	-	-	-	--
	Total		5312.98	456	1160	1616	8166	6550	5.05

Table 49. Economic analysis of the home garden at Location I (Second year)

Sl. No.	Enterprise	Population	Space used (m^2)	Input cost (Rs.)	Labour cost (Rs.)	Total expenditure (Rs.)	Gross return (Rs.)	Net return (Rs.)	B:C ratio
1.	Adult coconut	19 nos.	1155.58	735	460	1195	2326	1131	1.95
2.	Young coconut	40 nos.	785.00	550	400	950	100	-850	-0.11
3.	Jack	4 nos.	93.96	000	35	35	480	445	13.71
4.	Wild Jack	4 nos.	303.52	000	00	00	000	000	
5.	Nutmeg	13 nos.	483.94	150	330	480	2400	1920	5.00
6.	Mango	5 nos.	97.10	00	40	40	520	480	13.00
7.	Breadfruit	3 nos.	143.23	00	00	00	500	500	–
8.	Gmelina	1 no.	16.61	00	00	00	000	000	–
9.	Albizzia	2 nos.	113.76	00	00	00	000	000	–
10.	Mahogany	2 nos.	60.28	00	00	00	000	000	–
11.	Coffee	4 nos.	62.53	20	25	45	210	165	4.67
12.	Teak	3 nos.	41.03	00	00	00	000	000	–
13.	Cinnamon	2 nos.	30.02	00	00	00	000	000	–
14.	Bilimbi	1 no.	20.16	00	00	00	70	70	–
15.	Clove	3 nos.	9.42	20	30	50	320	270	6.40
16.	Banana	15 nos.	47.10	105	100	205	800	595	3.90
17.	Pepper	10 nos.	10.00	00	20	20	510	490	25.50
18.	Moringa	4 nos.	50.24	00	00	00	25	25	–
19.	Borassus	20 nos.	1004.80	00	72	72	615	543	8.54
20.	Colocasia	50 nos.	56.52	20	00	20	75	55	3.75
21.	Papaya	2 nos.	8.00	00	00	00	62	62	–
22.	Curry leaf	3 nos.	5.00	00	00	00	25	25	–
23.	Bamblimass	1 no.	80.64	20	25	45	225	180	5.00
24.	House & permanent structures	–	912.50	–	–	–	–	–	–
	Total		5590.94	1620	1537	3157	9263	6106	2.93

Fig. 42. Economic analysis of the home garden at Location I

At Location II (Tables 50 and 51), which was a coconut-based mixed farming system, the net cultivated area was 3700 and 3695 m^2, in the first and second years respectively, while the corresponding gross cropped area was 5369.49 and 5616.49 m^2. The respective cropping intensities were worked out to 145.12 and 152 per cent. In the first year (Table 50), the farmer invested Rs.44233/- and received a gross return of Rs.70870/-. The net profit from 35 enterprises was Rs.26637/- resulting in a benefit : cost ratio of 1.60 (Fig. 43). Among the different enterprises the highest net return was obtained from cow, followed by goat, poultry and coconut. But, the lower benefit : cost ratio for cow and goat was due to the higher expenditure incurred, which included mainly the input (feed) cost. The highest benefit : cost ratio obtained for pepper (26.66) was due to the very low expenditure (Rs.30). The input cost accounted for 93 per cent of the total expenditure. The increased input cost was mainly due to the amount incurred in purchasing cattle feed (Rs.32485) for the cow, being was an improved, cross bred and high yielding one. The input cost for cow alone constituted 79 per cent of the total annual expenditure on inputs. The gross (Rs.50475) and net return (Rs.16790) from cow accounted for 71 and 63 per cent of the total gross and net return received from the homestead respectively. Among the different crops, adult coconut which was most profitable accounted for 4.5, 5.6 and 7.5 per cent of the total expenditure, gross and net return respectively. However, among the cultivated annuals, banana gave maximum net return (Rs.950) with a benefit : cost ratio of 4.16. In the second year (Table 51), the total expenditure (Rs.20415) was less than the first year. This was due to the reduction in input cost (Rs.17030) which constituted 83 per cent of the total expenditure, unlike that in the first year (93 per cent).

Table 50. Economic analysis of the home garden at Location II (First year)

Sl. No.	Enterprise	Population	Space used (m²)	Input cost (Rs.)	Labour cost (Rs.)	Total expenditure (Rs.)	Gross return (Rs.)	Net return (Rs.)	B:C ratio
1.	Adult coconut	40 nos.	1038.60	1350	660	2010	4000	1990	1.99
2.	Young coconut	35 nos.	440.00	660	225	885	0000	-885	-
3.	Jack	2 nos.	78.94	60	30	90	600	510	6.66
4.	Tamarind	1 no.	50.24	30	00	30	000	-30	-
5.	Wild Jack	2 nos.	61.11	60	00	60	000	-60	-
6.	Mango	4 nos.	89.38	240	30	270	375	105	1.37
7.	Cashew	5 nos.	1524.45	575	50	625	1000	375	1.60
8.	Mahogany	2 nos.	74.55	60	00	60	000	-60	-
9.	Breadfruit	1 no.	12.56	30	00	30	150	120	5.00
10.	Bilimbi	5 nos.	60.73	30	00	30	100	70	3.33
11.	Annona	6 nos.	129.43	45	00	45	25	-20	0.55
12.	Tapioca	500 nos.	500.00	225	150	375	750	375	2.00
13.	Dioscorea	25 nos.	25.00	75	75	150	300	150	2.00
14.	Amorphophallus	25 nos.	37.50	75	75	150	375	225	2.50
15.	Colocasia	10 nos.	17.66	15	00	15	30	15	2.00
16.	Turmeric	25 nos.	12.50	75	75	150	300	150	2.00
17.	Pepper	15 nos.	15.00	30	00	30	800	770	26.66
18.	Arrowroot	1000 nos.	500.00	150	75	225	300	75	1.33
19.	Pineapple	50 nos.	50.00	150	35	185	500	315	2.70
20.	Arecanut	4 nos.	28.26	15	00	15	10	-5	0.66
21.	Indian Gooseberry	1 no.	26.42	15	00	15	20	5	1.33
22.	Cinnamon	1 no.	29.22	15	00	15	00	-15	-
23.	Sapota	1 no.	47.48	15	00	15	30	15	2.00
24.	Ailanthus	4 nos.	28.84	30	00	30	00	-30	-
25.	Moringa	10 nos.	70.65	75	15	90	120	30	1.33
26.	Neem	1 no.	19.62	00	00	00	00	00	-
27.	Teak seedlings	10 nos.	17.66	55	25	80	00	-80	-
28.	Bamblimass	1 no.	45.36	15	15	30	200	170	6.66
29.	Guava	5 nos.	141.30	30	00	30	40	10	1.33
30.	Morinda	15 nos.	105.97	90	00	90	00	-90	-
31.	Banana	25 nos.	78.50	150	150	300	1250	950	4.16
32.	Curry leaf	4 nos.	12.56	8	00	8	30	22	3.75
33.	Cow	1 no.	40.00	32485	1200	33685	50475	16790	1.50
34.	Goat	4 nos.	40.00	4015	00	4015	6570	2555	1.63
35.	Poultry	15 birds	20.00	250	150	400	2520	2120	6.30
36.	House & permanent structures	-	200.00	-	-	-	-	-	-
	Total		5669.49	41198	3035	44233	70870	26637	1.60

Table 51. Economic analysis of the home garden at Location II (Second year)

Sl. No.	Enterprise	Population	Space used (m^2)	Input cost (Rs.)	Labour cost (Rs.)	Total expenditure (Rs.)	Gross return (Rs.)	Net return (Rs.)	B:C ratio
1.	Adult coconut	40 nos.	1038.60	1440	1725	3165	6500	3335	2.05
2.	Young coconut	35 nos.	687.00	1260	525	1785	000	-1785	-
3.	Jack	2 nos.	78.94	00	00	00	500	500	-
4.	Tamarind	1 no.	50.24	00	00	00	000	00	-
5.	Wild Jack	2 nos.	61.11	00	00	00	000	00	-
6.	Mango	4 nos.	89.38	60	00	60	600	540	10.00
7.	Cashew	5 nos.	1524.45	350	00	350	1250	900	3.57
8.	Mahogany	2 nos.	74.55	00	00	00	000	00	-
9.	Breadfruit	1 no.	12.56	30	00	30	150	120	5.00
10.	Bilimbi	5 nos.	60.73	45	00	45	250	205	5.56
11.	Annona	6 nos.	129.43	45	00	45	120	75	2.67
12.	Tapioca	500 nos.	500.00	575	750	1325	3000	1675	2.26
13.	Dioscorea	25 nos.	25.00	75	40	115	313	198	2.72
14.	Amorphophallus	25 nos.	37.50	75	40	115	450	335	3.91
15.	Colocasia	10 nos.	17.66	15	00	15	15	00	1.00
16.	Turmeric	25 nos.	12.50	75	40	115	195	80	1.70
17.	Pepper	15 nos.	15.00	00	00	00	750	750	-
18.	Arrowroot	1000 nos.	500.00	225	75	300	500	200	1.67
19.	Pineapple	50 nos.	50.00	150	40	190	500	310	2.63
20.	Arecanut	4 nos.	28.26	00	00	00	25	25	-
21.	Indian Gooseberry	1 no.	26.42	00	00	00	20	20	-
22.	Cinnamon	1 no.	29.22	00	00	00	00	00	-
23.	Sapota	1 no.	47.48	00	00	00	12	12	-
24.	Ailanthus	4 nos.	28.84	00	00	00	00	00	-
25.	Moringa	10 nos.	70.65	75	00	75	100	25	1.33
26.	Neem	1 no.	19.62	00	00	00	00	00	-
27.	Teak seedlings	10 nos.	17.66	00	00	00	00	00	-
28.	Bamblimass	1 no.	45.36	30	00	30	240	210	8.00
29.	Guava	5 nos.	141.30	00	00	00	15	15	-
30.	Morinda	15 nos.	105.97	00	00	00	00	00	-
31.	Banana	25 nos.	78.50	245	150	395	1500	1105	3.80
32.	Curry leaf	4 nos.	12.56	00	00	00	125	125	-
33.	Cow	1 no.	40.00	7610	00	7610	15475	7865	2.03
34.	Goat	2 nos.	40.00	3650	00	3650	6015	2365	1.65
35.	Poultry	10 birds	20.00	00	00	00	2720	2720	-
36.	Apiculture	5 hives	5.00	1000	00	1000	2500	1500	2.50
37.	House & permanent structures	-	200.00	-	-	-	-	-	-
	Total		5921.49	17030	3385	20415	43840	23425	2.15

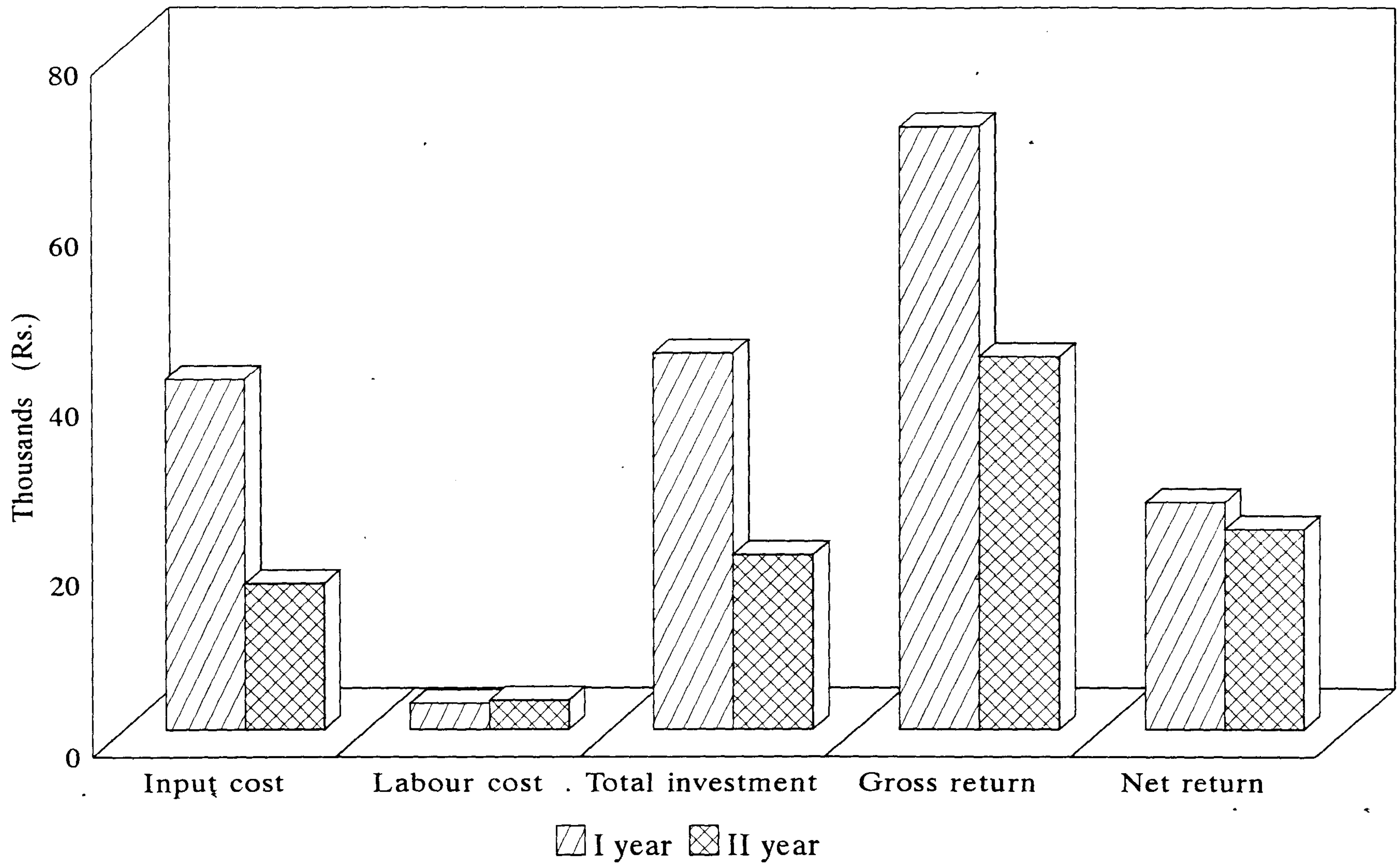


Fig. 43. Economic analysis of the home garden at Location II

The reduction in input cost was mainly due to the replacement of the cross bred cow by a local one which had lower feed requirement. The input cost incurred for cow, including the cost price of the new cow (Rs.2500), constituted 45 per cent of the total input cost. The total gross and net return from 36 enterprises were Rs.43840/- and Rs.23425/- resulting in a benefit : cost ratio of 2.15. Among the different enterprises, cow had given the maximum profit (Rs.7865) followed by adult coconut (Rs.3335), poultry (Rs.2720), goat (Rs.2365) and tapioca (Rs.1675) and they accounted for 34, 14, 12, 10 and 7 per cent of the total net profit received in the second year. Apiculture (5 hives) was an additional enterprise undertaken by the farmer in the second year. The gross and net return were Rs.2500/- and Rs.1500/- respectively. The profit from apiculture accounted for 6 per cent of the total return. The lower profit was due to the expenditure incurred on the purchase of hives. However, in subsequent years the net profit is likely to increase because of the lesser expenditure that will be incurred. The high benefit : cost ratio for mango (10) and bamblimass (8) was due to the low expenditure.

From the economic analysis of both the home gardens, it is observed that the needs of the farmer and his family could be met from the produce obtained from the different enterprises undertaken by the farmers. The farming practices adopted by the farmers were a deliberate strategy, aimed at producing harvests throughout the year, so that some products of economic value would be available for household use or sale. Similar observations on homesteads were made by Rathinam (1991) and Babu *et al.* (1992).

However, the higher returns from the home garden at location II, resulted due to the inclusion of cattle and poultry enterprises, combined with larger number of enterprises. Concurrent results of increase in income by adoption of animal husbandry was reported by Pasha (1991) and Kandaswamy and Chinnaswamy (1988).

Several tree components (tamarind, wild jack, cinnamon, ailanthus, neem, teak, morinda, albizzia, gmelina) are likely to generate higher income in future. The trees apparently served as assets upon which the farmers draw in emergency as suggested by Arnold (1987).

The net income obtained from the home gardens is comparable to the estimates of net return from coconut-based systems made by Nair (1976); Nelliat and Krishnaji (1976); Happy Mathew and Nair (1996).

4.2.4 Evaluation of the home gardens

In the selected home gardens, the crops and agricultural practices followed were purely traditional / subsistence and the farmers were operating in the home gardens in the absence of expert recommendations. The tree/crop components were planted haphazardly. However, the farmers knew, in a practical way, what and where to plant and how to manage the plants, indicating their awareness and perception of the specific site conditions and requirements of the crops.

The results of the study in both the home gardens indicated that trees and shrubs, when appropriately incorporated and properly managed, could significantly improve the fertility and overall productivity of the soil beneath them. The year round significant litter production by the tree species results in erosion control and maintains soil fertility. The trees helped in maintenance of the soil organic matter through continuous litterfall and by reduction of the rate of organic matter decomposition by shading. Further, transfer of nutrients from trees and plant parts to the soil takes place in varying degrees within the system, by way of litterfall, stemflow and throughfall. However, the rate of addition of nutrients varied with species. The trees provided favourable conditions for the input of nutrients by rainfall and dust, via throughfall and stemflow. It is logical to expect that the trees, by virtue of their deep roots, absorb nutrients from deeper layers, which would otherwise be lost by leaching. The nutrient requirements for various crops in the system could partly be met through the various nutrient cycling processes. The presence of cattle / poultry and nutrient recycling through incorporation of crop residues also augmented nutrient addition and was found to have a complimentary effect. The study further revealed that loss of nutrients takes place from the system through harvest. At both locations, maximum nutrient removal was accounted for by coconut through harvested leaves and nuts. However, the nutrient removal was found to be compensated through the various nutrient cycling processes taking place in the system.

The homestead soil had a lower bulk density, higher porosity, water holding capacity, moisture content and aggregation, consequent to the addition of varying amounts of litter from the trees. Even though the trees / crops absorbed large quantities of nutrients, the maintenance of a steady nutrient status of the soil could be expected, due to the return of nutrients back to the soil. Moreover, the increased number of trees and plant cover on the ground in the home gardens, prevented the direct loss of nutrients through runoff and soil erosion. The higher microbial population in the home garden was due to the high intensity of cropping in the homestead, addition of organic matter and subsequent favourable soil condition.

The study also showed an improvement in the physical, chemical and biological characteristics of the soil through crop diversification and by inclusion of trees in the homesteads which ultimately helped to conserve the fertility of the soil. Thus, the home gardens exhibited an almost closed nutrient cycling pathway and improved physical and chemical soil condition as that of natural vegetation.

The presence of a variety of trees coupled with the dense crop cover in the home garden, always helped in lowering of the soil temperature and maintained optimum relative humidity, which in turn, resulted in low evapotranspiration. The trees, thus, played a dominant role in ameliorating the microclimate in the home garden.

The percentage of light transmitted by the different trees and the amount of light available for the intercrops were considerably reduced owing to the high cropping intensity and canopy coverage. However, coconut occupying the largest area in the homestead, facilitated more infiltration of light, making it possible for the growth of annual crops beneath the trees, giving a reasonable yield, income and sustenance.

The system, in general, was found to be profitable. The system provided food, fuel, fodder, fruit, beverage, spices, small timber, manure and regular cash inflow for the farmer on one hand, and conserved production on a sustainable basis on the other. The species diversity was a deliberate strategy aimed at producing harvests throughout the year. There was always some product of economic value available for household use or cash sale. The tree-crop-livestock integration was a special feature of the home gardens, which increased income considerably. There is immense scope for maximising the profit in both the home gardens through optimisation of resource use.

4.3 Allelopathic studies

Laboratory experiments were conducted to assess the allelopathic influence of the leaf extracts and powdered litter of some of the commonly grown multipurpose tree species on rice and cowpea, the results of which are presented and discussed hereunder.

The effect of leaf extracts of different tree species on rice is given in Table 52.

Table 52. Allelopathic effect of leaf extracts of different tree species on rice

Treatment		Germination per cent	RI	Plumule length (cm)	RI	Radicle length (cm)	RI
Acacia	(T1)	73.33 (58.89)	-0.25	0.76	-0.85	0.03	-0.99
Eucalyptus	(T2)	82.66 (65.39)	-0.16	2.73	-0.48	3.20	-0.47
Casuarina	(T3)	82.66 (65.58)	-0.16	1.70	-0.68	1.73	-0.72
Albizzia	(T4)	82.66 (65.39)	-0.16	2.26	-0.57	1.16	-0.81
Leucaena	(T5)	81.33 (64.47)	-0.17	2.00	-0.62	1.93	-0.68
Jack	(T6)	84.00 (67.88)	-0.15	3.80	-0.28	4.10	-0.32
Mango	(T7)	92.00 (74.41)	-0.06	2.16	-0.59	2.10	-0.66
Ailanthus	(T8)	65.33 (53.99)	-0.33	0.83	-0.84	0.06	-0.99
Tamarind	(T9)	70.66 (57.19)	-0.28	1.00	-0.81	0.06	-0.99
Bombax	(T10)	89.33 (71.51)	-0.09	3.36	-0.36	4.50	-0.25
Nutmeg	(T11)	82.66 (65.50)	-0.16	2.03	-0.61	1.90	-0.68
Wild Jack	(T12)	84.00 (66.68)	-0.15	3.33	-0.37	2.06	-0.66
Portia	(T13)	76.00 (60.69)	-0.23	1.06	-0.79	0.46	-0.92
Cashew	(T14)	89.33 (71.51)	-0.09	1.63	-0.69	1.03	-0.83
Control	(T15)	98.66 (86.11)	0.00	5.30	0.00	6.06	0.00
CD (0.05)		8.807		0.420		0.649	

Figures in parenthesis represent transformed (angular) values.

RI - Response index which is a measure of the inhibition/stimulation

Germination of rice was significantly inhibited by all the tree species tested and the inhibition (as indicated by the response index) was found to range from 9 - 33 per cent. Ailanthus caused maximum inhibition and was on par with tamarind, acacia and portia. The germination of rice was reduced to 65.33, 70.66, 73.33 and 76 per cent by ailanthus, tamarind, acacia and portia respectively (Fig. 44). The inhibition was less pronounced in the case of mango (6 %), bombax (9 %) and cashew (9 %).

Plumule and radicle growth were also significantly inhibited by all tree species when compared to the control. The response indices revealed that in contrast to germination, inhibition of plumule and radicle growth was comparatively greater.

The inhibition of plumule growth ranged from 28 - 85 per cent. The plumule growth was suppressed most by acacia (85 %), ailanthus (84 %), tamarind (81 %) and portia (79 %) which were on par. This is evident from the shorter plumule length of rice treated with leaf extracts of acacia (0.76 cm), ailanthus (0.83 cm), tamarind (1.00 cm) and portia (1.06 cm), while that of control was 5.30 cm (Fig. 45). The inhibition was relatively less in the case of jack (28 %), bombax (36 %) and wild jack (37 %).

The inhibition of radicle growth was more pronounced than germination and plumule growth, and was found to range from 25 - 99 per

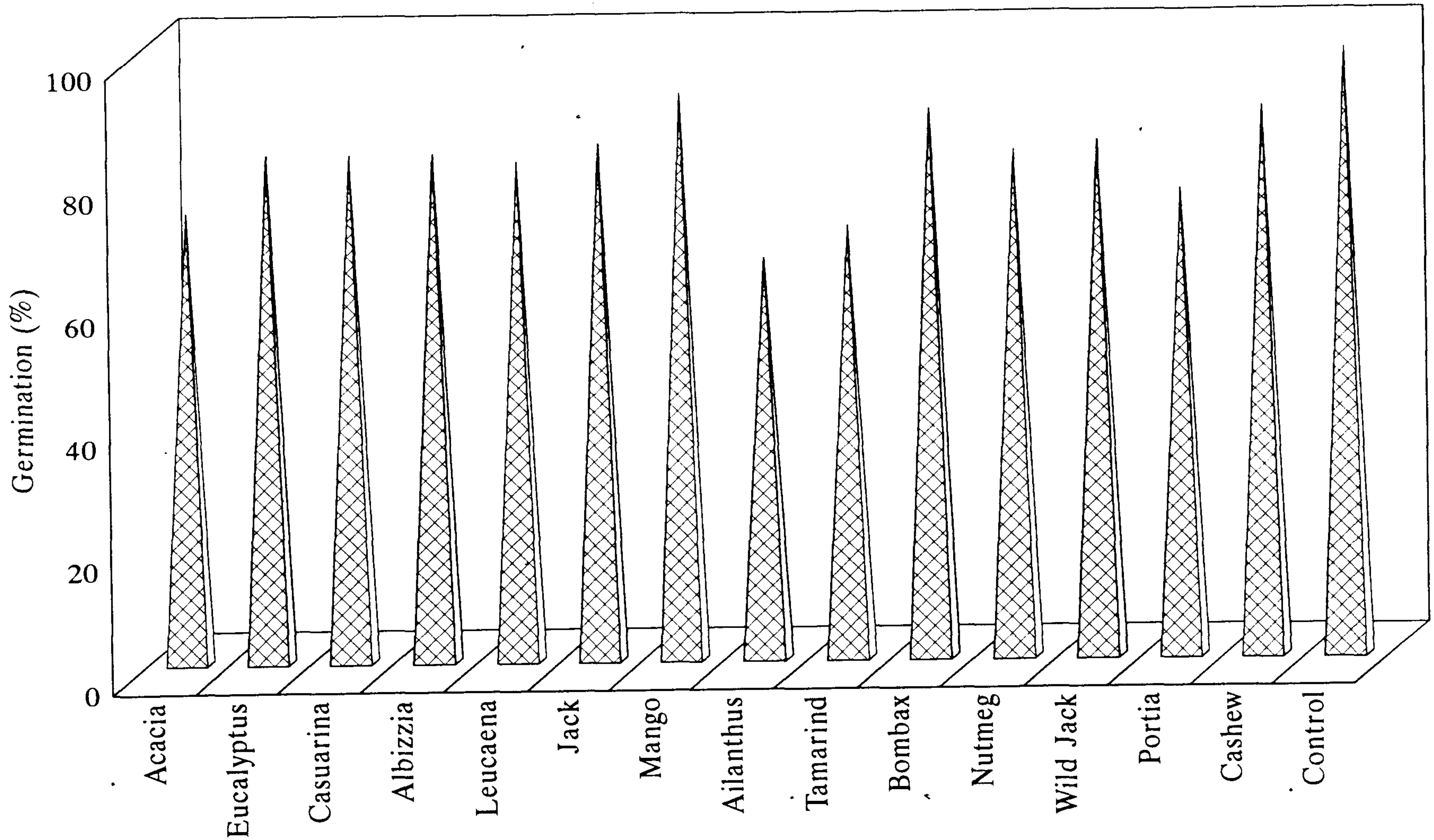


Fig. 44. Allelopathic effect of leaf extracts of trees on germination of rice

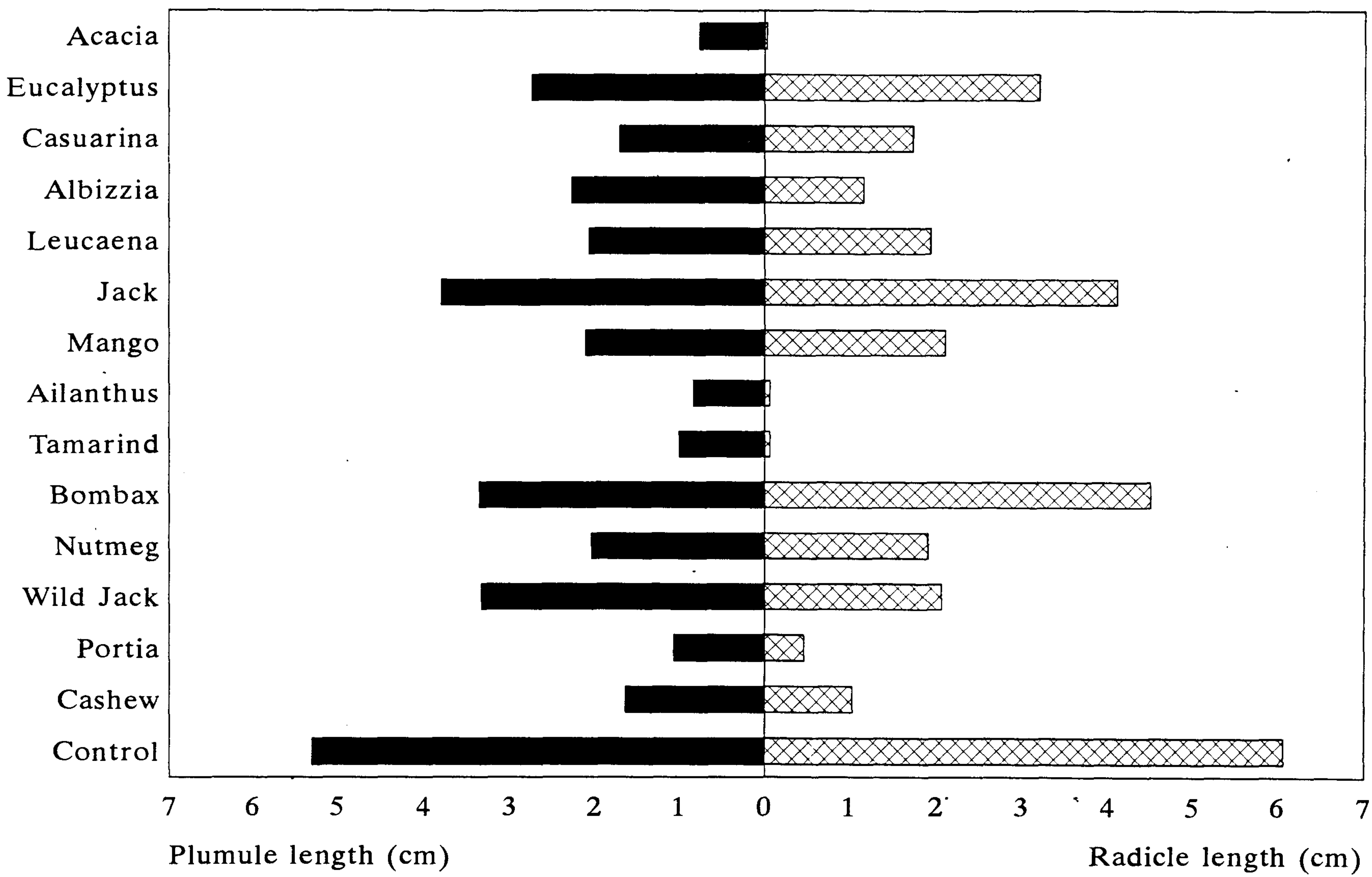


Fig. 45. Allelopathic effect of leaf extracts of trees on plumule and radicle length of rice

cent. The greatest inhibition was caused by acacia (99 %), ailanthus (99 %), tamarind (99 %) and portia (92 %), which were on par, and resulted in radicle lengths of 0.03, 0.06, 0.06 and 0.46 cm respectively (Fig. 45). The inhibition by bombax (25 %) and jack (32 %), though significant, was relatively less.

The influence of leaf extracts of the different tree species on cowpea is give in Table 53. Germination of cowpea was inhibited by the leaf extracts of acacia, eucalyptus, casuarina, ailanthus, tamarind, portia and cashew which reduced the germination to 74.67, 58.67, 84, 81.33, 68, 78.67 and 77.33 per cent respectively (Fig. 46). All the other trees were found to be on par with the control. The inhibition ranged from 4 - 38 per cent. The maximum inhibition was caused by eucalyptus (38 %) and tamarind (28 %) which were on par.

However, leaf extracts of all the tree species significantly inhibited plumule growth. The maximum inhibition was caused by ailanthus (84 %) and leucaena (79 %) which were on par. The resultant plumule lengths of seeds under these trees were 1.87 and 2.5 cm respectively while that of control was 12.03 cm (Fig. 47). Inhibition by jack (12 %) was the least.

Radicle growth was found to be significantly suppressed by all trees except jack. Maximum inhibition was caused by ailanthus (95 %), tamarind (90 %), cashew (89 %), albizzia (85 %) and eucalyptus (85 %) which were on par and resulted in radicle lengths of cowpea as low as 0.40, 0.90, 0.93, 1.27 and 1.30 cm respectively (Fig. 47). However, inhibition by jack (8 %) was comparatively low and the radicle length (7.93 cm) was on par with control (8.70 cm).

Table 53. Allelopathic effect of leaf extracts of different tree species on cowpea

Treatment		Germination per cent	RI	Plumule length (cm)	RI	Radicle length (cm)	RI
Acacia	(T1)	74.67 (59.77)	-0.21	8.93	-0.25	3.93	-0.54
Eucalyptus	(T2)	58.67 (49.97)	-0.38	4.20	-0.65	1.30	-0.85
Casuarina	(T3)	84.00 (66.86)	-0.11	3.63	-0.69	2.37	-0.73
Albizzia	(T4)	89.33 (70.98)	-0.05	4.70	-0.61	1.27	-0.85
Leucaena	(T5)	85.33 (68.37)	-0.10	2.50	-0.79	3.37	-0.60
Jack	(T6)	86.67 (68.60)	-0.08	10.33	-0.12	7.93	-0.08
Mango	(T7)	89.33 (71.79)	-0.05	3.23	-0.73	4.03	-0.52
Ailanthus	(T8)	81.33 (64.59)	-0.14	1.87	-0.84	0.40	-0.95
Tamarind	(T9)	68.00 (55.64)	-0.28	4.30	-0.64	0.90	-0.90
Bombax	(T10)	90.67 (72.61)	-0.04	8.20	-0.32	4.10	-0.53
Nutmeg	(T11)	88.00 (69.88)	-0.07	6.07	-0.49	5.27	-0.39
Wild Jack	(T12)	88.00 (71.63)	-0.07	7.70	-0.36	3.73	-0.56
Portia	(T13)	78.67 (62.49)	-0.17	5.87	-0.51	1.90	-0.78
Cashew	(T14)	77.33 (61.69)	-0.18	3.23	-0.73	0.93	-0.89
Control	(T15)	94.67 (76.80)	0.00	12.03	0.00	8.70	0.00
CD (0.05)		9.082		1.266		1.125	

Figures in parenthesis represent transformed (angular) values.

RI - Response index which is a measure of the inhibition/stimulation

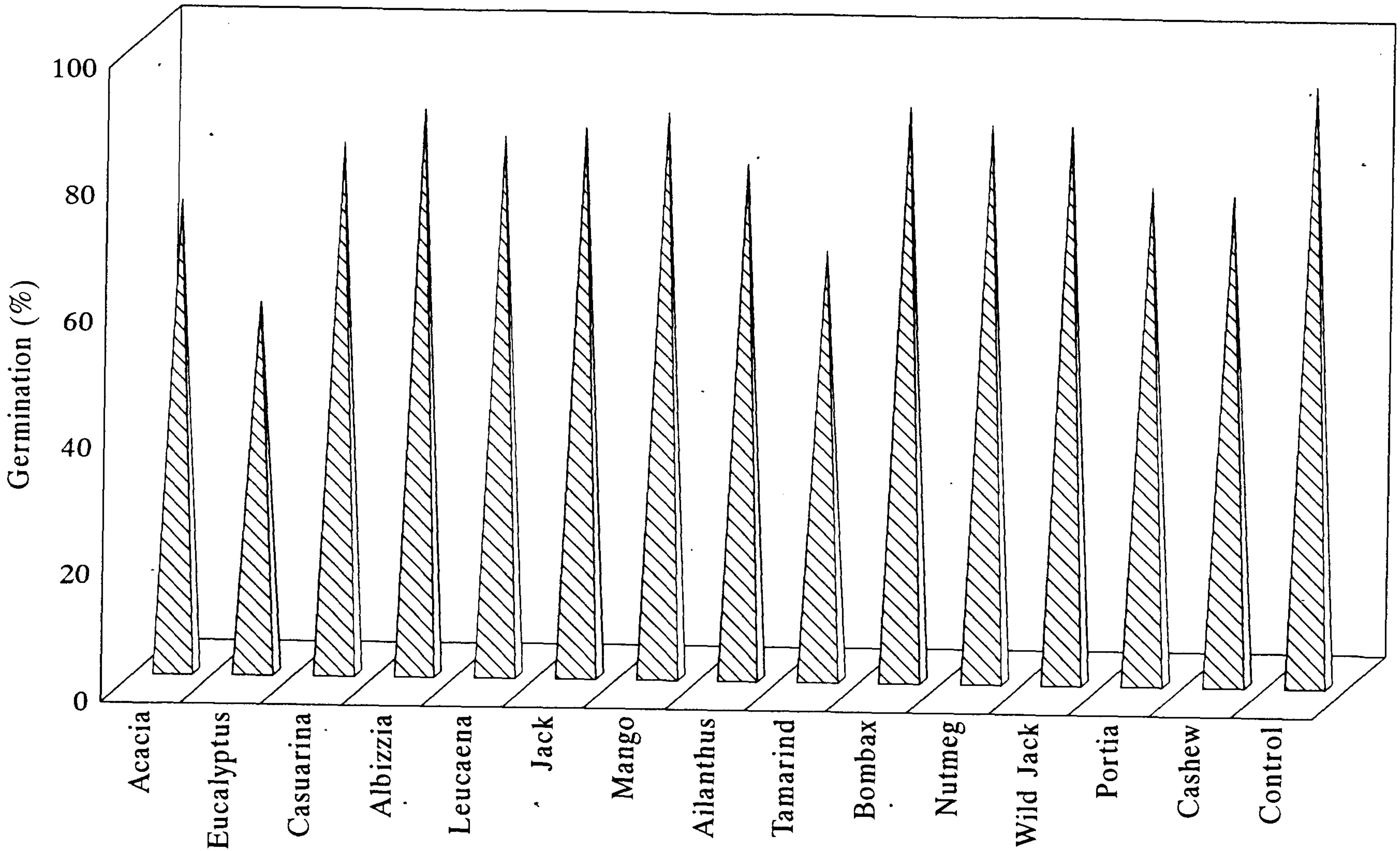


Fig. 46. Allelopathic effect of leaf extracts of trees on germination of cowpea

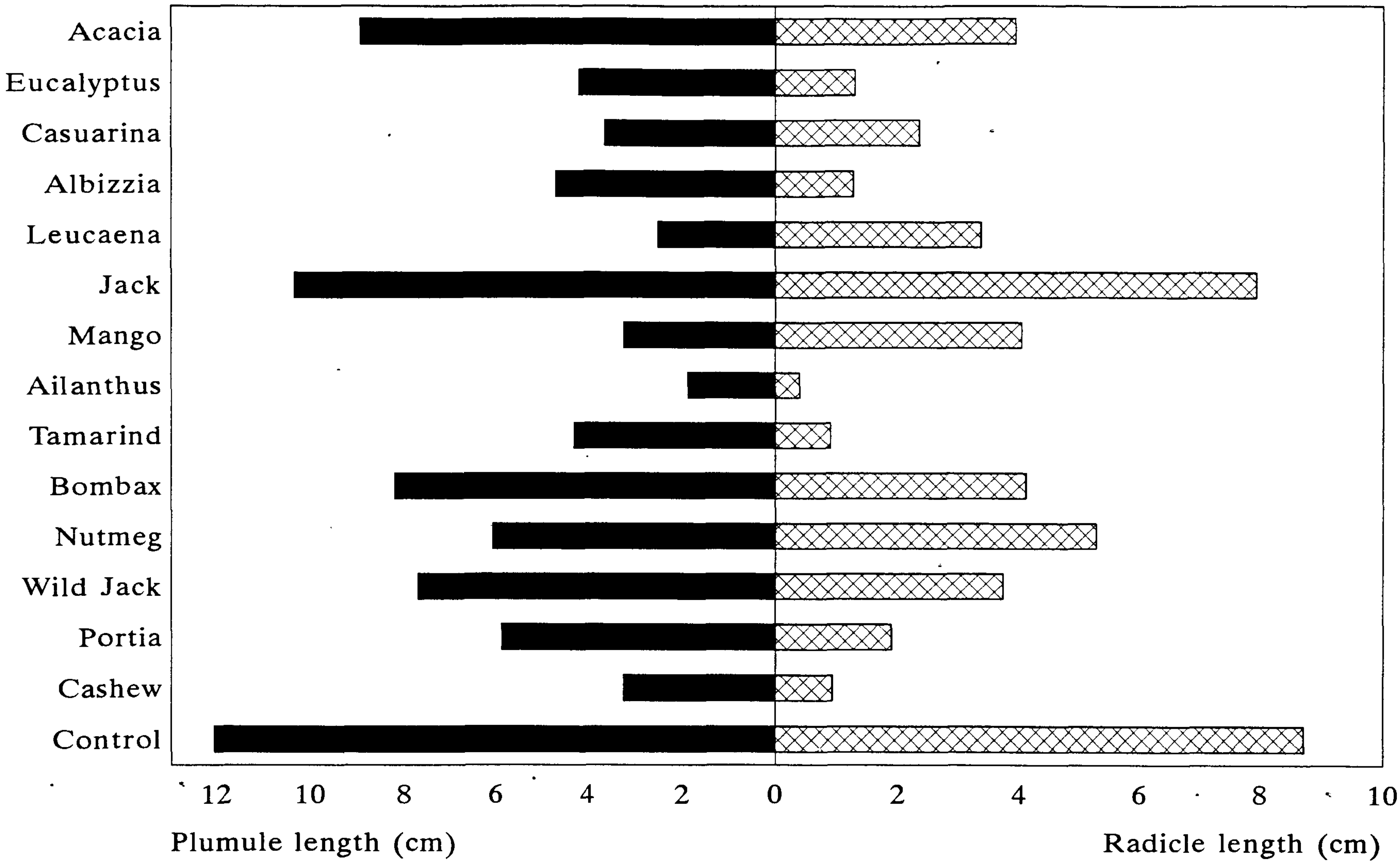


Fig. 47. Allelopathic effect of leaf extracts of trees on plumule and radicle length of cowpea

Response index values revealed that inhibition of radicle growth by the leaf extracts was more pronounced when compared to suppression of germination and plumule growth.

The effect of powdered leaf litter on rice is given in Table 54. The powdered leaf litter of all the trees inhibited rice germination (Fig. 48). The most severe inhibition was brought about by ailanthus (92 %) followed by tamarind (59 %) resulting in germination percentages of 6.66 and 37.33 respectively (Fig. 48). The least inhibition was observed under jack (7 %) and mango (10 %).

The growth of plumule was significantly suppressed by all the trees and its length varied from 0.86 - 8.20 cm, while in the control it was 9.46 cm (Fig. 49). Maximum suppression was brought about by ailanthus (90 %) as a result of which the plumule length was only 0.86 cm. This was followed by portia (58 %), eucalyptus (51 %) and cashew (51 %) which were on par. However, the inhibition caused by leucaena (13 %) and jack (17 %), though significant was comparatively less.

Radicle growth of rice was inhibited by all trees except jack (10.36 cm) which was on par with the control (Fig. 49). The radicle growth was least in seeds treated with the litter of ailanthus (0 cm), tamarind (1.26) and leucaena (1.26 cm) which caused 100, 87 and 87 per cent inhibition respectively. The inhibition by casuarina (18 %) and mango (39 %) was relatively less. The suppression by acacia (76 %) and eucalyptus (82 %) was also notable.

Table 54. Allelopathic effect of powdered leaf litter of different tree species on rice

Treatment		Germination per cent	RI	Plumule length (cm)	RI	Radicle length (cm)	RI
Acacia	(T1)	62.66 (52.32)	-0.30	5.40	-0.42	2.46	-0.76
Eucalyptus	(T2)	60.00 (50.76)	-0.33	4.60	-0.51	1.76	-0.82
Casuarina	(T3)	76.00 (60.69)	-0.16	6.56	-0.30	8.30	-0.18
Albizzia	(T4)	73.33 (58.89)	-0.19	6.60	-0.30	4.53	-0.55
Leucaena	(T5)	62.66 (52.32)	-0.30	8.20	-0.13	1.26	-0.87
Jack	(T6)	84.00 (66.50)	-0.07	7.83	-0.17	10.36	-0.01
Mango	(T7)	81.33 (64.40)	-0.10	6.40	-0.32	6.16	-0.39
Ailanthus	(T8)	6.66 (14.44)	-0.92	0.86	-0.90	0.00	-1.00
Tamarind	(T9)	37.33 (37.60)	-0.59	7.43	-0.21	1.26	-0.87
Bombax	(T10)	73.33 (58.89)	-0.19	7.20	-0.24	3.66	-0.64
Nutmeg	(T11)	64.00 (53.12)	-0.29	6.26	-0.33	3.60	-0.65
Wild Jack	(T12)	70.66 (57.19)	-0.22	6.16	-0.34	4.03	-0.60
Portia	(T13)	46.66 (43.05)	-0.48	4.00	-0.58	2.50	-0.75
Cashew	(T14)	76.00 (60.69)	-0.16	4.66	-0.51	5.90	-0.42
Control	(T15)	90.66 (72.26)	0.00	9.46	0.00	10.20	0.00
CD (0.05)		4.620		0.875		1.368	

Figures in parenthesis represent transformed (angular) values.

RI - Response index which is a measure of the inhibition/stimulation

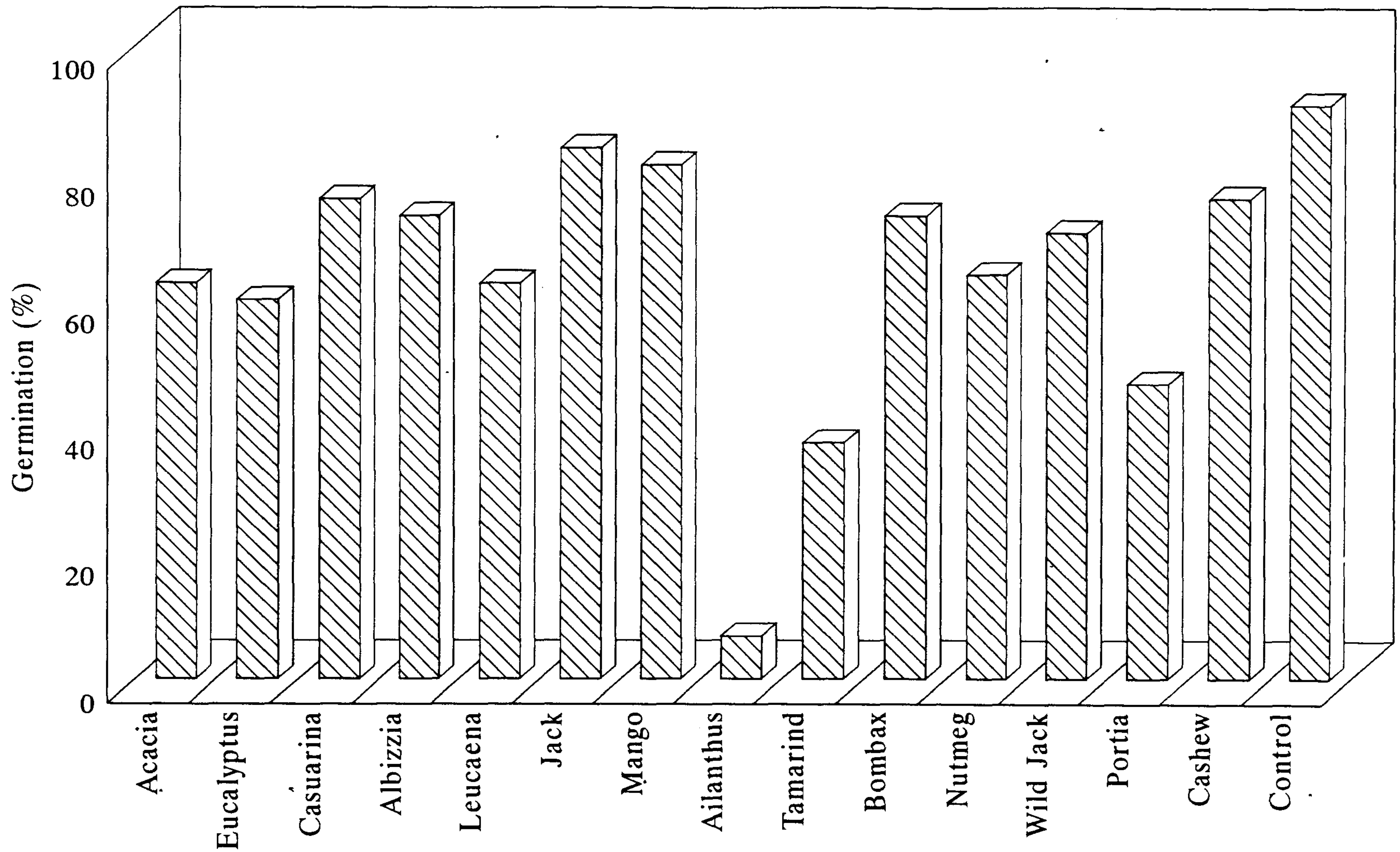


Fig. 48. Allelopathic effect of powdered litter of trees on germination of rice

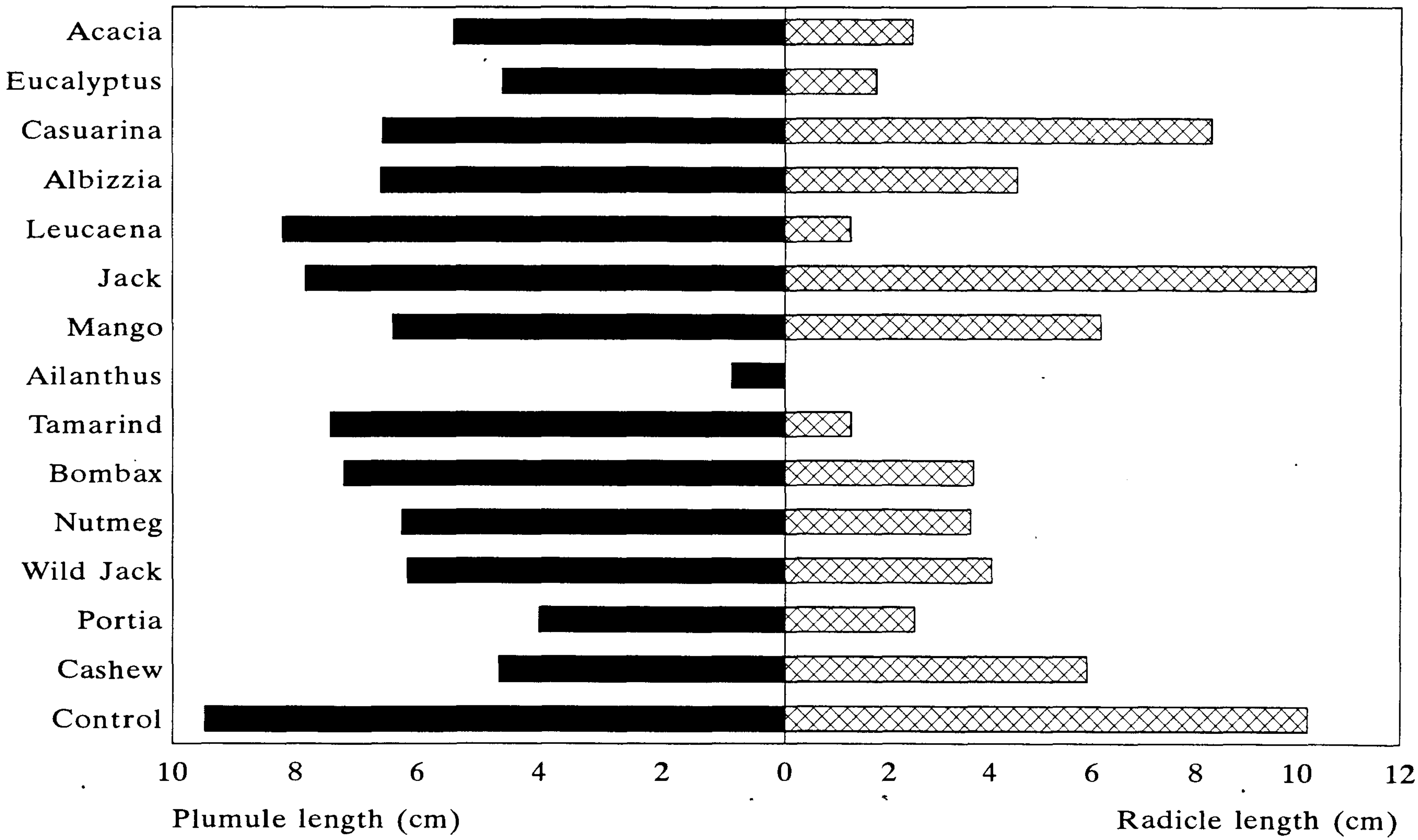


Fig. 49. Allelopathic effect of powdered litter of trees on plumule and radicle length of rice

The leaf extracts of all the trees inhibited germination and growth of plumule and radicle of rice. The effect of powdered litter of all trees showed a similar trend, except in the case of jack which did not inhibit radicle growth.

The effect of powdered litter of the different trees on cowpea is furnished in Table 55. Cowpea germination was significantly inhibited by the litter of all the trees except jack and mango which recorded 100 per cent germination and was on par with control. The germination was least in seeds treated with litter of nutmeg (40 %), ailanthus (41.33 %) and leucaena (50.67), which were on par (Fig. 50). The germination of cowpea was low under tamarind (56 %), eucalyptus (57.33 %) and acacia (58.67 %).

All the trees except cashew, casuarina and jack suppressed plumule growth of cowpea significantly (Fig. 51). The plumule length of germinated seeds treated with litter of casuarina (11.40 cm), jack (10.60 cm) and cashew (11.67 cm) was on par with control (11.33 cm). Maximum reduction of plumule growth was brought about by ailanthus (2.1 cm) followed by leucaena (3.43 cm) which caused 81 and 69 per cent inhibition respectively.

Radicle growth was significantly inhibited by all tree species and ranged from 20 - 97 per cent. The maximum inhibition was caused by ailanthus (97 %), tamarind (88 %) and cashew (88 %), which were on par, and the resultant radicle lengths were 0.27, 1.33 and 1.30 cm respectively (Fig. 51). The inhibition by jack (22 %) and mango (20 %) was comparatively less.

Table 55. Allelopathic effect of powdered leaf litter of different tree species on cowpea

Treatment		Germination per cent	RI	Plumule length (cm)	RI	Radicle length (cm)	RI
Acacia	(T1)	58.67 (49.99)	-0.41	5.40	-0.52	3.37	-0.70
Eucalyptus	(T2)	57.33 (49.20)	-0.42	6.50	-0.42	6.67	-0.40
Casuarina	(T3)	84.00 (66.50)	-0.16	11.40	0.00	5.90	-0.47
Albizzia	(T4)	81.33 (64.40)	-0.18	7.93	-0.30	3.60	-0.68
Leucaena	(T5)	50.67 (45.36)	-0.49	3.43	-0.69	1.67	-0.85
Jack	(T6)	100.00 (89.96)	0.00	10.60	-0.06	8.77	-0.22
Mango	(T7)	100.00 (89.96)	0.00	9.17	-0.19	8.97	-0.20
Ailanthus	(T8)	41.33 (39.97)	-0.58	2.10	-0.81	0.27	-0.97
Tamarind	(T9)	56.00 (48.46)	-0.44	7.57	-0.33	1.33	-0.88
Bombax	(T10)	78.67 (62.61)	-0.21	6.10	-0.46	7.30	-0.35
Nutmeg	(T11)	40.00 (39.20)	-0.60	9.83	-0.13	2.00	-0.82
Wild Jack	(T12)	82.67 (66.62)	-0.17	8.87	-0.21	7.27	-0.35
Portia	(T13)	84.00 (66.50)	-0.16	5.47	-0.52	5.83	-0.48
Cashew	(T14)	86.67 (68.60)	-0.13	11.67	+0.03	1.30	-0.88
Control	(T15)	100.00 (89.96)	0.00	11.33	0.00	11.27	0.00
CD (0.05)		6.723		1.174		1.096	

Figures in parenthesis represent transformed (angular) values.

RI - Response index which is a measure of the inhibition/stimulation

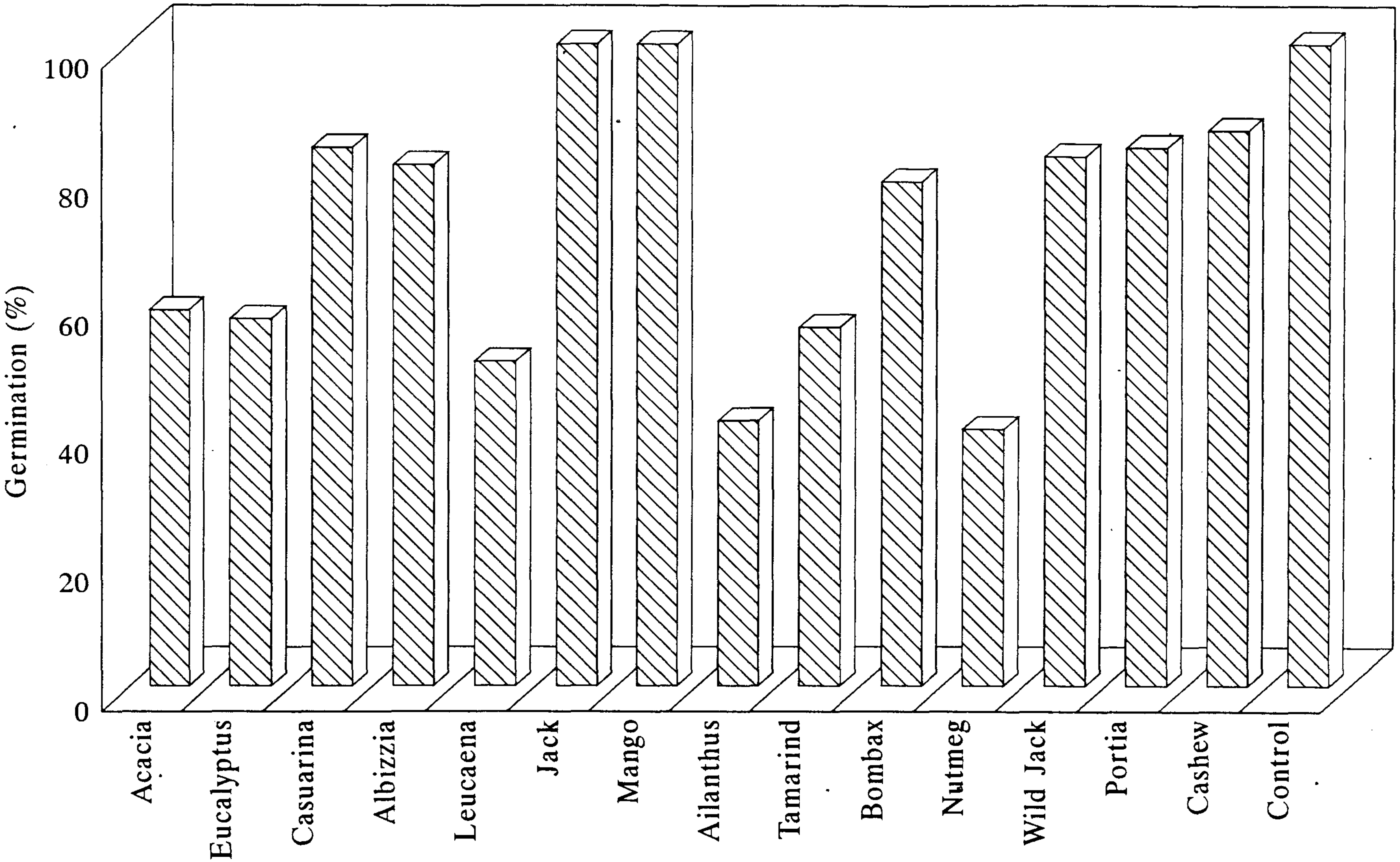


Fig. 50. Allelopathic effect of powdered litter of trees on germination of cowpea

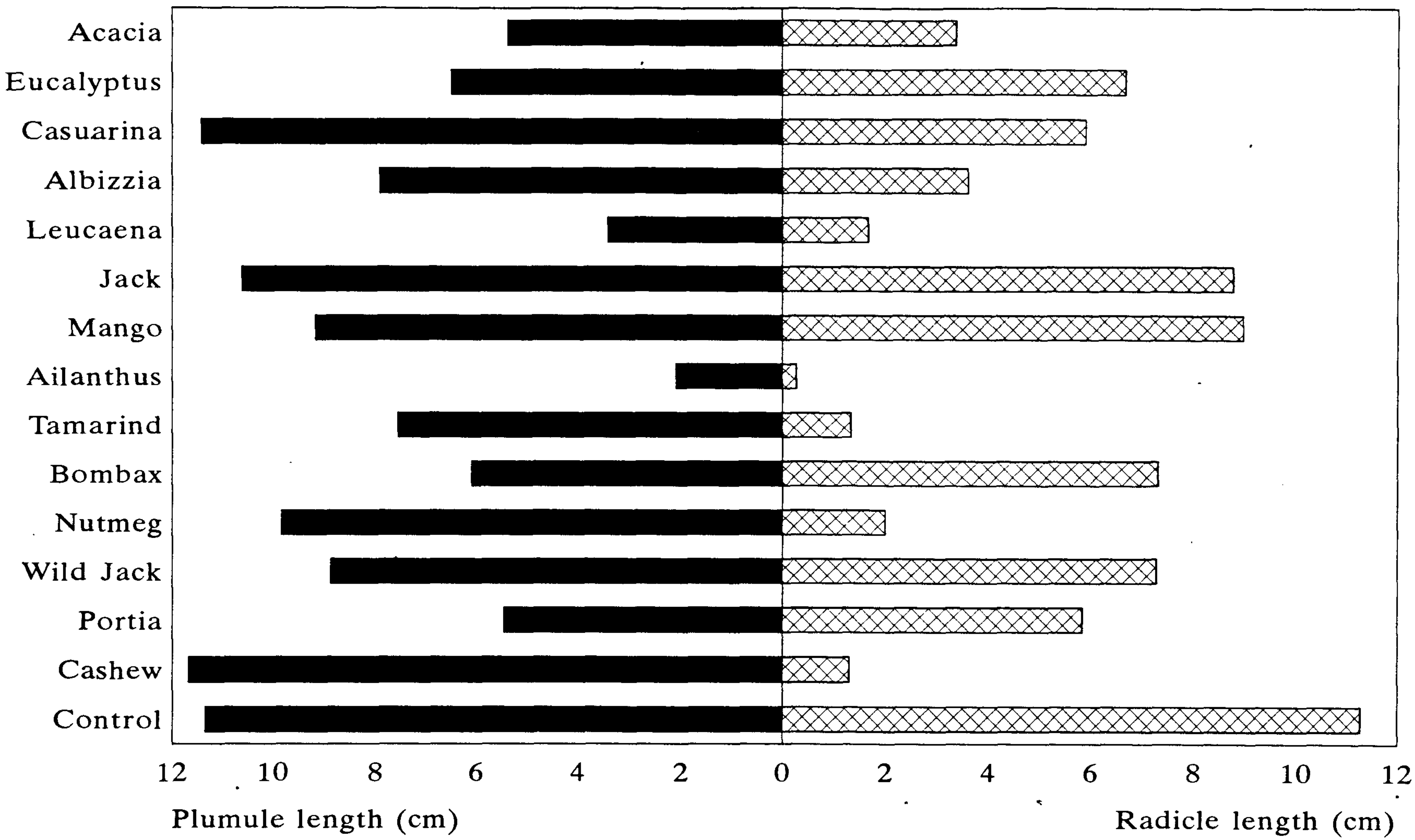


Fig. 51. Allelopathic effect of powdered litter of trees on plumule and radicle length of cowpea

Trees are rich sources of secondary metabolites (allelochemicals), and these chemicals impose certain kind of environmental stress on other plants growing in their vicinity, a phenomenon known as tree allelopathy. Allelochemicals may be produced by any part of the plant viz., roots, leaves, pollen, seeds and fruits. The accumulation of tree litter on the soil under agroforestry system of farming could have negative effects on the agricultural crops. Consequently, seed germination and establishment of certain crops may be inhibited. Quantitatively and qualitatively, production of allelochemicals is regulated by the stage of the plant and is modified by environmental stresses like soil temperature, drought, flooding or poor drainage, ultraviolet light or sunlight, microorganisms soil salinity, diseases, herbicides, minerals and even growth regulators or hormones. Allelopathic interaction by a plant is possible through leaching, volatilization from aerial parts, decay of fallen parts and/or exudation in the rhizosphere. Though many physiological processes are affected by allelochemicals retardation of growth is indicated to be the frequent response. The effect of allelochemicals on metabolic changes of receiver plants include effect on cell division, elongation and ultrastructure of cells, hormone induced growth, membrane permeability, mineral uptake, stomatal opening and photosynthesis, respiration, protein synthesis, lipid and organic acid metabolism, porphyrin synthesis, enzyme activity, xylem corking and clogging and internal water relations.

From the results of the studies it is evident that the leaf extracts and powdered litter of the different trees had significant allelopathic effects on both rice and cowpea.

Both the leaf extracts and powdered litter of eucalyptus inhibited germination and growth in rice and cowpea. Similar findings of inhibition of rice (Al-Mousawi and Al-Naib, 1975; Dhillon *et al.*, 1982; Tomer and Srivastava, 1986) and cowpea (Suresh and Rai, 1987; Kohli, 1990; Shivanna *et al.*, 1992) have been reported. The allelopathic effect of Eucalyptus has been attributed to the production of several volatile terpenes (Del Moral and Muller, 1969 and 1970) and some water soluble inhibitors by Eucalyptus leaves (Al-Mousawi and Al-Naib, 1975) some of which are toxic for seed germination and seedling growth. Singh and Kohli (1992) detected that the eucalyptus rhizosphere was found rich in chemicals (phenolic acids) which were injurious to the vegetation beneath it. Kohli (1990) reported that different parts of Eucalyptus yielded different amounts of organic components (aglycones) which were inhibitory. Sunil and Amarjeet (1991) tested the water extracts of leaves of *Eucalyptus tereticornis* and reported that leachates from green leaves were found to be most inhibitory in primary root development.

Acacia caused allelopathic inhibition both in rice and cowpea. This was probably due to the phytotoxin, tannin present in acacia leaves as suggested by Swaminathan *et al.* (1989). Concurrent results of inhibition in rice (Jadhav and Gayanar, 1992; Rao *et al.*, 1994; Phlomina and Srivasuki, 1996) and cowpea (Jadhav and Gayanar, 1992; Swaminathan *et al.*, 1989) have been reported.

Leucaena was found to cause inhibition in both rice and cowpea. However, leaf extracts did not suppress cowpea germination. The phytotoxic effects of leucaena may be attributed to mimosine which is a non-protein aminoacid present in the leaves (Kuo *et al.*, 1982). Mimosine inhibits the mobilization of stored food from cotyledon to embryo (Rizvi *et al.*, 1990; Singh and Nandal, 1993). The allelopathic inhibition by leucaena has been observed by Rizvi *et al.* (1990); Koul *et al.* (1991) and Rao *et al.* (1994) in rice, and by Suresh and Rai (1987) in cowpea.

Casuarina and cashew inhibited germination and growth of rice and cowpea. However, its powdered litter did not suppress plumule growth of cowpea. Albizzia, bombax, nutmeg and wild jack affected rice and cowpea, but their extracts did not inhibit cowpea germination. The inhibitions noticed may be due to allelochemicals in the leaves. Though reports of specific inhibition of rice and cowpea by these trees are not available, the general allelopathic effect of casuarina (Suresh and Rai, 1987; Srinivasan *et al.*, 1990; Joshi and Prakash, 1992) and albizzia (Bhatt and Todaria, 1990) have been recorded. The inhibition by bombax observed in the present study is contradictory to the findings of Joshi and Prakash (1992) who reported its general stimulatory effect.

In the current study, ailanthus and tamarind were found to cause allelopathic effects on germination and growth in rice and cowpea. Tannins present in plant parts have been identified as the most effective substance in causing allelopathy. This may be the reason for the very severe suppression caused by ailanthus and tamarind which has a high tannin content in its leaves. The observed inhibition by portia would probably be due to its leaf tannin content.

The leaf extracts of jack did not inhibit cowpea germination and radicle growth. Also, its powdered litter did not inhibit radicle growth in rice and germination and plumule growth in cowpea. In mango, leaf extract and litter powder did not inhibit cowpea germination. Hence, it could be inferred that mango inhibits only growth of cowpea. Moreover, it was observed that the inhibition by jack and mango were comparatively less in all cases where its effect was significant. However, the observed inhibition by jack and mango, might have been due to the tannins and phenols present their leaves.

The allelopathic effects of nutmeg, cashew, wild jack, portia, tamarind, ailanthus, jack and mango have not been investigated till date and hence supporting evidences are lacking.

The observed inhibition of germination and growth of rice and cowpea by the leaf extracts is due to phytotoxins present in the leaf extracts of the trees instead of osmotic inhibition because of the use of 10 per cent extract which ensures low osmolality (Richardson and Williamson, 1988).

The present study also revealed the disparate response of the test crops to extracts and litter of the trees. This differential response of cowpea and rice to both extracts and powdered litter of the same tree species cautions against the use of a single assay species in insinuating any allelopathic interference. Also, leaves from different tree species contain different phytotoxic compounds. The phytotoxic effects may be by more than one chemical compound, present in different trees and hence, crop species react differently to these trees.

The increased inhibition of plumule and radicle growth when compared to germination observed in the study is in accordance with the findings of Fisher (1980) which indicated retardation of growth to be the frequent response to allelochemicals.

From the above, it could be inferred that allelopathic interaction is made possible through leaching of inhibitors and decay of fallen leaves from trees. This has several management implications related to homestead farming, where a large number of intercrops are grown in the space available beneath the tree canopy. Richardson and Williamson (1988) found inhibition of germination to be highly correlated with precipitation as this provides an appropriate mechanism for water soluble inhibitors to leach down through foliar run-off resulting in poor growth of under-storey. It was observed from the field experiments conducted in both the homesteads that the trees added large quantities of litter to the soil. The inhibitory effect of litter largely depends on the amount of litter deposited. The increased amount of litter could lead to greater release of toxic chemicals. Moreover, the toxic substances added to the soil through the leaf litter remain for a long time, especially in low rainfall areas, and would have inhibitory effect on germination of crop plants. Therefore, while identifying suitable trees for homestead agroforestry systems, efforts should be made to select the species with the least allelopathic activity.

Natural conditions are, however, more complicated than laboratory bioassays. Hence, field experiments are necessary before any final conclusion is made on allelopathic effects of the investigated trees.

4.4 Linear programming

The technique of linear programming was employed to develop optimum models for the home gardens at Locations I and II. The optimum solutions are presented in Tables 56 to 59 and discussed below.

The optimization model for the home garden at Location I was developed after considering the farmer's tastes, preferences and constraints (Table 56, Fig. 52). The model is operative for a farm size of 0.50 ha. The household comprises a family of three members which includes the husband, wife and one son. The model aims to achieve the objective of profit maximization against the constraints that operated in the form of linear inequalities.

The constraints included :

Net main area : The total main area available was 0.50 ha.

Intercrop area : The interspaces available for planting of crops was assessed after excluding the area occupied by the house and permanent structures and the area occupied by the basins of coconut and other tree components. Thus, the intercropped area, which consisted of the understorey of the trees, was 0.30 ha.

Investment capacity of the farmer : All the activities are financed internally and the farmer was not dependent upon external financing in the form of credit.

He had at his disposal an amount of Rs. 3300/- as working capital and was not willing to invest more than Rs.3300/- in a year which included both input and labour cost. Based on the economics during the two years under study, the expenditure for each enterprise was worked out. The higher values of investment was considered while developing the model.

Population of components / enterprises : The tastes and preferences of the farmer and his constraints in increasing or decreasing the population of each enterprise was ascertained after consultation with the farmer. The farmer was not willing to change the population of various components (constraint denoted by =). The constraints with respect to the different enterprises included in the model were decided by the farmer, so as to meet the multiple demand of the farm family by enterprise diversification, to optimize the available resources and to maximize the gross returns.

At Location I, during the period under study in the first year (Table 48) the farmer invested Rs.1616/- and received a net profit of Rs.6550/- resulting in a benefit : cost ratio of 5.05. In the second year (Table 49), his investment was Rs.3157/- and net profit was Rs.6106/- with a benefit : cost ratio of 2.93. The cropping intensities in the I and II year were 107.66 and 114.46 per cent respectively.

According to the optimum model developed for the 0.50 ha home garden by investing Rs. 3262.30/- the farmer would receive a net profit of Rs. 10354.21 (Table 56). The model, developed with the objectives of resource optimization and profit maximization, has a cropping intensity of 117.83 per cent and a benefit : cost ratio of 4.17. It is a coconut-based model.

Table 56. Optimisation model for home garden at Location I

Sl. No.	Enterprise	Value	Space (m)		Expenditure (Rs)		Gross return (Rs)		Net return (Rs.)	Constraints
			Unit	Total	Unit	Total	Unit	Total		
	Main area									
1.	Adult coconut	27	60.800	1641.600	62.90	1698.30	122.42	3305.34	1607.04	< 60
2.	Jack	4	23.500	94.000	8.80	35.00	120.00	480.00	445.00	= 4
3.	Mango	7	19.400	135.800	8.00	56.00	104.00	728.00	672.00	< 7
4.	Bread fruit	3	47.700	143.100	0.00	0.00	166.67	500.01	500.01	= 3
5.	Moringa	4	12.600	50.400	0.00	0.00	6.25	25.00	25.00	= 4
6.	Borassus	20	50.200	1004.000	3.60	72.00	30.75	615.00	543.00	= 20
7.	Bamblimass	1	80.600	80.600	45.00	45.00	225.00	225.00	180.00	= 1
8.	Wild Jack	4	75.880	303.520	0.00	0.00	0.00	0.00	0.00	= 4
9.	Gmelina	1	16.610	16.610	0.00	0.00	0.00	0.00	0.00	= 1
10.	Albizzia	2	56.880	113.760	0.00	0.00	0.00	0.00	0.00	= 2
11.	Mahogany	2	30.140	60.280	0.00	0.00	0.00	0.00	0.00	= 2
12.	Teak	3	13.680	41.030	0.00	0.00	0.00	0.00	0.00	= 3
13.	Cinnamon	2	15.010	30.020	0.00	0.00	0.00	0.00	0.00	= 2
14.	House	1	912.500	912.500	0.00	0.00	0.00	0.00	0.00	= 1
	Main area Total			4628.020						< 5000
	Interspaces									
15.	Nutmeg	20	37.200	744.000	36.90	738.00	184.62	3692.40	2954.40	< 20
16.	Coffee	4	15.600	62.400	11.30	45.00	52.50	210.00	165.00	= 4
17.	Bilimbi	1	20.200	20.200	0.00	0.00	70.50	70.50	70.50	= 1
18.	Clove	6	3.100	18.600	16.70	100.00	106.67	640.02	540.02	< 6
19.	Banana	25	3.100	77.500	13.70	343.00	53.33	1333.25	990.25	< 25
20.	Pepper	30	1.000	30.000	2.00	60.00	51.00	1530.00	1470.00	< 30
21.	Colocasia	50	1.100	55.000	0.40	20.00	1.50	75.00	55.00	= 50
22.	Papaya	2	4.000	8.000	0.00	0.00	31.00	62.00	62.00	= 2
23.	Curry leaf	3	1.700	5.100	0.00	0.00	8.33	24.99	24.99	= 3
24.	Vegetables (unit)	2	40.000	80.000	25.00	50.00	50.00	100.00	50.00	< 2
	Interspace Total			1100.800						< 3000
	Grand Total					3262.30		13616.51	10354.21	

Main area < 5000 m^2

Total expenditure < Rs. 3300/-

Interspace < 3000 m^2

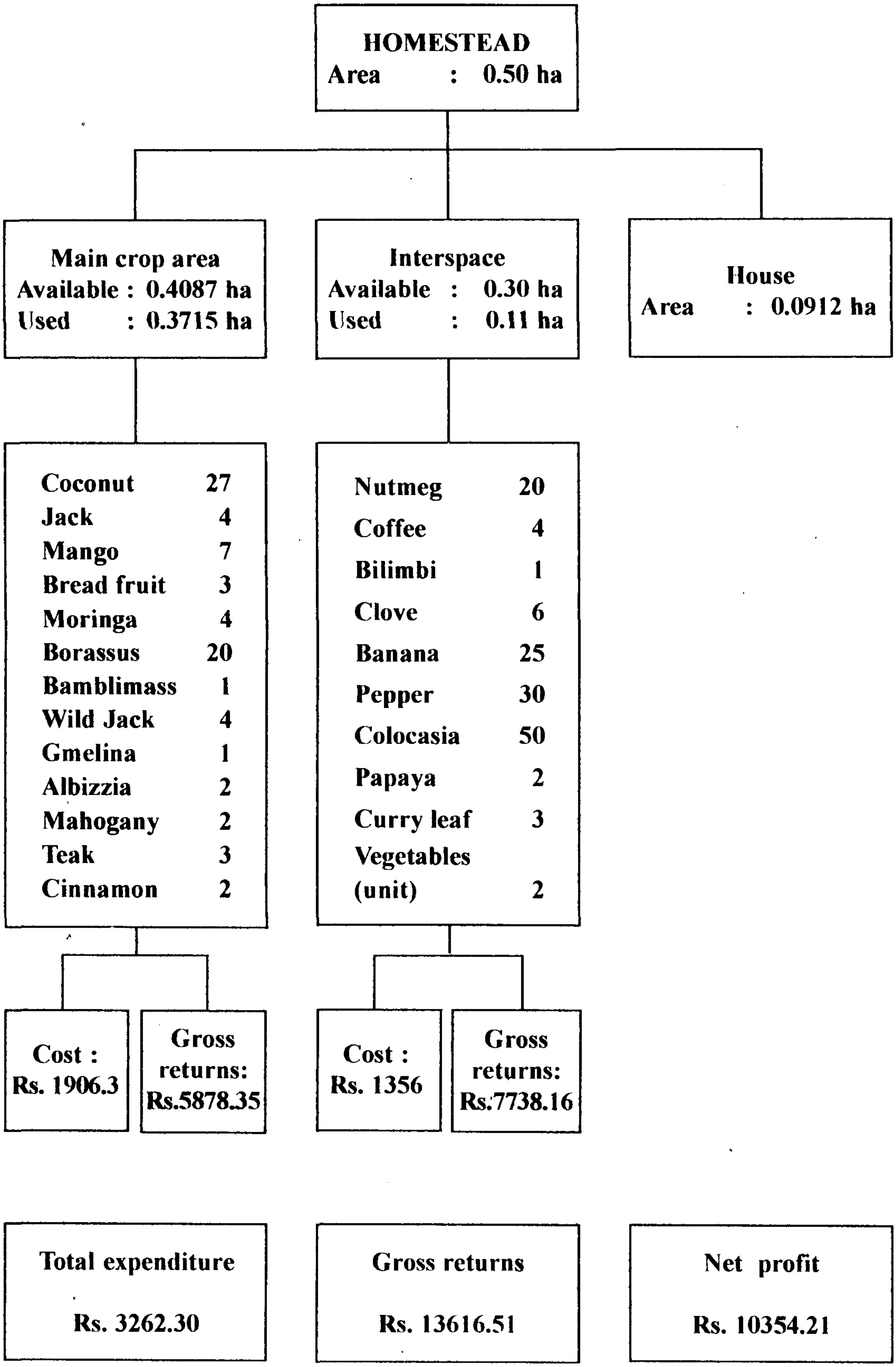


Fig. 52. Optimisation model for the home garden at Location I

The functional diversity of the components preferentially selected by the farmer, gives due consideration to the home requirements of food, fodder, fuel, timber and shelter.

The crops like coconut (27 nos.), banana (25), pepper (30), colocasia (50), curry leaf (3) and vegetables (2 units) are included to meet the food requirements of the members of the household. After meeting the home requirements, the surplus is expected to be marketed so as to purchase non-producible items. Among the crops, pepper and coconut contributed more to income generation than the others.

The tree components of the model comprising of jack (4), mango (7), breadfruit (3), moringa (4), borassus (20), bamblimass (1), wild jack (4), gmelina (1), albizzia (2), mahogany (2), teak (3), cinnamon (2), nutmeg (20), coffee (4), bilimbi (1), clove (6) and papaya (2) would help to meet the requirements of food, fuel and timber. The by-products of coconut such as dried leaves, spathe, husk, shell etc. available from 27 palms could meet the annual fuel requirements of the farm family. Abdul Salam *et al.* (1991b) reported that a family of five or six members, with 30-35 coconut palms could meet their fuel requirements from the farm itself. Nutmeg fetches a very high price in the local market of the area and hence the farmer was willing to increase the population upto 20 as against the current 13. Trees like wild jack, gmelina, teak and mahogany, though do not provide any returns at present, are included in the model as they are expected to meet the timber needs of the farmer and generate income in future.

An in depth analysis of the model (Table 57) revealed that, several changes could be suggested to increase the gross return and net profit of the farmer, if his constraints are removed. The dual price values indicate the increase or decrease in the gross returns of the model for unit change in value of the constraint within the given ranges of minimum and maximum RHS (right hand side). In the case of coconut, though the farmer was willing to maintain upto 60 palms, the optimum model has absorbed only 27. The analysis reveals that an increase in the population between 27 (minimum RHS) and infinity (maximum RHS) will not change the gross return of the model (dual price = 0). However, an increase in coconut population would give more return, but, at the expense of other more remunerative enterprises. The farmer is willing to invest a total amount of Rs.3300 only. If he spends more on coconut, he has to reduce the investment on certain other enterprises which are more remunerative (higher benefit : cost ratio).

At present, the farmer has expressed his inability to invest more than Rs.3300/-. The analysis shows that his investment could be increased upto Rs.3636.06, for which he would receive Rs.1.94 on every rupee invested (Table 57). Moreover, there is sufficient interspace (1899.20 m^2) which remains unutilised. Thus, if the farmer was willing to spend more, it could be suggested that the farmer could invest on profitable enterprises like jack (dual price = 102.87), mango (88.42), breadfruit (166.67), bamblimass (137.41), nutmeg (112.80), clove (74.16), banana (26.66), and pepper (47.10), the population of which may be increased upto 26, 35, 10, 10, 67, 109, 151 and 897 respectively.

Table 57. Linear programming analysis of Location I

Constraint	RHS	Minimum RHS	Maximum RHS	Slack (-) / Surplus (+)	Dual price
1 (<) Main area	5000.00	4628.0200	infinity	371.9800-	0.0000
2 (<) Expenditure	3300.00	1564.0997	3636.0616	37.7000-	1.9463
3 (<) Adult coconut	60.00	27.0000	infinity	33.0000-	0.0000
4 (=) Jack	4.00	0.0000	26.4383	0.0000	102.8729
5 (<) Mango	7.00	0.0000	35.8363	0.0000-	88.4299
6 (=) Bread fruit	3.00	0.0000	10.0532	0.0000	166.6700
7 (=) Moringa	4.00	0.0000	30.7012	0.0000	6.2500
8 (=) Borassus	20.00	0.0000	27.2011	0.0000	23.7434
9 (=) Bamblimass	1.00	0.0000	10.0678	0.0000	137.4181
10 (<) Interspace	3000.00	1100.7999	infinity	1899.2001-	0.0000
11 (<) Nutmeg	20.00	10.5676	67.0434	0.0000-	112.8029
12 (=) Coffee	4.00	0.0000	125.7436	0.0000	30.5072
13 (=) Bilimbi	1.00	0.0000	95.0198	0.0000	70.5000
14 (<) Clove	6.00	0.0000	109.9461	0.0000-	74.1674
15 (<) Banana	25.00	0.0000	151.7081	0.0000-	26.6662
16 (<) Pepper	30.00	0.0000	897.9501	0.0000-	47.1075
17 (=) Colocasia	50.00	0.0000	1393.5520	0.0000	0.7215
18 (=) Papaya	2.00	0.0000	476.8000	0.0000	31.0000
19 (=) Curry leaf	3.00	0.0000	1120.1765	0.0000	8.3300
20 (<) Vegetables	2.00	0.0000	49.4800	0.0000-	1.3434

RHS - Right hand side value

Though. it is not possible to increase the population of all the components upto the suggested limits, because of the constraint of space available, the farmer could select from among these enterprises and limits. It would be more practical to invest it in annuals or early yielding perennials.

The optimization model for the home garden at Location II is operative for a farm size of 0.40 ha (Table 58, Fig. 53). The household comprises a family of three members which includes the husband, wife and one daughter. The model aims to achieve the objective of profit maximization against the constraints that operated in the form of linear inequalities.

The constraints included :

Net main area : The total main area available was 0.40 ha.

Intercrop area : The interspaces available for planting of crops was assessed after excluding the area occupied by the house and permanent structures (cattle shed, poultry bin and roads etc) and the area occupied by the basins of coconut and other tree components. Thus, the intercropped area, which consisted of the understorey of the trees, was 0.27 ha.

Investment capacity of the farmer : All the activities are financed internally and the farmer was not dependent upon external financing in the form of credit. He had at his disposal an amount of Rs. 45000/- as working capital and was not willing to invest more than Rs.45000/- in a year which included both input and labour cost. Based on the economics during the two years under study, the expenditure for each enterprise was worked out. The higher values of investment was considered while developing the model.

Population of components / enterprises : The tastes and preferences of the farmer and his constraints in increasing or decreasing the population of each enterprise was ascertained after consultation with the farmer. The farmer was not willing to change the population of various components (constraint denoted by =). The constraints with respect to the different enterprises included in the model were decided by the farmer, so as to meet the multiple demand of the farm family by enterprise diversification, to optimize the available resources and to maximize the gross returns.

At Location II, during the period under study in the first year (Table 50), the farmer invested Rs.44233/- and received a net profit of Rs.26637/- resulting in a benefit : cost ratio of 1.60. In the second year (Table 51), his investment was Rs.20415/- and net profit was Rs.23425/- with a benefit : cost ratio of 2.15. The cropping intensities in the I and II year were 145.13 and 152 per cent respectively.

According to the optimum model developed for the 0.40 ha home garden, by investing Rs.45000/- the farmer would receive a net profit of Rs.32464.32. The model, developed with the objectives of resource optimization and profit maximization, has a cropping intensity of 141 per cent and a benefit : cost ratio of 1.72. It is a coconut-based mixed farming model.

Table 58. Optimisation model for home garden at Location II

Sl. No.	Enterprise	Value	Space (m)		Expenditure (Rs)		Gross return (Rs)		Net return (Rs.)	Constraints
			Unit	Total	Unit	Total	Unit	Total		
	Main area									
1.	Adult coconut	45	25.965	1168.425	64.68	2908.05	100.00	4496.06	1588.01	40 > < 75
2.	Jack	2	39.000	78.000	45.00	90.00	300.00	600.00	510.00	= 2
3.	Mango	4	22.340	89.360	67.50	270.00	93.75	375.00	105.00	= 4
4.	Cashew	5	304.800	1524.000	125.00	625.00	200.00	1000.00	875.00	= 5
5.	Gooseberry	1	26.000	26.000	15.00	15.00	20.00	20.00	5.00	= 1
6.	Wild Jack	2	30.550	61.110	0.00	0.00	0.00	0.00	0.00	= 2
7.	Tamarind	1	50.240	50.240	0.00	0.00	0.00	0.00	0.00	= 1
8.	Mahogany	2	37.270	74.550	0.00	0.00	0.00	0.00	0.00	= 2
9.	Cinnamon	1	29.220	29.220	0.00	0.00	0.00	0.00	0.00	= 1
10.	Ailanthus	4	7.210	28.840	0.00	0.00	0.00	0.00	0.00	= 4
11.	Neem	1	19.620	19.620	0.00	0.00	0.00	0.00	0.00	= 1
12.	Teak	10	1.760	17.660	0.00	0.00	0.00	0.00	0.00	= 10
13.	Morinda	15	7.060	105.970	0.00	0.00	0.00	0.00	0.00	= 15
14.	Cow	1	40.000	40.000	33685.00	33685.00	50475.00	50475.00	16790.00	= 1
15.	Goat	2	10.000	20.000	1003.75	2007.50	1642.50	3285.00	1277.50	= 2
16.	Poultry	15	1.333	20.000	13.33	200.00	174.67	2620.00	2420.00	= 15
17.	House	1	200.000	200.000	0.00	0.00	0.00	0.00	0.00	= 1
	Main area Total			3552.995						< 4000
	Interspaces									
18.	Breadfruit	1	12.000	12.000	30.00	30.00	150.00	150.00	120.00	= 1
19.	Bilimbi	5	12.000	60.000	6.00	30.00	20.00	100.00	70.00	= 5
20.	Annona	6	21.500	129.000	7.50	45.00	4.17	25.02	-19.98	= 6
21.	Tapioca	600	1.000	600.000	2.65	1590.00	6.00	3600.00	2010.00	< 600
22.	Dioscorea	40	1.000	40.000	6.00	240.00	12.00	480.00	240.00	< 40
23.	Amorphophallus	30	1.500	45.000	6.00	180.00	15.00	450.00	270.00	< 30
24.	Colocasia	15	1.700	25.500	1.50	22.50	3.00	45.00	22.50	< 15
25.	Turmeric	40	0.500	20.000	6.00	240.00	12.00	480.00	240.00	< 40
26.	Pepper	40	1.000	40.000	2.00	80.00	53.33	2133.20	2053.20	< 40
27.	Arrowroot	1000	0.500	500.000	0.30	300.00	0.50	500.00	200.00	= 1000
28.	Pineapple	70	1.000	70.000	3.70	259.00	10.00	700.00	441.00	< 70
29.	Arecanut	4	7.000	28.000	3.75	15.00	2.50	10.00	-5.00	= 4
30.	Sapota	1	47.000	47.000	15.00	15.00	30.00	30.00	15.00	= 1
31.	Moringa	10	7.000	70.000	9.00	90.00	12.00	120.00	30.00	= 10
32.	Bamblimass	1	45.000	45.000	30.00	30.00	200.00	200.00	170.00	= 1
33.	Guava	5	28.200	141.000	6.00	30.00	8.00	40.00	10.00	= 5
34.	Banana	25	3.120	78.000	15.80	395.00	60.00	1500.00	1105.00	= 25
35.	Curry leaf	4	3.000	12.000	2.00	8.00	7.50	30.00	22.00	= 4
36.	Apiculture	8	1.000	8.000	200.00	1600.00	500.00	4000.00	2400.00	< 8
	Interspace Total			1970.500						< 2700
	Grand Total					45000.00		77464.32	32464.32	

Main area < 4000 m^2
Total expenditure < Rs. 45000/-
Interspace < 2700 m^2

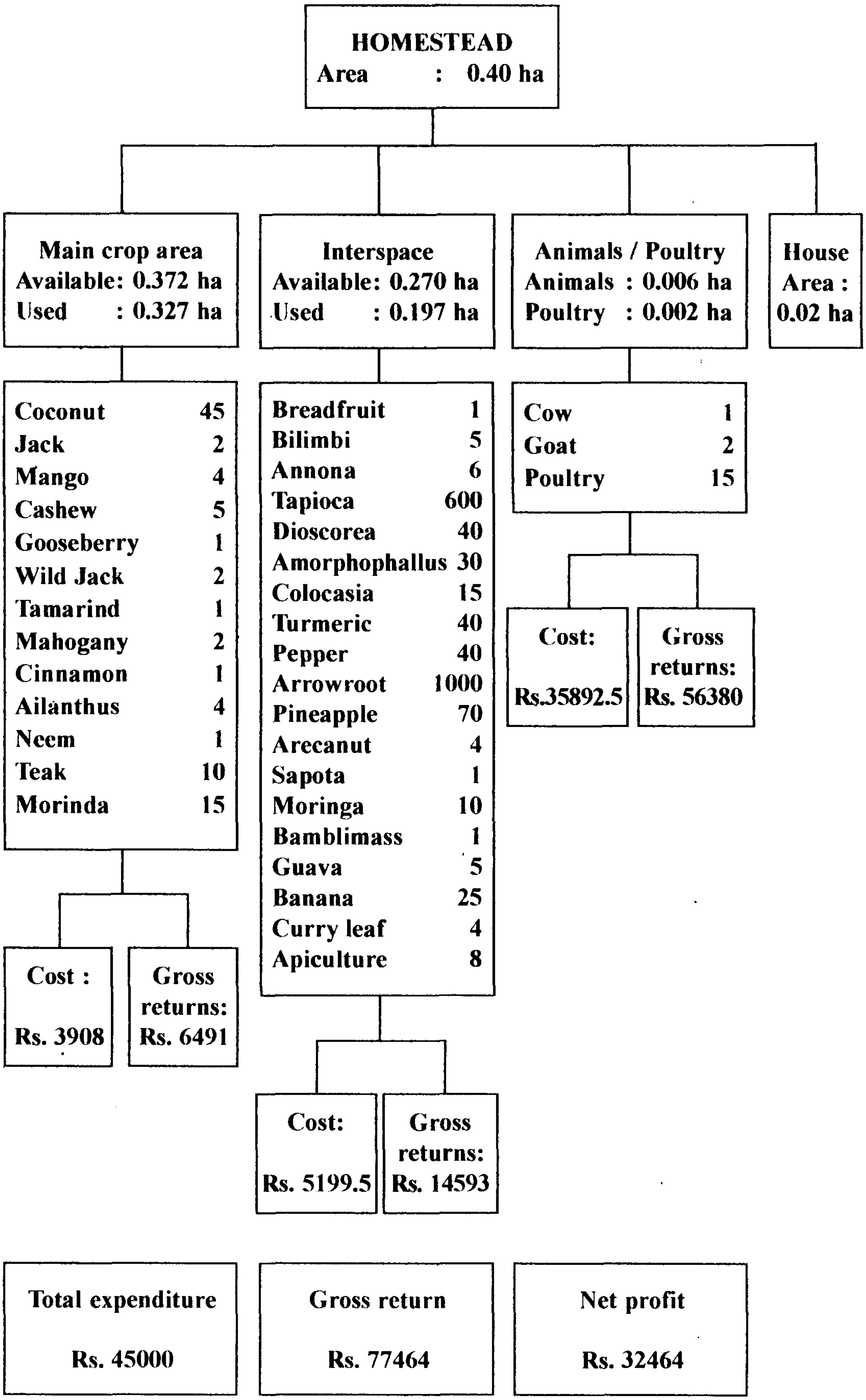


Fig. 53. Optimisation model for the home garden at Location II

The functional diversity of the components preferentially selected by the farmer, gives due consideration to the home requirements of food, fodder, fuel, timber and shelter.

The crops like coconut (45 nos.), tapioca (600), dioscorea (40), amorphophallus (30), colocasia (15), turmeric (40), pepper (40), arrowroot (1000), pineapple (70), banana (25) and curry leaf (4) are included to meet the food requirements of the members of the household. After meeting the home requirements, the surplus is expected to be marketed so as to purchase non-producible items. Among the crops, pepper, tapioca and coconut contributed more to income generation than the others.

The tree components of the model comprising of jack (2), mango (4), cashew (5), gooseberry (1), wild jack (2), tamarind (1), mahogany (2), cinnamon (1), ailanthus (4), neem (1), teak (10), morinda (15), breadfruit (1), bilimbi (5), annona (6), arecanut (4), sapota (1), moringa (10), bamblimass (1) and guava (5) help to meet the requirements of food, fuel, timber and fodder. The leaves from morinda are fed to the goats. The by-products of coconut such as dried leaves, spathe, husk, shell etc. available from 45 palms can largely meet the annual requirements of the farm family. Moreover, the leaves from the palms can also be used for thatching the cattle shed. Abdul Salam *et al.* (1991b) reported that a family of five or six members, with 30-35 coconut palms could meet their fuel requirements from the farm itself.

The livestock/poultry components of the model comprises of one cow, two goats and 15 poultry birds which are common animal components of homesteads in the State. Eight apiculture units are also included in the model. These enterprises will provide all the advantages inherent in a mixed farming system. The livestock system not only ensures enterprise diversification, but also augments farm income by the sale of surplus milk and eggs. The goat unit provides farm income by the sale of kids as well. The interaction between the crop and livestock system of the model facilitates a high degree of organic recycling between the systems. Continuous addition of organic manures from the livestock system helps maintain soil health and sustain productivity. The crop-livestock integration in the model is synergistic and is efficient not only economically but also ecologically.

An in depth analysis of the model (Table 59) revealed that, several changes could be suggested to increase the gross return and net profit of the farmer, if his constraints are removed. The dual price values indicate the increase or decrease in the gross returns of the model for unit change in value of the constraint within the given ranges of minimum and maximum RHS. In the case of coconut, an increase in the population between 44.96 (minimum RHS) and infinity (maximum RHS) will not change the gross return of the model (dual price = 0). However, an increase in coconut population will give more return, but, at the expense of other more remunerative enterprises.

Table 59. Linear programming analysis of Location II

Constraint			RHS	Minimum RHS	Maximum RHS	Slack (-) / Surplus (+)	Dual price
1	(<)	Main area	4000.00	3552.9950	infinity	447.005-	0.0000
2	(<)	Expenditure	45000.00	44679.1496	46116.1837	0.0000-	1.5461
3	(<)	Adult coconut	75.00	44.9606	infinity	30.0394-	0.0000
4	(=)	Jack	2.00	0.0000	9.1300	0.0000	230.4267
5	(=)	Mango	4.00	0.0000	8.7533	0.0000	-10.6099
6	(=)	Cashew	5.00	0.0000	6.7598	0.0000	6.7408
7	(=)	Gooseberry	1.00	0.0000	22.3900	0.0000	-3.1911
8	(=)	Cow	1.00	0.9668	1.0095	0.0000	-1604.4684
9	(=)	Goat	2.00	0.8597	2.3197	0.0000	90.6293
10	(=)	Poultry	15.00	0.0000	39.0698	0.0000	154.0608
11	(<)	Interspace	2700.00	1970.5000	infinity	729.5000-	0.0000
12	(=)	Bread fruit	1.00	0.0000	11.6950	0.0000	103.6178
13	(=)	Bilimbi	5.00	0.0000	58.4751	0.0000	10.7236
14	(=)	Annona	6.00	0.0000	39.9302	0.0000	-7.4255
15	(<)	Tapioca	600.00	178.7986	721.0756	0.0000-	1.9029
16	(<)	Dioscorea	40.00	0.0000	93.4751	0.0000-	2.7236
17	(<)	Amorphophallus	30.00	0.0000	83.4751	0.0000-	5.7236
18	(<)	Colocasia	15.00	0.0000	228.9003	0.0000-	0.6809
19	(<)	Turmeric	40.00	0.0000	93.4751	0.0000-	2.7236
20	(<)	Pepper	40.00	0.0000	200.4252	0.0000-	50.2379
21	(=)	Arrowroot	1000.00	0.0000	2069.5012	0.0000	0.0362
22	(<)	Pineapple	70.00	0.0000	156.7163	0.0000-	4.2795
23	(=)	Arecanut	4.00	0.0000	89.5601	0.0000	-3.2978
24	(=)	Sapota	1.00	0.0000	16.5213	0.0000	6.8089
25	(=)	Moringa	10.00	0.0000	45.6500	0.0000	-1.9147
26	(=)	Bamblimass	1.00	0.0000	11.6950	0.0000	153.6178
27	(=)	Guava	5.00	0.0000	30.8688	0.0000	-1.2764
28	(=)	Banana	25.00	0.0000	45.3070	0.0000	35.5720
29	(=)	Curry leaf	4.00	0.0000	164.4252	0.0000	4.4079
30	(<)	Apiculture	8.00	2.4191	9.6043	0.0000-	190.7854

RHS - Right hand side value

The farmer is willing to invest a total amount of Rs. 45000 only. If he spends more on coconut, he has to reduce the investment on certain other enterprises which are more remunerative (higher benefit : cost ratio).

In the case of cow, its exclusion will result in a profit of Rs. 1604.46. This is because of its lower benefit : cost ratio when compared to certain other enterprises. Though, the farmer is getting profit at present (per cow) it is at the expense of other remunerative enterprises. But, the inclusion of one cow in the model has been expressed as a necessity by the farmer to meet his needs of milk and dung. If the farmer decides to sell his cow at any point of time, it could be suggested that the farmer could invest the expenditure incurred on cow at present (Rs. 33685/-) on more remunerative enterprises like poultry (dual price = 154.06), pepper (50.23), apiculture (190.78), jack (230.42) etc. keeping in mind the space available.

At present, the farmer has expressed his inability to invest more than Rs.45000/-. The analysis shows that his investment could be increased upto Rs. 46116.18 for which he would receive Rs. 1.54 on every rupee invested (Table 59). Thus, if the farmer was willing to spend more, it could be suggested that the farmer invest it on profitable enterprises like jack (dual price = 230.42), cashew (6.74), poultry (154.06), breadfruit (103.61), amorphophallus (5.72), pepper (50.23), pineapple (4.27), bamblimass (153.61), banana (35.57) and apiculture (190.78) the population of which may be increased upto 9, 6, 39, 11, 83, 200, 156, 11, 45 and 9 respectively. Since perennials require more time to generate returns it would be more practical to invest it in annuals, poultry and apiculture.

SUMMARY

5. SUMMARY

A study entitled "Structure analysis and system dynamics of agroforestry home gardens of southern Kerala" was undertaken during the period from 1994 - 1997 in Thiruvananthapuram district of Kerala State. The study included a detailed agroforestry systems inventory description survey of the home gardens in the district. Investigations were also undertaken in two home gardens of the district for a comprehensive study of the dynamics of the system. Laboratory experiments were conducted to assess the allelopathic proclivities of some commonly grown multipurpose tree species. Integrated models for resource optimization and profit maximization in the selected home gardens were developed through linear programming. The results of the study are summarized hereunder :

1. The size of an overwhelming number of holdings was small (0.20-0.80 ha). Holding size was maximum in highlands followed by midlands.

2. The species diversity and average number of plants per home garden was considerably high.

3. Tuber crops were found to be the most dominant crop category and the average number of tuber crop plants per homestead was highest in

highlands. Fruit crops ranked second in predominance with the average number of plants per homestead being significantly higher in highlands. Coconut was the most dominant and important among oilseeds. Rubber was grown in several homesteads in the highlands of the district, in medium to large holdings and it was absent in the lowlands. Spice crops ranked fifth in the district and its agroecological regions, irrespective of the size of holdings. The average number of plants per home garden was significantly higher in highlands. Vegetables ranked sixth in the district and in the highlands its predominance was comparatively low. Fodder crops occupied the last position, among the different crop categories in the district and its different regions (except lowlands).

4. The tree intensity was found to increase as the size of the holding decreased. In the district and the various agroecological regions, the frequency of occurrence was highest for coconut followed by jack, mango, moringa, guava, wild jack and tamarind and lowest for the nitrogen fixing trees. Coconut had the highest relative predominance among different tree species in the district and its agroecological zones followed by rubber, arecanut, jack, ailanthus, mango, wild jack, moringa, teak and cashew. However, in highlands rubber was found to dominate, among the different trees. Significant difference in the average number of trees per home garden was noticed with respect to jack, mango, annona, papaya, ailanthus, cashew, tamarind, arecanut, rubber, portia, morinda and erythrina between zones. The average number of arecanut, rubber and erythrina was significantly higher in highlands.

5. The home gardens presented a multi-tier canopy configuration. However, there was no specific pattern or arrangement.

6. Rain and wells formed the main source of water for cultivation to the homestead farmers. Most of the farmers used local varieties and were unaware of the package of practice recommendations for various crops. Majority of the farmers practiced organic farming and did not adopt plant protection measures.

7. Most farm families had animals such as cow, bullock, goat, sheep, buffaloes and birds like chicken, duck, quail and turkey. Non-conventional feeds such as jack/tapioca/rice bran were the main items fed to cattle.

8. The farmers mainly approached co-operative societies for their requirement of credit. The marketing and sale of produce from the home gardens, invariably took place through middlemen or intermediaries.

9. The study of the constraints faced by the farmers revealed labour scarcity as the major issue. Added to this, the high labour cost resulted in increased cultivation cost. Problems relating to absence or lack of grading, lack of storage and transport facilities were being experienced by the farmers.

10. The economic analysis of the home gardens in the district revealed that the system, in general, was found to be profitable. The average total

returns, net profit and value of marketed produce obtained annually from the home gardens were significantly superior in highlands as compared to the lowlands and midlands.

11. Large quantities of litter was produced by the tree components at both home gardens. At Location I, maximum litter and nutrients was added by nutmeg whereas at Location II, the maximum was obtained from cashew. Among the different nutrient cycling processes (litterfall, stemflow and throughfall), litterfall was the major avenue for the addition of nutrients, especially N and P.

12. Addition of nutrients through stemflow was comparatively low, and at both locations highest quantity of nutrient added was potassium, followed by nitrogen.

13. Throughfall accounted for the largest input of potassium. Potassium was the most important nutrient added by throughfall followed by nitrogen. Among the various trees, contribution of nutrients by coconut was the highest at both locations.

14. Organic manures were the main source of nutrients used by the farmers at both locations. The main organic manure added in the home gardens was cowdung. In addition to this, the nutrient requirements, especially of coconut, were supplemented through inorganic fertilizers.

15. Harvested produce accounted for removal of large quantities of nutrients from the systems. Coconut was the single largest component in terms of removal of bioelements from the system at both locations.

16. The physical properties of the homestead soil were better than that of the control. The maximum water holding capacity, porosity and mean weight diameter (aggregate stability) were higher in the homestead soil as compared to the control. The bulk density of the homestead soil recorded a lower value than control. The moisture content in the homestead soil was greater than the control at both 15 and 30 cm depths.

17. The fertility status of the soil of both the homesteads was higher than that of their respective controls. The organic carbon content and available N, P and K status were higher in the homestead soil, as compared to that of the control. The pH of the homestead soil was lower than that of the control.

18. Intense microbial activity was observed in the homestead. The population of the micro-organisms (fungi, bacteria, actinomycetes and phosphorus solubilising bacteria) in the homestead soil recorded a higher value than control.

19. The soil temperature in the home garden was lower than that in the open, irrespective of the depth and period of measurement.

20. The light intensities at the floor of all the trees studied were less than that in the open. At Location I, the annual average percentage transmission of light was highest for coconut followed by mango, teak and mahogany and lowest for nutmeg. At Location II, the annual average percentage transmission of light was highest in the case of coconut, followed by mango, cashew and wild jack and lowest for cinnamon. The percentage transmission of light by each tree species remained almost constant during the different months.

21. Both the home gardens were found to be profitable. There was availability of various produce for household use or cash sale throughout. At Location II, the tree-crop-livestock integration was a special feature which increased income considerably.

22. Allelopathic inhibition of germination of rice was caused by leaf extracts of all the tree species. Ailanthus caused maximum inhibition and was on par with tamarind, acacia and portia. The inhibition was less pronounced in the case of mango, bombax and cashew.

23. Plumule growth of rice was significantly inhibited by leaf extracts of all tree species when compared to the control. The plumule growth was suppressed most by acacia, ailanthus, tamarind and portia, which were on par. The inhibition was relatively less in the case of jack, bombax and wild jack.

24. The inhibition of radicle growth of rice by leaf extracts was more pronounced than germination and plumule growth. The greatest inhibition was caused by acacia, ailanthus, tamarind and portia, which were on par. The inhibition by bombax and jack was relatively less.

25. Germination of cowpea was inhibited by the leaf extracts of acacia, eucalyptus, casuarina, ailanthus, tamarind, portia and cashew. All the other trees were found to be on par with the control. The maximum inhibition was caused by eucalyptus and tamarind which were on par.

26. Leaf extracts of all the tree species significantly inhibited cowpea plumule growth. The maximum inhibition was caused by ailanthus and leucaena which were on par. Inhibition by jack was the least.

27. Radicle growth of cowpea was found to be significantly suppressed by leaf extracts of all trees except jack. Maximum inhibition was caused by ailanthus, tamarind, cashew and eucalyptus which were on par. The inhibition of radicle growth by the leaf extracts was more pronounced when compared to suppression of germination and plumule growth.

28. The powdered leaf litter of all the trees inhibited rice germination. The most severe inhibition was brought about by ailanthus followed by tamarind. The least inhibition was observed under jack and mango.

29. The growth of plumule of rice was significantly suppressed by powdered leaf litter of all the trees. Maximum suppression was brought about by ailanthus followed by portia, eucalyptus and cashew which were on par. The inhibition caused by leucaena and jack was comparatively less.

30. Radicle growth of rice was inhibited by litter of all trees except jack which was on par with the control. Ailanthus, tamarind and leucaena caused maximum inhibition. The inhibition by casuarina and mango was relatively less.

31. Cowpea germination was significantly inhibited by the litter of all the trees except jack and mango which were on par with control. The germination was least in seeds treated with litter of nutmeg, ailanthus and leucaena, which were on par.

32. Powdered leaf litter of all the trees except cashew, casuarina and jack suppressed plumule growth of cowpea significantly. Maximum reduction of plumule growth was brought about by ailanthus followed by leucaena.

33. Radicle growth of cowpea was significantly inhibited by powdered leaf litter of all tree species. The maximum inhibition was caused by ailanthus, tamarind and cashew, which were on par. The inhibition by jack and mango was comparatively less.

34. The optimum coconut-based model developed for the 0.50 home garden at Location I with 23 enterprises will generate a profit of Rs. 10354.21 with an investment of Rs.3262.30.

35. The coconut-based mixed farming model developed for the 0.40 home garden at Location II with 35 enterprises will provide a net profit of Rs.32464.32 on investing Rs.45000/-.

Future Line of work

Agroforestry systems inventory description survey should be undertaken in the different agroclimatic zones of the State to generate quantitative information on the structure, function and biological efficiency of the homestead system. A comprehensive evaluation of the existing agroforestry practices throughout the State is also required to evolve information on the sustainability factors of home gardens. Field trials should be conducted to standardize the fertilizer requirements of different trees and intercrop components grown in home gardens after taking into account the nutrients added by trees through plant cycling (litterfall, throughfall and stemflow) and the system dynamics. Studies to ascertain the litter decomposition and nutrient release pattern of multipurpose tree species commonly grown in home gardens for synchronizing the nutrient release from the litter with the nutrient requirements of the intercrops are necessary. Allelopathic effects of trees on the germination, growth and development of crops need to be confirmed through pot culture and field studies. Tolerance of crops to different agroforestry tree species with allelopathic effects should be assessed and the most tolerant crops and their varieties may be recommended for agroforestry systems. Multipurpose trees of the State should be screened for their allelopathic effects, so that the least allelopathic species may be recommended for agroforestry. Research on identification and isolation of the allelopathic compounds present in the allelopathic trees for their use in weed control needs to be vigorously pursued. Attempts should be made to develop optimum homestead models by way of linear programming for each agroecological zone in the State.

REFERENCES

REFERENCES

Abdul Salam, M., Sathees Babu, K. and Mohanakumaran, N. 1992a. Home garden agroforestry in Kerala will prove more profitable with planning. *Indian Fmg.* **42** (5) : 22 - 24

Abdul Salam, M., Sathees Babu, K., Mohanakumaran, N., Sreekumar, D., Mammen, M.K., Girija, V.K., Meera Bai, M., Jayachandran, B.K., Balakrishnan A.R., Shehana, R.S. and Kunjamma, P.M. 1992b. Homestead model for the coastal uplands of south Kerala under irrigated agriculture. *Indian Cocon. J.* **23** : 2 - 6

Abdul Salam, M., Sathees Babu, K. and Sreekumar, D. 1991 a. Multipurpose farming system - a model. In : *Research Report*, Kerala Agricultural University, Sadanandapuram, Kottarakkara, Kerala. pp. 1 - 15

Abdul Salam, M., Sreekumar, D., Mohanakumaran, N. and Sathees Babu, K. 1991b. Coconut-based homestead farming : A model. *Indian Cocon. J.* **22** (4) : 4 - 12

Abdul Salam, M. and Sreekumar, D. 1990. Coconut-based mixed farming system to sustain productivity. *Indian Cocon. J.* **20** (10) : 3 - 5

Abdul Salam, M., Sreekumar, D. and Mammen, M.K. 1990. Mixed farming in homestead agriculture - An economical approach. *Indian Fmg.* **40** (5) : 14-16

Al-Mousawi, A.H. and Al-Naib, F.A.G. 1975. Volatile growth inhibitors produced by *Eucalyptus microtheca*. *Bull. Biol. Res. Centre* **7** : 17 - 23

Alvim, P. de T. 1981. A perspective appraisal of perennial crops in the Amazon basin. *Interciencia* **6** : 139 - 145

Araungeran, J., Escalante, G. and Herrera, R. 1982. Nitrogen cycle for tropical perennial crops under shade trees. *Pl. Soil* **67** : 249 - 269

Arnold, J.E.M. 1987. Economic considerations in agroforestry. In : *Agroforestry - A Decade of Development*, (eds.) Steppler, H.A. and Nair, P.K.R., ICRAF, Nairobi, pp. 157 -170

Atta-Krah, A.N., Sumberg, J.E., Reynolds, L. 1985. *Leguminous Fodder Trees in the Farming Systems : An Overview of Research at the Humid Zone Programming of ILCA in Southwestern Nigeria*. ILCA, Ibadan, Nigeria.

Babu, K.S., Jose, D. and Gokulapalan, C. 1992. Species diversity in Kerala homegarden. *Agroforestry Today* **4** (3) : 15

Babu, M.N. 1995. Evaluative perception of homestead farmers in relation to appropriateness of farming systems and cropping patterns. *M.Sc. (Ag) Thesis*, Kerala Agricultural University, Thrissur.

Baker, T.G. and Attiwill, P.M. 1987. Fluxes of elements in rain passing through forest canopies in south eastern Australia. *Biogeo. Chem.* **4** (1) : 27 - 39

Balasubramanian, V. 1983. *Alley cropping : Can it be Alternative to Chemical Fertilizers in Ghana*. IITA, Ibadan, Nigeria.

Balasubramanian, V. and Egli, A. 1986. The role of agroforestry in the farming systems in Rwanda with special reference to the Bugesera-Gisaka-Migonga (BGM) region. *Agroforestry Systems* **4** : 271 - 289

Bansal, G.L. 1988. Allelopathic effects of aqueous extracts of stem and leaves of three tree species on the germination of some crops and weeds. In : *Proc. Trends in Tree Science*, ISTS, Solan, India, pp. 118 - 123

Banwari, L., Singh, H.K. and Singh, C.B. 1996. Augmentation of tree biomass as an alternative source of nutrient for arable farming. In : *Proc. National Seminar on Organic Farming and Sustainable Agriculture*, U.A.S., Bangalore. p. 13

Bavappa, K.V.A., Kailasam, C., Khader, K.B.A., Biddappa, C.C., Khan, H.H., Kasthuri Bai, K.V., Ramadasan, A., Sundararaju, P., Bopaiah, B.M., George, V.T., Misra, L.P., Balasimha, D., Bhat, N.T. and Shama Bhat, K. 1986. Coconut and Arecanut based high density multispecies cropping systems. *J. Plant. Crops* **14** (2) : 74 - 87

Bavel, V.C.H.M. 1949. Mean weight diameter of soil aggregate as a structural index of aggregation. *Soil Sci. Soc. Am. Proc.* **14** : 20 - 23

Beneke, R.R. and Winterboer, R. 1978. *Linear Programming Applications to Agriculture*. Iowa State University Press, U.S.A.

Bernhard - Reversat, F. 1975. Nutrients in throughfall and their quantitative importance in rain forest mineral cycles. In : *Tropical Ecological Systems*, (eds.) Golley, F.B. and Medina, E., Springer Verlag, Berlin Heidelberg, New York.

Bhaskar, V. and Dasappa 1986. Allelopathic effects of eucalyptus. In : *Eucalyptus in India : Past, Present and Future*. (eds.) Sharma, T.S., Nair, S., and Kedarnath, S.

Bhatt, B.P. and Todaria, N.P. 1990. Studies on the allelopathic effects of some agroforestry tree crops of Garhwal Himalaya. *Agroforestry Systems* **12** : 251 - 255

Bhumibhamon, S., Ponoy, B. and Chaisurisri, K. 1980. Germination complex of teak fruit. In : *Proc. Symp. Trop. Forest Seed Problem*, Mexico, San Felipe-Bacalor.

Biswas, T.D. and Khosla, B.K. 1971. Building up of organic matter status of the soil and its relation to the physical properties. *Proc. Int. Symp. Soil Fertility Evaluation* **1** : 831 - 842

Boonkird, S.A., Fernandes, E.C.M. and Nair, P.K.R. 1984. Forest villages : an agroforestry approach to rehabilitating forest land by shifting cultivation in Thailand. *Agroforestry Systems* **2** : 87 - 102

Bormann, F.H., G.E. Likens and Mellilo, J.M. 1977. Nitrogen budget for an aggrading northern hardwood forest ecosystem. *Science* **196** : 981 - 982

Brierley, J.S. 1985. The West Indian Kitchen gardens. A historical perspective with current insights from Greneda. *Food Nutrition Bull.* **7** (3) : 52 - 60

Brinson, M. Bradshaw, H.D., Holmes, R.N. and Elkins, J.B. 1980. Litterfall, stemflow and throughfall nutrient fluxes in an alluvial swamp forest. *Ecology* **61** : 827 - 835

Bronstein, G.E., 1984. *Produccion comparada de una pastura de Cynodon plectostachyus asosciada con arboles de cordia alliodora, con arboles de Erythrina poeppigiana y sin arboles. Tesis Mag. Sci.*, CATIE, Turrialba, Costa Rica.

Budelman, A. 1989. Nutrient composition of the leaf biomass of three selected woody leguminous species. *Agroforestry Systems* **8** : 39 - 51

Carey, M.L., Farrell, E.P. and Mcaleese, D.M. 1981. Mobilisation of nutrients in a sitka spruce forest floor - Interaction of leaching with lime and fertilizers under lab conditions. *For. Ecol. Manage.* **3** (3) : 229 - 236

Charley, J.L. and Richards, B.N. 1983. Nutrient allocation in plant communities : Mineral cycling and terrestrial ecosystems. In : *Encyclopedia of Plant Physiology* (*New Series*) *Vol. 120*, (eds.) Lange, O.L. and Nobel, P.S., Berlin Heidelberg, New York, pp. 1 - 44

Chaturvedi, O.P. and Jha, A.N. 1992. Studies on allelopathic potential of an important agroforestry species. *For. Ecol. Manage.* **53** : 91 - 98

Chaubey, O.P., Ram Prasad and Mishra, G.P. 1988. Litter production and nutrient return in teak plantation and adjoining natural forests in Madhya Pradesh. *J. Trop. For.* **4** (3) : 242 - 254

Chinnamani, S. 1991. Agroforestry research in India. In: Proc. Indo-US-workshop - cum - training in agroforestry systems. Dr. Y.S. Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh.

Chou, C.H. 1986. The role of allelopathy in subtropical agroecosystems in Taiwan. In : *The Science of Allelopathy*, (eds.) Putnam, A.R. and Tang, C.S., John Wiley and Sons Inc., New York, pp. 57 - 73

Chou, C.H. and Kuo, Y.L. 1986. Allelopathic research of subtropical vegetation in Taiwan. III. Allelopathic exclusion of understorey by *Leucaena leucocephala* (Lam) de wit. *J. Chem. Ecol.* **12** : 1431 - 1448

Chou, C.H. and Yang, C.M. 1982. Allelopathic research of subtropical vegetation in Taiwan. II. Comparative exclusion of understorey by *Phyllostachys edulis* and *Cryptomeria japonica*. *J. Chem. Ecol.* **8** : 1489 - 1507

Clark, F.E. 1949. Soil micro-organisms and plant roots. *Adv. Agron.* **1** : 241 - 288

Cole, D.W. and Rapp, M. 1980. Elemental cycling in forest ecosystems. In : *Dynamic Properties of Forest Ecosystems*, (ed.) Reichle, D.E., Cambridge University Press, New York, pp. 341 - 409

Craig, I.A. and Saenalo, M. 1988. Effects of paddy-bund planted Eucalyptus trees on the performance of field crops. *Working Paper No.1 Nearad Project*, The Phar, Khon Kaen, Thailand.

Das, P.K. 1989. Economics of coconut-based farming systems *Cocomunity*. APCC/QS/19 : 1 - 12

Das, P.K. 1990. Economics of coconut based farming systems. In : *Proc. of the XXVII Cocotech Meeting*, Asia and Pacific Coconut Community, Jakarta, Indonesia. pp. 539 - 554

Das, A.K. and Ramakrishnan, P.S. 1985. Litter dynamics in Khasi pine of North East India. *For. Ecol. Manage.* **10** : 135 - 153

Del Moral, R. and Muller, R. 1969. Fog drip : a mechanism of toxin transport from *Eucalyptus globulus*. *Bull. Torrey Bot. Club* **96** : 467 - 475

Del Moral, R. and Muller, R. 1970. The allelopathic effects of *Eucalyptus camadulensis*. *American Midl. Nat.* **83** : 254 - 282

Dhillon, G.S., Singh, S., Dhillon, M.S. and Atwal, A.S. 1982. Developing agrisilvicultural practices : Studies on the shading effect of Eucalyptus on the yield of adjoining crops. *Indian J. Ecol.* **9** : 228 - 236

Divineau, J.L. 1976. Preliminary data on the litter and leaf fall in some semi deciduous forests of central Nong coast. *Oecoplantarum*, **11** (4) : 375 - 395

Edwards, P.J. 1982. Studies of mineral cycling in a montane rain forest in New Guinea. *J. Ecol.* **70** (3) : 807 - 827

Einhellig, F.A. 1989. Effect of allelopathic chemicals on crop productivity. In : *Bioregulators for Pest Control*, (ed.) Hedin, P.A., ACS Symp Series, Washington, **276** : 109 - 132

Escudero, A. 1985. Effect of isolated trees on the composition of the soil. *Revuede Cologie et de Biologiedu Sol* **22** (2) : 149 - 159

Etherington, D.M. and Mathews, D.J. 1983. Approaches to the economic evaluation of agroforestry systems. *Agroforestry Systems* **1** : 347 - 360

Fernandes, E.C.M. and Nair, P.K.R. 1986. An evaluation of the structure and function of tropical homegardens. *Agricultural Systems* **21** : 279 - 310

Fernandes, E.C.M., O'ktingati, A. and Maghembe, J. 1984. The Chágga home gardens : A multistoreyed agroforestry cropping system on Mount Kilimanjaro (northern Tanzania). *Agroforestry Systems* **2** : 73 - 86

Fisher, R.F. 1980. Allelopathy - a potential cause of regeneration failure. *J. For.* **78** : 346 - 350

Franke, N.W. and Leopoldo, P.R. 1982. Interception of precipitation in Amazon terrafirme forest. *Acta Amazonica* **12** (3) : 15 - 22

Friedman, J., Rsufkins, E. and Waller, G.R. 1982. Highly potent germination inhibitors in aqueous extract of fruits of Bishop's seed (*Arnmi majus* L.) and avoidance of autoinhibition. *J. Chem. Ecol.* **8** : 55 - 65

Gaba, R.K. 1987. Role of allelopathy in social forestry. In : *Social Forestry for Rural Development*, (eds.) Khosla, P.K. and Kohli, R.K., ISTS, Solan : 228 - 234

Gaur, A.C. and Mukherjee, D. 1980. Recycling of organic matter through mulch in relation to chemical and microbiological properties of soil and crop yields. *Pl. Soil* **56** : 273 - 280

George, M. 1979. Nutrients by stemflow, throughfall and rain water in a Eucalyptus (Mysore) hybrid plantation. *Indian For.* **105** (7) : 493 - 499

Gill, H.S., Abrol, T.P. and Samra. 1987. Nutrient cycling through litter production in young plantations of *Acacia nilotica* and *Eucalyptus tereticornis* in a highly alkaline soil. *For. Ecol. Manage.* **1 - 2** : 57 - 69

Golley, F.B., McGinnis, J.T., Clements, R.G., Child, G.I. and Duever, M.J. 1975. *Mineral Cycling in a Tropical Moist Forest Ecosystem*, University of Georgia Press, Athens, Georgia, U.S.A. p. 248

Gonzales-Jacomes, A. 1981. Homegardens in Central Mexico, their relationship with water control and their articulation to major society through productivity, labour and market. In : *Prehistoric Intensive Agriculture in the Tropics*, Canberra, Australian National University.

Goss, J.A. 1973. Physiology of plants and their cells. In : *Pergamon Biol. Sci. Series Vol. 1*, (ed.) Peter Gray, p. 457

Halibara, K., Aiba, Y. and Suetsugo, K. 1984. Nutrient content of throughfall in a *Cryptomieria japonica* plantation. *Bull. Expt. For.* **20** : 17 - 21

Hanman, F.M. 1986. Alternative ways of incorporating women concerns in farming systems research. In : *Report of the Asia Rice Farming Systems Working Group Meeting*, IRRI, Manila, Phillippines. p. 222

Happy Mathew 1993. Agronomic resource inventory of a homestead in the southern zone of Kerala. *M.Sc.(Ag) Thesis*, Kerala Agricultural University, Thrissur.

Happy Mathew, Jacob John and Nair, M.A. 1996. Dynamics of an agroforestry home garden in the humid tropics - a case study from southern Kerala. In : *Proc. of the Eighth Kerala Science Congress*, Palakkad, Kerala. p. 208

Happy Mathew and Nair, M.A. 1996. Sustainability of homestead farming system in Kerala based on benefit:cost analysis - A case study. In : *Proc. of the Eighth Kerala Science Congress*, Palakkad, Kerala. pp. 194 - 196

Harou, P.A. 1983. Economic principles to appraise agroforestry projects. *Agric. Admn.* **12** : 127 - 139

Harrison-Murray, R.S. and Lal, R. 1979. High soil temperature and response of maize to mulching in the humid tropics. In : *Soil Physical Properties and Crop Production in the Tropics*, (eds.) Lal, R. and Greenland, D.J., Wiley, Chichester, U.K. pp. 285 - 304

Harry, W.Y., Albert, L.L. and Raymond, E.L. 1978. Nutrient content of throughfall and stemflow in fertilized irrigated *Pinus resinosa* stands. *Pl. Soil* **50** : 433 - 495

Heady, E.O and Candler, W. 1959. *Linear Programming Methods*. Iowa State University Press, U.S.A.

Hegde, M.R., Yusuf, M. and Muliyar, M.K. 1993. Organic nutrition in coconut gardens. *Indian Cocon. J.* **24** : 2 - 6

Heisey, R.M. 1990. Evidence of allelopathy by tree of heaven (*Ailanthus altissima*). *J. Chem. Ecol.* **16** : 2039 - 2056

Helvey, J.D. and Patric, J.H. 1965. Canopy litter interception of rainfall by hardwood of eastern United States. *Water Resource Res.* **1** : 193 - 206

Henderson, G.S., Harris, W.F., Todd, D.E. and Grizzard, T. 1977. Quantity and chemistry of through fall as influenced by forest type and season. *J. Ecol.* **65** : 365 - 374

Hoekstra, D.A. 1985. *Economic Concepts of Agroforestry*. ICRAF, Nairobi, Kenya, pp. 1 - 12

Horsley, S.B. 1977. Allelopathic interference among plants II. Physiological modes of action. In : *Proc. Fourth North American Forest Biol. Workshop*, State University of New York, USA. pp. 93 - 136

Jacob, V.J. and Alles, W.S. 1987. Kandyan garden of Sri Lanka. *Agroforestry Systems* **5** : 123 - 137

Jackson, M.L. 1973. *Soil Chemical Analysis.* Second Edition, Prentice - Hall of India (Pvt.) Ltd., New Delhi.

Jadhav, B.B. and Gayanar, D.G. 1992. Allelopathic effects of *Acacia auriculiformis* on germination of rice and cowpea. *Indian J. Pl. Physiol.* **35** : 86 - 89

Jambulingam, R. and Fernandes, E.C.M. 1986. Multipurpose trees and shrubs on farmlands in Tamil Nadu State (India). *Agroforestry Systems* **4** : 17 - 23

Jasbir Singh 1986. Nutrient return through litter and rainfall in a humid forest ecosystem in North east India. *Van Vigyan* **24** : 4 - 7

Job, E., Asan, B.R. and Ramasubramonian, P.R. 1993. Economic analysis of coconut-based cropping system in Kerala. *Ind. Cocon. J.* **24** (4) : 2 - 3

Joshi, P.C. and Prakash, O. 1992. Allelopathic effects of litter extract of some tree species on germination and seedling growth of agricultural crops. In : *Proc. First National Symposium on Allelopathy in Agroecosystems.* Indian Society of Allelopathy, Hisar, India, pp. 127 - 128

Kadeba, O. and Aduayi, E.A. 1985. Litter production, nutrient recycling and litter accumulation in *Pinus caribea* var. hondurenses stands in northern Guinea Savanna of Nigeria. *Pl. Soil* **96** : 197 - 206

Kamtuo, A., Lertrat, K. and Wilariat, A. 1985. Traditional homegardening in Hinlând village. Khon Kaen Proovince, North east Thailand. In : *Proc. of the First International Workshop on Tropical Homegardens*, Bandung, Indonesia.

Kandaswamy, O.S. and Chinnaswamy, K.N. 1988. Integrated farming systems for marginal farmers of Dharmapuri district. In : *Proc. National Seminar on Farming Systems for Semi-arid Tropics, Abstract papers.* Centre for Development and Crop Management Studies, Tamil Nadu Agricultural University, Coimbatore.

Kang, B.T., Reynolds, L. and Atta-Krah, A.N. 1990. Alley farming. *Adv. Agron.* **43** : 315 - 359

Kang, B.T. and Wilson, G.F. 1987. The development of alley cropping as a promising agroforestry technology. In : *Agroforestry - A Decade of Development*, (eds.) Steppler, H.A. and Nair, P.K.R., ICRAF, Nairobi, Kenya. pp. 227 - 243

Karyono, E. 1981. Homegarden structure in the rural areas of the Citarum watershed, West Java. *Doctoral Thesis*, Padjadjaran University, Bandung, Indonesia.

Kass, D.C.L., Russo, R.O. and Quinlan, M.M. 1983. Leguminous trees as a nitrogen source for annual crops. *Agron. Abstracts* : **45**

KAU. 1989. *National Agricultural Research Project - Status Report of the Southern zone Vol. 1*. Kerala Agricultural University. p. 323

Keen, B.A. and Raczkowski, H. 1921. *J. Agric. Sci.* **11** : 441 - 449

Kellman, M. 1979. Soil enrichment by neotropical savanna trees. *J. Ecol.* **67** : 565 - 577

Kerala State Land Use Board. 1997. *Land Resource Based Perspective Plan for 2020 AD (A First Approximation)*. Vikas Bhavan, Thiruvananthapuram, Kerala. p. 14

Khanna, P.K. and Nair, P.K.R. 1977. Evaluation of fertilizer practices for coconuts under pure and mixed cropping systems in the west coast of India. In : *Proc. of Conference on Classification and Management of Tropical Soils*, Malaysian Society of Soil Science, Kuala Lumpur. pp. 457 - 466

King, K.F.S. 1979. Agroforestry and the utilization of fragile ecosystems. *For. Ecol. Manage.* **2** : 161 - 168

Kohli, R.K. 1990. Allelopathic properties of *Eucalyptus*. *MAB DOEn Project*, p. 199

Korikanthimath, V.S., Rajendra, H. and Ravindra, M. 1996. Biomass and residue management in cardamom (*Elettaria cardamomum*) plantations. In : *Proc. of National Seminar on Organic Farming and Sustainable Agriculture*, U.A.S., Bangalore. p. 16

Koul, V.K. 1990. The effect of soil beneath *Leucaena leucocephala* and its decomposed leaves on germination of rice. *Leucaena Research Report* **10** : 54 - 55

Koul, V.K., Raina, A., Khanna, Y.P., Tickoo, M.L. and Singh, H. 1991. Evaluation of certain farm grown tree species on rice. *Ind. J. For.* **14** : 54 - 57

Kuiters, A.T., Van Beckhoven, K. and Ernst, W.H.O. 1986. Chemical influences of tree litters on herbaceous vegetation. In : *Forest Dynamics Research in Western and Central Europe*, (ed.) Fanta, J., PUDOC, Wageningen.

Kumar, D.P., Hegde, M., Siddaramappa, R. and Siddarame Gowde, T.K. 1996. Cashew leaf litter - a good source of biomass for organic manure. In : *Proc. of National Seminar on Organic Farming and Sustainable Agriculture*, U.A.S., Bangalore, pp. 13 - 14

Kuo, Y.L., Chou, C.H. and Hu, T.W. 1982. Allelopathic potential of *Leucaena leucocephala*. In : *Allelochemicals and Pheromones*, (eds.) Chou, C.H. and Waller, G.R., Institute of Botany, Academia Sinica, Taipei, Taiwan. pp. 107 - 119

Lagemann, J. 1977. *Traditional Farming Systems in Eastern Nigeria*. Weltforum - Verlag, Munich, Germany.

Lal, R. 1989. Agroforestry systems and soil surface management of a tropical alfisol. Parts I - VI. *Agroforestry Systems* **8** (1, 2 & 3) : 1 - 6; 7 - 29; 97 - 111; 113 - 132; 197 - 215; 217 - 238; 239 - 242

Leninger, T.D. and Winner, W.E. 1988. Throughfall chemistry beneath *Quercus rubra* : atmospheric, foliar and soil chemistry condition., *Can. J. For. Res.* **18** (4) : 478 - 482

Leuschner, W.A. and Khalique, K. 1987. Homestead agroforestry in Bangladesh. *Agroforestry Systems* **5** : 139 - 151

Liyanage, M. De S., Tejwani, K.G. and Nair, P.K.R. 1984. Intercropping under coconuts in Sri Lanka. *Agroforestry Systems* **2** : 215 - 228

Ma, X.H. 1989. Effect of rainfall on nutrient cycling in forest of *Cunninghamia lanceolata* and *Pinus massoniana*. *Acta Oecologia* **9** (1) : 15 - 20

Malkania, N.P. 1987. Allelopathy and its significance on production of agroforestry plant associations. In : *Agroforestry for Rural Needs*, (eds.) Khosla, P.K. and Khurana, D.K., ISTS, Solan, India pp. 211 - 224

Manokaran, N. 1980. The nutrient contents of precipitation, throughfall and stemflow in a low and tropical rainforest in Peninsular Malaysia. *Malaysian For.* **43** (3) : 266 - 289

Mazurak, A.P., Chesmin, L. and Tiarks, A.E. 1975. Detachment of soil aggregation by simulated rainfall from heavily manured soils in eastern Nebraska. *Soil Sci. Soc. Am. Proc.* **39** : 732 - 736

Menges, R.M. 1987. Allelopathic effects of Palmer Amaranth and other plant residues in soil. *Weed Sci.* **35** : 1059 - 1072

Michon, G. 1983. Village-forest-gardens in Java. In : *Plant Research and Agroforestry*, (ed.) Huxley, P.A., ICRAF, Nairobi, Kenya. pp. 13 - 24

Michon, M.G., Mary, F. and Bompard, J. 1986. Multistoreyed agroforestry system in West Sumatra, Indonesia. *Agroforestry Systems* **4** : 315 - 338

Miller, H.G., Cooper, J.M. and Miller, J.D. 1976. Effect of nutrients in litterfall and crown leaching in a stand of Corsican pine. *J. Appl. Ecol.* **13** : 233-248.

Mitchell, J.E., J.B. Waide and R.L. Todd. 1975. A preliminary compartment model of the nitrogen cycle in a decidous forest ecosystem. In : *Mineral Cycling in South Western Ecosystem*, (eds.) Hawell, F.G., Gentry, J.B. and Smith, H., United States Group Research and Development, Virginia - USA.

Morachan, Y.B. 1978. *Crop Production and Management*, Oxford and IBH Publishing Co., New Delhi, pp. 101 - 103

Muller-Samann, K.M. 1986. *Bodenfruchtbarkeit and Standortgerechte Landwirtschäft. Schriftenreihe der GTZ*, No. 195, GTZ, Eschborn, Germany.

Nagaraja, M.S., Srinivasamurthy, C.S. and Parama, V.R.R. 1996. Biomass production : choice of species and their spacing geometry. In : *Proc. of National Seminar on Organic Farming and Sustainable Agriculture*, U.A.S., Bangalore. p. 15

Nair, C.T.S. and Krishnankutty, C.N. 1984. Socio-economic factors influencing farm forestry - A case study of tree cropping in the homesteads in Kerala, India. In : *Proc. EWC/FAO Workshop on Socioeconomic Aspect of Social Forestry in Asia -Pacific Region*. Bangkok, Thailand.

Nair, M.A. and Sreedharan, C. 1986. Agroforestry farming systems in the homesteads of Kerala, Southern India. *Agroforestry Systems* **4** : 339 - 363

Nair, M.A., Joise Abraham, Jacob John and Sanjeev, V. 1996. Biomass production and nutrient cycling for sustainability in agroforestry home gardens in Kerala - a case study. In : *Proc. of National Seminar on Organic Farming and Sustainable Agriculture*, U.A.S., Bangalore. pp. 19 - 20

Nair, M.G.K., Hegde, R.M., Yusuf, M. and Das, P.K. 1991. Mixed cropping in Coconut gardens. *Tech. Bull. 24*, CPCRI, Kasargod, India. p. 7

Nair, P.K.R. 1973. Quantitative changes in soil micro-organisms under rice-based multiple cropping in northern India. *Soil Biol. Biochem.* **5** : 387 - 389

Nair, P.K.R. 1976. Intensive cropping for stabilized income at enhanced rates from coconut plantations. *Financing Agric.* **7** (3) : 3 - 8

Nair, P.K.R. 1979. *Intensive Multiple Cropping with Coconuts in India. Principles, Programmes and Prospects.* Verlaug Paul Parey. Germany. pp. 149 - 150

Nair, P.K.R. 1983. Agroforestry with coconuts and other tropical plantation crops. In : *Plant Research and Agroforestry*, (ed.) Huxley, P.A., ICRAF, Nairobi, pp. 79 - 102

Nair, P.K.R. 1984. *Soil Productivity aspects of Agroforestry - ICRAF, Nairobi.*

Nair, P.K.R. 1993. *An Introduction to Agroforestry*. Kluwer Academic Publishers, Dordrecht, The Netherlands (in co-operation with ICRAF).

Nair, P.K.R. and Balakrishnan, T.K. 1976. Pattern of light interception by canopies in a coconut - cacao crop combination. *Indian J. agric. Sci.* **46** : 453 - 462

Nair, P.K.R. and Balakrishnan, T.K. 1977. Ecoclimate of a coconut + cacao crop combination on the west coast of India. *Agric. Meteorology* **18** : 455 - 462

Nair, S.K. and Rao, N.S.S. 1977. Microbiology of the root region of coconut and cacao under mixed cropping. *Pl. Soil* **46** : 511 - 529

Nambiar, I.P.S., Nambiar, P.K.R. and Rajan, K.C. 1988. Coconut-based farming systems. In : *Six Decades of Coconut Research*, (eds.) Aravindakshan, M., Nair, R.R. and Wahid, P.A., Kerala Agricultural University, Trichur, India. pp. 137 - 141

Nandal, D.P.S., Bisla, S.S., Narwal, S.S. and Kaushik, J.C. 1994. Allelopathic interactions in agroforestry systems. In : *Allelopathy in Agriculture and Forestry*, (eds.) Narwal, S.S. and Tauro, P., Scientific Publishers, Jodhpur. pp. 93 - 130

Narwal, S.S. 1994. Allelopathic problems in agriculture. In : *Allelopathy in Agriculture and Forestry*, (eds.) Narwal, S.S. and Tauro, P., Scientific publishers, Jodhpur, India. p. 1 - 21

Nelliat, E.V., Bavappa, K.V.A and Nair, P.K.R. 1974. Multistoreyed cropping - new dimension of multiple cropping in coconut plantation. *World Crops* **26** : 262 - 266

Nelliat, E.V. and Krishnaji, N. 1976. Intensive cropping in coconut garden. *Indian Fmg.* **27** : (9) 9-12

Nelliat, E.V. and Shamabhat, K. 1979. Multiple cropping in coconut and arecanut gardens. *Tech. Bull. 3*, CPCRI, Kasargod, India.

Ngambeki, D.S. and Wilson, G.F. 1984. Economic and on-farm evaluation of alley cropping with *Leucaena leucocephala*. *Activity Consolidated Report*, 1980 - 1983, IITA, Ibadan, Nigeria.

Ninez, V.K. 1984. Household gardens : theoretical considerations on an old survival strategy. *Research Series No. 1.* International Potato Centre, Lima, Peru.

O'Connell, A.M. 1985. Nutrient accessions to the forest floor in *Eucalyptus diversicolor. For. Ecol. Manage.* **10** (4) : 283 - 296

O'Connell, A.M. and Menage, P.M.A. 1982. Litterfall and nutrient cycling in Karri (*Eucalyptus diversicolor*) forest in relation to stand age. *Australian J. Ecol.* 7 (1) : 49 - 62

Ovington, J.D. 1962. Quantitative ecology and the wood land ecosystem concept. *Adv. Ecol. Res.* **1** : 103 - 192

Okafor, J.C. and Fernandes, E.C.M. 1987. The compound farms of south-eastern Nigeria : a predominant agroforestry homegarden system with crops and small livestock. *Agroforestry Systems* **5** : 153-168

Ortega, R.C., Anaya, A.L. and Ramos, L. 1988. Effects of allelopathic compounds of corn pollen on respiration and cell division of water melon. *J. Chem. Ecol.* **15** : 71 - 86

Pande, P.K. and Sharma, S.C. 1988. Litter nutrient dynamics of some plantations at New Forest, Dehradun. *J. Trop. For.* **4** (4) : 339 - 349

Parker, G.G. 1983. Throughfall and stemflow in the forest nutrient cycle. *Adv. Ecol. Res.* **13** : 58 - 113

Pasha, S.A. 1991. Sustainability and viability of small and marginal farmers, animal husbandry and common property resources. *Economic and Political Weekly* **26** (13) : 27 - 30

Pathak, A.N. 1954. Effect of manurial treatment on water stable aggregates and physical properties of the soil. *Ind. J. Soil Water Conserv.* **2** : 172 - 176

Phlomina, N.S. and Srivasuki, K.P. 1996. Allelopathic studies on agro-forestry species : effect of leaf leachates on seed germination of crop plants. *Indian J. For.* **19** (1) : 45 - 53

Pillai, N.G. and Davis, T.A. 1963. Exhaust of nutrients by the coconut palm - a preliminary study. *Indian Cocon. J.* 16 : 81 - 87

Proctor, J., Anderson, J.M. and Vallack, H.W. 1985. Comparative studies on forests, soils and litterfall at four altitudes on Gunung Mulu, Sarawak. *Malaysian For.* **46** (1) : 60 - 76

Pushkala, S. and Sumam, G. 1996. Influence of crops on physico-chemical properties of a sandy loam soil. In : *Proc. of the Eighth Kerala Science Congress*, Palakkad, Kerala. p. 223

Pushp, K.R. and Surendra, P.S. 1987. Dynamics of nutrients and leaf mass in Central Himalayan forest trees and shrubs. *Ecology* **68** : 1974 - 1983

Raintree, J.B. 1982. *Bioeconomic Considerations in the Design of Agroforestry Intercropping Systems*. ICRAF, Nairobi, Kenya. pp. 1 - 24

Rajput, R.P. and Sastry, P.S.N. 1987. Effect of soil amendments on the soil physico-chemical properties of sandy loam soil. II. Structural and hydrophysical properties. *Indian J. agric. Res.* **23** : 120 - 126

Ramakrishna, Y.S. and Sastri, A.S.R. 1977. Microclimate under *Acacia tortilis* plantation. In : *CAZRI Annual Progress Report, 1977*, CAZRI, Jodhpur, India. pp. 69 - 70

Ramsay, D.M. and Wiersum, K.F. 1974. Problems of watershed management and development in the upper Solo river basin. In : *Proc. Conference on Ecologic Guidelines for Forest, Land and Water Resources*, Institute of Ecology, Bandung, Indonesia.

Rangaswamy, A. and Jayanthi, C. 1996. March towards organic farming via farming systems. In : *Proc. National Seminar on Organic Farming and Sustainable Agriculture*, U.A.S., Bangalore. pp. 111 - 112

Rao, N.S. and Reddy, P.C. 1984. Studies on the inhibitory effects of eucalyptus (hybrid) leaf extracts on the germination of certain crops. *Indian For.* **110** : 218 - 222

Rao, O.P., Saxena, A.K. and Singh, B.P. 1994. Allelopathic effects of certain agroforestry tree species on the germination of wheat, paddy and gram. *Ann. For.* **2** (1) : 60 - 64

Rathinam, P. 1991. The coconut - now to the traditional regions. *Indian Hort.* **36** (3) : 4 - 9

Reddy, G.N.S., Doreswamy, C. and Annu Gowda, K. 1996. Biomass production for promotion of organic farming under rainfed conditions - a case study of B.R. Kaval village in Mysore district. In : *Proc. National Seminar on Organic Farming and Sustainable Agriculture*, U.A.S., Bangalore. pp. 20 - 21

Rice, E.L. 1979. Allelopathy - an update. *Bot. Rev.* **45** : 15 - 109

Rice, E.L. 1984. *Allelopathy*. Academic Press, New York.

Rice, E.L. 1994. Overview of allelopathy. In : *Allelopathy in Agriculture and Forestry*, (eds.) Narwal, S.S. and Tauro, P., Scientific Publishers, Jodhpur. pp. 1 - 21

Richardson, D.R. and Williamson, G.B. 1988. Allelopathic effects of shrubs of the sand pine scrub on pines and grasses of the sandhills. *For. Sci.* **34** (3) : 592 - 605

Rico-Gray, V., Jose, G.G.F., Alexandra, C., Armando, P. and Paulino, S. 1990. Species composition, similarity and structure of Mayan homegardens in Tixpeual and Tixcacaltuyub, Yucatan, Mexico. *Econ. Bot.* **44** : 470 - 482

Rizvi, S.J.H., Sinha, R.C. and Rizvi, V. 1990. Implication of mimosine allelopathy in agroforestry. In : *Proc. Nineteenth World Congress on Forestry* **2** : 22 - 27

Rodin, L.E. and Bazilevich, N.I. 1967. *Production and Mineral Cycling in Terrestrial Vegetation*. Oliver and Boyd Ltd., London.

Rowers, R.W. and Westman, W.E. 1977. Seasonal nutrient dynamics of litter in a subtropical eucalyptus forest, North Stroadbroke Island. *Australian J. Bot.* **25** (1) : 47 - 58

Rudrappa, T. and Hareesh, G.R. 1996. Forest litter - a manurial source in organic farming. In : *Proc. National Seminar on Organic Farming and Sustainable Agriculture*, U.A.S., Bangalore. pp. 18 - 19

Salter, P.J., Williams, I.B. and Harison, D.J. 1965. Effect of bulky organic manure on the available water capacity of the sandy loam. *Expt. Hort.* **13** : 69 - 75

Sanchez, P.A. 1987. Soil productivity and sustainability in agroforestry systems. In : *Agroforestry - A decade of Development*, (eds.) Steppler, H.A. and Nair, P.K.R., ICRAF, Nairobi, pp. 205 - 223

Sandhu, J. and Sinha, M. 1990. Nitrogen release from decomposing litter of *Leucaena leucocephala* inthe dry tropics. *Soil Biol. Biochem.* **22** (6) : 859 - 863

Sanjay, K. and Verma, R. 1987. Letters to the editor. *Indian For.* **113** (9) : 9

Santaregina, I. and Gallardo, J.F. 1989. Bio-geo-chemical cycles in forests of Sierra de Bejar (Spain) : return of bioelements in rainfall. *Acta Oecologia Plantarum* **10** (4) : 433 - 438

Santha, A.M., Shylaja, S. and Balakrishnan Asan, R. 1993. Technology utilisation and constraints in the maintenance of coconut palms. *Indian Cocon. J.* **24** : 6 - 9

Shajikumar, Y.M. and Ashokan, P.K. 1992. Nutrient cycling in coconut-based agroforestry system - contribution from litterfall of multipurpose trees. *Project Report*, College of Forestry, Kerala Agricultural University, Thrissur.

Shanmugasundaram, V.S. and Subramanian, K.S. 1993. Coconut based integrated farming system. *Indian Cocon. J.* **24** (1) : 3 - 4

Sharma, L.R., Bhati, J.P. and Singh, R. 1991. Emerging farming systems in Himachal Pradesh - key isssues in sustainability. *Ind. J. agric. Econ.* **43** (3) : 422 - 427

Shivanna, P., Lokesha, R. and Prasanna, K.T., 1992. Allelopathic effects of eucalyptus : an assessment on the response of agricultural crops. *Myforest* **28** (1) : 131 - 137

Sidhu, D.S. and Hans, A.S. 1988. Preliminary studies on the effect of eucalyptus leaf litter on accumulation of biomass in wheat. *J. Trop. For.* **4** : 318 - 323

Singh, D. and Kohli, R.K. 1992. Reasons of poor under floor vegetation of Eucalyptus. In : *Proc. First National Symposium on Allelopathy in Agroecosystems*, Indian Society of Allelopathy, Hisar, India, pp. 114 - 117

Singh, K.D., Gaur, S. and Varade, S.B. 1976. Structural and moisture retention characteristics of laterite soil as influenced by organic amendments. *J. Ind. Soc. Soil Sci.* **24** : 129 - 131

Singh, R.P. 1984. Nutrient cycle in *Eucalyptus tereticornis* plantation. *Indian For.* **110** (1) : 76 - 85

Singh, R.P. and Nandal, D.P.S. 1993. Allelopathic effects of aqueous leaf extracts of important tree species on some fodder crops. *For. Res.* **19** : 59 - 61

Snedecor, G.W. and Cochran, W.G. 1967. *Statistical Methods.* Oxford and IBH Publ. Co., Calcutta.

Soemarwoto, O. 1987. Homegardens : a traditional agroforestry system with a promising future. In : *Agroforestry - A Decade of Development*, (eds.) Steppler, H.A and Nair, P.K.R., ICRAF, Nairobi, pp. 157 -170

Soemarwoto, O.and Soemarwoto, I. 1984. The Javanese rural ecosystem. In : *An Introduction to Human Ecology Research on Agricultural Systems in Southeast Asia*, (eds.) Rambo, A.T. and Sajise, P.E., Los Banos, Philippines. pp. 254 - 287

Soemarwoto, O., Soemarwoto, Z., Karyono, Soekartadiredja, E.M. and Ramlan, A. 1976. The Javanese home garden as an integrated agro-ecosystem. In : *Science for a Better Environment*, Science Council of Japan, Tokyo, Japan.

Srinivasan, K., Ramasan, M. and Shanta, R., 1990. Tolerance of pulse crops to allelochemicals of tree species. *Indian J. Pulses Res.* **3** : 40 - 44

Stoler, A. 1978. Garden use and household economy in rural Java. *Bull. Indonesian Studies* **14** : 85 - 101

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci.* **25** : 259 - 260

Sundramoorthy, S., Kalra, N. and Sen, D.N. 1992. Allelopathic potential of *Acacia tortilis* on seed germination and seedling growth of some legumes. In : *Proc. First National Symposium on Allelopathy in Agroecosystems*. Indian Society of Allelopathy, Hisar, India, pp. 123 - 124

Sunil, P. and Amarjeet, K. 1991. Allelopathic effects of *Eucalyptus tereticornis* on *Phaseolus vulgaris* seedlings. *Int. Tree Crops J.* **6** : 287 - 293

Suresh, K.K. and Rai, R.S.V. 1987. Studies on the allelopathic effects of some agroforestry tree crops. *Int. Tree Crops J.* **4** : 109 - 115

Suresh, K.K. and Rai, R.S. 1988. Allelopathic exclusion of understorey by a few multipurpose trees. *Int. Tree Crops J.* **5** : 143 - 151

Susan, J. and Alice, A. 1996. Availability of nutrients as influenced by microbial proliferation during different seasons in red loam soils of Kerala. In : *Proc. of the Eighth Kerala Science Congress*, Palakkad, Kerala. p. 174

Swaminathan, C., Rai, R.S.V. and Suresh, K.K. 1989. Allelopathic proclivities of *Acacia nilotica* (L.) Willd. Ex del. *J. Trop. For. Sci.* **2** (1) : 56 - 60

Swaminathan, M.S. 1987. The promise of agroforestry for ecological and nutritional security. In : *Agroforestry - A Decade of Development*, (eds.) Steppler, H.A. and Nair, P.K.R., ICRAF, Nairobi, pp. 25 - 41

Swift, M.J. and Sanchez, P.A. 1984. Biological management of tropical soil fertility for sustained productivity. *Nature Resources* **20** (4) : 1 - 9

Switzer, G.L. and Nelson, L.E. 1972. Nutrient accumulation and cycling in Loblolly pine plantation ecosystems in the first twenty years. *Soil Sci. Soc. Am. Proc.* **36** (1) : 143 - 147

Tajuddin Ismail. 1986. Integration of animals in rubber plantations. *Agroforestry Systems* **4** : 55 - 66

Terra, G.T.A. 1954. Mixed-garden horticulture in Java. *Malaysian J. Trop. Geography* **4** : 33 - 43

Thaman, R.R. 1985. Mixed gardening in the Pacific Islands : present status and future prospects. *Proc. First Int. Workshop on Tropical Homegardens*, Bandung, Indonesia.

Timonin, M.I. 1940. The interaction of higher plants and soil microorganisms : Study of the microbial population of the rhizosphere in relation to resistance of plants to soil-borne diseases. *Can. J. Res.* **18** : 446 - 456

Tomer, G.S. and Srivastava, S.K. 1986. Preliminary studies of rice cultivation in association with trees. In : *Agroforestry Systems : A New Challenge*, (eds.) Khosla, P.K. and Puri, S., ISTS, Solan, India, pp. 207 - 211

Vasey, D.E. 1985. Household gardens and their niche in Port Moresby, Papau New Guinea. *Food Nutrition Bull.* 7 (3) : 37 - 43

Venkitaswamy, R. 1996. Organic farming in coconut. In : *Proc. National Seminar on Organic Farming and Sustainable Agriculture*, U.A.S., Bangalore. p. 21

Vergara, N.T. 1982. *New Directions in Agroforestry : The Potential of Tropical Legume Trees*. First Ed., East-West Centre, Hawaii, U.S.A. p. 28

Vergara, N.T. and Nair, P.K.R. 1985. Agroforestry in the South Pacific region : an overview. *Agroforestry Systems* **3** : 363 - 379

Vinha, S.G. and Pereira, R.C. 1983. Litter production and its seasonality in ten tree species native to southern Bahia, Brazil. *Revista Theobroma* **13** (4) : 327 - 341

Viswanath, D.P., Çhandrappa, H.M., Vaghesh, T.S. and Krishnappa, A.M. 1996. Recycling of plant nutrients through leaf fall of shade trees in cardamom plantation (hilly zone of Karnataka). In : *Proc. National Seminar on Organic Farming and Sustainable Agriculture*, U.A.S., Bangalore. pp. 15 - 16

Von Maydell, H.J.V. 1987. Agroforestry in the dry zones of Africa : past, present and future. In : *Agroforestry - A Decade of Development*, (eds.) Steppler, H.A. and Nair, P.K.R., ICRAF, Nairobi, pp. 89 - 116

Wells, E.G., Nicholas, A.K. and Bual, S.W. 1975. Some effects of fertilization on mineral cycling in Loblolly pine. In : *Mineral Cycling in Southeastern Ecosystem*, (eds.) Howell, F.G., Gentry, J.B. and Smith, M.H., US Energy Research Development, Administration and Technology Information Center, Washington DC.

Will, G.M. 1959. Nutrient return in litter and rainfall under some exotic conifer stands in New Zealand. *New Zealand J. Agric. Sci.* **2** : 719 - 724

Williamson, G.B. and Richardson, D.R. 1988. Bioassays for allelopathy : measuring treatment responses with independent controls. *J. Chem. Ecol.* **14** : 181 - 187

Yadav, A.K. and Mishra, G.P. 1985. Chemistry of stemflow and throughfall water for some tropical dry deciduous forest trees. *J. Trop. For.* **1** (1) : 51 - 60

Yadav, A.K. and Mishra, G.P. 1988. Distribution of precipitation under a tropical dry deciduous forest stand of Central India. *J. Trop. For.* **1** (3) : 182 - 197

Yamoah, C.F. and Mulongoy, K. 1984. In : *IITA Annual Report 1983*, Ibadan, Nigeria.

Yoder, R.E. 1937. The significance of soil structure in relation to the tilth problem. *Soil Sci. Soc. Am. Proc.* **2** : 21 - 23

Young, A. 1986. Effects of trees on soils. In : *Amelioration of Soils by Trees : A Review of Current Concepts and Practices*, (eds.) Prinsley, R.T. and Swift, M.J., Commonwealth Council, London.

APPENDICES

APPENDIX I

Questionnaire

Agroforestry Systems Inventory Description Survey

1.
   a. Name of the Panchayat :
   b. Name of the farmer :
   c. Address :
   d. Area of the Homestead :
   e. Soil type :
   f. Topography :

2. Total number of crop/tree species present in the home garden

3. Identification of the different tree/crop species present

4. Inventory of Crops and Trees

Category	Population	Variety	
		Local	Improved
Oilseeds			
Tubers			
Fruits			
Spices and Condiments			
Vegetables			
Fodder Grass			
Timber/Fuel Trees			
Rubber			
Others			

5. Method of recycling of tree parts : Mulch / Fuel / Manure / Animal Feed

6. General opinion of the farmer in having treesinthe home garden : Positive / Negative

7. Structure of the home gardens (through visual observation)

   a. Planting pattern
   b. Number of vertical strata and the components in each strata

8. Farming practices adopted by the homestead farmers

   a. Source of irrigation
   b. Extent of adoption of package of practice recommendations
   c. Nutrient management : Organic / Inorganic / Both
   d. Extent of adoption of plant.protection measures

9. Farming systems followed in home gardens

   a. Crops alone
   b. Crops + Cattle
   c. Crops + Poultry
   d. Crops + Cattle + Poultry

10. Inventory of Cattle / Poultry

Category	Population	Breed	Feeding Pattern
Cow			
Buffalo			
Poultry			
Sheep/Goat			

11. Credit facilities

Agency	Membership	
	Yes	No
Co-operative society		
Consumer society		
Milk Marketing society		
Credit society		
Primary Co-operative society		
Co-operative Bank		

12. Marketing facilities

Open market / Regulated market / Contract / Middleman / Co-operative society

13. Difficulties / Constraints experienced by the farmers :

Constraint	High	Medium	Low
Cultivation cost			
Availability of labour			
Availability of loan			
Availability of technical information			
Availability of manures/fertilizers			
Availability of P.P chemicals			
Marketing facilities			
Storage facilities			

14. Economics of farming (Annual)

a. Total Investment
b. Gross Returns
c. Value of marketed produce
d. Value of consumed produce
e. Net Profit

STRUCTURE ANALYSIS AND SYSTEM DYNAMICS OF AGROFORESTRY HOME GARDENS OF SOUTHERN KERALA

By

JACOB JOHN

ABSTRACT OF A THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLAYANI
THIRUVANANTHAPURAM

1997

ABSTRACT

A study entitled "Structure analysis and system dynamics of agroforestry home gardens of southern Kerala" was undertaken during the period from 1994 - 1997 in Thiruvananthapuram district of Kerala State. The study comprised of a detailed agroforestry systems inventory description survey of the home gardens in the district, investigations on the system dynamics of two home gardens of the district, laboratory experiments to assess the allelopathic tendencies of some commonly grown multipurpose tree species and linear programming to develop integrated homestead models.

The results of the survey revealed that the size of an overwhelming number of holdings was small. The species diversity and average number of plants per home garden was considerably high. Tuber crops ranked first among the crops, followed by fruits, oilseeds, rubber, spices, vegetables, timber and fuel trees and fodder crops. The tree intensity was found to increase as the size of the holding decreased. The frequency of occurrence was highest for coconut, followed by jack, mango, moringa, guava, wild jack and tamarind and lowest for the nitrogen fixing trees. Differences between the agroecological zones of the district with respect to the predominance of crop categories and tree species were also observed. The home gardens presented a multi-tier

canopy configuration. There was no specific planting pattern or arrangement. The system, as a whole, was found to be profitable.

The two year long field investigation on the dynamics of home gardens revealed that the tree components contributed considerable amounts of nutrients by way of litterfall, stemflow and throughfall. Nutrient addition took place mainly through organic manures at both locations. Harvested biomass accounted for removal of large quantities of nutrients from the systems. Coconut accounted for maximum biomass production and nutrient removal at both sites.

The physical, chemical and microbiological properties of the homestead soil were better than that of the control. The soil in the homestead had a lower bulk density, high water holding capacity, porosity and moisture content. An enhanced soil organic carbon content, available N, P and K status were also observed in the home garden. The soil microbial population (bacteria, fungi, actinomycetes and phosphorus solubilizing bacteria) was comparatively higher in the home garden. Nutrient cycling, recycling of crop residues and addition of organic manures helped in improving and maintaining the soil physico-chemical and biological properties of the system in a sustainable manner.

The presence of trees lowered the soil temperature in the homestead, whereas relative humidity was maintained at an optimum level when compared to open condition. The light intensities at the floor of all the trees studied were invariably less than that in the open.

Both the home gardens were found to be profitable. The tree-crop-livestock integration was a special feature which increased income considerably.

Allelopathic inhibition of germination and growth of rice was caused by leaf extracts of all the tree species.

Germination of cowpea was inhibited by the leaf extracts of acacia, eucalyptus, casuarina, ailanthus, tamarind, portia and cashew. Growth of cowpea was suppressed by leaf extracts of all the tree species except jack.

The powdered leaf litter of all the trees inhibited rice germination and growth. However, jack did not suppress radicle growth.

Cowpea germination was inhibited by the powdered litter of all the trees except jack and mango. Cashew, casuarina and jack did not suppress plumule growth of cowpea. Radicle growth of cowpea was inhibited all tree species.

The integrated model for the 0.50 ha home garden with 23 enterprises was found to generate a profit of Rs. 10354.21 with an investment of Rs. 3262.30.

The coconut-based mixed farming model developed for the 0.40 ha home garden with 35 enterprises provided a net profit of Rs. 32464.32 on investing Rs. 45000/-.