

BIO-ECONOMIC APPRAISAL OF AGROFORESTRY LAND USE SYSTEMS

THESIS

By

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Submitted in partial fulfilment of the requirements for the

Degree of

MASTER OF SCIENCE

IN

AGROFORESTRY



COLLEGE OF FORESTRY
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HORTICULTURE AND FORESTRY
SOLAN (HP) 173 230
INDIA
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DEDICATED

to My

Reverend Grand Father

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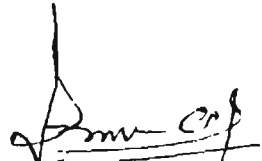
CERTIFICATE-I

This is to certify that the thesis entitled "Bio-economic appraisal of agroforestry land use systems", submitted in partial fulfilment for the award of the degree of **MASTER OF SCIENCE** in **AGROFORESTRY** to Dr Yashwant Singh Parmar University of Horticulture & Forestry, Nauni, Solan, is a faithful record of bonafide research work carried out by Mr Manoj Kumar (F-93-9-M) under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigation have been fully acknowledged.

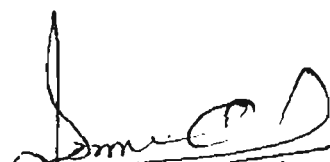
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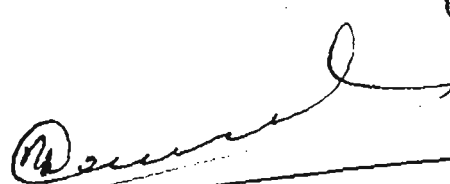
CERTIFICATE-II

This is to certify that the thesis entitled "Bio-economic appraisal of agroforestry land use systems", submitted by Mr Manoj Kumar to Dr Yashwant Singh Parmar University of Horticulture & Forestry, Nauni, Solan, in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in AGROFORESTRY has been approved by Student's Advisory Committee after an oral examination of the same in collaboration with the Nominee of the Dean.


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ACKNOWLEDGEMENTS

With limitless humility, I would like to commend and thank, 'God' - The Almighty, the Merciful, the Compassionate, who bestowed me with health and courage enough to go through this impasse.

With an overwhelming sense of legitimate pride and a genuine obligation which gives me exuberant pleasure and privilege to express my heartfelt gratitude and indebtedness to my condign and acuminous advisor Dr KS Verma, Associate Professor, Department of Silviculture and Agroforestry, for his kind stewardship, erudite guidance, constructive criticism, innovative ideas, prompt help and keen interest during the tenure of this investigation and finally scanning the manuscript in a scientific and acuminous way. I shall always remain deeply indebted to him for his personal affection and generosity bestowed on me.

I emphatically owe my sincere thanks and obligations to Dr VK Mishra and Dr D Tripathi, members of my advisory committee for their inspiring guidance blended with invaluable suggestions.

I am highly grateful to Dr SP Dhall and Dr R Malhotra for statistical guidance, Dr AL Nadda, Dr LR Sharma, Dr R Prashar and Dr NK Gupta for their continuous help as and when required.

I gratefully acknowledge the award of UNDP Fellowship for this investigation. Thanks are also due to the laboratory, field and ministerial staff of the Department of Silviculture and Agroforestry, for their cordial cooperation.

Exultant and enviable company provided by my coterie Chaman, Hitender, Bhagwan, Pathak, Pant and Verma kept me in a exalted state even during moments of despondency.

I sincerely acknowledge the help and encouragement received from friends Ravinder, Rajesh, Ramesh, Harmeet, Kaler, Dinesh, Vishal, Hitesh, Pandey, Goswami, Vinay, Banyal and Sephia. Benevolence and generosity of Dr MM sharma and Dr Satish Bhardwaj is duly acknowledged.

My special thanks are also due to Mr Asha Ram whose tireless efforts and intense finger touches made my efforts live by setting this manuscript well in time. *paneg*

Above all, I bow to my adorable parents Smt and Shri Nek Ram Thakur, who provided me every comfort at the cost of theirs and words are no mean to penegrise their sacrifices for the betterment of their sometimes intolerant son. The contribution of my brother Krishan, Bhabhi Anju, niece Shivani and nephew Shabu is beyond my expression. Parental love and homely comforts provided to me during my stay at Nauni by my uncle Shri Raj Mal Mandhotra and his family will remain an ineluctable memory.

It is perhaps inevitable that some errors of facts, interpretation or emphasis will be found, but I trust no one will attribute these to any one, but me.

Solan

Dated: January 27th, 1996

Manoj
(Manoj Kumar)

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Acronyms

CD	=	Critical difference
%	=	per cent
R.I.	=	Relative illumination
cm	=	centimeter
m	=	meter
ha	=	hectare
g	=	gram
kg	=	kilogram
q	=	quintal
SC	=	Sole cropping
AS	=	Agrisilviculture
AH	=	Agrihorticulture
AHS	=	Agrihortisilviculture

Chapter 1

INTRODUCTION

Agroforestry is a collective name for land use systems and technologies where woody perennials (trees, shrubs, palms, bamboos etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components (Lundgren and Raintree, 1982). There are an almost unlimited number of agroforestry systems in use all over the world. Most are traditional systems developed over time in response to particular combinations of agroecological and socioeconomic circumstances; some are recent systems linked to commercial crops (coffee, oil, palm, tea etc.), still others are in different stages of development through research and early extension efforts (e.g. alley farming).

Common to all these systems, practices and technologies is the deliberate use of trees and shrubs in order to achieve higher productivity, sustainability and diversity of output from land use system. This is what makes agroforestry a distinct discipline which, although obviously related to and dependent on the body of knowledge existing in conventional agriculture and forestry disciplines, require its own set of approaches and methodologies. The science and practice of agroforestry is thus a matter of finding and developing the relevant combinations of woody and non-woody (crops/livestock) components in relation to the land user's problems, aspirations and potential and to develop spatial arrangement, and management practices which minimize the competitive interactions between the components and maximize the productive and service functions of trees and shrubs.

Agroforestry was institutionalized for the first time in 1977 with the establishment of International Centre for Research in Agroforestry (ICRAF). In India first agroforestry seminar was held at Imphal in 1979 which gave a good deal of thought for the establishment of scientific agroforestry in India. Consequently, Government of India through Indian Council of Agricultural Research (ICAR) launched an All India Coordinated Research Project on Agroforestry during 1983. Presently 31 centres covering major ecological zones in India are engaged in agroforestry research. The major task before each centre is the appraisal of existing agroforestry systems, practices and their management. During the last 15 years much work has been done on the identification and development of agroforestry land use practices for producing fuel, fodder, fibre, small timber and other alternate products. However, management has remained commodity oriented and a lot of work is needed to study the tree-crop interaction to minimize the competitive attributes and maximize the productive potential of such land use systems.

In a country like India, the vast human population coupled with ever proliferating cattle number needs progressively increasing amounts of food, fodder and fuel. Besides, there is a growing demand of raw material for various forest based industries. The widespread depletion of forest wealth in the country in recent past has extended not only to conventional forest area but the trees growing in farm lands have also met indiscriminate felling. Such a huge reduction in tree cover has affected not only the rural and industrial sector but also created many eco-mishaps. Moreover, the ecosystem management programmes designed to overcome these problems

have failed to yield fruitful results because they have not been evaluated at the grass root level (village level).

In the state of Himachal Pradesh, average annual per capita consumption of fuelwood is 0.6 tonne per head amounting to a total of 2.3 million tonnes per annum (Singh, 1982a, 1982b). About 60 to 70 per cent requirement of the firewood is met from the arboreal components. Grass (green/dry) fodder is too scanty to support a large cattle population and only 60 per cent of the total requirement is available in the state. This huge deficit of about 40 per cent is partially supplemented through tree leaf fodder especially during the winter when grass vegetation withers away (Verma *et al.*, 1989). Also there is an acute shortage of packaging material to transport horticulture produce, since this industry depends entirely upon forests. According to one estimate, in the state of Himachal Pradesh alone, wood worth of 20 million boxes equivalent to 0.2 million m³ is axed every year for packaging of apples, other stone fruits and fresh vegetables (Stokes, 1983). Agroforestry land use systems viz., agrisilviculture, agrisilvihorticulture and silvipasture have been reported to be more prevalent in the low and mid-hills of Himachal Pradesh (Verma *et al.*, 1989). These systems are being managed traditionally by the farmers to meet their demands for food, fuel, fodder, fibre and small timber. This has resulted into the impoverishment of the soil fertility, high rate of erosion, paucity of fodder for animals as well as wood for timber and non-timber uses.

In order to combat the aforesaid problems, a fresh look for an integrated land use satisfying both environmental needs as well as tangible

products seems to be ideal. Since there is no scope for horizontal expansion of land for cultivation, the only alternative left is for vertical expansion and diversification of farm enterprises with less demand on space and time. This is particularly true for small and marginal farmers (>70%) who do not have much of resources, especially in rainfed areas.

To realize the full potential of the various components of agroforestry land use systems i.e., restore and sustain the land productivity while diversifying the farm output, systematic scientific research efforts are needed to explore these systems which are biologically more complex than other ways of using land alone through arable farming, fruit cultivation or forest farming. Efforts are afoot to study the spatial arrangement and other management practices of agrisilviculture, agrisilvihorticulture and silvipasture land use systems in order to diversify the farm production while increasing the overall productivity in a sustainable manner.

The present study ⁹propose₉ to test the hypothesis that "growing of trees with agricultural crops in a suitable spatial arrangement using standard canopy management can help in increasing the sustained farm production". To verify the said hypothesis following objectives have been laid out:

- 1] Evaluate the biomass productivity of agrisilviculture and agrihortisilviculture systems
- 2] Study the nutrient dynamics in the systems
- 3] Work out the relative efficiency of the systems in terms of economic returns

Chapter 2

REVIEW OF LITERATURE

Agroforestry systems are biologically more complex than other means of using land either through arable farming, fruit cultivation or forest farming. A common hypothesis is strongly implied to the agroforestry systems that integration of trees with annual crops increase the overall productivity and improves physical and chemical properties of soil. However, literature reveals ample vacuum as regards systematic studies on biomass productivity, nutrient cycling, economic evaluation and competitive or complementary reciprocal effects of different components of the system. In this chapter an attempt has been made to review the information available on these aspects of agroforestry systems under the following heads:

- 2.1 Growth and productivity
 - 2.1.1 Field crops
 - 2.1.2 Fodder and fruit trees
 - 2.1.3 Shade and relative illumination
- 2.2 Plant nutrient content and uptake
 - 2.2.1 Field crops
 - 2.2.2 Fodder and fruit trees
- 2.3 Soil moisture
- 2.4 Nutrient dynamics
- 2.5 Economic evaluation

2.1 Growth and productivity

To sustain life, biomass plays and is going to play a strategic role in future, as we are dependent on this renewable source for most of our needs. It is true that trees do compete with agricultural crops for

nutrients, soil moisture and light in the agroforestry systems. But through the use of suitable spatial arrangement and other management practices, agroforestry systems diversify the output and provide maximum production because being able to tap solar radiation and soil pools more efficiently.

2.1.1 Field crops

Intercropping maize with 1-year old *Acacia auriculiformis* in rainfed conditions, Anonymous (1987) noticed maize plant height of 162.9, 155.4 and 160.4 cm with trees spaced at 4mx1m, 4mx2m and 2mx2m respectively. While evaluating the performance and effect of common tree species; *Acacia nilotica*, *Azadirachta indica* and *Eucalyptus* hybrid (400 trees ha⁻¹) on sorghum and safflower, Srivastava *et al.* (1993) reported that tree species had a marked effect on the plant height, number of branches and capsules of safflower whereas in sorghum only the plant height was affected.

Yamoah *et al.* (1986) observed an insignificant reduction in maize height, stover and cob weights, for the maize rows close to the shrub hedge rows compared to those in the middle of alleys. Lal (1989) conducted field experiments on a tropical alfisil at Ibadan, Nigeria and reported that maize germination and crop stand were normal while that of cowpea were suppressed by both *Leucaena* and *Gliricidia*. He further reported that grain yield of maize in agroforestry system was 10 per cent less whereas cowpea yield was 30-50 per cent less than the control. Krim *et al.* (1991) while studying the effect of young *leucaena* on the growth and yield of maize, sweet potato and cowpea in an agroforestry system in Sierra Leone reported that *leucaena* tended to reduce grain yield of maize, tuber and vine yields of sweet potato in the row in the immediate vicinity of the trees.

Rao and Coe (1992) reported that the tree species that ranked high in terms of height and diameter growth were also the most competitive with crops. Similarly, species that produced wide crowns tends to suppress crop yield. They recorded average row crop yield of beans relative to sole crop as 46 per cent when grown adjacent to *Melia azedarach* and *Cordia abyssinica* having 4.36 m and 3.62 m height and 11.1 m and 9.3 m root collar diameter. Whereas the yield was 146 per cent when grown adjacent to *Alnus acuminata* having 1.24 m height and 3.2 m root collar diameter.

Crop yield of plants adjacent to hedgerow trees have been reported to be lower than in the centre of alley by Yamoah *et al.* (1986a), Krim (1987) and Huxley *et al.* (1989). In a study of hedgerow plantation of *Leucaena leucocephala* with maize, black gram and cluster bean, Mittal and Singh (1985) reported an average reduction of 38, 34 and 29 per cent in the yields of inter crops over pure crops viz. maize, black gram and cluster bean respectively.

Maiti *et al.* (1993) reported maximum yield of maize (herbage), rice (grain), sorghum (herbage) and mustard (grain) to be 69.1, 38.2, 19.2, 87.9 and 10.2 q ha⁻¹, respectively under sole cropping as compared to those under alley cropping system with subabul; 32.0, 14.3, 8.6, 19.9 and 4.9 q ha⁻¹, respectively. Srivastva *et al.* (1993) observed average annual grain yield of sorghum, safflower and Bengal gram in 4.50 m alleys of leucaena; 1155, 161 and 143 kg ha⁻¹ over two seasons, compared to pure crop production of 1367, 341 and 301 kg ha⁻¹, respectively. The competition from leucaena resulted in 15, 33 and 52 per cent decrease in grain yield of sorghum, safflower and Bengal gram, respectively.

The impact of adverse effects is greatest in the close vicinity of the trees and diminishes as the distance increases (Dhillon et al., 1979; Sharma, 1987; Diwedi, 1987). Such effects were observed in different crops with a combination of different tree species. Khan and Aslam (1974) reported a decrease in wheat yield upto 30.88 per cent, 23.60 per cent and 12.70 per cent at the distances of 3, 4.5 and 6 m, respectively from single shisham tree, as compared to the yield recorded from the centre of field. Similar results were reported by Sheikh and Cheema (1976) while studying the effect of poplar wind breaks (tree rows) on the yield of wheat crop. In another study conducted in a 20 year old plantation of *Eucalyptus tereticornis* at Kota, it was found that the yields of rainfed black gram, green gram and sorghum were adversely affected upto a distance of 2 m from tree line (Shrivastav and Narain, 1980). A maximum loss within a radius of 2 m from the tree was reported by Sheikh (1987) while studying the wheat crop yield in association with *Acacia nilotica* and *Dalbergia sissoo*.

Akbar et al. (1990) while studying the effect of tree species viz. *Eucalyptus*, *Albizia*, *Morus* and *Leucaena* on the wheat crop indicted that trees' impact on wheat yield can be experienced upto 2 m distance, there is little, if any, impact upto 6 m distance and almost no impact at 8, 10 and 12 m distances. Similar results were reported by Puri and Bangarwa (1992) while studying the effect of *Azadirachta indica*, *Prosopis cineraria*, *Dalbergia sissoo* and *Acacia nilotica* on the yield of irrigated wheat crop.

Sharma (1992) conducted a study to find out the influence of single row bund plantation of *Acacia nilotica* on the growth and yield of associated wheat crop under irrigated conditions in Haryana. The

indications are that the tree line does effect all crop parameters like height, growth, shoot number, ear length, grain number and grain yield in the vicinity of trees upto 4 m distance from the tree line and establishes that as the distance from the tree line increases the growth and yield of wheat crop also improves.

Khybri *et al.* (1992) in a tree-crop interaction studies; *Grewia optiva*, *Morus alba* and *Eucalyptus* hybrid were tried along with rice-wheat rotation under rainfed conditions in Dehra Dun valley, observed 39 per cent decrease in crop yield upto 1 m, 33 per cent from 1-2 m, 25 per cent from 2-3 and 12 per cent from 3-5 m distance from tree row.

Ong *et al.* (1992) conducted an experiment at Machakos in November, 1989 to assess the importance of above ground competition between single rows of *Leucaena leucocephala* and adjacent maize. They reported that the influence of *Leucaena* extended to about 5 meters beyond this distance, maize yields were close to the level achieved on sole maize plots.

Dhillon *et al.* (1982) studied the effect of direction of planting of *Eucalyptus* on rice, wheat and potato yield and reported that N-S direction caused less reduction in the crop yields than in E-W direction. The shade tolerance was highest and correspondingly the yield reduction lowest in potato followed by rice and wheat. In another study with *Dalbergia sissoo* and *Acacia nilotica*, Dhillon *et al.* (1984) reported lesser reduction of wheat and paddy yield on southern aspect and more loss on western aspect. More yield reduction was observed due to *Acacia nilotica* than *Dalbergia sissoo*. Similar results were reported by Sheikh (1987) while studying wheat crop yield in association with *Acacia nilotica* and *Dalbergia sissoo*.

2.1.2 Fodder and fruit trees

When tree species are introduced on agricultural fields or grasslands, the ground cover of crops/grasses exerts a considerable influence on the establishment and growth of the tree component in any agroforestry practice. Harsh and Tewari (1993) noticed a considerable negative effect on the growth of the tree seedlings upto a 3 year period, when *Acacia tortilis* was grown with *Cenchrus ciliaris*. Similar observations were recorded from another study in which trees (*Acacia albida* and *Prosopis cineraria*) were planted with some agricultural crops (cluster beans, pearl millet and moong beans). Srivastva *et al.* (1993) reported a reduction in the leucaena biomass to the tune of 12 per cent under sorghum and 3 per cent under Bengal gram and a marginal increase by 5 per cent under safflower.

Maiti *et al.* (1993) reported that highest herbage yield of subabul ($290 \text{ q ha}^{-1}\text{yr}^{-1}$) was obtained under a sole cropping system. The yield of subabul decreased by 3.8, 2.4 and 6.6 per cent respectively due to alley cropping in the sequence of maize-cowpea-mustard, fallow-rice-mustard and maize-sorghum-mustard crop sequences. In the alley cropping system, the productivity of subabul was higher (283 q ha^{-1}) when grown in fallow-rice-mustard sequence as compared to those grown in maize-cowpea-mustard (280 q ha^{-1}) and maize-sorghum-mustard (271 q ha^{-1}) sequence.

While studying tree-crop interactions under rainfed conditions in Dehra Dun valley for 13 years during 1977 to 1990, Khybri *et al.* (1992) reported that *Grewia optiva* could produce $1.08 \text{ t ha}^{-1}\text{yr}^{-1}$ of branches and $0.26 \text{ t ha}^{-1}\text{yr}^{-1}$ of leaves were obtained from *Morus alba*. Wood (ADT)

produced by the trees was 33.6 t ha⁻¹ from *Eucalyptus*, 9.5 t ha⁻¹ from *Grewia optiva* and 11.6 t ha⁻¹ from *Morus alba*.

In Rajasthan a full grown tree of *P. cineraria* is expected to yield 59 kg of fresh leaves on complete lopping when only the central leading shoot is left (Bhimaya *et al.*, 1964). IN similar situations, a yield of 25-30 kg of fresh leaves is expected from moderately sized tree of *P. cineraria* (Bohra and Ghosh, 1980). An average fall grown tree of *A. excelsa* yields about 5-7 kg of green leaves twice a year (Bhandari and Gupta, 1973). An average fodder yield of 15-20 kg tree⁻¹ is reported from *B. variegata* (Negi *et al.*, 1979). Five year old plantations of *Kydia calycina* are reported to yield about 7-10 t ha⁻¹ of green fodder ha⁻¹ (Singh, 1982). A leaf fodder yield of 11 t ha⁻¹ is reported from 2 year old plants of *G. optiva* in Kashmir. In the same species, the green fodder yield per adult tree in the Kangra district of the HP is reported to be about 12-15 kg tree⁻¹ (Negi *et al.*, 1979). Roy and Deb Roy (1986) reported fresh fodder yields of 1.1 kg tree⁻¹yr⁻¹ from 9 year old *A. tortilis*, 25.3 kg tree⁻¹yr⁻¹ from 9 year old *A. amara*, 6.7 kg tree⁻¹yr⁻¹ from 9 year old *H. binata*, 8.5 kg tree⁻¹yr⁻¹ from 6 year old *A. lebbeck* and 30.8 kg tree⁻¹year⁻¹ from 6 year old *A. procera*. The same workers reported a fresh fodder yield of 10.2 kg tree⁻¹yr⁻¹ from 5 year old *Bauhinia purpurea* during 1983.

Arora and Mohan (1986) studied the interaction effect of short duration companion crops on the growth and yield of peach and indicated that cowpea and soybean had no marked adverse effect on the height and crown diameter of the trees when compared to control(tree alone) upto 7th year. However, in the 7th year sesame had shown slight inhibiting effect on

the tree height on the other hand, soybean exhibited increase in tree height by this time. On the basis of fruit yield, cowpea (36 kg tree^{-1}) and sesame (34 kg tree^{-1}) had no adverse effect on peach yield as it was as good as control (33 kg tree^{-1}) in 7th year of orchard. Association of soybean produced better fruit yield (43 kg tree^{-1}). On the other hand while studying the interaction effect of long duration companion crops on the growth and yield of peach these authors reported that intercropping with pine apple ($40.1 \text{ kg tree}^{-1}$) or turmeric (30 kg tree^{-1}) gave relative better fruit yields than lemon grass (14 kg tree^{-1}) and in control ($24.6 \text{ kg tree}^{-1}$).

Jamir (1985) while studying performance of some promising cultivars under mid hill conditions of Himachal Pradesh reported that 8 year old July Elberta fruit yield ranged between 17.20 to 18.50 kg plant^{-1} . Sankhyayan (1969) reported that July Elberta gave an average fruit yield of 20.667 kg plant^{-1} .

While studying the nutritional status of peach orchards in Rajgarh area of Himachal Pradesh, Kumar (1994) reported that the mean fruit weight of 10 to 12 years old peach tree being 82.8 and 84.2 g and mean fruit yield 34 and 34.4 kg tree^{-1} during 1992 and 1993, respectively. At maturity, the fruit weight of Collins and Elberta peach cultivars ranged from 113 to 122 g and 171 to 194 g, respectively (Ninkovski, 1972). Garg *et al.* (1975) reported average fruit weight of Crawford's Early and Golden Bush peach at maturity to be 68.60 and 104.4 g, respectively.

Singh (1992) reported that eight year old July Elberta peach trees spaced at 5x5 m yielded pruned wood of 4.38 to 5.78 kg tree^{-1} in 1990 and

3.41 to 4.87 in 1991, whereas fruit yield being 32.41 to 40.68 in 1990 and 46.90 to 51.78 in 1991.

Gupta *et al.* (1982) in a study conducted on the intercropping of Rabi and Kharif crops with peach in Doon valley of Uttar Pradesh reported that on an average, five year old tree provides about 10-15 kg tree⁻¹ of pruned wood and 10 kg of leaf litter during November-December.

2.1.3 Shade and relative illumination

Donald (1961) emphasized that light differed from the other resources in that it could not be regarded as a reservoir from which demands could be made as required: light is 'instantaneously available' and has to be 'instantaneously intercepted' if it is to be used for photosynthesis. Because of this Willey and Roberts (1976) emphasized that light was probably the most important factor when better temporal use of resources was achieved. Investigations on light interception and competition in agroforestry systems are generally scarce. An additional problem is the difficulty to compare the available results because of the differences in methodologies used in the investigations. However, some insights originate from the few available studies, including some on intercropping of herbaceous species.

Some field experiments have been carried out to examine how one species, by reducing light intensity, can affect the productivity of another. For example, in studies examining the resource sharing ability of multipurpose trees in an intercropping system, crop yield was found to be depressed by competition with the trees for light (Srinivasan *et al.*,

1990), a finding previously observed in studies on canopy effects (Kira and Kumura, 1983). Studies in Nigeria (Kang et al., 1981) using *Leucaena leucocephala* intercropped with maize similarly indicated that above ground competition for light was more important than below ground competition, whilst an investigation in Sierra Leone to assess the effects of *Leucaena leucocephala* on the productivity of maize, cowpea and sweet potato (Krim et al., 1991) revealed reduced yield of maize and sweet potato in the rows immediately adjacent to the trees, more notably in the plots where nitrogen fertilizer was added to remove possible nutrient limitation.

✓ Shading was found to be more important than below ground competition in an intercropping study with pearl millet and groundnut in India (Wiley and Reddy, 1981). Similarly, Verinumbe and Okali (1985) showed that competition for light was a more critical factor than root competition for intercropped maize between teak trees (*Tectona grandis*) in Nigeria. Neumann and Pietrowicz (1989), who studied competition in an agroforestry combination of *Grevillea robusta*, maize and beans in Rwanda, reported that the shade cast by *Grevillea* appeared more important than other effects of the trees.

In a field study to determine the effect of various degrees of shading, Wahna and Miller (1978) noticed that the dry weight of the soybean decreased curvilinearly with the increase in shade. Eriksen and Whitney (1984) reported that shading caused 34 per cent average reduction in dry matter and grain yield, of three legumes (soybean, cowpea and bush bean). The response of soybean to shade was recorded to be intermediate with no reduction in dry matter and grain yield at 70 per cent sun. Bush bean was

least affected by shading. Conversely, the cowpea was noticed to be least shade tolerant. In fact maximum yield was obtained at 70 per cent sun. At 27 per cent sun, dry matter yield was similar for all three crops. Crookston *et al.* (1975) reported that shading reduced leaf number, area and thickness of two dry beans (*Phaseolus vulgaris* L.) cultivars. Photosynthesis per unit area of shaded leaves decreased by an average of 38 per cent whereas the effect on transpiration was non-significant. Shading reduced the pigeon pea yield intercropped with legumes and cereals (Goyal *et al.*, 1991). Similarly, yield of wheat was shown to be increased due to decrease in shade, of the plants growing away from tree line by Dadhwal and Narain (1984). Similar findings were reported by Jimenez *et al.* (1991) in maize grown with *Erythrina*.

Sheikh and Haq (1978) studied the effect of shade of *Acacia nilotica* and *Dalbergia sissoo* on wheat yield. The study revealed that both the factors i.e. distance from tree base and the direction of tree shade had a highly significant effect on the wheat yield for both tree species. The yield was lowest at a distance of 2 m from the center of the tree and when the plots were on the northern, north-eastern and north-western sides of the trees. Arora and Mohan (1986) in a study on agrihorticulture land use systems involving young peach 'Flordasun' orchard in Doon Valley under rainfed conditions on class II land revealed that out of the short duration intercrops cowpea (587 kg ha⁻¹) and sesame (398 kg ha⁻¹) can be grown until 6 years and beyond this the yield decline to uneconomic levels due to shade effect of the trees.

Iorquebiau and Akyeampog (1994) reported that beans were not affected at all by a 27 per cent reduction in light whereas a decrease of light to 42 per cent of total radiation decreased yield of dry grain to 37 per cent of the control. Maize was more affected by shade than the beans. A light reduction of 27 per cent caused a 23 per cent reduction in the dry grain yield of maize; 50 per cent less light cut yields by 47 per cent. Interestingly, banana plants under 50 per cent shade produced yields about 20 per cent ^e greater than those in no shade.

Biomass production in the understorey is a function of photosynthetic active radiation (PAR) falling on the ground surface (Hazara and Tripathi, 1986). They reported that *Leucaena leucocephala* and *Acacia tortilis* severely reduced the barseem yield whereas *Hardwickia binnata* has little impact because of the fact that leucaena allowed the least amount of light infiltration which was 48 per cent of the full light availability in the open, *Acacia* and *Hardwickia* allowed 65 and 80 per cent, respectively. Hazara (1989) reported that a reduction of 20-30 per cent in light intensity decreased the dry matter yields by 6 and 22 per cent in *Trifolium alexandrium* under *Acacia nilotica* and *Leucaena leucocephala*, respectively, compared with yields in the open field. Singh et al. (1989) reported that leucaena hedgerows in a 10 m wide alley cropping system caused a light reduction of 30 to 85 per cent of full sunlight.

Studies on microclimatic variation around the tree cover by Ramakrishna (1984) revealed that under silvi-pastoral system in 13 year old *Acacia tortilis* plantation, the total incident radiation just beneath the tree canopy was only 14 to 30 per cent of that received in open areas and

was thus insufficient for a good growth of grass cover (*Chenchrus ciliaris*).

Jaswal *et al.* (1993) while studying the performance of two rhizomatous crops i.e. ginger and turmeric as inter crops with 5 year old poplars planted at three spacings viz. 5x5 m, 5x4 m and 5x3 m reported an average illumination of 53, 46 and 38 per cent of incident radiation under the canopies, respectively. Likewise, Dinssa (1993) reported relative illumination of 40 and 48 per cent of incident radiation below poplar canopies spaced at 5x3 m and 5x4 m, respectively while below morus spaced at 8x2 m it was 35 per cent under mid hill conditions of Himachal Pradesh.

2.2 Plant nutrient content and their uptake

Foliar analysis has been regarded as an index of nutritional status of the crops irrespective of nutrient supply in the soil. The amount of nutrients taken up by the plants primarily depends upon the concentration of that nutrient in the close proximity to the root surface (Black, 1968 and Russell, 1973). Hence, two or more tree-crop components exploring the same soil volume for their respective nutrient requirements are liable to be influenced due to one another's reciprocal effect in agroforestry situations.

2.2.1 Field crops

Haggar and Beer (1993) while evaluating the effect of interaction between increased nitrogen availability and competition with trees on maize growth in alley cropping at CATIE, Costa Rica, reported that maize growing next to Erythrina hedgerows had 44 per cent lower biomass and 35 per cent

lower N content than maize growing in the middle of alleys whereas, maize growing next to *Gliricida* hedgerows had the same biomass but 56 per cent higher N content than maize growing in the middle of alleys. It has also been found that the maize growing next to the trees responded less to nitrogen fertilization than maize in the centre of alleys presumably due to greater competition for light, water and/or nutrients near to trees (Krim, 1987; Yamoah *et al.*, 1986a).

Thakur (1986) indicated that N P and K-content in maize grain ranged between 1.61-1.71, 0.28-0.31 and 0.21-0.22 per cent, respectively whereas the respective values for maize stover ranged between 0.79-0.84, 0.135-0.140 and 1.07-1.11 per cent. The N, P and K-uptake by maize grain recorded to be 68.02-104.08, 11.79-19.30 and 9.50-13.85 kg ha⁻¹, respectively whereas for maize stover the respective values ranged between 70.63-119.21, 11.93-19.72 and 95.57-157.04 kg ha⁻¹. Manuja (1992) reported that N, P and K concentration in main and by product of maize were 1.68, 0.32, 0.43 and 0.66, 0.08, 0.87 per cent, respectively. For wheat the respective values being 1.66, 0.33, 0.36 and 0.43, 0.13, 0.64 per cent while for soybean the concentration were 4.80, 0.44, 0.93 and 3.02, 0.09, 0.62 per cent.

While studying tree-crop interactions in mid hills of Himachal Pradesh (Dinssa, 1993) observed an increase in N and P content in pulse crops (cowpea, horsegram and black gram) in alley cropping with morus as compared to monoculture. However, the K-content failed to show any particular trend in both the systems. The N, P and K concentrations in soybean in intercropping were 3.00, 0.36 and 0.76 per cent, respectively while in monoculture their respective values being 2.96, 0.29 and 0.64 per cent.

2.2.2 Fodder and fruit trees

Pal et al. (1979) analysed the composition of some fodder trees of Himachal Pradesh and reported that *Morus alba* contains 16.6 per cent crude protein on dry matter basis, 0.23 per cent P, 3.62 per cent Ca, 2.3 per cent ether extract, 14.4 per cent crude fibre, 49.7 per cent nitrogen free extract, 17.00 per cent total ash and 32.2 per cent insoluble ash. Debroy et al. (1980) reported that *Morus alba* and other *Morus* spp. contains 15.00, 2.42, 0.24 and 71 per cent of crude protein, lime, phosphate and digestibility coefficient respectively.

Khatta and Katoch (1983) while analysing the nutrients composition of some fodder tree leaves available in sub-mountainous region of Himachal Pradesh reported that on dry matter basis morus leaves contain 26.40, 11.63, 5.06, 16.28, 40.63, 2.38 and 0.35 per cent of crude protein, crude fibre, ether extract, ash, nitrogen free extract, calcium and phosphorus respectively in the Palampur locality, whereas their respective values for Jawalamukhi locality being 18.24, 10.28, 6.21, 13.84, 51.43, 3.91 and 0.48 per cent, respectively.

The chemical composition and nutritive value of some of the tree fodders are indicated by Sen et al. (1978), Gulati et al. (1982), Singh (1992). *Morus alba* contains 15.0-27.6, 10.7, 59.6, 9.1-15.3, 2.4-4.7 and 0.2-1.0 per cent of crude protein, digestible crude protein, total digestible nutrients, crude fibre, calcium and phosphorus respectively.

Kapur (1978) laid emphasis on planting of trees to combat fuel and fodder shortage in Punjab and reported that crude protein content of dry

leaves of *Albizzia lebbeck*, *Dalbergia sissoo* and *Acacia nilotica* was 29.2, 24.1 and 13.9 per cent, respectively, thus indicating higher nutritional value of the leaf fodder.

Shear and Faust (1980) reported N, P and K deficiency values to be <1.7, <1.1, <0.75 per cent for peach plants while the normal range of these nutrients being 2.5-4.0, 0.14-0.40 and 1.5-2.0 per cent, respectively. While examining the influence of companion crops on the leaf nutrient status of peach, Arora and Mohan (1986) observed N, P and K-contents to be 1.98, 0.17 and 1.23 per cent, respectively when intercropped with soybean as compared to 1.75, 0.28 and 1.80 per cent in control. Khera *et al.* (1981) on the basis of peach orchard surveillance, reported 1.91-2.71, 0.14-0.17 and 1.02-1.23 per cent of N, P, K respectively as tentative critical levels for Sharbati peach. Verma (1986) in Rajgarh area (HP) found that N, P, K, Ca and Mg in peach leaves varied from 1.5-2.6, 0.15-0.28, 1.76-3.20, 1.80-2.70 and 0.25-0.50 per cent, respectively.

2.3 Soil moisture

With the exception of areas with well distributed rainfall, or azonal sites with a continuous supply of below ground water, water competition is likely to occur in most agroforestry systems at some period of time; this period may be as short as dry spell of one or two weeks. The effect of these events depends on the severity of the drought and the drought tolerance of the plants. It also depends on the degree of competition for other resources, especially nutrients.

The influence of micro-environment on the growth and yield of cowpea, castor and sorghum was investigated in a 10 m wide leucaena based alley cropping system by Singh *et al.* (1989). Growth and yield of crops declined from 15 to 30 per cent of sole crop as the distance from the hedgerows decreased from 5 to 0.3 m. These authors observed that alley cropping induces competition for moisture between the trees and crops which may severely reduce crop yields. Corlett *et al.* (1989) reported similar results for an alley cropping mixture of leucaena and millet. Examining soil moisture effects of 3.5 year old *Eucalyptus tereticornis* on mustard and wheat yields next to the tree line in semi arid India, Malik and Sharma (1990) reported reductions of over 30 per cent for the crops growing at a distance of less than 10 m from the tree line.

Alley cropping experiments at ICRISAT, India; and ICRAF, Kenya, in which annual crops were grown between woody hedges of *Leucaena leucocephala*, showed that though marked decrease in crop yield was observed when alley width was reduced below 5 m, the results suggested that changes in crop growth were predominantly due to below ground competition between trees and crops for water, nutrients or both (Singh *et al.*, 1989; Rao *et al.*, 1990 and Ong *et al.*, 1991b).

The presence of trees may have both positive and negative overall effects on the water budget of the soil and the crops growing in between or beneath them. Examining the water content of the top 0.1 m soil on a farm in Turrialba, Costa Rica, Bronstein (1984) found a higher moisture content under *Erythrina poeppigiana* than in open fields or under *Cordia alliodora* during the dry season. The light transmission through the canopy of

Erythrina was only 40 per cent, while cordia was leafless at that time. Lal (1989) conducted field experiments on a tropical Alfisol at Ibadan, Nigeria to evaluate the effects on soil moisture and crop yields of three agroforestry systems and reported that soil moisture content in the top 0-5 cm layer in agroforestry systems was generally higher than that in the control during both wet and dry seasons.

Srivastva *et al.* (1993) noticed better soil moisture regime under leucaena at 4.50 m alleys as compared to pure stand spaced at 0.75 m. The combination of leucaena+sorghum resulted in more soil moisture depletion, than Leucaena alone in alleys and the depletion was faster in 30 to 45 cm and 45 to 60 cm layers under leucaena planted at 0.75 and 4.50 m, respectively. On the other hand, while evaluating the performance and effect of common tree species, *Acacia nilotica*, *Azadirachta indica* and *Eucalyptus* hybrid on sorghum and safflower these authors indicated poor moisture regime near the tree row. The moisture being 20.8 in 0-1 m and 24.1 cm at 5-10 cm distance in sorghum while in safflower it was 24.5 cm in 0-1 m and 23.9 cm in 5-10 m distance. Tree-safflower combinations resulted in a faster depletion of soil moisture (24.7 to 14.0 cm) than in sorghum (22.6 to 17.8 cm) at 30 and 60 days after sowing (DAS), respectively. Cornor (1983) also reported that the higher evaporative demands of woody species caused a rapid depletion of water resources.

Thus water completion, is likely to play a major role in the productivity of agroforestry systems, especially in dry areas.

2.4 Nutrient dynamics

The plant species vary widely in their nutrient accumulation status inherently in addition to their growing environment. Extensive studies on nutrient dynamics have been attempted with agricultural as well as horticultural crops as compared to forest crops. However, in forest ecosystems, quantification of litter fall and then nutrient cycling to the soil seemed to be a habitual practice.

Nutrient cycling occurs to varying degree in all land use systems (Roswall, 1980). Agroforestry and other tree based systems are commonly credited with more efficient nutrient cycling and, in turn, a greater potential to improve soil fertility than many other systems because of the presence of woody perennials in the system and their suggested beneficial effects on soil (Nair, 1984; Lundren and Nair, 1985; Kang and Juo, 1986). However, only a few studies in the recent past have been conducted to collect data on nutrient cycling in agroforestry systems. Sanchez *et al.* (1985) examined the role of trees as tropical soil improvers and summarized that some of the beneficial effects of trees on soil after the trees close canopy are expected and that the main deleterious effects of tree-crops on soil properties occurs during their establishment phase. Kellman (1979) reported that in addition to translocation of nutrients from soil layers beyond the reach of annual crops or pasture species, enhancement of nutrient status beneath tree canopies is attributed to canopy capture of precipitation.

The studies conducted by Singh and Lal (1969), Yadav and Singh (1970), Aggarwal *et al.* (1975), Shankar and Narayan (1984) and Atta-Krah *et*

a1. (1985) revealed that the soils beneath the tree cover were slightly more acidic than bare soils, however, organic carbon, nitrogen, phosphorus and potassium were maximum under the canopy cover and minimum under the bare soils of open fields.

After six years of alley cropping with *Leucaena leucocephala* on a pH 6 Entisol, plots receiving prunings had a higher nutrient status than plots not receiving prunings (Kang et al., 1984). In a study comparing two species, Beer (1988) showed that *Erythrina poeppigiana*, when pruned two or three times a year, with prunings added to the soil, can return the same amount of nutrients to the litter layer of coffee plantations as the crop fertilized with inorganic fertilizers at the highest rates recommended for Costa Rica (i.e. 270 kg N ha⁻¹yr⁻¹, 60kg P ha⁻¹yr⁻¹ and 150 kg K ha⁻¹yr⁻¹). Inter-cropping of peach with both Rabi and Kharif crops, Gupta et al. (1982) reported about 10 kg of leaf litter during November-December when trees attain the age of 5 years. The leaf litter gets recycled into the soil, thus providing 35 kg N, 8 kg P, 25 kg K and 15 kg Ca ha⁻¹yr⁻¹.

Yamoah et al. (1986) compared the effect of *C. siamea*, *G. sepium* and *F. macrophylla* in alley cropping trials, and found that soil organic matter and nutrient status were maintained at higher levels with *C. siamea* (which, surprisingly is not a N₂-fixing species). Another set of observations from IITA by Lal (1989) showed that, over a period of six years (12 cropping season), the relative rates of decline in the status of nitrogen, pH and exchangeable bases of soil were much less under alley cropping than under non alley cropped (continuous cropping without trees) control plots. The study also implied a possible nutrient cycling

capability of *L. leucocephala* hedgerow, as there was evidence of a slight increase of soil pH and exchangeable bases during third and fourth years after the establishment of these hedgerows.

Nair *et al.* (1988) reported that organic carbon content of the soil was found to increase when cassava was monocropped or grown mixed with other crops. Available nutrients (N, P, K, Ca and Mg) remained at medium to high levels when cassava was grown along with perennials and seasonals. In general, the fertility status of the soil was high in the crop combination involving banana. Nitrogen, phosphorus and potassium content (%) of the soil have been reported (Maiti *et al.*, 1993) to be appreciably reduced after growing of non-leguminous crops like maize, rice, sorghum and mustard. The magnitude of reduction was greater under the sole cropping system than under alley cropping system. Similar observations were also reported by Sharma and Singh (1970), Thind *et al.* (1979), Singh *et al.* (1981), Misra *et al.* (1985), Maiti *et al.* (1986) and Chatterjee *et al.* (1986).

Ramakrishnan and Toky (1981) made a comparative study for fertility changes in three jhum cycles of 30, 10 and 5 years. Depletion in soil carbon continued throughout the cropping period of one year and extended upto a 5 year fallow. Available phosphorus build up in the fallows also started only beyond a 5 year fallow period, cationic concentration in the soil also rapidly declined in the early phases of regrowth of vegetation. In general, short jhum cycles of 5 year permit only low levels of soil fertility with very poor recovery during the fallow period.

Jensen (1983) studied a homegarden in West Java, Indonesia for production, nutrient in and out as well as internal circulation. Total amounts of nutrients circulated internally in the homegarden each year were estimated as: 223 kg N, 38 kg P, 373 kg K, 135 kg Ca and 50 kg Mg per hectare. This corresponded to 22, 44, 50, 20 and 30 per cent of nutrients stored in the plant biomass, respectively. Similarly, Toky *et al.* (1989b) while studying the natural agroforestry systems in the mid hills of Himachal Pradesh, reported that in agrihortisilvicultural and agrihorticultural systems, considerable quantity of nutrients upto nitrogen-169, phosphorus-14, potassium-165, calcium-97 and magnesium-65 kg ha⁻¹, was recycled through debris of crop and tree leaf litter, while recycling rate was almost half in agrisilvicultural system. In the same study area, Majumdar (1991) observed maximum input and withdrawal of nutrients in HAG and maximum storage in HS systems.

2.5 Economic evaluation

Data on economic evaluation of arable crops either in isolation or in association are available. But for tree based farming systems such informations appear to scanty. Riley (1986) suggested that it would be better to compare the biomass in terms of money to get a conclusive idea about the system.

The incorporation of trees in agriculture will increase the overall productivity and the marginal fall in agricultural production will be compensated by the general beneficial environmental impacts. For individual farmers the financial returns from sale of wood will compensate the reduction in agricultural yields (Chaturvedi, 1991). Whereas, Harsh and

Tewari (1993) reported that overall economics favour tree-crop combinations, rather than the sole cultivation of a crop or a simple plantation of a tree species. Tewari (1985) while estimating the economics of various agroforestry systems showed that per hectare net return could be increased upto three times (Rs.598.62) by adopting agrisilviculture system in comparison to existing cropping patterns. However, the adoption of agrisilvipastoral system increased the net returns to Rs.1350.69. Grewal *et al.* (1992) developed some conservation based agroforestry systems and reported that agrisilvihorticulture system could provide an average net returns income of Rs.17066 ha⁻¹ over a period of 4 years as compared to an average net returns of Rs.7852 from cropping alone. The former was 117 per cent more than the latter.

Vega *et al.* (1985) observed that *Zea mays*, *Manihot esculenta* and *Colocasia esculenta* grown simultaneously with the tropical fruit tree species in alternating line yielded 1.2, 9.2 and 1.6 t ha⁻¹ respectively. Cost and income thus worked out indicated the feasibility of such system. Anonymous (1987) reported that growing ginger in mandarin orchards has been highly profitable with a net returns of Rs.7810 ha⁻¹ than in mandarin grown with rice (Rs.1760), soybean (Rs.2460), groundnut (Rs.3530) and turmeric (Rs.4510). Similarly, the studies conducted with the local practice of growing maize plus pigeon pea by the tribal farmers revealed that Ber and cluster bean combination gave the highest net returns of Rs.14,630 ha⁻¹ and the lowest returns of Rs.616 ha⁻¹ from the maize and pigeon pea combination (Raturi and Hiwale, 1990).

Reddy and Korwar (1985) made a comparative economic evaluation of agroforestry, silvo-agriculture and silvo-pastoral system by discounting technique. All the systems were found to be economically feasible. The annuity value worked out to Rs.799 in case of agroforestry, Rs.598 in case of silvo-agriculture and Rs.1142 in case of silvo-pastoral system. The corresponding benefit cost ratios were 1.45, 1.29 and 1.25. A study on agrisilvihorticulture system on red gravelly soils of Dharwad, Karnataka involving field crops like sorghum, groundnut, chilli and ragi, along with teak and papaya, a total income of Rs.45667 for 10 m row and Rs.40786 for 20 m row spacings between two rows for 4 years as compared to growing only field crops can be obtained (Anonymous, 1989b).

Mittal and Singh (1989) conducted a field study for six years (1981-86) on sandy loam soil on intercropping hedge rows of *Leucaena leucocephala* with three field crops viz. maize, black gram and cluster bean and reported mean maximum net returns from intercrops of leucaena and cluster bean (Rs.3540 ha⁻¹yr⁻¹) which were significantly higher than the returns from pure crop of leucaena at wide spacing but similar to the returns from pure crops of cluster bean. Leucaena with maize (Rs.3273 ha⁻¹yr⁻¹) and black gram (Rs.3125 ha⁻¹yr⁻¹) gave significantly higher net returns over pure crops of leucaena at wide spacing, maize and black gram.

Majumdar (1991) while studying the four production systems in the mid hills of Himachal Pradesh reported that HAG system furnished highest gross returns amounting Rs.91577.2 annually which was about 6.6 and 31.5 fold higher than those of HSP and GL systems, respectively. He further observed that crops were the major contributors even in HAG system

providing 69.4 per cent of the total return mostly through their grains/fruits. Trees primarily through their fruits gave the highest per cent returns by 85.9 in HSP while the grasses put only 13.5 per cent. Maiti *et al.* (1993) obtained highest monetary advantage of Rs.8751 ha⁻¹ when maize-cowpea-mustard crops in sequence were alley cropped with subabul planted at 2mx0.5m per plant spacing and harvested at 30 day interval as compared to other two sequences (Rs.6331 ha⁻¹).

Chapter 3

MATERIALS AND METHODS

The present investigations entitled "Bio-economic appraisal of agroforestry land use systems" were conducted at the experimental farm of the Department of Silviculture and Agroforestry, Dr YS Parmar University of Horticulture and Forestry, Solan (HP) during 1994-95. The details about experimental site, materials used and methodology adopted in undertaking these studies are given below:

3.1 Experimental site

3.1.1 Location

The experimental site falls in the mid-hill zone of Himachal Pradesh at an elevation of 1250 m above mean sea level. It is located 15 km south east of Solan representing 30°51'N latitude and 76°11'E longitude (Survey of India Toposheet No.55F/1).

3.1.2 Climate

The climate of the area is transitional between sub-humid subtropical to subtemperate. There was a considerable variation in the seasonal and diurnal temperatures at the experimental site. May and June are the hottest months whereas, December and January are the coldest and experiences severe frost. The average annual temperature ranges from 3°C to 32°C whereas, mean annual temperature (MAT) is 18°C. The area receives an average annual rainfall of 1150 mm, most of which was concentrated in the monsoon period (mid June-mid September). The meteorological data for the experimental site recorded for the period under studies has been presented in Appendix-I.

3.2 Experimental methodology

The present investigations comprised of two agroforestry systems studied simultaneously. The details for both the systems are given below:

3.2.1 Agrisilviculture system

A) Fodder tree	:	<i>Morus</i> spp. (M-5)
Planting geometry	:	Line planting
Spacing	:	8x3.5 m
Plot size	:	8x8 m
Design	:	RBD
Replications	:	3
Date of planting	:	January 1989 ✓
Lopping intensity	:	Complete lopping
Lopping height	:	1.5 m
Lopping time	:	Winter season

B) Field crops

- i) Season-I (Kharif)
 - a) Maize
 - b) Soybean

- ii) Season-II (Rabi)
 - a) Wheat
 - b) Lentil

- iii) Cropping pattern-I : Maize-Lentil
- iv) Cropping pattern-II : Soybean-Wheat

B) Treatment details : Tree-crop treatments were superimposed on the original layout in order to study the tree-crop interactions more precisely. Hence, the following superimposed treatments were used in the study, however, conclusions have been drawn considering the agroforestry systems as planned originally.

i) Tree-crop

- T₁ = 3 *Morus* trees+Field crops (Maize/soybean/wheat/lentil)
- T₂ = 2 *Morus* trees+Field crops (Maize/soybean/wheat/lentil)
- T₃ = 1 *Morus* tree +Field crops (Maize/soybean/wheat/lentil)
- T₄ = Only field crops (Maize/soybean/wheat/lentil)

ii) Distance

D_1 = 1 m away from tree row

D_2 = 2 m away from tree row

D_3 = 4 m away from tree row

iii) Direction

DR_1 = North of tree row

DR_2 = South of tree row

3.2.2 Agrihortisilviculture system

A) Fruit tree : *Prunus persica* Batsch.

B) Fodder tree : *Morus* spp. (M-5)

Planting geometry : Line planting

Spacing : 10x5 m

(Fodder tree has been planted as a filler between the two fruit trees)

Plot size : 10x10 m

Design : RBD

Replications : 3

Date of planting : January 1989

Pruning frequency : Once a year

Lopping intensity : Complete lopping

Lopping height : 1.5 m

Pruning and lopping time : Winter season

C) Field crops : Same as in case of agrisilviculture system

D) Treatment details

i) Tree crop

T_1 = 2 *Morus* + 1 peach tree + Field crops (Maize/soybean/wheat/lentil)

T_2 = 2 Peach + 1 *Morus* tree + Field crops (Maize/soybean/wheat/lentil)

T_3 = 1 Peach + 1 *Morus* tree + Field crops (Maize/soybean/wheat/lentil)

T_4 = 1 Peach tree + Field crops (Maize/soybean/wheat/lentil)

T_5 = 1 *Morus* tree + Field crops (Maize/soybean/wheat/lentil)

T_6 = Only field crops (Maize/soybean/wheat/lentil)

ii) Distance

D_1 = 1 m away from tree row

D_2 = 2 m away from tree row

D_3 = 4 m away from tree row

iii) Direction

DR_1 = North of tree row

DR_2 = South of tree row

3.2.3 Land use systems

In order to facilitate comparison between different production systems, the aforesaid tree-crop treatments of both the systems viz. agrisilviculture and agrihortisilviculture have been grouped into following four land use systems:

1. Sole cropping = T_4 of agrisilviculture system/ T_6 of agrihortisilviculture system
2. Agrisilviculture = $T_1+T_2+T_3$ of agrisilviculture system
3. Agrihorticulture = T_4 of agrihortisilviculture system
4. Agrihortisilviculture = $T_1+T_2+T_3$ of agrihortisilviculture system

3.3 Observations recorded

3.3.1 Plant

A) Growth and productivity

Fodder tree : Collar diameter, height, crown spread, branch and leaf biomass of morus

Fruit tree : Collar diameter, height, crown spread, number of fruits plant⁻¹, fruit yield and pruned biomass of peach

Field crops : Plant height, number of plants m⁻², crop maturity, number of cobs/pods/spikes plant⁻¹, 1000 grain weight, grain yield, straw yield and harvest index

B) Nutrient content : N, P and K in harvested plant components and uptake

3.3.2 Soil

- A) Soil pH, organic carbon, available N, P and K
- B) Soil moisture

3.3.3 Relative illumination

3.3.4 Economic evaluation of the system

3.4 Observational procedure

The details about the observational procedure related to different parameters studied are given as below:

3.4.1 Growth and productivity

3.4.1.1 Fodder and fruit tree

Collar diameter

Diameter was measured in centimeters at 5 cm above the ground level in case of morus and 5 cm above the graft union in peach with the help of a Calliper, in two directions corresponding to major and minor axis of the tree trunk and the average of two was computed to get collar diameter. The measurements were made in October, 1994 and May, 1995, the harvesting period of Kharif and Rabi crops.

Plant height

Plant height was measured in metres from ground level to the tip of main shoot with the help of a properly graduated wooden rod. The measurements were made in October, 1994 and May, 1995, the harvesting period of Kharif and Rabi crops.

Crown spread

Crown spread was measured in metres from the tree trunk in east, west, north and south directions with the help of a properly graduated wooden rod. The measurements were made in October, 1994 and May, 1995, the harvesting period of Kharif and Rabi crops.

Branch and leaf biomass

Branch and leaf biomass of morus was recorded in October, 1994. The branches were lopped completely, separated from leaves and their individual fresh weight was taken in the field. Branch samples were oven dried at 110°C to calculate dry weight. Leaf and branch biomass was expressed in kg plant^{-1} as well as q ha^{-1} on fresh weight and dry weight basis respectively.

Number of fruits plant^{-1}

Fruits from a peach plant were harvested in July, 1995, counted and expressed as the average number of fruits plant^{-1} .

Fruit yield

The yield was recorded during harvesting season of 1994-95 (July, 1995) by weighing the total number of fruits on a plant at the time of harvest and expressed in kg plant^{-1} as well as q ha^{-1} on fresh weight basis.

Pruned biomass

The weight of pruned wood was recorded at the time of pruning in

January, 1995 and expressed as the average of dry weight kg plant^{-1} as well as g ha^{-1} after oven drying the samples at 110°C .

3.4.1.2 Field crops

A) Cultural schedule

The details about the cultural schedules adopted for different field crops are presented as under:

Maize

Variety	:	Hybrid maize 3485
Date of sowing	:	2.7.1994
Seed rate	:	20 kg ha^{-1}
Spacing	:	$60 \times 20 \text{ cm}$
Manure and fertilizer applied :	Entire dose of FYM @ 10 tonnes ha^{-1} was applied before sowing the crop. The phosphorus and potassium were applied in the form of SSP and MOP @ 45 and 30 kg ha^{-1} as basal dose. 1/3 dose of nitrogen (30 kg ha^{-1}) through CAN was applied at the time of sowing. The remaining nitrogen was top-dressed in two equal splits.	
Cultural practice	:	The package of practices was followed as recommended by State Department of Agriculture for raising Kharif crops
Weedicide application	:	Tafazine @ 2 kg ha^{-1} in 800 L water was sprayed as pre-emergence
Date of harvesting	:	14.10.1994

Soybean

Variety	:	Punjab No.1
Date of sowing	:	2.7.1994
Seed rate	:	70 kg ha^{-1}
Spacing	:	$45 \times 10 \text{ cm}$

Manure and fertilizer applied : Entire dose of FYM @ 10 tonnes ha^{-1} was applied before sowing the crop. 10 kg nitrogen ha^{-1} through CAN, 30 kg phosphorus ha^{-1} through SSP and 30 kg potassium ha^{-1} through MOP were applied at the time of sowing

Cultural practice : The package of practices was followed as recommended by State Department of Agriculture for raising Kharif crops

Weedicide application : Goal @ 1 L ha^{-1} in 800 L water was sprayed as pre-emergence

Date of harvesting : 4.10.1994

Wheat

Variety : S-308
 Date of sowing : 24.12.1994
 Seed rate : 120 kg ha^{-1}
 Spacing : 22 cm

Fertilizer applied : Entire quantity of phosphorus @ 25 kg ha^{-1} through SSP, 25 kg potassium ha^{-1} through MOP along with 1/2 dose of nitrogen (25 kg ha^{-1}) was applied at the sowing time. The remaining half dose of nitrogen was top dressed after 45 days

Cultural practice : The package of practice was followed as recommended by State Department of Agriculture for raising Rabi crops

Weedicide application : 2,4-D @ 1 kg ha^{-1} in 800 L water was sprayed as post-emergence

Date of harvesting : 12.5.1995

Lentil

Variety : HPL-5
 Date of sowing : 24.12.1994
 Seed rate : 30 kg ha^{-1}
 Spacing : 25-30 cm

Fertilizer applied	:	Whole quantity of nitrogen @ 10 kg ha ⁻¹ through CAN and phosphorus @ 40 kg ha ⁻¹ through SSP was applied as basal dose
Cultural practice	:	The package of practice was followed as recommended by State Department of Agriculture for raising Rabi crops
Weedicide application	:	Lasso @ 3 L ha ⁻¹ in 800 L water was sprayed as pre-emergence
Date of harvesting	:	5.5.1995

B) Observational procedure

The details of the observations related to growth and yield attributes of field crops viz. maize, soybean, wheat and lentil are given as below:

For recording the observations on growth and yield attributes, 1 m² sampling plot was laid out in each treatment at a distance of 1 m, 2 m and 4 m in both the direction i.e. north and south of the tree row and studied just before the harvest of each crop. The following methodology was adopted:

I) Growth parameters

Plant height

Plant height was measured, in centimeters, from the ground level to the tip of the plant and expressed as average plant height by dividing with total number of plants in 1 m² sampling plot.

Number of plants m^{-2}

Total number of plants in 1 m^2 sampling plot was counted and expressed as number of plants m^{-2} .

Crop maturity

When the plants turned yellowish and started drying, the grains hardened, the date was noted and number of days taken from the date of sowing to maturity was calculated.

II) Yield and yield attributes

Number of cobs/pods/spikes $plant^{-1}$

All the cobs/pods/spikes of maize; soybean and lentil; and wheat respectively occurring in 1 m^2 sampling plot were counted and the number was divided by total number of plants in the 1 m^2 sampling plot to get the number of cobs/pods/spikes $plant^{-1}$.

1000 grain weight

A random sample of grains from the produce of 1 m^2 plot was taken, thousand grains counted and the weight was expressed in grams.

Grain yield

The weight of the total produce of 1 m^2 plot was recorded and then threshed and cleaned. The weight of the grains obtained was recorded and expressed in $q\ ha^{-1}$.

Straw yield

After deducting the weight of grain from weight of total produce, the straw yield of 1 m² plot was obtained and expressed in q ha⁻¹.

Harvest index

It was calculated as per the standard formula:

$$\text{Harvest index(\%)} = \frac{\text{Grain yield}}{\text{Biological yield(grain+straw)}} \times 100$$

3.4.2 Nutrient analysis

3.4.2.1 Plant samples

A) Nutrient content

Plant samples representing the harvested portion of field crops (grain and straw), fodder and fruit tree (branches, leaves and fruits) were collected randomly from each sampling unit a week before their respective harvesting period and brought to the laboratory in paper bags. All the samples were washed in series, first with tap water, then 0.1 N HCl followed by distilled water. The washed samples were allowed to dry in air and subsequently in oven at 60±5°C till constant weight. The dried samples were than² ground in willy mill and analysed for N P and K as outlined below.

For estimation of total N, 1 g of plant material was digested in concentrated sulphuric acid, in the presence of a digestion mixture composed of K₂SO₄ (400 parts), CuSO₄ (20 parts), Hg(3 parts) and Se-powder (2 parts). After digestion, N was determined by micro-kjeldhal method (Black, 1965).

For the estimation of total P and K, the wet digestion of plant samples was carried out in di-acid mixture consisting of nitric acid and perchloric acid in the ratio of 4:1 and final volume of the digest was made to 100 ml. Total P in the digest was determined by Vanado-molybdo-phosphoric yellow colour method using Spectronic 20-D and total K was estimated with Flame photometer as described by Jackson (1973).

B) Nutrient uptake

Uptake of total N, P and K by different harvested components of field crops, fodder and fruit tree was worked out by multiplying the percentage of each nutrient with respective dry matter i.e.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content} \times \text{dry matter (kg ha}^{-1}\text{)}}{100}$$

3.4.2.2 Soil samples

Soil samples were collected from 0-30 cm depth before the start and after the completion of each crop cycle. Random samples were collected from 5 places in the net plot with the help of post hole auger, composited plot wise, air dried, crushed, passed through 2 mm sieve and analysed for various chemical characteristics as given below:

Soil pH was determined in 1:2.5 soil water suspension with the help of digital pH meter. The organic carbon was estimated by wet combustion method prescribed by Walkley and Black (1934). Available N was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956). Available P was extracted by Olsen's reagent (Olsen *et al.*, 1954) and

determined with the help of Spectronic-20. Available K was extracted by neutral normal ammonium acetate (Merwin and Peech, 1951) and determined flame photometrically.

3.4.3 Nutrient addition and removal

Nutrients (N, P and K) added to maize, soybean, wheat and lentil in the form of fertilizers and FYM during 1994-95 were worked out system-wise on the basis of net cropped area in each system. However, in case of agrihorticulture and agrihortisilviculture systems, nutrients added to peach trees through fertilizers, FYM as well as peach leaf litter were also taken into consideration. While calculating nutrient addition through FYM, only one-third of nitrogen, two-third of phosphorus and three-fourth of potash of the total composition was considered as being available to the crops in the first year of application. The details of nutrient addition was appended in Appendix-II.

Nutrient removal (Appendix-III) from the systems was worked out by adding up the nutrients removed in the form of grain, straw, fruits, leaves and branches from the respective systems during 1994-95 to get total nutrient removal.

3.4.4 Nutrient balance

An attempt was made to work out a balance of major nutrients (nitrogen, phosphorus and potassium) in the soil as affected by different land use systems and cropping patterns, after the harvest of second successive crop i.e. wheat/lentil. For this purpose, the following assumptions were made:

- i) Detailed considerations such as loss of nutrients by leaching and the rate of release of slowly available forms of these nutrients to available forms were not considered
- ii) Amount of nutrients retained by the non-harvested tree components are not included since complete harvest of tree was not practicable.

Net gain or net loss of particular nutrient in the soil was worked out by computing the difference between expected balance and actual balance of that nutrient in soil. Expected balance was worked out as follows:

Expected balance of nutrient in soil	=	Initial status	+	Quantity added	-	Quantity removed by field crops and trees in a sequence
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3.4.5 Soil moisture

Soil moisture regimes were determined at monthly intervals²³ with the help of "NEUTRON SOIL MOISTURE PROBE". Soil moisture measurements were made in each treatment at different distances and directions from the tree row of morus and peach as well as in the open control for 0-30 cm depth from June, 1994 to May, 1995 the cropping period of Kharif and Rabi crops.

3.4.6 Relative illumination (RI)

Light intensity measurements were made in open and below the morus and peach canopies simultaneously for calculating the relative illumination under morus and peach respectively. The measurements were recorded on cloudy days (Blackman and Wilson, 1951) a week before the harvesting of Kharif and Rabi crops, respectively during October, 1994 and May, 1995.

3.4.7 Economic studies

A) Cost of cultivation

The cost of cultivation of different field crops as well as maintenance of fodder and fruit tree and harvest of their produce was worked out for each land use system on the basis of net cropped area and number of trees ha^{-1} (Appendices V-VII). The requirements of labour and mechanical power for different operations such as ploughing, harrowing, weeding, and harvesting were calculated per hectare as per the rates prevalent at Experimental Farm (Appendix-IV). Cost of inputs such as fertilizers, seed, insecticide, fungicide, weedicide were calculated based on the actual amounts applied to each land use systems in both the cropping patterns (Appendix-IV).

B) Gross returns

The yields of different field crops, fodder and fruit trees were converted into gross return in rupees ha^{-1} based on the prevailing local market prices. But the fuelwood value of morus branch and peach pruned wood was computed on the basis of calorific value. The ultimate values were worked out land use system-wise under both the cropping patterns. The market prices of the harvested products have been given in Appendix-IV.

C) Net return

Net return for each land use system under both the cropping patterns was calculated by deducting the total cost from the gross return.

$$\text{Net return} = \text{Gross return} - \text{Total cost}$$

3.4.8 Statistical analysis

The data obtained from the present investigations were subjected to the statistical analysis using RBD of experimentation as per the procedure suggested by Gomez and Gomez (1984). Wherever, the effects exhibited significance at 5 per cent level of probability, the least significant difference (LSD) was calculated. Analysis was carried out on computer using the package "STATISTIX".

Chapter 4

EXPERIMENTAL RESULTS

The results of the present investigations "Bio-economic appraisal of agroforestry land use systems" are presented in this chapter. The informations obtained have been produced on the studied parameters of the two agroforestry systems viz., agrisilviculture and agrihortisilviculture. The details of the scientific informations generated are given as under:

4.1 Agrisilviculture system

4.1.1 Growth and yield of field crops viz., maize, soybean, wheat and lentil

4.1.2 Growth and biomass yield of morus

4.1.3 Nutrient content and uptake in field crops viz., maize, soybean, wheat and lentil

4.1.4 Nutrient content and uptake in morus

4.1.5 Soil moisture content

4.1.6 Relative illumination

4.2 Agrihortisilviculture system

4.2.1 Growth and yield of field crops viz., maize, soybean, wheat and lentil

4.2.2 Growth and biomass yield of morus and peach

4.2.3 Nutrient content and uptake in field crops viz., maize, soybean, wheat and lentil

4.2.4 Nutrient content and uptake in morus and peach

4.2.5 Soil moisture content

4.2.6 Relative illumination

4.3 Comparative performance of different land use systems

4.3.1 Biomass productivity

4.3.2 Nutrient dynamics

4.3.2.1 Soil fertility status

4.3.2.2 Addition and removal of N, P and K nutrient elements

4.3.2.3 Balance of N, P and K nutrient elements

4.3.3 Economic returns

4.3.3.1 Annual gross returns

4.3.3.2 Annual total costs and net returns

4.1 Agrisilviculture system

4.1.1 Growth and yield of field crops

The growth and yield performance of field crops viz., maize, soybean, wheat and lentil were studied under this system. The results so obtained have been tabulated in Tables 1-8 and described as under:

4.1.1.1 Maize:

The growth and yield performance of maize crop grown in association with morus was evaluated studying the various growth and yield attributes. The data presented in Tables 1 and 2 reveal the effect of morus tree, distance and direction of the crop from tree row on the growth and yield characteristics of maize crop.

A) Growth parameters

Plant height (cm): An analysis of the data given in Tables 1 and 2 have exhibited that plant height decreased significantly due to treatments effects. Among T_1 , T_2 and T_3 treatments, maximum plant height was found in T_3 (184.40 cm) which was significantly higher than T_1 (177.30 cm) but statistically equal to T_2 (181.20 cm). Treatments T_1 and T_2 were also

Table 1. Effect of tree and crop distance on growth and yield of maize in agrisilviculture system

A) Growth

Treatment	Plant height(cm)				Number of plants(m ⁻²)				Crop maturity(days)			
	Distance D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
T ₁	160.40	176.60	195.00	177.30	5.83	6.33	6.50	6.22	108.00	106.20	103.50	105.90
T ₂	161.90	179.70	202.10	181.20	6.33	6.50	6.83	6.56	106.00	105.20	102.50	104.60
T ₃	163.00	184.40	205.90	184.40	6.33	6.50	6.83	6.56	104.80	102.80	100.00	102.60
T ₄	181.60	194.40	209.10	195.00	6.17	6.83	7.17	6.72	100.80	99.50	98.17	99.50
Mean	166.70	183.80	203.10		6.17	6.54	6.83		104.90	103.40	101.00	
CD _(0.05)												
Treatment(T)		6.48				NS				2.38		
Direction(DR)		6.40				NS				2.34		
TxD _R		6.83				NS				2.66		

B) Yield

Treatment	Number of cobs(plant ⁻¹)				1000 grain weight(g)				Grain yield (q ha ⁻¹)				Straw yield (q ha ⁻¹)				Harvest index(%)			
	Distance D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
T ₁	0.89	0.82	0.91	0.87	193.70	198.50	207.00	199.70	35.11	39.13	42.34	38.86	64.02	66.18	71.36	67.19	35.41	37.15	37.23	36.60
T ₂	0.85	0.86	0.86	0.86	195.80	204.00	208.50	202.80	35.75	39.52	42.94	39.41	65.32	68.57	71.86	68.58	35.36	36.55	37.39	36.43
T ₃	0.88	0.90	0.90	0.89	198.80	205.50	209.80	204.70	36.10	39.49	42.50	39.36	65.89	69.52	71.03	68.81	35.39	36.21	37.42	36.34
T ₄	0.89	0.88	0.91	0.90	205.30	207.50	212.50	208.60	39.93	41.28	45.28	42.17	67.29	70.02	73.69	70.34	37.23	37.08	38.05	37.46
Mean	0.88	0.87	0.90		198.50	203.90	209.50		36.72	39.86	43.26		65.63	68.57	71.99		35.85	36.75	37.52	
CD _(0.05)																				
Treatment(T)		NS				1.33				1.07				1.31				0.24		
Distance(D)		NS				1.15				0.93				1.13				0.22		
TxD		NS				2.29				NS				NS				0.44		

statistically alike. Distance and direction of the crop from tree row also influenced the plant height significantly. It was observed to increase with the increase in distance of the crop from tree row (Table 1). Direction DR₂ had significantly higher (188.50 cm) plant height than DR₁ (180.50) (Table 2).

The effect of interaction between treatment x distance on plant height was found to be significant (Table 1). Treatment T₃D₃ have shown the maximum value (205.90 cm) and T₁D₁ the minimum (195.00 cm). Although treatment T₄D₃ i.e. open control gave the maximum value of 209.10 cm, yet it was found to be statistically at par with T₃D₃. The interaction between treatment and direction was also found to influence the plant height significantly (Table 2). Maximum plant height (198.20 cm) was observed in treatment T₃DR₂ and minimum (173.30 cm) in T₁DR₁.

Number of plants (m⁻²): The results pertaining to the effect of treatment, distance, direction, interactions treatment x distance and treatment x direction on number of plants per metre square were found to be statistically non-significant (Table 1 and 2).

Crop maturity (days): Crop maturity expressed in number of days required to mature the crop (Table 1 and 2) have indicated that in treatment T₁ crop took maximum number of days (105.90) to mature followed by T₂ (104.60) and T₃ (102.60). Treatments T₁, T₂ and T₂, T₃ were however, statistically alike. Treatment T₄ i.e. open control utilized minimum number of days (99.50) to attain maturity which were significantly less than treatment T₁, T₂ and T₃.

Table 2. Effect of tree and crop direction on growth and yield of maize in agrisilviculture system

[illegible]

Distance of the crop from the tree row reduced the period of maturity significantly as it increased from D_1 (104.90 days) to D_3 (101.00 days) position however, distance D_1 and D_2 were statistically alike (Table 1).

The effect of direction in general and interaction between treatment x direction on crop maturity were found to be statistically non-significant (Table 2), however, interaction effect between treatment and distance were observed to be statistically significant (Table 1).

B) Yield and yield attributes

Number of cobs (plant^{-1}): The results pertaining to effect of treatment, distance, direction; treatment x distance and treatment x direction interactions on number of cobs per plant were found to be statistically non-significant (Table 1 and 2).

Thousand grains weight (g): It is evident from the data given in Table 1 and 2 that grain weight increased significantly with the decrease in number of trees per treatment and maximum value (204.70 g) was observed in treatment T_3 , among the tree-crop treatments. However, it was significantly less than the treatment T_4 i.e. open control showing its value of 208.60 g. Distance of the crop from tree row also exhibited an increasing trend in grain weight as it increased from distance D_1 to D_3 (Table 1). Direction DR_2 had significantly higher (205.30 g) thousand grain weight than direction DR_1 (202.60 g) (Table 2).

The interaction between treatment x distance proved to be statistically significant (Table 1), whereas treatment x direction have shown non-significant values (Table 2).

Grain yield (q ha^{-1}): A perusal of the data (Table 1 and 2) indicated that the grain yield did not differ significantly among the various tree-crop treatments. However, it registered maximum value (39.41 q ha^{-1}) in T_2 treatment. All the tree-crop treatments gave significantly less values than open control i.e. treatment T_4 , having its value of 42.17 q ha^{-1} . It was further observed from the data (Table 1) that grain yield increased significantly with the increase in distance from D_1 to D_3 positions. Maximum grain yield (43.26 q ha^{-1}) was observed at distance D_3 and minimum (36.72 q ha^{-1}) at D_1 . The effect of direction on the grain yield was similar to thousand grain weight i.e. direction DR_2 gave significantly higher yield than DR_1 (Table 2).

The interactions between treatment x distance (Table 1); and treatment x direction (Table 2) were found to be statistically non-significant.

Straw yield (q ha^{-1}): Results similar to grain yield were observed in case of straw yield (Table 1 and 2) however, no significant difference was observed between treatments T_3 and T_4 , showing their respective values of 68.31 and 70.34 q ha^{-1} . Distance and direction of the crop also behaved as above.

Treatment x distance (Table 1) and treatment x direction (Table 2) interactions were found to be statistically non-significant.

Harvest index (%): An examination of the data presented in Table 1 and 2 have revealed that harvest index did not differ significantly among the tree-crop treatments. Treatment T_4 i.e. open control (37.46%) have shown

significantly higher value than all other treatments. The harvest index increased significantly from distance D_1 to D_3 (Table 1). Further data given in Table 2 revealed that it was found to be significantly higher (36.88%) in direction DR_2 as compared to DR_1 (36.53%).

The interaction between treatment x distance was observed to influence the harvest index significantly (Table 1). Treatment combination T_4D_3 gave the maximum value (38.05%) whereas T_1D_1 gave the minimum value (35.41%). The interaction between treatment x direction (Table 2) was found to be statistically non-significant.

4.1.1.2 Soybean

A) Growth parameters

Plant height (cm): The data presented in Table 3 and 4 have revealed that treatment T_4 i.e. open control showed significantly higher value (64.78 cm) and treatment T_1 exhibited significantly lower value (54.18 cm) over all the treatments. In respect of distance effect, plant height increased significantly with the increase in distance from D_1 to D_3 (Table 3). Similarly, direction DR_2 displayed a significant increase in plant height over DR_1 showing their respective values of 59.50 cm and 57.59 cm (Table 4).

The interaction between treatment x distance (Table 3) influenced the plant height significantly showing maximum value (68.04 cm) at T_4D_3 and minimum (51.35 cm) at T_1D_1 . The interaction between treatment x direction (Table 4) also had a significant effect on plant height, giving maximum value (65.68 cm) in T_4DR_2 and minimum (53.52 cm) in T_1DR_1 .

Table 3. Effect of tree and crop distance on growth and yield of soybean in agrisilviculture system

A) Growth

Treatment	Plant height(cm)				Number of plants(m ⁻²)				Crop maturity(days)				
	Distance	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
T ₁		51.35	53.64	57.56	54.18	14.83	16.33	18.00	16.39	95.17	93.17	90.17	92.83
T ₂		52.49	56.81	60.75	56.68	15.33	17.00	18.50	16.94	94.17	90.17	90.00	91.44
T ₃		54.59	58.10	63.46	58.72	16.17	18.17	19.17	17.83	92.17	90.00	89.00	90.39
T ₄		61.09	65.21	68.04	64.78	17.33	18.50	19.83	18.56	89.00	87.50	86.17	87.56
Mean		54.88	58.44	62.45		15.92	17.50	18.87		92.62	90.21	88.83	
CD(0.05)													
Treatment(T)		1.14				0.32				0.38			
Distance(D)		1.12				0.28				0.32			
TxD		1.26				NS				0.66			

B) Yield

Treatment	Number of pods(plant ⁻¹)				1000 grain weight(g)				Grain yield (q ha ⁻¹)				Straw yield (q/ha ⁻¹)				Harvest index(%)				
	Distance	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
T ₁		32.79	33.53	34.67	33.60	141.50	143.30	145.70	143.50	13.76	15.69	18.11	15.85	37.34	41.73	46.40	41.83	26.92	27.32	28.05	27.43
T ₂		32.91	33.77	35.33	34.00	142.30	145.30	148.20	145.40	14.41	16.68	19.37	16.82	38.42	43.50	47.84	43.36	27.11	27.71	28.80	27.88
T ₃		33.41	34.37	35.66	34.48	143.70	146.70	149.00	146.40	15.50	18.31	20.37	18.06	40.94	46.87	51.16	46.32	27.46	28.08	28.47	28.01
T ₄		38.27	39.38	39.98	39.20	147.70	151.30	152.30	150.50	17.64	19.78	22.22	19.88	45.56	50.73	55.06	50.45	27.91	28.05	28.75	28.24
Mean		34.34	35.26	36.40		143.90	146.70	148.80		15.33	17.62	20.02		40.64	45.71	50.12		27.35	27.79	28.52	
CD(0.05)																					
Treatment(T)		0.10				0.36				0.32				0.85				0.14			
Distance(D)		0.08				0.30				0.28				0.72				0.12			
TxD		0.18				0.62				NS				NS				0.24			

Number of plants (m^{-2}): The number of plants per metre square (Table 3 and 4) increased significantly with the decrease in number of trees per treatment and treatment T_4 gave the highest value of 18.56 followed by T_3 (17.83), T_2 (16.94) and T_1 (16.39). In case of distance effect, number of plants per metre square increased significantly from distance D_1 to D_3 (Table 3). The direction effect (Table 4) have shown that direction DR_2 (17.78) and significantly higher number of plants than DR_1 (17.08).

The interaction between treatment x distance (Table 3) had a significant influence on number of plants per metre square whereas, treatment x direction (Table 4) was found to be statistically non-significant.

Crop maturity (days): The data in respect of time taken by the crop to attain maturity revealed that crop maturity delayed significantly with the increase in number of trees per treatment (Table 3 and 4). The crop required significantly higher (92.83) number of days to mature at closest distance i.e. D_1 from the tree row and minimum (88.83) at farthest distance i.e. D_3 (Table 3). In direction DR_2 (90.06 days) the crop matured in significantly lesser number of days than DR_1 (91.06) (Table 4).

The interaction between treatment x distance (Table 3) had a significant influence on crop maturity whereas, treatment x direction (Table 4) was found to be statistically non-significant.

B) Yield and yield attributes

Number of pods ($plant^{-1}$): The results regarding number of pods per plant followed a trend similar to number of plants per metre square but treatment

x distance (Table 3) and treatment x direction interaction (Table 4) had significant influence on it.

The treatment x distance x interaction showed significantly higher value (39.96) at T_4D_3 and lowest (32.79) at T_1D_1 over the other treatment combinations whereas, the interaction between treatment x direction recorded maximum (39.31) number of pods per plant in T_4DR_2 and minimum (33.38) in T_1DR_1 .

Thousand grain weight (g): A perusal of the data given in Table 3 and 4 have revealed that thousand grain weight increased significantly with the decrease in number of trees per treatment as well as the increase in distance from tree row. Treatment T_4 gave the maximum (150.50 g) value whereas treatment T_1 exhibited the lowest value (143.50 g). Regarding effect of direction (Table 4) on this character, a significant increase was observed in direction DR_2 over DR_1 . Their respective values were found to be 147.20 g and 145.70 g.

It was further deduced from the data that treatment x distance (Table 3) and treatment x direction (Table 4) interactions influenced thousand grain weight significantly. Among the various treatment x distance combinations, T_3D_3 gave the maximum (149.00 g) value whereas T_1D_1 exhibited the lowest (141.50 g). However, open-control i.e. T_4D_3 combination gave the highest (152.30 g) value which was significantly higher than all other treatment combinations.

Grain yield ($q\ ha^{-1}$): It is evident from the data presented in Tables 3 and 4 that treatment T_4 i.e. open control exhibited significantly higher (19.88

Table 4. Effect of tree and crop direction on growth and yield of soybean in agrisilviculture system

Treatment	Growth												Yield												
	Plant height (cm)			Number of plants (m ⁻²)			Crop maturity (days)			Number of pods (plant ⁻¹)			1000 grain weight (g)			Grain yield (q ha ⁻¹)			Straw yield (q ha ⁻¹)			Harvest index (%)			
	Direction	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean
T ₁		53.52	54.85	54.18	15.89	16.89	16.39	93.33	92.33	92.83	33.38	33.94	33.60	142.80	144.20	143.50	15.17	16.53	15.85	40.41	43.24	41.83	27.26	27.60	27.43
T ₂		55.48	57.89	56.68	16.56	17.33	16.94	92.00	90.89	91.44	33.77	34.24	34.00	144.60	146.30	145.40	16.20	17.43	16.82	42.24	44.47	43.36	27.67	28.08	27.88
T ₃		57.87	59.57	58.72	17.56	18.11	17.83	91.00	89.78	90.39	34.15	34.81	34.48	145.40	147.40	146.40	17.48	18.64	18.06	45.38	47.27	46.32	27.77	28.24	28.01
T ₄		63.89	65.68	64.78	18.33	18.78	18.56	87.89	87.22	87.56	39.10	39.31	39.20	150.00	151.00	150.50	19.47	20.29	19.88	49.78	51.12	50.45	28.10	28.37	28.24
Mean		57.69	59.50		17.08	17.78		91.06	90.06		35.10	35.57		145.70	147.20		17.08	18.22		44.45	46.53		27.70	28.07	
CD _(0.05)																									
Treatment(T)		1.14			0.32			0.38			0.10			0.36			0.32			0.85			0.14		
Direction(DR)		0.70			0.22			0.26			0.08			0.24			0.24			0.60			0.10		
TxDR		1.22			NS			NS			0.14			0.60			NS			NS			NS		

q ha⁻¹) grain yield as compared to other treatments. Among the various tree-crop treatments the grain yield followed an increasing trend with the decrease in number of trees per treatment. Treatment T₁ recorded the minimum (15.85 q ha⁻¹) grain yield preceded by T₂ (16.82 q ha⁻¹) and T₃ (18.06 q ha⁻¹) respectively. With respect to distance (Table 3) maximum (20.02 q ha⁻¹) grain yield was obtained at D₃ followed by D₂ ((17.62 q ha⁻¹) and D₁ (15.33 q ha⁻¹). The direction influenced the grain yield significantly (Table 4) having its maximum (18.22 q ha⁻¹) value in DR₂ and minimum (17.08 q ha⁻¹) in DR₁.

Interactions between treatment x distance (Table 3); and treatment x direction (Table 4) were found to be statistically non-significant.

Straw yield (q ha⁻¹): Results pertaining to the effect of tree-crop treatments on straw yield followed the trend similar to grain yield (Table 3 and 4). It was observed from the data that number of trees per treatment, distance and direction of the crop from the trees influenced the straw yield significantly. Whereas, interaction effects were observed to be statistically non-significant.

Harvest index (%): The harvest index also exhibited the similar results as in case of grain and straw yield with the exception that interaction between treatment x distance (Table 3) had a significant effect on it showing maximum (28.80%) value at T₂D₃ which was significantly higher than all other tree-crop treatments but statistically at par with T₄D₃ i.e. open control (28.75%). Treatment combination T₁D₁ showed minimum (26.92%) harvest index which was significantly lower than all other treatments.

4.1.1.3 Wheat

A) Growth parameters

Plant height (cm): A critical examination of the data in Table 5 and 6 have revealed that plant height was reduced significantly with the morus treatments over control. Treatment T_2 (81.21 cm) and T_3 (81.30 cm) among the morus treatments were found to be statistically alike. Distance of the crop (Table 5) from tree row was also found to increase the plant height with the increase in distance showing its maximum value of 84.13 cm at D_3 and minimum value of 79.24 cm at distance D_1 . Similarly direction of the crop (Table 6) gave significantly higher plant height in DR_2 over DR_1 , the respective values for direction DR_1 and DR_2 were 81.41 cm and 81.74 cm.

Treatment x distance (Table 5) and treatment x direction (Table 6) interactions were also observed to be significant. Maximum plant height due to treatment x distance interaction was observed at T_4D_3 (84.57 cm) and minimum at T_1D_1 (78.32 cm). Treatment x direction interaction also exhibited its highest value at T_4DR_2 (83.18 cm) and minimum at T_1DR_1 (80.90 cm).

Number of plants (m^{-2}): The number of plants per metre square increased significantly from treatment T_1 (52.44) to T_4 (57.33). All the treatments were found to be statistically different from one another. A similar trend was evident due to the distance of crop from tree row (Table 5). In case of direction, significantly more (55.61) number of plants per metre square were observed in direction DR_2 over DR_1 (53.75 plants m^{-2}) (Table 6).

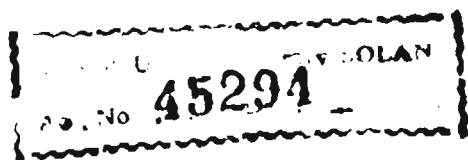


Table 5. Effect of tree and crop distance on growth and yield of wheat in agrisilviculture system

A) Growth

Treatment	Plant height(cm)				Number of plants(m ⁻²)				Crop maturity(days)				
	Distance	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
T ₁		78.32	80.84	83.39	81.01	47.50	51.00	58.83	52.44	137.00	135.70	134.80	135.80
T ₂		78.64	80.93	84.01	81.21	48.50	52.33	60.17	53.67	136.20	135.50	134.70	135.40
T ₃		78.78	81.05	84.05	81.30	49.33	54.67	61.83	55.28	136.20	135.00	134.30	135.20
T ₄		81.23	82.57	84.57	82.79	53.33	56.50	62.17	57.33	135.00	134.70	134.50	134.70
Mean		79.24	81.36	84.13		49.67	53.62	60.75		136.10	135.20	134.60	
CD _(0.05)													
Treatment(T)		0.16				0.35				0.40			
Distance(D)		0.14				0.30				0.34			
TxD		0.26				0.60				0.68			

B) Yield

Treatment	Number of spikes(plant ⁻¹)				1000 grain weight(g)				Grain yield (q ha ⁻¹)				Straw yield (q ha ⁻¹)				Harvest index(%)				
	Distance	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
T ₁		6.35	7.00	7.91	7.09	37.97	39.45	40.63	39.35	25.30	28.15	34.22	29.22	48.57	52.97	61.54	54.36	34.24	34.69	35.73	34.89
T ₂		6.97	8.46	8.98	8.14	39.03	40.45	42.08	40.52	26.15	29.57	36.05	30.59	49.83	54.42	63.06	55.77	34.41	35.20	36.36	35.32
T ₃		7.18	8.14	9.21	8.18	39.52	41.25	43.19	41.32	26.76	31.64	37.52	31.97	50.76	57.06	65.04	57.62	34.51	35.66	36.58	35.58
T ₄		7.93	8.14	9.40	8.48	39.49	41.05	43.28	41.27	32.58	34.70	38.28	35.19	55.98	59.46	65.46	60.30	36.80	36.85	36.89	36.85
Mean		7.11	7.94	8.87		39.01	40.55	42.30		27.70	31.01	36.52		51.29	55.97	63.78		34.99	35.60	36.39	
CD _(0.05)																					
Treatment(T)		0.30				0.20				0.22				0.34				0.08			
Distance(D)		0.26				0.18				0.18				0.28				0.08			
TxD		NS				0.34				0.38				0.58				0.16			

The interaction between treatment x distance (Table 5) indicated that among the tree-crop treatments, T_3D_3 exhibited higher (61.83 plants m^{-2}) value over all other treatments, however, it was found to be statistically at par with T_4D_3 (62.17 plants m^{-2}) i.e. open control. The interaction between treatment x direction (Table 6) was found to be statistically non-significant.

Crop maturity (days): Crop maturity was influenced significantly due to various tree-crop treatments. It is seen from the data (Table 5 and 6) that treatment T_4 i.e. open control took significantly lesser time (134.70 days) over all other treatments (T_1 , T_2 and T_3). But treatments T_1 , T_2 and T_2 , T_3 remained at par between themselves. A further analysis of the data (Table 5) revealed that crop took maximum (136.10) number of days to mature at distance D_1 and minimum (134.60) at distance D_3 . Direction also influenced the crop maturity significantly (Table 6). Direction DR_2 (135.10 days) took lesser time over DR_1 (135.50 days).

The interaction treatment x distance (Table 5) affected the crop maturity significantly whereas treatment x direction (Table 6) interaction did not cause any significant change in it.

B) Yield and yield attributes

Number of spikes ($plant^{-1}$): Number of spikes per plant (Table 5 and 6) were found to increase significantly with the decrease in number of trees per treatment. Treatment T_4 i.e. open control recorded maximum (8.48) whereas, T_1 registered the minimum (7.09) value. However, treatments T_2 , T_3 and T_3 , T_4 were found to be statistically at par between themselves. A further

Table 6. Effect of tree and crop direction on growth and yield of wheat in agrisilviculture system

Treatment	Growth												Yield												
	Plant height (cm)			Number of plants (m ⁻²)			Crop maturity (days)			Number of spikes (plant ⁻¹)			1000 grain weight (g)			Grain yield (q ha ⁻¹)			Straw yield (q ha ⁻¹)			Harvest index (%)			
	Direction	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean
T ₁	80.90	81.13	81.01	51.44	53.44	52.44	136.10	135.60	135.80	6.85	7.32	7.09	39.07	39.64	39.35	28.35	30.10	29.22	53.23	55.49	54.38	34.88	35.10	34.89	
T ₂	81.12	81.31	81.21	52.67	54.67	53.67	135.70	135.20	135.40	7.86	8.42	8.14	39.92	41.12	40.52	29.65	31.52	30.59	54.64	56.90	55.77	35.09	35.56	35.32	
T ₃	81.24	81.38	81.30	54.33	56.22	55.28	135.40	134.90	135.20	7.76	8.59	8.18	40.78	41.88	41.32	31.08	32.87	31.97	56.33	58.71	57.82	35.36	35.81	35.58	
T ₄	82.40	83.18	82.79	56.56	58.11	57.33	134.90	134.60	134.70	8.48	8.51	8.49	40.83	41.72	41.27	34.66	35.71	35.19	59.44	61.16	60.30	36.84	36.86	36.85	
Mean	81.41	81.74		53.75	55.61		135.50	135.10		7.74	8.21		40.14	41.09		30.93	32.55		55.96	58.07		35.49	35.83		
CD(0.05)																									
Treatment(T)		0.16			0.35			0.40			0.30			0.20			0.22			0.34			0.08		
Direction(DR)		0.10			0.24			0.28			0.22			0.14			0.16			0.24			0.08		
TxDR		0.22			NS			NS			NS			0.28			0.30			NS			0.12		

analysis of the data revealed that with the increase in distance from the tree row, number of spikes per plant increased significantly (Table 5). A significant increase in number of spikes per plant was observed in direction DR₂ (8.21) over DR₁ (7.74) (Table 6).

The interactions between treatment x distance (Table 5); and treatment x direction (Table 6) were found to be statistically non-significant.

Thousand grain weight (g): It is evident from the data (Table 5 and 6) that among different tree-crop treatments (T₁, T₂ and T₃) the treatment T₃ recorded significantly higher (41.32 g) thousand grain weight however, it remained at par with treatment T₄ i.e. open control, showing its value of 41.27 g. In case of distance effect, a significant increasing trend was observed with the increase in distance from distance D₁ (39.01 g) to D₃ (42.30 g) (Table 5). The data showing the effect of direction on this character recorded in Table 6 indicated that direction DR₂ gave significantly higher (41.09 g) thousand grain weight than the direction DR₁ (40.14 g).

The interaction effect between treatment x distance (Table 5) was also found to be statistically significant. It is seen from the data that T₄D₃ treatment recorded maximum (43.28 g) value whereas, T₁D₁ recorded the minimum (37.97 g) value. The treatment x direction (Table 6) interaction have shown that among the tree-crop treatments T₃DR₂ recorded highest (41.88 g) thousand grain weight followed by T₄DR₂ i.e. open control (41.72 g). However, both were statistically alike.

Grain yield (q ha^{-1}): A perusal of the data (Table 5 and 6) indicated that grain yield increased significantly with the decrease in trees per treatment. Though all the treatments were significantly different from one another yet maximum (35.19) value was shown by T_4 treatment i.e. open control. It is further seen from the data (Table 5) that distance D_3 showed maximum (36.52 q ha^{-1}) grain yield followed by D_2 (31.01 q ha^{-1}) and D_1 (27.70 q ha^{-1}). All the values were significantly different from one another. Likewise data in Table 6 have indicated that the grain yield was significantly higher (32.55 q ha^{-1}) in direction DR_2 than DR_1 (30.93 q ha^{-1}).

The treatment x distance (Table 5) and treatment x direction (Table 6) interactions were found to be statistically significant. Maximum grain yield was found to be at treatment combination T_4D_3 (38.28 q ha^{-1}) followed by T_3D_3 (37.52 q ha^{-1}) and T_2D_3 (36.05 q ha^{-1}). Minimum grain yield was recorded at T_1D_1 (25.30 q ha^{-1}) preceded by T_2D_1 (26.15 q ha^{-1}).

Straw yield (q ha^{-1}): A perusal of the data presented in Table 5 on the effect of different tree-crop treatments and distance of the crop from tree row whereas, data in Table 6 on the effect of various tree-crop treatments and direction of the crop from tree row, it is evidently clear that the straw yield followed the trend similar to that of grain yield. However, treatment x direction (Table 6) interaction did not cause any significant effect on straw yield.

Harvest index (%): An examination of the data presented in Table 5 and 6 have revealed that harvest index differ significantly due to different tree-crop treatments. Treatment T_4 i.e. open control (36.85%) have shown

significantly higher value than all other treatments. The harvest index had shown a significant increasing trend from distance D_1 (34.99%) to D_3 (36.39%) (Table 5). Further data given in Table 6 revealed that it was found to be significantly higher (35.83%) in direction DR_2 as compared to DR_1 (35.49%).

It was also deduced from the data that interactions treatment x distance (Table 5) and treatment x direction (Table 6) influenced harvest index significantly. Among the various treatment x direction combinations T_4DR_2 gave the maximum (36.85%) value whereas T_1DR_1 exhibited the minimum (34.68%) value.

4.1.1.4 Lentil

A) Growth parameters

Plant height (cm): The data presented in Table 7 and 8 have shown that treatment T_4 i.e. open control recorded significantly higher (32.95 cm) plant height as compared to T_1 , T_2 and T_3 . However, the latter three treatments remained at par with one another. The data (Table 7) further revealed that distance D_3 exhibited maximum (32.24 cm) value whereas, distance D_1 gave the minimum (30.88). The direction of the crop from tree row also influenced the plant height significantly (Table 8). It showed maximum value in direction DR_2 (31.96 cm) over DR_1 (31.40 cm).

The treatment x distance (Table 7) and treatment x direction (Table 8) interactions were found to be statistically non-significant.

Number of plants (m^{-2}): It is evident from the data (Table 7 and 8) that number of plants per metre square increased significantly with the decrease

Table 7. Effect of tree and crop distance on growth and yield of lentil in agrisilviculture system

A) Growth

Treatment	Plant height(cm)				Number of plants(m ⁻²)				Crop maturity(days)			
	Distance D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
T ₁	30.27	31.04	31.70	31.00	52.33	55.67	58.17	55.39	131.70	129.00	128.70	129.80
T ₂	30.18	30.95	32.01	31.05	53.33	56.67	59.67	56.56	129.50	128.70	128.70	128.90
T ₃	30.27	32.67	32.22	31.72	54.33	57.33	60.50	57.39	129.70	128.70	128.30	128.90
T ₄	32.82	32.99	33.04	32.95	56.17	59.00	61.00	58.72	124.00	123.20	122.80	123.30
Mean	30.88	31.91	32.24		54.04	57.17	59.83		128.70	127.40	127.10	
CD(0.05)												
Treatment(T)		0.72				0.32				0.84		
Distance(D)		0.62				0.28				0.72		
TxD		NS				0.56				NS		

B) Yield

Treatment	Number of pods(plant ⁻¹)				1000 grain weight(g)				Grain yield (q ha ⁻¹)				Straw yield (q ha ⁻¹)				Harvest index(%)			
	Distance D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
T ₁	55.50	57.17	60.17	57.61	21.79	22.47	23.39	22.55	12.68	14.43	16.47	14.52	35.00	39.47	43.66	39.38	26.58	26.78	27.38	26.91
T ₂	56.83	58.83	61.17	58.94	22.14	23.01	23.87	23.01	13.39	15.30	17.52	15.41	35.89	41.12	45.60	40.87	27.17	27.31	27.75	27.41
T ₃	57.50	59.50	62.83	59.94	22.41	23.59	24.50	23.50	13.97	16.10	18.59	16.22	37.16	42.15	47.04	42.12	27.31	27.63	28.17	27.70
T ₄	60.00	61.50	63.00	61.50	24.15	24.57	24.81	24.50	16.62	18.02	19.20	17.95	38.95	45.96	47.80	44.24	29.91	28.34	28.65	28.97
Mean	57.46	59.25	61.79		22.62	23.41	24.14		14.16	15.96	17.94		36.75	42.18	46.02		27.74	27.52	27.99	
CD(0.05)																				
Treatment(T)		0.38				0.06				0.10				0.24				0.16		
Distance(D)		0.32				0.06				0.08				0.20				0.14		
TxD		0.66				0.10				0.16				0.42				0.28		

in number of trees per treatment. It was found to be maximum in treatment T_4 (58.72) followed by T_3 (57.39), T_2 (56.56) and T_1 (55.39). Distance of the crop from tree row (Table 7) was also found to increase the number of plants per metre square significantly showing their highest value of 59.83 at distance D_3 followed by D_2 (57.17) and D_1 (54.04). Effect of direction on this character (Table 8) have revealed that direction DR_2 exhibited maximum value (57.56 plants m^{-2}) and DR_1 the minimum (56.47 plants m^{-2}) and both values were statistically different from one another. The treatment x distance (Table 7) interaction effect was observed to be significant whereas, treatment x direction (Table 8) effect was found to be statistically non-significant.

Crop maturity (days): It is evident from the data (Table 7 and 8) that crop took maximum time (129.80 days) to mature in treatment T_1 and minimum (123.30) number of days at treatment T_4 i.e. open control, treatments T_2 and T_3 remained at par with each other. As regards distance (Table 7), the crop matures in significantly lesser time (127.10 days) at distance D_3 than D_1 (128.70 days), but distances D_2 and D_3 behaved statistically alike.

The effect of direction, treatment x direction (Table 8) interaction as well as treatment x distance (Table 7) interaction effects were found to be statistically non-significant.

B) Yield and yield attributes

Number of pods ($plant^{-1}$): A perusal of the data (Table 7 and 8) have indicated that different tree-crop treatments affected the number of pods per plant significantly. Treatment T_3 have shown significantly higher

(59.94 pods plant⁻¹) value over T₁ and T₂. However, it was significantly lower than treatment T₄ (61.50 pods plant⁻¹) i.e. open control. Distance of the crop from tree row (Table 7) also influenced the number of pods per plant significantly wherein distance D₃ showed maximum (61.79 pods plant⁻¹) value followed by D₂ and least value (57.46 pods plant⁻¹) was observed at distance D₁. It was further evident from the data in Table 8 that direction of crop exhibited a significant increase in this character showing the maximum value in direction DR₂.

The treatment x distance (Table 7) interaction effect was observed to be significant whereas, interaction between treatment and direction (Table 8) was found to be statistically non-significant.

Thousand grain weight (g): A perusal of the data given in Table 7 and 8 have revealed that different tree-crop treatments affected the thousand grain weight significantly. Treatment T₄ i.e. open control gave the maximum value of 24.50 g followed by T₃ (23.50 g), T₂ (23.01 g) and T₁ (22.55 g). All the treatments were found to be statistically different from one another. Distance of the crop from tree row (Table 7) also affected thousand grain weight significantly showing its maximum value at distance D₃ (24.14 g) followed by D₂ (23.41 g) and D₁ (22.62 g). It was further observed from the data that treatment x distance (Table 7) interaction also influenced the thousand grain weight significantly showing its maximum value of 24.81 g at T₄D₃ treatment followed by T₄D₂ and T₃D₃. The effect of direction of the crop and treatment x direction interaction on thousand grain weight (Table 8) have exhibited that direction DR₂ (23.55 g) had significantly higher grain weight than DR₁ (23.23 g).

Table 8. Effect of tree and crop direction on growth and yield of lentil in agrisilviculture system

Treatment	Growth												Yield												
	Plant height (cm)			Number of plants (m ⁻²)			Crop maturity (days)			Number of pods (plant ⁻¹)			1000 grain weight (g)			Grain yield (q ha ⁻¹)			Straw yield (q ha ⁻¹)			Harvest index (%)			
	Direction	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean
T ₁		30.84	31.17	31.00	54.89	55.89	55.39	129.40	130.10	129.80	57.22	58.00	57.61	22.24	22.86	22.55	14.11	14.94	14.52	38.61	40.15	39.38	26.74	27.08	26.91
T ₂		30.77	31.33	31.05	56.00	57.11	56.58	129.00	128.90	128.90	58.44	59.44	58.98	22.96	23.06	23.01	15.06	15.75	15.41	39.97	41.77	40.87	27.35	27.48	27.41
T ₃		31.08	32.36	31.72	56.67	58.11	57.39	128.90	128.90	128.90	59.22	60.67	59.94	23.26	23.75	23.50	15.66	16.78	16.22	41.08	43.16	42.12	27.58	27.84	27.70
T ₄		32.92	32.98	32.95	58.33	59.11	58.72	123.80	122.90	123.30	61.11	61.89	61.50	24.47	24.55	24.50	17.68	18.22	17.95	43.84	44.63	44.24	28.79	29.14	28.97
Mean		31.40	31.96		56.47	57.56		127.80	127.70		59.00	60.00		23.23	23.55		15.63	16.42		40.87	42.43		27.61	27.89	
CD _(0.05)																									
Treatment(T)		0.72			0.32			0.84			0.38			0.06			0.10			0.24			0.18		
Direction(DR)		0.50			0.22			NS			0.28			0.04			0.06			0.16			0.12		
TxDR		NS			NS			NS			NS			0.08			0.14			0.34			NS		

Grain yield (q ha^{-1}): An examination of the data in Table 7 and 8 have revealed that grain yield increased significantly from treatment T_1 (14.52 q ha^{-1}) to treatment T_4 (17.95 q ha^{-1}). It also exhibited a significant increasing with the increase in distance from tree row (Table 7). Maximum grain yield was recorded at distance D_3 followed by D_2 and D_1 . Grain yield (Table 8) further displayed a significantly higher value of 16.42 q ha^{-1} in direction DR_2 over 15.63 q ha^{-1} obtained in direction DR_1 .

The interaction between treatment x distance (Table 7) indicated a significant effect on grain yield. Treatment T_4D_3 showed the maximum grain yield of 19.20 q ha^{-1} followed by T_3D_3 having its value of 18.59 q ha^{-1} . The interaction treatment x direction (Table 8) also exhibited the trend similar to treatment x distance interaction.

Straw yield (q ha^{-1}): A perusal of the data presented in Table 7 and 8 revealed that the straw yield increased significantly from treatment T_1 (39.38 q ha^{-1}) to T_4 (44.24 q ha^{-1}). All the treatments were found to be statistically different from one another. A significantly higher value of 46.02 q ha^{-1} followed by 42.18 q ha^{-1} and 36.75 q ha^{-1} was exhibited at distance D_3 , D_2 and D_1 , respectively (Table 7). In case of direction (Table 8) significantly more (42.43 q ha^{-1}) yield was observed in direction DR_2 over DR_1 (40.87 q ha^{-1}).

The interaction between treatment x distance (Table 7) indicated that combination T_4D_3 exhibited significantly higher (47.80 q ha^{-1}) value and T_1D_1 have shown significantly lower (35.00 q ha^{-1}) value as compared to other combinations. The interaction between treatment x direction (Table 8)

revealed that combination T_4DR_2 have shown significantly higher (44.63 q ha^{-1}) grain yield over T_4DR_1 (43.84 q ha^{-1}).

Harvest index (%): A perusal of the data (Table 7 and 8) indicated that harvest index increased significantly with the decrease in trees per treatment. Though all the treatments were significantly different from one another yet maximum (28.97%) value was shown by T_4 treatment i.e. open control. It is further seen from the data (Table 7) that distance D_3 exhibited significantly higher (27.99%) harvest index followed by D_1 (27.74%) and D_2 (27.52%). A further analysis of the data (Table 8) revealed that harvest index was significantly more (27.89%) in direction DR_2 over DR_1 (27.61%).

The interaction between treatment x distance (Table 7) indicated that T_4D_1 combination exhibited significantly higher (29.91%) harvest index followed by T_4D_3 (28.65%) and T_4D_2 (28.34%). The interaction between treatment x direction (Table 8) was found to be statistically non-significant.

4.1.2 Growth and biomass yield of morus

A) Growth

Growth and development of morus grown under agrisilviculture system having two different cropping patterns were studied during the year 1994-95. The observations were recorded in October, 1994 and May, 1995 the harvesting time of maize/soybean and lentil/wheat, respectively. The results so obtained have been described yearwise as under:

Season-I(October,1994)

The data presented in Table 9 have shown that cropping pattern-I i.e. maize-lentil affected the height, diameter and crown spread of morus significantly. The height was found to be significantly higher (4.75 m) in treatment T₃ followed by T₂ (4.67 m) whereas minimum value was obtained in T₁ (4.30 m). Similarly, T₃ had shown maximum (13.80 cm) diameter followed by T₂ (13.00 cm) and T₁ (12.90 cm), however, T₁ and T₂ behaved statistically alike. The crown spread increased significantly from T₁ to T₃ but treatments T₁, T₂ and T₂, T₃ in case of north direction remained statistically alike between themselves.

Alike cropping pattern-I, the height, diameter and crown spread were found to be significant in cropping pattern-II also (Table 9). But in case of crown spread, treatments T₁, T₂ in east, west and north directions; whereas T₁, T₂; and T₂, T₃ in south direction remained at par among themselves. It exhibited its maximum values of 2.26, 2.53, 1.96 and 2.18 m in east, west, north and south directions respectively in treatment T₃, whereas respective minimum values of 1.92, 1.66, 1.81 and 1.95 m were recorded in treatment T₁.

Season-II(May,1995)

It is evident from the data (Table 9) that different tree-crop treatments in cropping pattern-I did not influence the morus height significantly, but had a significant influence on diameter and crown spread. The maximum (13.84 cm) diameter was obtained in treatment T₃ whereas minimum (12.92 cm) in T₁, the latter being statistically at par

Table 9. Growth and development of morus in agrisilviculture system

Treat- ment	Season-I(June-October, 1994)												Season-II(November, 1994-May, 1995)											
	Cropping Pattern-I						Cropping pattern-II						Cropping Pattern-I						Cropping pattern-II					
	Height (m)	Diameter (cm)	Crown spread (m)				Height (m)	Diameter (cm)	Crown spread (m)				Height (m)	Diameter (cm)	Crown spread (m)				Height (m)	Diameter (cm)	Crown spread (m)			
			East	West	North	South			East	West	North	South			East	West	North	South			East	West	North	South
T ₁	4.30	12.30	1.52	1.47	1.65	1.90	4.45	13.40	1.92	1.66	1.81	1.95	2.15	12.92	0.25	0.50	0.45	0.55	2.20	13.44	0.40	0.30	0.54	0.42
T ₂	4.67	13.00	1.88	1.60	1.74	2.02	4.72	13.95	2.02	1.68	1.84	2.08	2.22	13.05	0.30	0.52	0.20	0.30	2.35	13.98	0.45	0.50	0.60	0.50
T ₃	4.75	13.80	2.12	1.72	1.95	2.10	4.81	14.20	2.26	2.53	1.96	2.18	2.36	13.84	0.50	0.70	0.69	0.62	2.52	14.25	0.65	0.70	0.68	0.72
T ₄ *	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CD _(0.05)	0.04	0.22	0.14	0.10	0.12	0.09	0.08	0.20	0.10	0.08	0.05	0.14	NS	0.16	0.15	0.08	0.10	0.05	NS	0.18	0.06	0.12	0.18	0.10

*Treatment, T₄ does not contain morus

with T_2 . Crown spread gave maximum values in treatment T_3 and minimum in T_1 but in case of south direction it had shown minimum value in treatment T_2 .

It was further indicated from the data (Table 9) that morus height remained non-significant but diameter and crown spread were influenced significantly due to different tree-crop treatments in cropping pattern-II i.e. soybean-wheat. The height, diameter and crown spread have shown an increasing trend from treatment T_1 to T_3 . The maximum values (2.52 m, 14.25 cm, 0.65 m, 0.70 m, 0.68 m and 0.72 m) for height, diameter and crown spread in east, west, north, south directions, respectively were obtained in treatment T_3 however, their respective minimum values of 2.20 m, 13.44 cm, 0.40 m, 0.30 m, 0.54 m and 0.42 m were obtained at treatment T_1 . In respect of crown spread, treatments T_1 , T_2 in east; T_1 , T_2 and T_2 , T_3 in north whereas, T_1 , T_2 in south direction behaved statistically alike.

B) Biomass yield

The data presented in Table 10 shows the branch and leaf biomass yield of morus as influenced by different tree-crop treatments in cropping pattern-I i.e. maize-lentil and cropping pattern-II i.e. soybean-wheat obtained during October, 1994. The values shown have been expressed as the average of oven dry weight per plant as well as per hectare for branch and average of fresh weight per plant as well as per hectare for leaf biomass yield.

An analysis of the data have revealed that maize-lentil cropping pattern had significant influence on branch and leaf biomass yield of morus. These attributes showed an increasing trend from treatment T_1 to T_3 .

The treatment T_1 has shown minimum (45.06 q ha^{-1}) branch biomass yield, whereas T_3 exhibited maximum (49.84 q ha^{-1}). However, the treatments T_1 and T_2 remained at par with each other. The leaf biomass yield increased with the decrease in number of morus trees per treatment showing maximum (19.66 q ha^{-1}) and minimum (16.36 q ha^{-1}) values in treatment T_3 and T_1 , respectively.

Table 10. Branch and leaf biomass yield (q ha^{-1}) of morus in agrisilviculture system (October, 1994)

Treat- ments	Cropping pattern-I		Cropping pattern-II	
	Branch	Leaf	Branch	Leaf
T_1	45.06 (12.62)	16.36 (4.58)	45.80 (12.83)	16.62 (4.66)
T_2	46.77 (13.10)	17.12 (4.80)	47.62 (13.34)	18.23 (5.11)
T_3	49.84 (13.96)	19.66 (5.61)	50.97 (14.28)	20.44 (5.73)
* T_4	-	-	-	-
CD(0.05)	1.80	0.87	2.10	1.65

*Treatment T_4 does not contain morus

Figures in parentheses are biomass yield kg plant^{-1}

It was further observed from Table 10 that branch and leaf biomass yields of morus were influenced significantly by cropping pattern-II i.e. soybean-wheat. The branch yield was noticed to be increased with the decrease in number of morus trees per treatment exhibiting maximum value (50.97 q ha^{-1}) in treatment T_3 and minimum (45.80 q ha^{-1}) in T_1 but the treatments T_1 and T_2 remained at par with each other. Similar to branch

biomass yield, the leaf biomass yield also exhibited an increasing trend from treatment T_1 to T_3 . The leaf biomass yield was recorded to be 16.62, 18.23 and 20.44 q ha⁻¹ in treatment T_1 , T_2 and T_3 , respectively.

4.1.3 Nutrient content and uptake in field crops

Nitrogen, phosphorus and potassium-content as well as uptake in grain and straw components of maize, soybean, wheat and lentil were studied under agrisilviculture system. The results obtained have been tabulated in Tables 11-14 and described as under:

4.1.3.1 Maize

A) Content: N, P and K-content in grain as well as straw was found to be influenced significantly due to morus tree association under agrisilviculture system. It is revealed from the data (Table 11) that N-content in grain was found to be significantly higher in treatment T_4 i.e. open control followed by T_3 , T_2 and T_1 with their respective values of 1.754, 1.706, 1.693 and 1.678 per cent. A similar trend was observed in N-content of straw also. It was further observed from the data that distance and direction of the crop from tree also had a significant effect on N-content of grain as well as straw. The N-content increased with the increase in distance from D_1 to D_3 and was found to be significantly higher in direction DR_2 over DR_1 for both grain and straw. P and K-content in grain and straw followed the trend similar to N however, P-content was found to be higher in direction DR_1 than DR_2 .

Uptake: It is evident from the data shown in Table 11 that treatment T_4 gave the maximum uptake of N, P and K which was found to be 74.01, 14.28

Table 11. Effect of tree, crop distance and direction on NPK-content and uptake in maize in agrisilviculture system

Treat- ments	Content(%)						Uptake (kg ha ⁻¹)					
	N		P		K		N		P		K	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
A) Tree												
T ₁	1.678	0.510	0.291	0.163	0.229	0.819	65.24	34.31	11.36	11.02	8.97	55.12
T ₂	1.693	0.521	0.298	0.170	0.235	0.825	66.75	35.75	11.78	11.70	9.34	56.64
T ₃	1.706	0.527	0.307	0.173	0.242	0.831	67.17	36.29	12.11	11.92	9.59	57.21
T ₄	1.754	0.547	0.338	0.198	0.275	0.860	74.01	38.53	14.28	13.97	11.64	60.55
CD(0.05)	0.004	0.005	0.005	0.004	0.004	0.004	4.84	1.82	0.87	0.89	0.79	2.21
B) Crop distance												
D ₁	1.691	0.509	0.288	0.155	0.220	0.804	62.16	33.34	10.62	10.21	8.12	52.80
D ₂	1.712	0.528	0.313	0.180	0.248	0.841	68.29	36.20	12.46	12.36	9.90	57.68
D ₃	1.720	0.542	0.325	0.193	0.268	0.856	74.44	39.02	14.07	13.89	11.64	61.66
CD(0.05)	0.004	0.004	0.004	0.004	0.004	0.003	4.59	1.72	0.82	0.84	0.75	1.97
C) Crop direction												
DR ₁	1.694	0.514	0.318	0.185	0.235	0.823	66.50	35.01	12.53	12.62	9.30	55.99
DR ₂	1.721	0.538	0.299	0.167	0.255	0.845	70.09	37.43	12.24	11.69	10.46	58.77
CD(0.05)	0.003	0.003	0.004	0.003	0.003	0.003	2.30	1.58	0.26	0.28	0.21	1.79

and 11.64 kg ha^{-1} , respectively in case of grain, whereas their respective maximum values obtained for straw were 38.53, 13.97 and 60.55 kg ha^{-1} . Treatment T_4 i.e. open control was followed by T_3 , T_2 and T_1 for all the three nutrients namely N, P and K. It was further seen from the data that distance and direction of the crop from tree row also influenced the N P and K-uptake significantly. It was found to increase with the increase in distance and the maximum values were shown by distance D_3 , whereas D_1 exhibited the minimum for each of the nutrient both in grain as well as straw. The directional effect in both cases i.e. grain and straw was found to be significantly higher in direction DR_2 over DR_1 .

4.1.3.2 Soybean

A) Content: N, P and K-content in soybean grain and straw at harvest differed significantly due to different tree-crop treatments, distance and direction (Table 12). It followed an increasing trend from treatment T_1 to treatment T_4 , both for grain as well as straw. A further analysis of the data revealed that nutrient content in grain have shown maximum values of 4.790, 0.213 and 1.119 per cent for N P and K, respectively at distance D_3 , whereas their respective minimum values of 4.512, 0.168 and 1.082 were observed at distance D_1 . Variations in nutrient content due to distance evinced the similar pattern in case of straw too. Further N and K-content increased significantly in direction DR_2 over DR_1 however, P-content was observed to be significantly higher in direction DR_1 over DR_2 .

B) Uptake: A perusal of the data on N, P and K uptake by soybean grain and straw have shown that it was affected significantly due to different tree-crop treatments, distance and direction (Table 12). Significantly higher

Table 12. Effect of tree, crop distance and direction on NPK-content and uptake in soybean in agrisilviculture system

Treat- ments	Content(%)						Uptake (kg ha ⁻¹)					
	N		P		K		N		P		K	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
A) Tree												
T ₁	4.753	3.286	0.176	0.0666	1.078	0.683	75.39	137.50	2.82	2.79	17.14	23.66
T ₂	4.756	3.289	0.182	0.0673	1.093	0.689	75.42	142.70	3.10	2.93	18.42	29.97
T ₃	4.768	3.296	0.189	0.0682	1.098	0.694	86.15	152.70	3.45	3.17	19.87	32.22
T ₄	4.831	3.326	0.222	0.0737	1.142	0.723	96.07	167.80	4.43	3.72	22.73	36.52
CD _(0.05)	0.240	0.004	0.005	0.0004	0.004	0.004	8.57	6.74	0.41	0.25	2.39	2.56
B) Crop distance												
D ₁	4.512	3.278	0.168	0.0655	1.082	0.673	69.55	133.30	2.60	2.67	16.63	27.43
D ₂	4.781	3.301	0.196	0.0690	1.108	0.703	84.27	150.90	3.48	3.16	19.56	32.20
D ₃	4.790	3.318	0.213	0.0722	1.119	0.715	95.94	166.40	4.27	3.62	22.43	35.89
CD _(0.05)	0.200	0.004	0.004	0.0004	0.004	0.004	8.09	6.36	0.40	0.25	2.33	2.49
C) Crop direction												
DR ₁	4.594	3.289	0.201	0.0698	1.096	0.692	79.07	146.40	3.40	3.12	18.80	30.89
DR ₂	4.795	3.309	0.184	0.0681	1.110	0.703	87.44	154.00	3.52	3.19	20.28	32.79
CD _(0.05)	0.170	0.003	0.003	0.0003	0.003	0.003	6.52	4.93	0.08	0.04	0.27	0.80

values were recorded at treatment T_4 i.e. open control as compared to other treatments (T_1 , T_2 and T_3). Distance D_3 gave the maximum uptake of N P and K which was found to be 95.94, 4.27 and 22.43 kg ha⁻¹, respectively in case of grain, whereas their respective maximum values obtained in case of straw were 166.40, 3.62 and 35.89 kg ha⁻¹. Distance D_1 depicted the minimum values for all the three nutrients (N, P and K) and for both the components viz. grain and straw. All of the above nutrient elements showed higher uptake in direction DR_2 as compared to direction DR_1 .

4.1.3.3 Wheat

The content and uptake of nutrient elements namely N, P and K in wheat grain and straw at harvest were found to be influenced significantly due to morus association over pure crop (Table 13).

A) Content: A perusal of the results tabulated in Table 13 have evidently shown a significantly higher N P and K-content in treatment T_4 i.e. pure crop compared to intercropped treatments (T_1 , T_2 and T_3). It was found to increase with the increase in distance and have shown maximum values at D_3 and minimum at D_1 . The direction DR_2 exhibited higher values for all the three nutrients as compared to DR_1 .

B) Uptake: On comparing different tree-crop treatments (T_1 , T_2 , T_3), wheat as pure crop (T_4) recorded significantly higher N P and K uptake in grain as well as straw. However, N-uptake in treatments T_1 , T_2 and T_2 , T_3 in grain as well as straw whereas, K-uptake in treatments T_1 , T_2 and T_2 , T_3 in grain and treatments T_1 , T_2 in straw did not exhibit significant difference between themselves. The maximum values for N, P and K-uptake in grains

Table 13. Effect of tree, crop distance and direction on NPK-content and uptake in wheat in agrisilviculture system

Treat- ments	Content(%)						Uptake (kg ha ⁻¹)					
	N		P		K		N		P		K	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
A) Tree												
T ₁	1.382	0.266	0.351	0.167	0.438	0.653	40.40	14.51	10.27	9.12	13.40	35.53
T ₂	1.386	0.271	0.354	0.170	0.459	0.656	42.41	15.19	10.86	9.53	14.06	36.59
T ₃	1.396	0.277	0.360	0.174	0.462	0.662	44.65	16.00	11.54	10.10	14.80	38.16
T ₄	1.407	0.289	0.378	0.192	0.482	0.664	49.53	17.47	13.32	11.57	16.96	40.04
CD _(0.05)	0.005	0.004	0.004	0.004	0.004	0.005	2.37	1.22	0.36	0.36	1.15	1.35
B) Crop distance												
D ₁	1.387	0.263	0.354	0.166	0.457	0.651	38.45	13.52	9.83	8.56	12.69	33.42
D ₂	1.392	0.278	0.362	0.176	0.467	0.660	43.21	15.56	11.25	9.87	14.49	36.93
D ₃	1.398	0.287	0.367	0.185	0.472	0.665	51.08	18.29	13.42	11.81	17.24	42.39
CD _(0.05)	0.004	0.003	0.004	0.004	0.004	0.004	2.32	1.19	0.34	0.33	1.13	1.30
C) Crop direction												
DR ₁	1.390	0.272	0.357	0.174	0.463	0.655	43.03	15.31	11.10	9.79	14.37	36.71
DR ₂	1.396	0.279	0.364	0.178	0.467	0.662	45.46	16.28	11.90	10.38	15.24	38.46
CD _(0.05)	0.003	0.003	0.003	0.003	0.003	0.003	1.26	0.16	0.31	0.28	0.71	1.25

obtained at distance D_3 being 51.08, 13.42 and 17.24 kg ha⁻¹, respectively, whereas, nutrient uptake in straw showed maximum values of 18.29, 11.81 and 42.39 kg ha⁻¹ at distance D_3 . It was found to be significantly higher in direction DR_2 over DR_1 .

4.1.3.4 Lentil

A) Content: An examination of the data (Table 14) reveals that all the treatments which had morus as a component (T_1 , T_2 , T_3) produced grain and straw with significantly lower nutrient concentration than the pure crop treatment (T_4). It is further seen from the data that nutrient content in lentil grain and straw increased with the increase in distance. The direction DR_2 showed a maximum values of 3.682, 0.232 and 1.238 per cent for N, P and K-content in grains, respectively, whereas their respective minimum values obtained at direction DR_1 being 3.677, 0.224 and 1.229 per cent. N, P and K-content in straw followed the similar trend as exhibited by their contents in grain.

B) Uptake: Alike nutrient content, their uptake in lentil grain and straw followed the similar trend (Table 14). The treatment T_4 i.e. open control have shown significantly higher nutrient uptake followed by T_3 , T_2 and T_1 . It was observed to be increased with the increase in distance. Direction DR_2 exhibited significantly higher values compared to DR_1 .

4.1.4 Nutrient content and uptake in morus

The data in respect of N P and K-content as well as their uptake in leaf and branch components of morus influenced due to different tree-crop treatments involving various combinations of morus and agricultural crops

Table 14. Effect of tree, crop distance and direction on NPK-content and uptake in lentil in agrisilviculture system

Treat- ments	Content(%)						Uptake (kg ha ⁻¹)					
	N		P		K		N		P		K	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
A) Tree												
T ₁	3.670	1.625	0.222	0.0814	1.226	0.686	53.23	64.02	3.24	3.21	17.83	27.04
T ₂	3.675	1.628	0.223	0.0816	1.228	0.689	56.63	66.55	3.45	3.34	18.94	28.19
T ₃	3.681	1.632	0.229	0.0821	1.231	0.696	59.71	68.75	3.74	3.46	19.98	29.35
T ₄	3.693	1.643	0.237	0.0835	1.249	0.707	66.30	72.71	4.27	3.70	22.42	31.28
CD(0.05)	0.004	0.004	0.005	0.0004	0.004	0.005	4.37	4.42	0.29	0.14	1.14	1.23
B) Crop distance												
D ₁	3.668	1.625	0.218	0.0817	1.222	0.686	51.97	59.74	3.10	3.00	17.34	25.22
D ₂	3.682	1.632	0.230	0.0823	1.235	0.696	58.80	68.87	3.67	3.47	19.73	29.37
D ₃	3.689	1.638	0.236	0.0825	1.243	0.702	66.20	75.41	4.24	3.80	22.31	32.31
CD(0.05)	0.003	0.003	0.004	0.0003	0.004	0.004	4.32	4.36	0.28	0.12	1.12	1.20
C) Crop direction												
DR ₁	3.677	1.628	0.224	0.0818	1.229	0.690	57.49	66.59	3.52	3.34	19.23	28.23
DR ₂	3.682	1.636	0.232	0.0826	1.238	0.699	60.49	69.43	3.83	3.51	20.35	29.70
CD(0.05)	0.003	0.003	0.003	0.0003	0.003	0.003	2.26	2.30	0.26	0.10	0.50	0.96

under cropping pattern-I and II in agrisilviculture systems have been given in Table 15.

A) Content

The results pertaining to the effect of tree-crop association on the N P and K content in leaves and branches of morus under cropping pattern-I and II were found to be statistically non-significant (Table 15).

B) Uptake

Cropping pattern-I: It is evident from Table 15 that N-uptake in branch followed a significant increasing trend from treatment T_1 to T_3 showing a maximum value of 37.88 kg ha^{-1} in treatment T_3 followed by T_2 (34.61 kg ha^{-1}) and T_1 (32.89 kg ha^{-1}). The P and K-uptake also exhibited the similar trend as shown by N-uptake. However, the treatments T_1 and T_2 in case of P-uptake remained at par with each other. The K-uptake was found to be significantly higher (30.90 kg ha^{-1}) in treatment T_3 over T_2 (29.00 kg ha^{-1}) and T_1 (27.49 kg ha^{-1}).

A further analysis of the data indicated that maximum values for N P and K-uptake in leaf component were obtained in treatment T_3 which were 19.11, 1.66 and 11.78 kg ha^{-1} , respectively, whereas their respective minimum values recorded in treatment T_1 were 15.69, 1.22 and 9.59 kg ha^{-1} .

Cropping pattern-II: An examination of the data presented in Table 15 have shown that N-uptake in branch was found to be significantly higher (40.28 kg ha^{-1}) in treatment T_3 and minimum (34.81 kg ha^{-1}) in treatment T_1 . Similarly, P and K-uptake in branch was significantly higher (8.16 and

Table 15. NPK-content and uptake in morus in agrisilviculture system

Treat- ments	Cropping pattern-I												Cropping pattern-II											
	Content(%)						Uptake (kg ha ⁻¹)						Content(%)						Uptake (kg ha ⁻¹)					
	Branch			Leaf			Branch			Leaf			Branch			Leaf			Branch			Leaf		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
T ₁	0.73	0.13	0.61	2.96	0.23	1.81	32.89	5.86	27.49	15.69	1.22	9.59	0.76	0.14	0.62	3.04	0.23	1.83	34.81	6.41	28.40	16.38	1.24	9.85
T ₂	0.74	0.13	0.82	2.97	0.24	1.84	34.61	6.08	29.00	16.48	1.33	10.21	0.78	0.15	0.63	3.06	0.25	1.85	37.14	7.12	30.00	18.08	1.48	10.93
T ₃	0.76	0.16	0.62	3.00	0.26	1.85	37.88	7.97	30.90	19.11	1.66	11.78	0.79	0.16	0.65	3.09	0.26	1.86	40.28	8.16	33.13	20.49	1.72	12.33
T ₄ *	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CD(0.05)	NS	NS	NS	NS	NS	NS	1.56	0.28	1.32	0.82	0.15	0.68	NS	NS	NS	NS	NS	NS	2.16	0.56	1.43	1.62	0.32	1.15

*Treatment T₄ does not contain morus

33.13 kg ha⁻¹) in treatment T₃ followed by T₂ (7.12 and 30.00 kg ha⁻¹) and T₁ (6.41 and 28.40 kg ha⁻¹).

The N-uptake in leaves was found to be significantly higher (20.49 kg ha⁻¹) in treatment T₃ followed by T₂ (18.08 kg ha⁻¹) and T₁ (16.36 kg ha⁻¹). The P-uptake in leaf component also followed an increasing trend from treatment T₁ to T₃, however, treatments T₁, T₂; and T₂, T₃ remained at par between themselves. The K-uptake in leaf was found to be significantly higher (12.33 g ha⁻¹) in treatment T₃ followed by T₂ (10.93 g ha⁻¹) and T₁ (9.85 kg ha⁻¹).

4.1.5 Soil moisture content

The observations on soil moisture content at 0-30 cm depth were recorded on 30th of every month in agrisilviculture system, under maize and soybean during the cropping period June, 1994 to October, 1994; whereas in wheat and lentil during November, 1994 to May, 1995. The results obtained have been presented in Tables 16 and 17 and described as under:

4.1.5.1 Maize

The data in Table 16 shows that various tree-crop treatments had a significant influence on the soil moisture content in the months of June, September and October but noticed to be non-significant during July and August. The maximum values have been obtained in treatment T₄ i.e. open control during June, September and October which were 16.70, 14.70 and 7.85 per cent, respectively. Their respective minimum values obtained in treatment T₁ were 13.97, 12.49 and 6.06 per cent. The distance and direction effects on the soil moisture content were observed to be

Table 16. Effect of tree, crop distance and direction on soil moisture content(%)in agrisilviculture system (June-October,1994)

Treat- ments	Season-I(June-October,1994)									
	Maize					Soybean				
	June	July	August	September	October	June	July	August	September	October
A) Tree										
T ₁	13.97	21.50	20.00	12.49	6.06	13.78	21.22	20.14	12.09	7.02
T ₂	15.30	22.04	21.05	13.43	6.90	15.56	22.26	21.39	14.08	7.48
T ₃	15.42	22.61	21.14	13.67	7.43	16.00	22.94	21.76	14.66	7.52
T ₄	16.70	22.97	22.41	14.07	7.85	16.91	23.03	22.16	15.22	7.69
CD(0.05)	1.89	NS	NS	1.20	1.45	1.62	NS	0.82	0.51	NS
B) Crop distance										
D ₁	13.12	20.07	19.94	12.50	6.86	14.02	21.90	20.09	12.06	7.04
D ₂	16.03	22.20	21.07	13.44	7.10	15.90	22.32	21.34	13.97	7.42
D ₃	16.89	22.56	22.44	14.30	7.22	16.77	22.85	22.66	15.00	7.82
CD(0.05)	1.24	NS	1.06	0.80	0.18	0.74	NS	0.78	0.44	0.15
C) Crop direction										
DR ₁	14.27	22.09	20.11	12.75	6.80	15.07	22.02	20.31	13.08	6.95
DR ₂	16.42	22.47	22.19	14.08	7.32	16.05	22.70	22.42	14.94	7.91
CD(0.05)	1.10	NS	1.02	0.74	0.14	0.65	NS	0.72	0.39	0.12

significant in the months of June, August, September and October. It was found to increase with the increase in distance from the tree row giving significantly higher value at distance D_3 and minimum at distance D_1 . However, the distances D_2 and D_3 remained at par with one another in the months of June and October. Direction DR_2 gave significantly higher values of 16.42, 22.19, 14.08 and 7.32 per cent over DR_1 (14.27, 20.11, 12.75, 6.80) in the months of June, August, September and October, respectively.

4.1.5.2 Soybean

A perusal of the data (Table 16) indicated that various tree-crop treatments, crop distance and direction from tree row had influenced the soil moisture content significantly during all the months of growth period excepting July. However, the influence of tree-crop treatments during the month of October was found to be statistically non-significant. Soil moisture content tended to increase from treatment T_1 to T_4 i.e. as the number of trees decreased per treatment. Treatment T_1 gave significantly lower values compared to all other treatments and maximum values were observed at treatment T_4 . Treatments T_2 , T_3 and T_4 behaved statistically alike during June and August. A significant increasing trend was observed in soil moisture content due to distance with its increase from D_1 to D_3 . Distance D_3 exhibited significantly higher values of 16.77, 22.66, 15.00 and 7.82 per cent in the months of June, August, September and October, whereas, their respective minimum values obtained at distance D_1 were 14.02, 20.09, 12.06 and 7.04 per cent. Direction DR_2 recorded significantly higher soil moisture content over DR_1 excepting the month of July in which case it remained statistically non-significant.

4.1.5.3 Wheat

The data presented in Table 17 revealed that various tree-crop treatments had a significant influence on the soil moisture content in the months of December, January, February, March and April, wherein a significantly higher values of 8.19, 15.45, 17.74, 15.47 and 7.06 per cent respectively were obtained in T₄ treatment and the respective minimum values of 6.64, 12.30, 12.24, 13.15 and 5.92 per cent were recorded in T₁ treatment. Treatments T₁, T₂, T₃ and T₃, T₄ in the month of December; T₁, T₂, T₃ during January and February; T₁, T₂; T₂, T₃ and T₃, T₄ during March; T₂, T₃, T₄ in the month of April behaved statistically alike. Distance and direction of the crop from tree row also influenced the soil moisture content significantly. It was found to increase with the increase in distance from D₁ to D₃. Direction DR₂ showed higher values over DR₁ from November to February whereas, from March to May direction DR₁ showed higher values over DR₂.

4.1.5.4 Lentil

It is evident from the data (Table 17) that various tree-crop treatments, distance and direction of the crop from tree row influenced the soil moisture content significantly. However, tree-crop treatments effects in general were observed to be non-significant in November and May. The maximum soil moisture content was observed in treatment T₄ followed by T₃, T₂ and T₁. Owing to distance it was found to be maximum at D₃ in each month having the values of 4.73, 8.57, 15.85, 15.62, 16.77, 7.08 and 4.20 per cent for November, December, January, February, March, April and May, respectively whereas, their respective minimum values obtained at distance

Table 17. Effect of tree, crop distance and direction on soil moisture content in agrisilviculture system (November, 1994-May, 1995)

Treat- ments	Season-II (November, 1994-May, 1995)													
	Wheat							Lentil						
	Nov	Dec	Jan	Feb	March	April	May	Nov	Dec	Jan	Feb	March	April	May
A) Tree														
T ₁	3.41	6.64	12.30	12.24	13.15	5.92	3.29	4.10	6.97	13.45	13.72	13.65	6.10	3.52
T ₂	3.89	7.20	12.37	12.50	13.34	6.96	3.60	4.22	7.14	14.33	13.97	14.42	6.13	3.77
T ₃	4.04	7.43	13.28	12.56	14.92	7.03	3.71	4.14	7.90	14.64	15.06	15.54	6.23	3.82
T ₄	4.27	8.19	15.45	17.74	15.47	7.06	4.07	4.58	9.79	15.58	17.22	17.69	8.30	4.16
CD(0.05)	NS	0.85	1.02	2.84	1.82	0.78	NS	NS	1.46	1.05	1.48	1.20	0.96	NS
B) Crop distance														
D ₁	3.50	6.90	11.86	12.81	13.00	5.11	3.42	3.69	7.41	13.21	13.91	13.72	6.27	3.42
D ₂	3.92	7.43	13.71	13.76	14.22	6.77	3.71	4.36	7.87	14.44	14.71	15.48	6.71	3.84
D ₃	4.18	7.99	14.71	14.70	15.44	8.34	3.95	4.73	8.57	15.85	15.62	16.77	7.08	4.20
CD(0.05)	0.38	0.48	0.92	0.90	1.10	0.72	0.24	0.34	0.76	0.88	0.74	1.12	0.38	0.26
C) Crop direction														
DR ₁	3.62	7.29	12.75	12.71	14.30	7.41	3.89	4.07	7.71	13.63	14.03	15.74	7.33	4.04
DR ₂	4.12	7.59	14.11	14.81	13.13	6.07	3.50	4.44	8.19	15.37	15.46	14.91	6.05	3.60
CD(0.05)	0.32	0.22	0.78	0.85	0.86	0.64	0.22	0.28	0.64	0.74	0.62	0.76	0.32	0.22

D_1 were 3.69, 7.41, 13.21, 13.91, 13.72, 6.27 and 3.42 per cent. The direction DR_2 gave significantly higher values over DR_1 from November to February, thereafter a reverse trend was observed from March to May.

4.1.6 Per cent relative illumination (RI)

The data presented in Table 18 indicates per cent RI below the morus canopies in north and south direction of the trees. The observations have been taken just before the harvest of each crop i.e. in the month of October, 1994 and May, 1995.

Table 18. Relative illumination (%) in agrisilviculture system

Field crops	North of the tree	South of the tree
A. Season-I		
i) Maize	43	48
ii) Soybean	38	45
B. Season-II		
i) Wheat	68	72
ii) Lentil	65	70
Observations have been taken below morus canopy		

It is evident from the data that during Kharif season, per cent RI was more in maize as compared to soybean. South direction of the trees exhibited higher value than north for both the crops combinations and during both the seasons. In general, season-II depicted higher RI over season-I.

4.2 Agrihortisilviculture system

4.2.1 Growth and yield of field crops

The growth and yield performance of field crops viz., maize, soybean, wheat and lentil were evaluated under this system. The results so obtained have been tabulated in Tables 19-26 and described as under:

4.2.1.1 Maize

The growth and yield performance of maize was evaluated by studying the effect of different tree-crop treatments, distance and direction of the crop from tree row on the following growth and yield attributes.

A) Growth parameters

Plant height (cm): A perusal of the data presented in Table 19 and 20 have shown that plant height was influenced significantly due to different tree-crop treatments. Maximum plant height was observed in treatment T₆ i.e. open control followed by T₄, T₅, T₃, T₂ and T₁ showing their respective values of 195.00, 190.90, 188.30, 183.80, 181.30 and 179.30 cm. However, treatments T₆, T₄; T₄, T₅, T₃ and T₂ were found to be statistically at par among themselves. Distance also had a significant effect on the plant height as it was found to increase with the increase in distance from the tree row (Table 19). Distance D₃ depicted the highest value of 204.50 cm which was significantly higher than D₁ and D₂. Direction DR₂ (Table 20) recorded significantly higher value (190.10 cm) over DR₁ (182.80 cm) for plant height.

The interaction effect between treatment x distance (Table 19) as well as treatment x direction (Table 20) were also found to influence the plant height significantly. It is evident from the data (Table 19) that treatment combination T_4D_3 gave the maximum value (211.30 cm) followed by T_5D_3 (208.60 cm). Treatment T_1D_1 gave the minimum (162.80 cm) value. The maximum value obtained at treatment combination T_4D_3 was found to be significantly higher even than the value of 209.10 cm obtained at T_6D_3 combination i.e. open control.

Number of plants (m^{-2}): The main effects as well as interaction effect due to treatment x distance and treatment x direction on number of plants per metre square were found to be statistically non-significant (Table 19 and 20).

Crop maturity (days): It is evident from the data (Table 19 and 20) that crop maturity was found to be affected significantly due to different treatments. Treatment T_6 i.e. open control took significantly less time (99.50 days) as compared to other treatments. Among tree-crop combinations, treatment T_1 , T_2 , T_3 and T_2 , T_3 , T_4 , T_5 were found to be statistically alike among themselves. As regards distance (Table 19) the crop matured in significantly lesser time (100.80 days) at distance D_3 compared to D_1 and D_2 . However, distance D_1 and D_2 behaved statistically alike. The direction of the crop as is evident from the data in Table 20 that it did not effect the crop maturity significantly.

The interaction between treatment x distance (Table 19) had a significant influence on the crop maturity whereas, treatment x direction (Table 20) did not cause a significant influence on it.

Table 19. Effect of tree and crop distance on growth and yield of maize in agrihortisilviculture system

A) Growth

Treatment	Plant height(cm)				Number of plants(m ⁻²)				Crop maturity(days)				
	Distance	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
T ₁		162.80	177.90	197.30	179.30	5.83	6.33	6.50	6.22	107.30	105.80	102.80	105.30
T ₂		164.70	180.30	199.00	181.30	5.50	6.17	6.50	6.06	106.80	105.20	102.20	104.70
T ₃		167.10	182.60	201.70	183.80	5.67	6.33	6.67	6.22	105.70	104.20	101.20	103.70
T ₄		172.30	189.00	211.30	190.90	5.83	6.33	6.67	6.28	104.50	102.80	100.00	102.40
T ₅		170.30	186.00	208.60	188.30	6.00	6.33	7.00	6.44	105.00	103.20	100.50	102.90
T ₆		181.60	194.40	209.10	195.00	6.17	6.83	7.17	6.72	100.80	99.50	98.17	99.50
Mean		169.80	185.00	204.50		5.83	6.39	6.75		105.00	103.40	100.80	

CD_(0.05)

Treatment(T)	6.42	NS	2.34
Distance(D)	6.30	NS	2.24
TxD	6.72	NS	2.58

B) Yield

Treatment	Number of cobs(plant ⁻¹)				1000 grain weight(g)				Grain yield (q ha ⁻¹)				Straw yield (q/ha ⁻¹)				Harvest index(%)				
	Distance	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
T ₁		0.89	0.90	0.91	0.90	192.30	201.70	207.00	200.30	34.75	38.48	40.79	38.00	62.64	67.02	69.83	66.50	35.67	36.47	36.87	36.34
T ₂		0.92	0.95	0.95	0.94	190.70	199.30	205.50	198.50	32.86	36.69	37.84	35.80	62.01	64.80	69.12	65.31	34.63	36.11	36.27	35.67
T ₃		0.89	0.95	0.93	0.92	196.30	205.50	209.50	203.80	35.01	39.36	41.46	38.61	63.22	68.50	71.52	67.74	35.64	36.46	36.69	36.26
T ₄		0.89	0.93	0.96	0.92	201.30	206.50	211.70	206.50	35.58	37.54	42.37	38.50	63.74	68.34	72.12	68.07	35.82	35.42	37.00	36.08
T ₅		0.90	0.93	0.96	0.93	202.70	206.70	211.50	206.90	35.82	37.26	43.60	38.89	62.60	68.49	71.99	67.69	36.40	35.20	37.13	36.44
T ₆		0.89	0.88	0.91	0.90	205.80	207.50	212.50	208.60	39.93	41.28	45.28	42.17	67.29	70.02	73.69	70.34	37.23	37.08	38.05	37.46
Mean		0.89	0.92	0.94		198.20	204.50	209.60		35.66	38.44	41.89		63.58	67.86	71.38		35.90	36.12	37.10	

CD_(0.05)

Treatment(T)	NS	1.20	1.31	1.48	0.47
Distance(D)	NS	0.86	0.93	1.04	0.33
TxD	NS	2.08	NS	NS	0.82

B) Yield and yield attributes

Number of cobs (plant^{-1}): The results pertaining to the effect of treatment, distance, direction, treatment x distance and treatment x direction interaction on number of cobs per plant were found to be statistically non-significant (Table 19 and 20).

Thousand grain weight (g): A perusal of the data (Table 19 and 20) revealed that thousand grain weight was affected significantly due to various tree-crop treatments showing its highest (208.60 g) value at T_6 and the lowest (198.50 g) at treatment T_2 . It increased significantly with the increase in distance from tree row (Table 19). Distance D_3 gave the maximum value of 209.60 g followed by D_2 and D_1 , showing their respective values of 204.50 g and 198.20 g. Direction of the crop (Table 20) also had a significant effect on this character which gave higher value in DR_2 over DR_1 .

The interaction between treatment x distance (Table 19) was found to be significant wherein maximum thousand grain weight (212.50 g) was obtained at treatment combination T_6D_3 i.e. open control and minimum (190.70 g) at T_2D_1 . On the other hand, treatment x direction interaction (Table 20) was found to be statistically non-significant.

Grain yield (q ha^{-1}): It is evident from the data (Table 19 and 20) that grain yield was influenced significantly due to different tree-crop treatments. Treatment T_6 showed highest grain yield (42.17 q ha^{-1}) and treatment T_2 the lowest (35.80 q ha^{-1}) over all other treatments. However, treatments T_1 , T_3 , T_4 and T_5 were found to be statistically at par with one another. Distance as well as direction of the crop had a significant

Table 20. Effect of tree and crop direction on growth and yield of maize in agrihortisilviculture system

[illegible]

influence on the grain yield. It increased with the increase in distance (Table 19) but higher grain yield was evident (Table 20) in direction DR₂ (39.24 q ha⁻¹) over DR₁ (38.08 q ha⁻¹).

The treatment x distance (Table 19) and treatment x direction (Table 20) interactions were found to be non-significant.

Straw yield (q ha⁻¹): Straw yield also exhibited the trend more or less similar to the grain yield showing maximum (70.34 q ha⁻¹) value at T₆ i.e. open control and minimum (65.31 q ha⁻¹) at T₂ (Table 19 and 20). Similarly, distance (Table 19) and direction (Table 20) of the crop from tree row increased the straw yield with the increase in distance from D₁ to D₃ and from direction DR₁ to DR₂, respectively.

Harvest index (%): An examination of the data given in Table 19 and 20 have indicated that among the various tree-crop treatments, T₂ showed significantly lower (35.67%) value and T₅ the highest (36.44%) compared to all other treatments. However, treatments T₁, T₃, T₄ and T₅ were found to be statistically at par with one another. It was further revealed from the data that treatment T₆ i.e. open control showed a value of 37.46 per cent which was significantly higher over all the tree-crop treatments. It increased with the increase in distance from D₁ to D₃ (Table 19) whereas, direction DR₂ showed significantly higher value over DR₁ (Table 20).

The interaction between treatment x distance (Table 19) had a significant influence whereas, treatment x direction (Table 20) did not influence the harvest index significantly.

4.2.1.2 Soybean

The data presented in Tables 21 and 22 showed the effect of different tree-crop treatments, distance and direction of the crop from trees row; treatment x distance and treatment x direction interactions on the growth performance, yield and yield attributes of soybean.

A) Growth parameters

Plant height (cm): The data (Table 21 and 22) in respect of plant height expressed in centimetres have shown that among the various tree-crop treatments, T₄ exhibited maximum (62.66 cm) plant height and treatment T₁ recorded the minimum (57.80 cm). Treatment T₆ i.e. open control observed a significantly higher (64.78 cm) value over the remaining. The plant height followed a linear increase with the increase in distance (Table 21) and showed maximum (61.95 cm) value in direction DR₂ and minimum (59.41 cm) in DR₁ (Table 22).

The interactions between treatment x distance (Table 21) and treatment x direction (Table 22) were found out be non-significant.

Number of plants (m⁻²): The number of plants per metre square (Table 21 and 22) increased significantly from treatment T₁ to T₄ and then showed a significant decrease at treatment T₅ over T₄. However, treatment T₆ i.e. open control have shown a value of 18.56 plants per metre square which was significantly higher in comparison to all other treatments. Distance (Table 21) and direction (Table 22) also influenced this character significantly.

The interaction effect between treatment x distance (Table 21) and

treatment x direction (Table 22) were observed to be statistically non-significant.

Crop maturity (days): A perusal of the data (Table 21 and 22) indicated that crop took significantly less number of days (87.56) to mature in treatment T_6 i.e. open control, whereas treatment T_1 took highest (92.22) number of days to attain maturity. The crop matured in significantly lesser time as the distance increased from tree row. It was found to mature significantly earlier in direction DR_2 (89.57 days) than in direction DR_1 (90.33 days) (Table 22).

The interaction between treatment x distance (Table 21) influenced the crop maturity significantly, whereas treatment x direction (Table 22) interactions were found to be statistically non-significant.

B) Yield and yield attributes

Number of pods (plant^{-1}): An examination of the data given in Table 21 and 22 have revealed that different tree-crop treatments had a significant influence on number of pods per plant. The maximum number of pods per plant were recorded in treatment T_6 (39.20) followed by T_4 (34.62), T_5 (34.05), T_3 (33.89), T_2 (33.79) and T_1 (33.72). However, treatments T_1 and T_2 were observed to be statistically alike. Distance (Table 21) and direction (Table 22) of the crop from tree row also exerted a significant influence on this character. Distance D_3 (35.90 pods plant^{-1}) depicted the highest value and D_1 (33.93 pods plant^{-1}) the lowest. Likewise direction DR_2 gave higher value over DR_1 .

Table 21. Effect of tree and crop distance on growth and yield of soybean in agroforestry system

A) Growth

Treatment	Plant height(cm)				Number of plants(m ⁻²)				Crop maturity(days)			
	Distance D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
T ₁	54.49	57.82	61.10	57.80	15.33	16.67	18.00	16.67	94.17	92.47	89.83	92.22
T ₂	55.33	59.08	63.40	59.27	16.00	16.83	18.50	17.11	93.50	91.33	89.17	91.33
T ₃	55.98	61.00	60.38	59.12	16.33	17.17	18.83	17.44	92.67	90.67	88.17	90.50
T ₄	57.66	62.96	67.38	62.66	17.00	18.00	19.50	18.17	90.67	88.67	86.50	88.61
T ₅	56.76	59.64	64.99	60.46	16.67	17.67	19.17	17.83	91.50	89.83	87.17	89.50
T ₆	61.09	65.21	68.04	64.78	17.33	18.50	19.83	18.56	89.00	87.50	86.17	87.56
Mean	56.89	60.95	64.22		16.44	17.47	18.97		91.92	90.11	87.83	
CD(0.05)												
Treatment(T)		1.81				0.32				0.36		
Distance(D)		1.30				0.22				0.24		
TxD		NS				NS				0.62		

B) Yield

Treatment	Number of pods(plant ⁻¹)				1000 grain weight(g)				Grain yield (q ha ⁻¹)				Straw yield (q ha ⁻¹)				Harvest index(%)			
	Distance D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
T ₁	32.82	33.58	34.74	33.72	142.20	144.20	146.20	144.10	14.31	16.14	18.26	16.24	38.71	42.71	46.48	42.64	26.98	27.42	28.20	27.53
T ₂	32.89	33.64	34.84	33.79	142.70	144.80	147.20	144.90	15.01	18.39	18.96	16.79	40.61	43.19	48.04	43.95	26.98	27.51	28.29	27.59
T ₃	33.00	33.74	34.94	33.89	143.20	145.70	147.80	145.60	15.42	16.89	19.45	17.25	41.54	44.16	49.12	44.94	27.07	27.63	28.36	27.69
T ₄	33.49	34.51	35.84	34.62	144.20	146.70	149.80	146.90	18.41	18.22	20.94	18.52	43.72	46.93	52.24	47.63	27.28	27.96	28.61	27.95
T ₅	33.09	33.98	35.09	34.05	143.50	146.00	148.30	145.90	15.82	17.53	19.94	17.76	42.54	45.53	50.08	46.05	27.10	27.78	28.47	27.79
T ₆	38.27	39.38	39.96	39.20	147.70	151.30	152.50	150.50	17.64	19.78	22.22	19.88	45.56	50.73	55.06	50.45	27.91	28.05	28.75	28.24
Mean	33.93	34.81	35.90		143.90	146.90	148.60		15.77	17.49	19.96		42.11	45.54	50.17		27.22	27.73	28.45	
CD(0.05)																				
Treatment(T)		0.08				0.32				0.34				0.82				0.10		
Distance(D)		0.06				0.24				0.24				0.58				0.08		
TxD		0.14				0.58				NS				NS				0.18		

The interaction between treatment x distance (Table 21) showing a significant effect on number of pods per plant recorded maximum value at T_6D_3 (39.96) and minimum at T_1D_1 (32.82). Treatment x direction (Table 22) interaction was also found to be statistically significant and followed the trend similar to treatment x distance interaction.

Thousand grain weight (g): A perusal of the data (Table 21 and 22) have shown that thousand grain weight was affected significantly by different tree-crop treatments. Treatment T_6 i.e. open control gave the maximum value of 150.50 g followed by T_4 (146.90 g), T_5 (145.90 g) and T_3 (145.60 g). However, treatments T_5 and T_3 were found to be statistically alike. Distance of the crop from tree row also had a significant influence on this character (Table 21). It followed an increasing trend with the increase in distance as maximum thousand grain weight was observed at D_3 followed by D_2 and D_1 with their respective values of 148.60, 146.90 and 143.90 g. Direction of the crop (Table 22) indicated statistically significant and higher value in DR_2 over DR_1 .

It was further evident from the data (Table 21) that interaction between treatment x distance had a significant effect on thousand grain weight exhibiting higher value (152.50 g) at T_6D_3 and lowest (142.20 g) at T_1D_1 combinations. Treatment x direction (Table 22) interaction did not exhibit any significant difference.

Grain yield ($q\ ha^{-1}$): A critical examination of the data (Table 21 and 22) have revealed that grain yield increased significantly from treatment T_1 to T_4 and tended to decrease at T_5 . The decrease in yield was significant over T_4 , however, significantly higher than T_1 , T_2 and T_3 treatments. Maximum

Table 22. Effect of tree and crop direction on growth and yield of soybean in agrihortisilviculture system

Treatment	Growth												Yield												
	Plant height (cm)			Number of plants (m ⁻²)			Crop maturity (days)			Number of pods (plant ⁻¹)			1000 grain weight (g)			Grain yield (q ha ⁻¹)			Straw yield (q ha ⁻¹)			Harvest index (x)			
	Direction	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean
T ₁		58.61	59.00	57.80	15.22	17.11	16.07	92.67	91.78	92.22	33.43	34.00	33.72	143.40	144.80	144.10	15.59	16.88	16.24	41.34	43.93	42.64	27.36	27.71	27.53
T ₂		58.71	60.33	59.27	16.78	17.44	17.11	91.78	90.89	91.33	33.51	34.07	33.79	144.20	145.60	144.90	16.24	17.34	16.79	42.98	44.92	43.95	27.39	27.80	27.59
T ₃		58.28	61.96	59.12	17.11	17.78	17.44	90.89	90.11	90.50	33.62	34.16	33.89	144.80	146.30	145.60	16.69	17.81	17.25	44.00	45.68	44.94	27.46	27.92	27.69
T ₄		61.52	63.81	62.66	17.78	18.56	18.17	89.00	88.22	88.61	34.31	34.93	34.62	146.10	147.70	146.90	17.86	19.19	18.52	46.35	48.91	47.63	27.77	28.13	27.95
T ₅		59.98	60.94	60.46	17.44	18.22	17.83	89.16	89.22	89.50	33.74	34.37	34.05	145.10	146.80	145.90	17.11	18.41	17.76	44.91	47.19	46.05	27.55	28.03	27.79
T ₆		63.89	65.68	64.78	18.33	18.76	18.56	87.89	87.22	87.58	39.10	39.31	39.20	150.00	151.00	150.50	19.47	20.29	19.88	49.78	51.12	50.45	28.10	28.37	28.24
Mean		59.41	61.95		17.28	17.98		90.33	89.57		34.62	35.14		145.80	147.00		17.18	18.32		44.89	46.99		27.60	27.99	
CD _(0.05)																									
Treatment(T)		1.81				0.32			0.36			0.08		0.32		0.34		0.82		0.10					
Direction(DR)		1.06				0.18			0.20			0.04		0.20		0.20		0.48		0.08					
TxDR		NS				NS			NS			0.10		NS		NS		NS		NS					

(19.88 q ha⁻¹) grain yield was obtained at T₆ i.e. open control. It showed a significant linear increase with the increase in distance from tree row (Table 21). Effect of direction on this character (Table 22) revealed that direction DR₂ (18.32 q ha⁻¹) recorded significantly more grain yield than DR₁ (17.16 q ha⁻¹).

The interactions between treatment x distance (Table 21) and treatment x direction (Table 22) remained statistically non-significant.

Straw yield (q ha⁻¹): Straw yield also exhibited similar results as shown by grain yield (Table 21 and 22).

Harvest index (%): It is evident from the data (Table 21 and 22) that treatment T₆ i.e. open control have shown significantly higher values over intercrop treatments T₁, T₂, T₃, T₄ and T₅. As the distance increased from D₁ to D₃, the harvest index also increased significantly (Table 21) whereas, direction DR₂ (27.99%) recorded significantly more value than DR₁ (27.60%) (Table 22).

The interaction between treatment x distance (Table 21) proved to be statistically significant whereas, treatment x direction (Table 22) failed to effect the harvest index significantly.

4.2.1.3 Wheat

A) Growth parameters

Plant height (cm): It was construed from the data in Table 23 and 24 that different tree-crop treatments influenced the plant height significantly. Among the tree-crop combinations, treatment T₅ recorded significantly

higher (91.12 cm) plant height whereas treatment T_2 exhibited the minimum (80.88 cm) value. However, treatments T_1 , T_2 , T_3 and T_4 were observed to be statistically at par with one another. Treatment T_6 i.e. open control showed significantly higher (82.79 cm) value for plant height over all other tree-crop treatments. Distance of the crop (Table 23) and direction from the tree row (Table 24) also influenced the plant height significantly. Maximum plant height was obtained at distance D_3 (83.96 cm) followed by D_2 (81.05 cm) and D_1 (78.79 cm). Direction DR_2 gave significantly higher value over DR_1 with their respective values of 81.45 and 81.08.

The interaction between treatment x distance (Table 23) and treatment x direction (Table 24) were also found to effect this character significantly.

Number of plants (m^{-2}): Data on number of plants per metre square as influenced by different tree-crop treatments are presented in Tables 23 and 24. It was found to decrease significantly at treatment T_2 (49.72) over T_1 (51.44) and then increased to attain its maximum value of 55.00 at treatment T_5 among the different tree-crop treatments. However, open control i.e. T_6 treatment gave the highest value (57.33 plants m^{-2}) over all other treatments. Distance of the crop gave maximum value at D_3 (59.36 plants m^{-2}) followed by D_2 and D_1 (Table 23). All the distances were found to be statistically different from one another. Data in Table 24 showing the effect of direction on this character showed that direction DR_2 recorded significantly higher (54.44) number of plants per metre square than DR_1 (52.37).

Table 23. Effect of tree and crop distance on growth and yield of wheat in agroforestry system

Treatment	Plant height(cm)				Number of plants(m ⁻²)				Crop maturity(days)			
	Distance D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
T ₁	78.23	80.71	83.79	80.91	45.83	50.83	57.67	51.44	140.30	138.40	136.80	138.70
T ₂	78.25	80.61	83.76	80.88	44.17	48.83	56.17	49.72	143.20	141.70	138.80	141.20
T ₃	78.27	80.74	83.32	80.94	47.33	52.17	59.33	52.94	139.70	138.30	136.20	138.10
T ₄	78.28	80.75	83.84	80.96	48.17	53.83	60.00	54.00	139.10	137.80	135.70	137.60
T ₅	78.47	80.91	83.97	81.12	49.50	54.67	60.83	55.00	137.20	135.80	134.80	135.90
T ₆	81.23	82.57	84.57	82.79	53.33	56.50	62.17	57.33	135.00	134.70	134.50	134.70
Mean	78.79	81.05	83.96		48.06	52.81	59.36		139.10	137.90	136.10	
CD(0.05)												
Treatment(T)		0.12				0.34				0.32		
Distance(D)		0.08				0.24				0.23		
TxD		0.22				0.58				0.56		

B) Yield

Treatment	Number of spikes(plant ⁻¹)				1000 grain weight(g)				Grain yield (q ha ⁻¹)				Straw yield (q ha ⁻¹)				Harvest index(%)			
	Distance D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
T ₁	6.04	6.40	7.13	6.52	37.06	38.38	39.96	38.46	23.90	26.95	32.20	27.68	46.62	52.21	60.12	52.98	33.87	34.04	34.88	34.27
T ₂	5.83	6.35	6.92	6.36	35.98	37.72	38.62	37.44	22.47	25.55	30.54	26.19	44.71	49.81	57.76	50.76	33.45	33.40	34.58	33.48
T ₃	6.32	6.64	6.91	6.62	37.82	39.12	41.18	39.37	24.88	28.05	33.80	28.91	48.22	53.52	61.37	54.37	34.03	34.38	35.51	34.64
T ₄	6.38	6.88	7.39	6.88	38.05	39.39	41.40	39.61	25.66	29.36	34.46	29.83	49.17	55.33	62.42	55.64	34.29	34.65	35.56	34.84
T ₅	6.71	7.15	7.92	7.26	38.97	40.57	42.06	40.53	27.32	31.12	35.26	31.23	50.66	56.31	63.64	56.77	35.02	35.59	35.97	35.53
T ₆	7.93	8.14	9.40	8.50	39.49	41.22	43.28	41.33	32.58	34.70	38.28	35.19	55.98	59.46	65.46	60.30	36.80	36.85	36.85	36.85
Mean	6.53	6.93	7.61		37.90	39.40	41.08		26.14	29.29	34.09		49.23	54.44	61.75		34.58	34.90	35.57	
CD(0.05)																				
Treatment(T)		0.36				0.14				0.22				0.34				0.06		
Distance(D)		0.26				0.10				0.16				0.24				0.04		
TxD		NS				0.24				0.40				0.58				0.10		

The interaction between treatment x distance (Table 23) was also observed to be significant showing its higher value (62.17) at T_6D_3 and the minimum (45.83) at T_1D_1 treatment combination. Treatment x direction (Table 24) interaction also exhibited the similar results in which maximum value of 58.11 plants per metre square was obtained in T_6DR_2 and minimum (50.22 plants m^{-2}) in T_1DR_1 .

Crop maturity (days): It was seen from the Table 23 and 24 that crop maturity delayed significantly in all the treatments (T_1 , T_2 , T_3 , T_4 and T_5) under tree-crop combinations compared to open control (T_6). The crop took minimum (136.10) number of days to mature at distance D_3 (Table 23) and in direction DR_2 (137.40) (Table 24).

The interaction effects between treatment x distance (Table 23) influenced the crop maturity significantly whereas, treatment x direction (Table 24) did not cause a significant change in it.

B) Yield and yield attributes

Number of spikes ($plant^{-1}$): A critical examination of the data (Table 23 and 24) revealed that treatment T_6 i.e. open control recorded a significantly higher (8.50 spikes $plant^{-1}$) value when compared with other treatments. However, treatments T_1 , T_2 , T_3 and; T_3 , T_4 behaved statistically alike among themselves. Distance (Table 23) D_3 (7.61) had significantly higher number of spikes per plant followed by D_2 (6.93) and D_1 (6.53). Direction DR_2 with maximum value of 7.14 differed significantly from DR_1 having 6.91 spikes per plant (Table 24).

Table 24. Effect of tree and crop direction on growth and yield of wheat in agrihortisilviculture system

Treatment	Growth												Yield												
	Plant height (cm)			Number of plants (m ⁻²)			Crop maturity (days)			Number of spikes (plant ⁻¹)			1000 grain weight (g)			Grain yield (t ha ⁻¹)			Straw yield (t ha ⁻¹)			Harvest index (%)			
	Direction	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean	DR ₁	DR ₂	Mean
T ₁		80.75	81.07	80.91	50.22	52.67	51.44	139.00	138.30	138.70	6.35	6.70	6.52	38.09	38.84	38.46	26.83	28.54	27.68	51.60	54.36	52.98	34.17	34.37	34.27
T ₂		80.73	81.02	80.88	48.67	50.78	49.72	141.70	140.80	141.20	6.26	6.47	6.36	37.11	37.78	37.44	25.36	27.02	26.19	49.57	51.95	50.76	33.80	34.16	33.98
T ₃		80.78	81.11	80.94	52.00	53.89	52.94	138.30	137.80	138.10	6.49	6.75	6.62	38.96	39.79	39.37	28.10	29.72	28.91	53.33	55.41	54.37	34.45	34.84	34.64
T ₄		80.79	81.12	80.96	52.89	55.11	54.00	138.00	137.20	137.60	6.79	6.98	6.88	39.26	39.97	39.61	28.91	30.74	29.83	54.49	56.79	55.64	34.82	35.06	34.84
T ₅		81.02	81.21	81.12	53.89	56.11	55.00	136.10	135.80	135.90	7.07	7.44	7.26	40.11	40.96	40.53	30.55	31.92	31.23	55.55	57.99	56.77	35.44	35.62	35.53
T ₆		82.40	83.18	82.79	56.56	58.11	57.33	134.90	134.60	134.70	8.48	8.51	8.50	40.83	41.83	41.33	34.66	35.71	35.19	59.44	61.16	60.30	36.84	36.86	36.85
Mean		81.08	81.45		52.37	54.44		138.00	137.40		6.91	7.14		39.06	39.36		29.07	30.81		54.00	56.28		34.88	35.15	
CD _(0.05)																									
Treatment(T)		0.12			0.34			0.32			0.36			0.14			0.22			0.34			0.06		
Direction(DR)		0.08			0.20			0.19			0.20			0.08			0.14			0.20			0.04		
TxDR		0.18			NS			NS			NS			NS			0.32			NS			0.08		

The interaction between treatment x distance (Table 23) and treatment x direction (Table 24) did not show a significant change in number of spikes per plant.

Thousand grain weight (g): The data on thousand grain weight have experienced statistically significant effect due to various tree-crop treatments (Table 23 and 24). It tended to decrease significantly at treatment T_2 (37.44 g) over T_1 (38.46 g) and thereafter, it followed an increasing trend from treatment T_3 showing its maximum value in T_6 (41.33 g). Distance of the crop from tree row (Table 23) gave maximum thousand grain weight at D_3 followed by D_2 and D_1 . Direction DR_2 gave significantly higher value over DR_1 (Table 24).

It was further perused from the Table 23 that treatment x distance interaction influenced this character significantly whereas treatment x direction (Table 24) effect was statistically non-significant.

Grain yield ($q\ ha^{-1}$): The data presented in Table 23 and 24 have revealed that among various tree-crop treatments, T_5 have shown maximum ($31.23\ q\ ha^{-1}$) grain yield, whereas treatment T_2 exhibited minimum ($26.19\ q\ ha^{-1}$) value. Treatment T_6 i.e. open control recorded significantly higher ($35.19\ q\ ha^{-1}$) grain yield over all other treatments. A further analysis of the data (Table 23) have shown that grain yield increased significantly from distance D_1 to D_3 . Direction DR_2 revealed a significant increase in it as compared to DR_1 (Table 24).

The interactions between treatment x distance (Table 23) and treatment x direction (Table 24) also had a significant influence on grain yield.

Straw yield ($q\ ha^{-1}$): The straw yield also behaved similar to grain yield but the interaction between treatment x direction (Table 24) proved to be statistically non-significant.

Harvest index (%): As seen from the data (Table 23 and 24) that the harvest index was maximum (35.53%) at treatment T_5 and minimum (33.48%) at T_2 among the various tree-crop treatments. However, treatment T_6 i.e. open control had shown a significantly higher value of 36.85 per cent compared to all other tree-crop treatments. It also exhibited a significant increasing trend as the distance was increased from D_1 to D_3 (Table 23). The directional effect of the crop (Table 24) have shown a significantly higher (35.15%) value in direction DR_2 over DR_1 (34.88%).

The interactions between treatment x distance (Table 23) and treatment x direction (Table 24) also influenced the harvest index significantly. The latter have shown maximum (36.86%) value at T_6DR_2 and minimum (34.17%) at T_1DR_1 .

4.2.1.4 Lentil

A) Growth performance

Plant height (cm): An examination of the data (Table 25 and 26) have evinced a significant effect of different tree-crop treatments on the plant height. Treatment T_2 (27.74 cm) gave the lowest value preceded by T_1 (28.36 cm), T_3 (28.56 cm), and T_4 (28.71 cm). Treatments T_1 , T_3 and T_4 remained statistically at par ^{among} between themselves, however, significantly higher than T_2 . Plant height was also observed to increase from distance D_1 to D_3 (Table 25) and the increase was significantly higher in direction DR_2 over DR_1 (Table 26).

It was further deduced from the data that treatment x distance (Table 25) interaction had significantly higher (33.04 cm) value at T_6D_3 and minimum (27.43 cm) at T_2D_1 . The interaction between treatment x direction (Table 26) was found to be statistically non-significant.

Number of plants (m^{-2}): It is deduced from the data (Table 25 and 26) that treatment T_6 i.e. open control has shown maximum (58.72) number of plants per metre square and treatment T_2 the minimum (51.17). Treatments T_3 , T_4 , T_5 and T_6 gave significantly higher values over T_2 , however, T_3 and T_4 were observed to be statistically alike. The increase in distance from tree row tended a significant increase in this character (Table 25). The number of plants per metre square (Table 26) noticed to be higher in direction DR_2 (55.33 plants m^{-2}) than DR_1 (54.20 plants m^{-2}).

It was further inferred from the data that the treatment x distance (Table 25) interaction was statistically significant displaying its maximum value at T_6D_3 (61.00 plants m^{-2}) and the minimum (48.50 plants m^{-2}) at T_2D_1 treatment. ^{whereas} whereas, treatment x direction (Table 26) interaction was also found to be statistically significant.

Crop maturity (days): It is evident from the data (Table 25 and 26) that crop took maximum (132.60 days) time to mature at treatment T_2 , whereas treatment T_6 i.e. open control attain maturity in minimum number of days (123.30). The distance of the crop from the tree row (Table 25) influenced the crop maturity significantly which was evidently lesser at D_3 , closely followed by D_2 and D_1 . The respective values obtained at these distances were 128.20, 130.00 and 131.40 days. The effect of direction on the crop

Table 25. Effect of tree and crop distance on growth and yield of lentil in agrihortisilviculture system

A) Growth

Treatment	Plant height(cm)				Number of plants(m ⁻²)				Crop maturity(days)			
	Distance D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
T ₁	27.58	28.56	28.98	28.36	50.00	54.00	56.17	53.39	133.80	132.00	129.50	131.80
T ₂	27.43	27.68	28.12	27.74	48.50	51.00	54.00	51.17	134.20	133.00	130.50	132.60
T ₃	27.79	28.76	29.13	28.56	51.50	54.67	57.50	54.56	133.20	131.50	129.00	131.20
T ₄	27.88	28.86	29.40	28.71	51.67	55.33	57.83	54.94	133.00	131.00	129.00	131.00
T ₅	28.08	29.10	29.88	29.02	53.33	55.67	58.50	55.83	130.50	129.50	128.70	129.60
T ₆	32.82	32.99	33.04	32.95	56.17	59.00	61.00	58.72	124.00	123.20	122.80	123.30
Mean	28.60	29.32	29.75		51.86	54.94	57.50		131.40	130.00	128.20	
CD(0.05)												
Treatment(T)		0.24				0.39				0.39		
Distance(D)		0.16				0.27				0.28		
TxD		0.40				0.68				0.68		

B) Yield

Treatment	Number of pods(plant ⁻¹)				1000 grain weight(g)				Grain yield (q ha ⁻¹)				Straw yield (q ha ⁻¹)				Harvest index(%)			
	Distance D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
T ₁	53.17	56.17	59.17	56.17	19.71	20.26	20.91	20.29	10.55	12.37	13.98	12.30	32.06	36.67	40.59	36.34	24.76	25.47	25.61	25.28
T ₂	51.00	54.17	58.17	54.44	19.24	19.66	19.90	19.60	9.57	10.90	12.54	11.00	29.60	33.02	37.45	33.36	24.33	24.81	25.08	24.74
T ₃	54.17	57.17	60.17	57.17	19.86	20.38	21.01	20.42	11.12	12.78	14.61	12.84	33.68	38.35	42.75	38.26	24.83	24.99	25.47	25.09
T ₄	55.17	57.83	60.88	57.94	19.92	20.51	21.22	20.55	11.37	13.12	14.92	13.14	34.43	38.95	43.88	39.09	24.82	25.20	25.37	25.13
T ₅	56.50	59.00	62.17	59.22	19.99	20.66	21.48	20.71	12.10	13.57	15.67	13.78	36.56	40.07	45.06	40.56	24.86	25.29	25.80	25.32
T ₆	60.00	61.50	63.00	61.50	24.15	24.58	24.81	24.51	16.62	18.02	19.20	17.95	38.95	45.96	47.80	44.24	29.91	28.17	28.65	28.91
Mean	55.00	57.64	60.58		20.48	21.01	21.55		11.89	13.46	15.15		34.21	38.79	42.92		25.58	25.66	26.00	
CD(0.05)																				
Treatment(T)		0.34				0.06				0.10				0.40				0.14		
Distance(D)		0.24				0.04				0.08				0.22				0.10		
TxD		0.60				0.08				0.18				0.60				0.26		

maturity (Table 26) was observed to be statistically significant. It took 129.60 days to mature the crop in direction DR₂ and 130.20 days in DR₁.

The interaction treatment x distance (Table 25) revealed that T₂D₁ and T₆D₃ gave maximum (134.20 days) and minimum (122.80 days) values respectively, which were significantly different from each other. The treatment x direction interaction, however, was statistically non-significant (Table 26).

B) Yield and yield attributes

Number of pods (plant⁻¹): The data presented in Table 25 and 26 have demonstrated that different tree-crop treatments affected the number of pods per plant significantly pertaining to the influence of treatments in general, distance and direction of the crop followed the trend as was evident in case of number of plants per metre square. Maximum number of pods per plant were recorded in treatment T₆ i.e. open control followed by T₅, T₄, T₃ and T₁, whereas, treatment T₂ gave the lowest value.

The interaction between treatment x distance (Table 25) showed maximum (62.17 pods plant⁻¹) value at T₅D₃ among various tree-crop treatments which was found to be significantly less than the value (63.00 pods plant⁻¹) obtained at T₆D₃ i.e. open control. On the other hand, treatment x direction interaction proved to be non-significant (Table 26).

Thousand grain weight (g): Thousand grain weight expressed in grams suffered a significant decline due to various tree-crop treatments when compared with open control i.e. T₆ (Table 25 and 26). Among various tree-crop treatments, maximum value was observed at treatment T₅ closely

Table 26. Effect of tree and crop direction on growth and yield of lentil in agroforestry system

Treatment	Growth												Yield												
	Plant height (cm)			Number of plants (m ⁻²)			Crop maturity (days)			Number of seeds (plant ⁻¹)			1000 seed weight (g)			Grain yield (t ha ⁻¹)			Stubble yield (t ha ⁻¹)			Total yield (t ha ⁻¹)			
	Direction	DR ₁ DR ₂		DR ₁ DR ₂		DR ₁ DR ₂		DR ₁ DR ₂		DR ₁ DR ₂		DR ₁ DR ₂		DR ₁ DR ₂		DR ₁ DR ₂		DR ₁ DR ₂		DR ₁ DR ₂		DR ₁ DR ₂		DR ₁ DR ₂	
		Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
T ₁	28.28	28.44	28.36	52.89	53.89	53.39	132.10	131.40	131.80	55.67	56.67	56.17	21.15	21.44	21.29	11.29	12.51	11.90	22.87	23.32	23.10	25.16	25.17	25.16	
T ₂	27.63	27.86	27.74	50.78	51.56	51.17	132.90	133.20	132.80	53.39	55.20	54.44	19.52	19.53	19.53	11.78	12.25	12.00	22.73	23.36	23.05	24.22	24.38	24.30	
T ₃	28.44	28.68	28.56	53.89	55.22	54.56	131.60	130.90	131.20	56.67	57.67	57.17	21.26	21.57	21.42	12.47	12.27	12.34	23.24	23.87	23.56	25.17	25.18	25.18	
T ₄	28.58	28.85	28.71	54.44	55.44	54.94	131.40	130.60	131.00	57.44	58.44	57.94	20.37	20.73	20.55	12.81	13.43	13.14	23.43	23.73	23.58	24.57	24.74	24.66	
T ₅	28.77	29.27	29.02	54.89	56.78	55.83	129.70	129.40	129.60	58.55	59.89	59.22	20.43	20.33	20.71	13.24	14.22	13.73	23.26	24.77	24.52	25.13	25.42	25.28	
T ₆	32.92	32.98	32.95	58.33	59.11	58.72	123.80	122.90	123.30	61.11	61.83	61.50	24.47	24.55	24.51	17.33	19.22	17.95	42.24	44.53	44.24	29.73	29.13	29.43	
Mean	29.10	29.34		54.20	55.33		130.20	129.60		57.22	58.26		20.22	21.15		13.16	13.25		37.85	39.42		25.53	25.88		
CD _(0.05)																									
Treatment(T)	0.24			0.39			0.39			0.34			0.25			0.10			0.42			0.14			
Direction(DR)	0.14			0.22			0.23			0.20			0.02			0.25			0.24			0.13			
TxDR	NS			0.56			NS			NS			0.38			0.14			0.45			NS			

followed by T_4 , T_3 , T_1 and T_2 . All these treatments were statistically different from one another. Distance of the crop as well as direction from the tree row exerted significant effect on this character showing highest value of 21.55 g at distance D_3 whereas the lowest value of 20.48 g at D_1 (Table 25). Direction DR_2 gave higher value over DR_1 . The respective values for these directions were 21.15 and 20.88 g (Table 26).

The effect of interactions due to treatment x distance (Table 25) as well as treatment x direction (Table 26) were also found to be statistically significant.

Grain yield ($q\ ha^{-1}$): Grain yield was affected significantly due to the use of different tree-crop treatments (Table 25 and 26). Maximum ($13.78\ q\ ha^{-1}$) grain yield was recorded at treatment T_5 and minimum ($11.00\ q\ ha^{-1}$) at treatment T_2 . Treatment T_6 i.e. open control exhibited significantly higher value ($17.95\ q\ ha^{-1}$) value compared to all other treatments. Distance of the crop from the tree row exhibiting its significant effect on grain yield (Table 25) displayed the highest value of $15.15\ q\ ha^{-1}$ at D_3 followed by D_2 ($13.46\ q\ ha^{-1}$) and D_1 ($11.89\ q\ ha^{-1}$). On the other hand direction of the crop recorded a value of $13.85\ q\ ha^{-1}$ in direction DR_2 which was significantly higher than the value of $13.16\ q\ ha^{-1}$ obtained in DR_1 (Table 26).

It was further deduced from the data that interaction effects due to treatment x distance (Table 25) and treatment x direction (Table 26) exerted statistically significant influence on grain yield.

Straw yield ($q\ ha^{-1}$): The data presented in Table 25 and 26 pertaining to

the effects of different tree-crop treatments, distance and direction of the crop from tree row, treatment x distance as well as treatment x direction interactions followed the similar trend as was exhibited by the grain yield.

Harvest Index (%): It is evident from the data (Table 25 and 26) that treatment T_6 i.e. open control indicated significantly higher (28.91%) harvest index compared to other treatments T_1 , T_2 , T_3 , T_4 and T_5 . The latter treatments have shown the value of 25.28, 24.74, 25.09, 25.13 and 25.32% respectively. However, treatments T_1 , T_5 as well as T_3 , T_4 were statistically alike between themselves. A further analysis of the data (Table 25) revealed that with the increase in distance from D_1 to D_3 the harvest index increased significantly. Direction DR_2 has shown significantly higher value (25.86%) than DR_1 (25.63%) (Table 26).

The interaction effect due to treatment x distance was statistically significant (Table 25) whereas treatment x direction was observed to be statistically non-significant (Table 26).

4.2.2 Growth and biomass yield of morus and peach

4.2.2.1 Growth

Growth and development of morus and peach grown under agrihortisilviculture system in two different cropping patterns were studied during the years 1994-95. The observations were recorded on the effects of different tree-crop treatments under each cropping pattern during October, 1994 and May, 1995. The results thus obtained have been described as below:

A) Morus

Season-I (October, 1994): It is clear from the data (Table 27) that growth and development of morus was influenced significantly due to different tree-crop treatments under cropping pattern-I (maize-lentil). The height of morus was observed to be maximum (3.38 m) in treatment T₅ whereas, T₁ have shown the minimum (3.08 m) value. However, treatments T₁, T₂ and T₃, T₅ remained at par between themselves. The crown spread in east direction was maximum (1.45 m) in treatment T₅ and minimum (1.09 m) in treatment T₁. Whereas in west direction it was maximum (1.48 m) in T₅ and minimum (1.05 m) in T₂. Similarly in north direction it was maximum (1.36 m) in T₅ and minimum (1.08 m) in T₁, whereas in south direction it showed higher value (1.48 m) in T₃ and lowest (1.15 m) in T₁. The results indicated that crown development in all the four directions was independent of the treatments as no specific trend was observed due to treatment effects. However, treatment T₅ gave maximum values for the directions east and north, whereas, T₁ exhibited the minimum values.

It was further observed from the data (Table 27) that height, diameter and crown spread were influenced significantly due to various tree-crop treatments in cropping pattern-II i.e. soybean-wheat. Treatment T₅ revealed the maximum (3.55 m) height followed by T₃, T₂ and T₁. The latter two treatments viz. T₁ and T₂ were found to be statistically at par with each other. Diameter followed the trend similar to plant height. Crown spread in all the four directions viz. east, west, north and south was found to be maximum in treatment T₅ showing their respective values of 1.60, 1.40, 1.32 and 1.64 m. However, their respective minimum values were found to be 1.00, 1.12, 0.90 and 1.20 m in treatment T₁.

Table 27. Growth and development of morus in agrihortisilviculture system

Treatment	Season-I (June-October, 1994)												Season-II (November, 1994-May, 1995)											
	Cropping Pattern-I						Cropping pattern-II						Cropping Pattern-I						Cropping pattern-II					
	Height (m)	Diameter (cm)	Crown spread (m)				Height (m)	Diameter (cm)	Crown spread (m)				Height (m)	Diameter (cm)	Crown spread (m)				Height (m)	Diameter (cm)	Crown spread (m)			
			East	West	North	South			East	West	North	South			East	West	North	South			East	West	North	South
T ₁	3.08	9.30	1.09	1.19	1.08	1.15	3.22	9.82	1.00	1.12	0.90	1.20	2.05	9.34	0.40	0.32	0.52	0.45	2.18	9.85	0.35	0.50	0.54	0.40
T ₂	3.15	9.50	1.25	1.05	1.16	1.35	3.27	9.90	1.15	1.26	1.00	1.38	2.25	9.55	0.42	0.45	0.42	0.50	2.20	9.93	0.40	0.40	0.38	0.45
T ₃	3.32	10.80	1.38	1.40	1.32	1.48	3.42	11.40	1.35	1.30	1.25	1.58	2.28	10.85	0.48	0.52	0.40	0.48	2.35	11.43	0.60	0.45	0.40	0.55
T ₄ *	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T ₅	3.38	11.60	1.45	1.48	1.36	1.40	3.55	12.00	1.60	1.40	1.32	1.64	2.32	11.69	0.55	0.60	0.35	0.55	2.44	12.04	0.68	0.42	0.45	0.46
T ₆ *	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CD(0.05)	0.10	0.26	0.12	0.15	0.05	0.09	0.06	0.12	0.18	0.15	0.07	0.12	NS	0.32	NS	0.09	0.06	NS	NS	0.18	0.12	NS	0.08	NS

* Treatments T₄ and T₆ do not contain morus

Season-II(May,1995): It is apparent from the data (Table 27) that cropping pattern-I i.e. maize-lentil had significant influence on diameter growth, however, variation in height growth due to different treatments was statistically non-significant. Maximum diameter growth was observed in treatment T₅ (11.69 cm) and minimum in T₁ (9.34 cm). Crown spread as noticed from the data was found to be influenced significantly in west and north directions whereas, it remained statistically non-significant in east and south directions. In west direction it was noticed to be maximum in treatment T₅ (0.60 m) and minimum in T₁ (0.32 m). Crown development in north direction followed the pattern opposite to west.

The data recorded in Table 27 showing the effect of different tree-crop treatments on growth and development of morus under cropping pattern-II have revealed that variation in height growth was statistically non-significant. However, diameter growth was influenced significantly showing its maximum value of 12.04 cm in treatment T₅ followed by T₃ (11.43 cm), T₂ (9.93 cm) and T₁ (9.85 cm). Crown spread was observed to be influenced significantly on the east and north directions only whereas west as well as south directions did not exhibit statistically significant variations. In east direction it followed an increasing order from treatment T₁ to T₅ however, treatments T₁, T₂ and T₃, T₅ remained statistically alike between themselves. Its value in north direction was maximum in treatment T₁ (0.54 m) and minimum (0.38 m) in treatment T₂.

B) Peach

Season-I (October, 1994): It is evident from the data that different tree-crop treatments under cropping pattern-I i.e. maize-lentil had significant

influence on peach height, diameter and crown spread (Table 28). The peach height was found to be maximum (3.40 m) in treatment T₄ and minimum in T₂ (3.05 m), however, T₁, T₃ and T₃, T₄ were statistically at par between themselves. The diameter showed minimum value in treatment T₂ (6.42 cm) and maximum in treatment T₄ (7.55 cm), but T₁, T₂ behaved statistically alike. Crown spread in east direction was minimum (1.10 m) in treatment T₁ and maximum (1.50 m) in T₄, whereas, in west direction minimum (1.05 m) and maximum (1.55 m) values were obtained in treatments T₂ and T₄, respectively. As regard to north and south directions minimum values (1.00 m and 0.95 m) were obtained in treatment T₂ and maximum (1.28 m and 1.39 m) have been recorded in T₄.

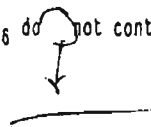
The results obtained under cropping pattern-II i.e. soybean-wheat (Table 28) have evinced that height, diameter growth and crown development of peach was influenced significantly due to various tree-crop treatments. Maximum height and diameter growth of 3.60 m and 7.80 cm were observed in treatment T₄ whereas, minimum values of 3.10 m and 6.60 cm were found in treatment T₂, respectively. As regards crown development, treatment T₁ exhibited minimum value (1.20 m) and treatment T₄ have shown maximum value (1.72 m) for east direction whereas, in west direction it was observed to be minimum (0.96 m) in treatment T₂ and maximum (1.60 m) in T₄. In north and south directions crown spread was minimum (1.25 m and 1.30 m) in T₁ and maximum (1.45 m and 1.50 m) in T₃.

Season-II(May,1995): An examination of the data (Table 28) have shown that peach height growth was not influenced significantly due to various tree-crop treatments under cropping pattern-I. However, diameter growth

Table 28. Growth and development of peach in agrihortisilviculture system

Treatment	Season-I (June-October, 1994)												Season-II (November, 1994-May, 1995)											
	Cropping Pattern-I						Cropping pattern-II						Cropping Pattern-I						Cropping pattern-II					
	Height (m)	Diameter (cm)	Crown spread (m)				Height (m)	Diameter (cm)	Crown spread (m)				Height (m)	Diameter (cm)	Crown spread (m)				Height (m)	Diameter (cm)	Crown spread (m)			
			East	West	North	South			East	West	North	South			East	West	North	South			East	West	North	South
T ₁	3.22	6.65	1.10	1.22	1.24	1.15	3.32	6.96	1.20	1.00	1.25	1.30	2.30	6.69	1.20	1.10	1.12	0.70	2.70	6.99	1.10	1.15	0.95	1.35
T ₂	3.05	6.42	1.25	1.05	1.00	0.95	3.10	6.60	1.32	0.96	1.35	1.40	2.70	6.52	1.10	1.15	0.95	1.25	2.65	6.64	1.00	0.85	1.20	1.30
T ₃	3.32	7.22	1.42	1.10	1.05	1.38	3.42	7.20	1.28	1.42	1.45	1.50	3.05	7.24	1.30	1.20	1.00	1.35	2.95	7.26	1.22	1.32	1.30	1.38
T ₄	3.40	7.55	1.60	1.55	1.28	1.39	3.60	7.80	1.72	1.60	1.32	1.45	3.20	7.60	1.35	1.60	1.10	0.90	3.10	7.88	1.30	1.55	1.28	1.40
T ₅ *	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T ₆ *	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CD _(0.05)	0.10	0.25	0.16	0.12	0.08	0.06	0.15	0.42	0.06	0.20	0.12	0.08	NS	0.20	NS	0.14	0.08	0.12	NS	0.38	0.15	0.22	0.06	0.08

*Treatments T₅ and T₆ do not contain peach



exhibited statistically significant difference. Maximum diameter was obtained in treatment T₄ followed by T₃, T₁ and T₂ showing their respective values of 7.80, 7.24, 6.89 and 6.52 cm. Crown spread was observed to be influenced significantly in west, north and south directions whereas it was found to be statistically non-significant in east direction. In north and south direction it was maximum in T₁ and T₃ treatments whereas minimum in T₂ and T₄, respectively. PV. 22x 26

It is further seen from the data presented in Table 28 that diameter and crown spread were influenced significantly due to various tree-crop treatments in cropping pattern-II, however, variations in height growth remained statistically non-significant. Treatment T₄ exhibited significantly higher (7.88 cm) diameter and treatment T₂ have shown minimum value (6.64 cm). Treatments T₂ and T₁ were however, statistically alike. As regards crown development, in east and west direction minimum values (1.00 and 0.85 m) were observed in treatment T₂ and maximum (1.30 and 1.55 m) in treatment T₄. But in case of north direction minimum values of 0.95 m was recorded in T₁ and maximum of 1.30 m in treatment T₃, while in south direction treatment T₂ showed minimum value of 1.30 m and treatment T₄ indicated maximum value (1.40 m).

4.2.2.2 Biomass yield

The data recorded in Table 29 indicates the branch and leaf biomass yield of morus as well as fruit and pruned wood biomass yield of peach grown under cropping patterns-I and II in agrihortisilviculture system. The branch biomass yield of morus and pruned wood biomass yield of peach has been expressed as the average of oven dry weight; and leaf biomass yield of

morus and fruit yield of peach as the average of fresh weight, per plant as well as per hectare basis. The results so obtained have been described as under:

A) Morus

The data (Table 29) on branch wood and leaf biomass yield of morus have indicated that different tree-crop treatments under cropping pattern-I i.e. maize-lentil affected both these characters significantly. Treatment T₅ produced highest branch biomass yield (25.41 q ha⁻¹) whereas treatment T₁ recorded the lowest value (20.90 q ha⁻¹). However, treatments T₁, T₂; T₂, T₃ and T₃, T₄ did not differ significantly between themselves. Leaf biomass yield exhibited the trend similar to branch showing maximum (12.01 q ha⁻¹) value in treatment T₅ and minimum (8.47 q ha⁻¹) in T₁. But the treatments T₁, T₂ and T₃, T₅ behaved statistically alike between themselves.

The branch and leaf biomass yield under cropping pattern-II i.e. soybean-wheat was also observed to be influenced significantly due to various tree-crop treatments (Table 29). Treatment T₅ gave the maximum branch biomass yield (25.65 q ha⁻¹) followed by T₃ (24.89 q ha⁻¹), T₂ (23.18 q ha⁻¹) and T₁ (21.37 q ha⁻¹). However, the treatments T₃ and T₅ behaved statistically alike. The leaf biomass yield noticed to be maximum (14.47 q ha⁻¹) in treatment T₅ and minimum (11.02 q ha⁻¹) in treatment T₁.

B) Peach

The data recorded in Table 29 showing the effect of different tree-crop treatments under cropping pattern-I on the number of fruits, fruit

Table 29. Branch and leaf biomass yield (q ha^{-1}) of morus; pruned wood and fruit yield (q ha^{-1}) of peach in agrihortisilviculture system

Treatment	Season-I(October 1994)				Season-II(May 1995)					
	Cropping Pattern-I		Cropping pattern-II		Cropping Pattern-I			Cropping pattern-II		
	Morus		Morus		Peach			Peach		
	Branch	Leaf	Branch	Leaf	Fruits plant ⁻¹	Fruit yield	Pruned wood yield	Fruits plant ⁻¹	Fruit yield	Pruned wood yield
T ₁	20.90 (10.45)	8.47 (4.24)	21.37 (10.69)	11.02 (5.51)	88	16.00 (8.00)	6.75 (3.38)	74	13.60 (6.80)	7.08 (3.54)
T ₂	22.50 (11.25)	9.60 (4.80)	23.18 (11.59)	12.20 (6.10)	79	15.72 (7.86)	6.21 (3.11)	83	12.64 (6.32)	6.31 (3.16)
T ₃	23.87 (11.94)	11.53 (5.77)	24.89 (12.45)	13.06 (6.53)	90	16.64 (8.32)	7.59 (3.80)	96	14.20 (7.10)	7.62 (3.81)
T ₄ *	-	-	-	-	102	17.00 (8.50)	9.35 (4.68)	105	14.80 (7.40)	9.38 (4.69)
T ₅ **	25.41 (12.71)	12.01 (6.01)	25.65 (12.83)	14.47 (7.24)	-	-	-	-	-	-
T ₆ ***	-	-	-	-	-	-	-	-	-	-
CD(0.05)	1.80	1.11	0.95	1.20	10.02	0.82	1.56	6.35	1.09	1.89

Figures in parentheses are biomass yield kg plant^{-1}

* Treatment T₄ does not contain morus

** Treatment T₅ does not contain peach

***Treatment T₆ does not contain morus and peach

yield and pruned wood biomass yield of peach have shown that number of fruits per plant were significantly higher in treatment T_4 over T_3 , T_2 and T_1 . Significantly higher fruit yield was obtained in treatment T_4 (17.00 q ha^{-1}) over T_1 (16.00 q ha^{-1}) and T_2 (15.72 q ha^{-1}). A further analysis of the data showed significantly higher (9.35 q ha^{-1}) pruned wood biomass yield in T_4 over T_3 (7.59 q ha^{-1}), T_1 (6.75 q ha^{-1}) and T_2 (6.21 q ha^{-1}). However, treatments T_1 , T_2 , T_3 behaved statistically alike among themselves.

The results obtained under cropping pattern-II have shown significant influence on the number of fruits, fruit yield and pruned biomass yield due to different tree-crop treatments. Maximum number of fruits per plant were recorded in treatment T_4 (105) followed by T_3 (96), T_2 (83) and T_1 (74).

Maximum fruit yield (14.80 q ha^{-1}) was obtained in treatment T_4 and minimum (12.64 q ha^{-1}) in T_2 . However, treatments T_1 , T_2 ; T_1 , T_3 and T_3 , T_4 remained statistically alike between themselves. Treatment T_4 exhibited maximum (9.38 q ha^{-1}) pruned wood biomass yield followed by t_3 (7.62 q ha^{-1}), T_1 (7.08 q ha^{-1}) and T_2 (6.31 q ha^{-1}). But the treatments T_1 , T_2 , T_3 and T_3 , T_4 remained at par between themselves.

4.2.3 Nutrient content and uptake in field crops

Nitrogen, phosphorus and potassium content and uptake in grain and straw components of maize, soybean, wheat and lentil were studied under agrihortisilviculture system. The results obtained have been presented in Tables 30-33 and described as under:

4.2.3.1 Maize

A) Content: It is evident from the data (Table 30) that nutrient content in maize grain and straw was found to be affected significantly due to different tree-crop treatments. Maximum N, P and K-content was observed in treatment T₆ i.e. open control followed by T₄, T₅, T₃, T₂ and T₁ both in grain and straw. It was also seen that maize growing in association with morus as a dominant component (T₁ and T₅) had lesser nutrient content in grain as well as straw than the treatments having dominance of peach trees (T₂) or peach alone (T₄), respectively.

It was further observed from the data that distance and direction also had a significant influence on nutrient content of maize. The distance D₃ showed maximum content of N, P and K which was found to be 1.726, 0.334 and 0.270 per cent in case of grains whereas, their respective maximum values obtained in case of straw were 0.545, 0.210 and 0.863 per cent. Distance D₃ was followed by D₂ and least values were shown by D₁. N and K contents were found to be significantly higher in direction DR₂ over DR₁ but P-content attained its maximum value in direction DR₁ than DR₂.

B) Uptake: It is seen from the data (Table 30) that treatment T₆ i.e. open control exhibited significantly higher N-uptake in grain followed by T₅, T₄, T₃, T₁ and T₂ with their respective values of 74.01, 66.71, 66.46, 65.91, 64.18 and 60.86 per cent. Similar trend was observed in N uptake of straw also. A further analysis of the data revealed that distance and direction from tree row also had a significant influence on N-uptake in grain as well as straw. It increased with the increase in distance and have shown significantly higher values at direction DR₂ over DR₁. P and K uptake

Table 30. Effect of tree, crop distance and direction on NPK-content and uptake in maize in agrohortisilviculture system

Treatments	Content(%)						Uptake (kg ha ⁻¹)					
	N		P		K		N		P		K	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
A) Tree												
T ₁	1.688	0.514	0.302	0.170	0.236	0.827	54.13	34.25	11.50	11.53	3.13	55.14
T ₂	1.699	0.517	0.315	0.176	0.242	0.829	60.36	33.93	11.36	11.55	3.77	54.23
T ₃	1.706	0.521	0.313	0.180	0.246	0.837	65.97	35.36	12.14	12.15	3.58	56.79
T ₄	1.726	0.540	0.326	0.195	0.257	0.849	66.46	36.37	12.58	13.37	3.34	57.30
T ₅	1.714	0.531	0.320	0.187	0.251	0.844	65.78	36.82	12.49	13.72	3.79	57.29
T ₆	1.754	0.547	0.338	0.199	0.275	0.860	74.01	38.53	14.29	14.07	11.54	60.55
CD(0.05)	0.004	0.004	0.004	0.004	0.005	0.004	4.23	1.92	0.45	0.37	0.36	2.29
B) Crop distance												
D ₁	1.700	0.511	0.295	0.166	0.228	0.811	60.66	32.55	10.53	10.54	3.17	51.62
D ₂	1.718	0.529	0.324	0.188	0.256	0.849	65.05	35.93	12.44	12.73	3.93	57.51
D ₃	1.726	0.545	0.334	0.210	0.270	0.863	72.35	38.72	14.00	14.32	11.32	61.62
CD(0.05)	0.003	0.003	0.003	0.003	0.003	0.003	4.57	1.58	0.32	0.35	0.75	1.99
C) Crop direction												
DP ₁	1.701	0.517	0.330	0.193	0.241	0.830	64.80	34.65	12.62	12.94	9.24	55.64
DP ₂	1.729	0.541	0.305	0.177	0.262	0.852	67.91	36.95	12.03	12.12	10.33	58.26
CD(0.05)	0.002	0.002	0.002	0.002	0.003	0.003	2.28	1.47	0.26	0.21	0.21	1.73

in grain and straw followed the trend similar to N uptake however, P uptake was found to be higher in direction DR₁ than DR₂.

4.2.3.2 Soybean

A) Content: It is evident from the data presented in Table 31 that treatment T₆ i.e. open control has shown higher N, P and K concentration in soybean grain and straw as compared to treatments which had tree as a component (T₁, T₂, T₃, T₄, T₅). Among tree-crop treatments highest nutrient concentrations were observed in treatment T₄ whereas T₁ exhibited lowest, both in grain as well as straw. A further analysis of the data revealed that nutrient concentrations had increased significantly with the increase in distance. Direction DR₂ have shown significantly higher values for N and K over DR₁ whereas, for P maximum values were obtained in direction DR₁ than DR₂.

B) Uptake: Alike nutrient content, the nutrient uptake in soybean grain and straw followed the similar trend, but direction DR₂ exhibited significantly higher (3.23 kg ha⁻¹) value over DR₁ (3.18 kg ha⁻¹) for P uptake (Table 31).

4.2.3.3 Wheat

A) Content: It is evident from the data (Table 32) that N content in grains was found to be significantly higher in treatment T₆ i.e. open control followed by T₅, T₄, T₃, T₁ and T₂ with their respective values of 1.406, 1.396, 1.384, 1.379, 1.378 and 1.369 per cent. A similar trend was observed in N content of straw. A further analysis of the data revealed that distance and direction from tree row also had a significant influence on N content of grain as well as straw. It had increased with the increase in

Table 31. Effect of tree, crop distance and direction on NPK-content and uptake in soybean in agrihortisilviculture system

Treat- ments	Content(%)						Uptake (kg ha ⁻¹)					
	N		P		K		N		P		K	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
A) Tree												
T ₁	4.767	3.302	0.190	0.0672	1.091	0.689	77.43	140.90	3.10	2.88	17.74	29.46
T ₂	4.770	3.306	0.197	0.0675	1.102	0.696	80.10	145.40	3.32	2.98	18.53	30.64
T ₃	4.784	3.313	0.197	0.0682	1.108	0.699	82.54	148.90	3.41	3.07	19.13	31.47
T ₄	4.801	3.327	0.212	0.0709	1.121	0.714	88.94	158.50	3.95	3.39	20.79	34.04
T ₅	4.791	3.321	0.206	0.0688	1.114	0.706	85.12	153.00	3.67	3.18	19.83	32.54
T ₆	4.831	3.326	0.221	0.0737	1.142	0.723	96.07	167.80	4.43	3.72	22.73	36.52
CD(0.05)	0.004	0.004	0.005	0.0004	0.005	0.004	6.63	6.71	0.31	0.26	2.41	2.59
B) Crop distance												
D ₁	4.780	3.289	0.184	0.0658	1.092	0.684	75.40	138.60	2.91	2.78	17.25	28.87
D ₂	4.792	3.327	0.210	0.0696	1.118	0.712	83.84	151.60	3.68	3.18	19.58	32.45
D ₃	4.800	3.331	0.218	0.0726	1.129	0.717	95.86	167.10	4.35	3.65	22.56	36.02
CD(0.05)	0.003	0.003	0.004	0.0003	0.003	0.003	6.15	6.92	0.28	0.24	2.29	2.47
C) Crop direction												
DR ₁	4.774	3.306	0.212	0.0704	1.106	0.698	81.97	148.50	3.67	3.18	19.04	31.42
DR ₂	4.808	3.325	0.196	0.0683	1.120	0.711	88.10	156.30	3.62	3.23	20.55	33.47
CD(0.05)	0.003	0.002	0.003	0.0002	0.003	0.002	4.94	4.57	0.03	0.03	0.24	0.84

distance from D_1 to D_3 and was found to be significantly higher in direction DR_2 over DR_1 for grains as well as straw. P and K content in grains as well as in straw followed the trend similar to N, however, K content in grains was found to be significantly higher (0.463%) in direction DR_1 as compared to direction DR_2 (0.457%).

B) Uptake: A critical examination of the data (Table 32) revealed that treatment T_6 i.e. open control gave the maximum uptake of N, P and K which was found to be 49.47, 13.32 and 16.96 kg ha⁻¹ in case of grains, whereas their respective maximum values obtained in case of straw were 17.47, 11.57 and 40.04 kg ha⁻¹. Treatment T_6 was followed by T_5 , T_4 , T_3 , T_1 , and T_2 for all the three nutrients namely N P and K. It was further seen from the data that distance and direction of the crop from tree row also influenced the nutrient uptake significantly. It was found to increase with the increase in distance and maximum values were shown at distance D_3 , whereas D_1 exhibited the minimum for each of the nutrient both in straw and grain. The directional effect in respect of nutrient uptake was found to be significantly higher in direction DR_2 as compared to direction DR_1 .

4.2.3.4 Lentil

A) Content: significantly higher nutrient content in grains as well as straw were observed in open control (T_6) compared to inter-cropped treatments (T_1 , T_2 , T_3 , T_4 and T_5). It is evident from the data presented in Table 33 that nutrient content was found to increase with the increase in distance and have shown maximum values at distance D_3 and minimum at distance D_1 . Direction DR_2 exhibited higher values of nutrients in grain and straw for all the three nutrients namely, N, P and K over direction DR_1 .

Table 32. Effect of tree, crop distance and direction on NPK-content and uptake in wheat in agrihortisilviculture system

Treat- ments	Content(%)						Uptake (kg ha ⁻¹)					
	N		P		K		N		P		K	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
A) Tree												
T ₁	1.378	0.258	0.342	0.156	0.444	0.636	38.18	13.77	9.50	8.28	12.34	33.74
T ₂	1.369	0.254	0.339	0.152	0.442	0.628	35.88	13.02	8.92	7.78	11.61	31.97
T ₃	1.379	0.265	0.346	0.161	0.446	0.638	39.88	14.49	10.01	8.75	12.93	34.74
T ₄	1.384	0.267	0.351	0.166	0.452	0.641	41.29	14.94	10.50	9.24	13.51	35.70
T ₅	1.396	0.274	0.359	0.175	0.463	0.645	43.60	15.60	11.23	9.98	14.49	36.64
T ₆	1.406	0.289	0.378	0.192	0.482	0.664	49.47	17.47	13.32	11.57	16.96	40.04
CD _(0.05)	0.005	0.004	0.005	0.004	0.005	0.004	2.33	1.24	0.37	0.35	1.18	1.34
B) Crop distance												
D ₁	1.379	0.252	0.345	0.159	0.444	0.632	36.09	12.45	9.07	7.86	11.66	31.15
D ₂	1.385	0.271	0.353	0.168	0.456	0.641	40.61	14.77	10.38	9.21	13.41	34.92
D ₃	1.391	0.282	0.360	0.173	0.464	0.653	47.45	17.43	12.29	10.73	15.85	40.34
CD _(0.05)	0.003	0.003	0.003	0.003	0.003	0.003	2.24	1.17	0.32	0.28	1.13	1.24
C) Crop direction												
OR ₁	1.382	0.265	0.350	0.164	0.463	0.639	40.23	14.43	10.22	8.96	13.23	34.60
OR ₂	1.388	0.271	0.356	0.169	0.457	0.644	42.54	15.33	10.94	9.58	14.04	36.34
CD _(0.05)	0.003	0.002	0.003	0.002	0.003	0.002	1.19	0.14	0.30	0.24	0.70	1.12

B) Uptake: N, P and K uptake in grain as well as straw was found to be significantly higher in treatment T_6 i.e. open control over the remaining tree-crop treatments viz. T_1 , T_2 , T_3 , T_4 and T_5 (Table 33). However, unlike their content, uptake was higher in straw as compared to grain but P uptake in grain was noticed to be higher than straw at treatment T_6 . It was further evidenced from the data that distance and direction of the crop from tree row also influenced the nutrient uptake significantly. The respective maximum values for N, P and K uptake in grain recorded at distance D_3 being 55.89, 3.56 and 18.75 kg ha⁻¹, whereas minimum values obtained at distance D_1 were 43.52, 2.53 and 14.38 kg ha⁻¹. Alike nutrient uptake in grain, the nutrient uptake in straw showed similar results as regards distance effect. It was found to be significantly higher at direction DR_2 over DR_1 for all the three nutrients viz. N, P and K.

4.2.4 Nutrient content and uptake in morus and peach

The data presented in Table 34 and 35 show the effect of different treatments involving various combinations of morus, peach and field crops on the N, P and K content and their uptake in leaf and branch of morus and pruned wood and fruit of peach under cropping pattern-I and cropping pattern-II of agrihortisilviculture system. It was seen from the data that changes in N, P and K content due to different tree-crop treatments were statistically non-significant, however, it expressed a significant influence on N, P and K uptake in both cropping pattern-I as well as cropping pattern-II.

A) Morus

Cropping pattern-I: It was observed from Table 34 that branch N uptake

Table 33. Effect of tree, crop distance and direction on NPK-content and uptake in lentil in agroforestry monoculture system

Treat- ments	Content(%)						Uptake (kg ha ⁻¹)					
	N		P		K		N		P		K	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
A) Tree												
T ₁	3.664	1.612	0.218	0.0806	1.215	0.583	45.09	58.63	2.70	2.39	14.37	24.38
T ₂	3.655	1.602	0.209	0.0803	1.211	0.675	40.24	53.45	2.32	2.58	13.35	22.57
T ₃	3.669	1.616	0.221	0.0807	1.216	0.684	47.12	61.34	2.55	3.09	15.63	25.22
T ₄	3.670	1.617	0.228	0.0812	1.220	0.686	48.24	63.24	3.01	3.13	16.15	26.57
T ₅	3.679	1.629	0.226	0.0817	1.222	0.691	50.73	66.12	3.13	3.32	16.56	28.07
T ₆	3.693	1.643	0.237	0.0835	1.249	0.707	66.30	72.71	4.27	3.78	22.42	31.28
CD(0.05)	0.004	0.004	0.004	0.0005	0.005	0.004	4.37	4.57	0.25	0.13	1.13	2.22
B) Crop distance												
D ₁	3.657	1.611	0.211	0.0806	1.206	0.675	43.52	55.18	2.53	2.75	14.38	23.14
D ₂	3.671	1.619	0.224	0.0814	1.224	0.686	49.45	62.85	3.04	3.16	16.51	26.53
D ₃	3.687	1.629	0.234	0.0820	1.236	0.702	55.89	69.96	3.56	3.52	18.75	30.16
CD(0.05)	0.003	0.003	0.003	0.0003	0.003	0.003	4.27	4.40	0.25	0.12	1.10	2.20
C) Crop direction												
DR ₁	3.668	1.617	0.219	0.0809	1.218	0.683	48.31	61.29	2.91	3.07	16.07	25.93
DR ₂	3.676	1.623	0.227	0.0818	1.227	0.692	50.93	64.04	3.17	3.23	17.03	27.35
CD(0.05)	0.002	0.002	0.002	0.0003	0.003	0.002	2.22	2.33	0.20	0.09	0.48	1.16

increased significantly from treatment T_1 to T_5 . Highest N uptake in branch was recorded in treatment T_5 (19.06 kg ha^{-1}) and lowest (14.84 kg ha^{-1}) in treatment T_1 . The P uptake in branch was found to be significantly higher (4.07 kg ha^{-1}) in treatment T_5 followed by T_3 (3.58 kg ha^{-1}), T_2 (2.93 kg ha^{-1}) and T_1 (2.30 kg ha^{-1}). The K uptake in branch followed a trend which is consistent with N and P uptake.

Leaf N, P and K uptake were recorded to be maximum (11.55 , 0.97 and 7.16 kg ha^{-1}) in treatment T_5 and minimum (8.03 , 0.58 and 4.93 kg ha^{-1}) in treatment T_1 . However, treatments T_3 , T_4 for N uptake ; T_1 , T_2 and T_3 , T_4 for P uptake; and T_2 , T_3 and T_3 , T_4 for K uptake remained at par among themselves.

Cropping pattern-II: An examination of the data in Table 34 revealed that branch N uptake was found to be significantly higher (19.49 kg ha^{-1}) in treatment T_5 followed by T_3 (18.67 kg ha^{-1}), T_2 (17.15 kg ha^{-1}) and T_1 (15.39 kg ha^{-1}). However, treatments T_3 and T_5 behaved statistically alike. The P and K uptake were found to be significantly higher (4.10 and 16.16 kg ha^{-1}) in treatment T_5 followed by T_3 (3.73 and 15.43 kg ha^{-1}), T_2 (3.25 and 13.91 kg ha^{-1}) and T_1 (2.35 and 12.61 kg ha^{-1}).

A further analysis of the data showed that N, P and k uptake in leaf was maximum (13.93 , 1.22 and 8.63 kg ha^{-1}) in treatment T_5 and minimum (10.50 , 0.75 and 6.46 kg ha^{-1}) in treatment T_1 , respectively.

B) Peach

Cropping pattern-I: It is seen from the data (Table 35) that N uptake in peach pruned wood was significantly higher (8.32 kg ha^{-1}) in treatment T_4

Table 34. NPK-content and uptake in morus in agrihortisilviculture system

Treat- ments	Cropping pattern-I												Cropping pattern-II											
	Content(%)						Uptake (kg ha ⁻¹)						Content (%)						Uptake (kg ha ⁻¹)					
	Branch			Leaf			Branch			Leaf			Branch			Leaf			Branch			Leaf		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
T ₁	0.71	0.11	0.58	2.93	0.21	1.80	14.84	2.30	12.12	8.03	0.59	4.33	0.72	0.11	0.53	2.34	1.21	0.81	13.28	2.25	12.91	11.51	1.75	2.45
T ₂	0.72	0.13	0.60	2.95	0.22	1.82	16.20	2.93	13.50	9.17	0.69	5.55	0.74	0.14	0.60	2.35	1.23	0.83	17.95	2.35	13.31	11.25	1.91	7.33
T ₃	0.74	0.15	0.61	2.96	0.24	1.83	17.66	3.58	14.56	11.04	0.90	6.83	0.75	0.15	0.62	2.36	1.24	0.83	18.61	2.73	15.43	12.52	2.12	7.74
T ₄ ^a	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T ₅	0.75	0.16	0.62	2.97	0.25	1.84	19.06	4.07	15.75	11.55	0.97	7.16	0.76	0.16	0.63	2.97	0.25	1.34	19.63	4.00	15.05	12.53	2.22	8.33
T ₆ ^a	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CD(0.05)	NS	NS	NS	NS	NS	NS	1.52	0.70	1.10	0.64	0.16	1.23	NS	NS	NS	NS	NS	NS	1.16	0.58	0.58	1.22	0.18	0.48

Treatments T₄ and T₆ do not contain morus

over T_3 (6.68 kg ha^{-1}), T_1 (5.94 kg ha^{-1}) and T_2 (5.34 kg ha^{-1}). However, treatments T_1 , T_2 , T_3 were found to be statistically at par with one another. The P uptake in pruned wood was maximum (2.15 kg ha^{-1}) in treatment T_4 and minimum (1.24 kg ha^{-1}) in T_2 . The K uptake in pruned wood followed a trend similar to N and P uptake showing its maximum value of 4.86 kg ha^{-1} in treatment T_4 and minimum value of 3.11 kg ha^{-1} in T_2 . However, treatments T_1 , T_2 , T_3 behaved statistically alike.

Fruit N, P and K uptake were recorded to be maximum (23.84 , 2.52 and 16.46 kg ha^{-1}) in treatment T_4 and minimum (21.70 , 1.90 and 14.78 kg ha^{-1}) in treatment T_2 . However, the treatments T_1 , T_2 and T_3 , T_4 for all the three nutrients uptake remained statistically alike between themselves.

Cropping pattern-II: It is evident from the data presented in Table 35 that N uptake in pruned wood was maximum (8.25 kg ha^{-1}) in treatment T_4 followed by T_3 (6.63 kg ha^{-1}), T_1 (6.16 kg ha^{-1}) and T_2 (5.36 kg ha^{-1}). The P and K uptake in pruned wood noticed to be maximum (2.25 , 5.07 kg ha^{-1}) in treatment T_4 and minimum (1.39 , 3.22 kg ha^{-1}) in treatment T_2 . However, the treatments T_1 , T_2 , T_3 for both P and K uptake did not show any significant difference among themselves.

Fruit N uptake was significantly higher (20.83 kg ha^{-1}) in treatment T_4 over T_1 (19.00 kg ha^{-1}) and T_2 (17.45 kg ha^{-1}). However, the treatments T_1 , T_2 ; T_1 , T_3 and T_3 , T_4 were statistically alike among themselves. P uptake in fruit was recorded to be maximum (2.12 kg ha^{-1}) in treatment T_4 and minimum (1.67 kg ha^{-1}) in T_2 . The K uptake in fruit exhibited the trend similar to N and P uptake showing its maximum value (14.40 kg ha^{-1}) in

Table 35. NPK-content and uptake in peach in agrihortisilviculture system

Treat- ments	Cropping pattern-I												Cropping pattern-II											
	Content(%)						Uptake (kg ha ⁻¹)						Content(%)						Uptake (kg ha ⁻¹)					
	Pruned wood			Fruit			Pruned wood			Fruit			Pruned wood			Fruit			Pruned wood			Fruit		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
T ₁	0.88	0.22	0.52	2.53	0.24	1.74	5.94	1.49	3.71	22.26	2.11	15.31	0.87	0.23	0.53	2.54	0.25	1.76	6.16	1.63	3.75	19.00	1.87	13.16
T ₂	0.86	0.20	0.50	2.51	0.22	1.71	5.34	1.24	3.11	21.70	1.90	14.78	0.85	0.22	0.51	2.51	0.24	1.73	5.36	1.39	3.22	17.45	1.67	12.03
T ₃	0.88	0.22	0.52	2.54	0.26	1.75	6.68	1.67	3.95	23.25	2.38	16.02	0.87	0.23	0.54	2.55	0.26	1.76	6.63	1.75	4.10	19.92	2.03	13.75
T ₄	0.89	0.23	0.52	2.55	0.27	1.76	8.32	2.15	4.86	23.84	2.52	16.46	0.88	0.24	0.54	2.56	0.26	1.77	8.25	2.25	5.07	20.83	2.12	14.40
T ₅ *	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T ₆ *	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CD _(0.05)	NS	NS	NS	NS	NS	NS	1.40	0.40	0.87	0.68	0.22	0.56	NS	NS	NS	NS	NS	NS	1.28	0.38	0.89	1.62	0.22	0.82

*Treatments T₅ and T₆ do not contain peach

treatment T_4 and minimum (12.03 kg ha^{-1}) in T_2 . However, the treatments T_1 , T_3 and T_4 behaved statistically alike.

4.2.5 Soil moisture content

The data in respect of soil moisture content at 0-30 cm depth were recorded on 30th of every month in agrihortisilviculture system, under maize and soybean during the cropping period June, 1994 to October, 1994 and under wheat and lentil during November, 1994 to May, 1995. The results thus obtained have been presented in Table 36 and 37 and described as under:

4.2.5.1 Maize

It is evident from the data (Table 36) that various tree-crop treatments, distance and direction of the crop from tree row exercised a significant influence on the soil moisture content during all the months of growth period excepting July. The maximum soil moisture content was observed to be maximum in treatment T_6 i.e. open control whereas, T_1 exhibited the minimum. However, the treatments T_1 , T_2 , T_3 , T_4 , T_5 in June; T_1 , T_2 , T_3 , T_4 , T_5 and T_4 , T_6 in August and September; T_1 , T_2 ; T_2 , T_3 ; T_3 , T_5 ; T_4 , T_5 and T_5 , T_6 in October remained statistically at par among themselves. Further, it was found to increase significantly from distance D_1 to D_3 . The maximum values in the months of June, August, September and October obtained at distance D_3 were 16.33, 22.09, 15.05 and 7.95 per cent respectively. Whereas, their respective minimum values of 14.73, 20.64, 12.46 and 7.08 per cent were shown by D_1 . The direction DR_2 recorded significantly higher soil moisture content over DR_1 in all the months.

Table 36. Effect of tree, crop distance and direction on soil moisture content(%)in agrihortisilviculture system (June-October,1994)

Treat- ments	Season-I(June-October,1994)									
	Maize					Soybean				
	June	July	August	September	October	June	July	August	September	October
A) Tree										
T ₁	14.87	21.95	20.60	13.38	7.17	14.37	21.38	20.83	13.36	6.48
T ₂	15.09	22.14	21.06	13.58	7.28	14.74	22.03	21.15	13.61	6.65
T ₃	15.26	22.20	21.18	13.62	7.52	15.00	22.29	21.35	13.71	6.72
T ₄	15.52	22.39	21.52	13.99	7.96	15.44	22.43	21.91	14.09	7.10
T ₅	15.39	22.32	21.33	13.90	7.69	15.30	22.38	21.65	14.02	6.81
T ₆	16.70	22.97	22.41	14.07	7.85	16.91	23.03	22.16	15.22	7.69
CD(0.05)	0.72	NS	0.95	0.54	0.28	0.96	NS	0.86	0.92	NS
B) Crop distance										
D ₁	14.73	22.00	20.64	12.46	7.08	14.50	21.74	19.81	12.25	6.55
D ₂	15.50	22.31	21.32	13.76	7.71	15.29	22.40	21.45	14.23	6.80
D ₃	16.33	22.68	22.09	15.05	7.95	16.06	22.63	23.26	15.53	7.35
CD(0.05)	0.65	NS	0.64	0.46	0.21	0.85	NS	0.74	0.84	0.22
C) Crop direction										
DR ₁	14.47	22.08	20.70	13.50	7.28	14.21	22.11	20.06	13.21	6.60
DR ₂	16.58	22.48	22.00	14.01	7.88	16.17	22.40	22.96	14.80	7.20
CD(0.05)	0.61	NS	0.58	0.42	0.18	0.78	NS	0.68	0.72	0.18

4.2.5.2 Soybean

Soil moisture content was found to be influenced significantly due to various tree-crop treatments, distance and direction of the crop from tree row in the months of June, August and September. However, differences in soil moisture content due to tree-crop treatments in the month of October were observed to be statistically non-significant (Table 36). Among tree-crop treatments, treatment T_4 recorded higher soil moisture content and T_1 the minimum. The treatment T_6 i.e. open control gave higher values compared to all other treatments. It was further observed from the data that distance D_3 recorded significantly higher soil moisture content over D_2 and D_1 . The maximum values of 16.06, 23.26, 15.53 and 7.35 per cent were obtained at distance D_3 for the months of June, August, September and October, respectively, whereas, their respective minimum values (14.50, 19.81, 12.25 and 6.55%) were obtained at D_1 . Significantly higher values of 16.17, 22.96, 14.80 and 7.20 per cent in direction DR_2 and lower values of 14.21, 20.06, 13.21 and 6.60 per cent in direction DR_1 were obtained in the months of June, August, September and October, respectively.

4.2.5.3 Wheat

A perusal of the data on soil moisture content have shown that it was affected significantly due to different tree-crop treatments, distances and directions of the crop from tree row from December to April. However, variations in soil moisture content due to distance and direction of the crop were found to be significant in May also (Table 37). Treatment T_6 i.e. open control gave maximum values of 8.19, 15.45, 17.74, 15.47 and 7.06 per cent in the months of December, January, February, March and April whereas,

their minimum values obtained in treatment T_2 were 7.50, 13.34, 14.30, 13.06 and 5.85 per cent. Distance D_3 and D_2 gave significantly higher soil moisture content over D_1 , however, D_2 and D_3 remained at par with each other in the months of December and April. Direction DR_2 have shown significantly higher values (8.05, 15.11 and 17.83%) over DR_1 (7.75, 14.44 and 15.38%) in the months of December, January and February respectively while, direction DR_1 exhibited significantly higher values of 15.00, 7.33 and 4.01 per cent over DR_2 (13.38, 6.00 and 3.85%) in March, April and May.

4.2.5.4 Lentil

It is seen from the data (Table 37) that various tree-crop treatments, distance and direction of the crop from tree row had a significant influence on the soil moisture content in all the months of crop growth period excepting November. However, treatment effects in general during May was found to be non-significant. Soil moisture content was found to be higher in treatment T_6 i.e. open control and minimum in treatment T_2 in all the months of observations. Distance D_3 exhibited maximum values of 9.73, 15.69, 17.52, 17.95, 8.02 and 4.31 per cent in the months of December, January, February, March, April and May whereas, their respective minimum values obtained at D_1 were 8.91, 12.33, 15.27, 14.33, 6.72 and 3.71 per cent. However, distances D_2 and D_3 in the months of December and April; D_1 , D_2 in May behaved statistically alike with each other. Direction DR_2 have shown significantly higher values over DR_1 from December to February thereafter a reverse trend crop was observed from March to May.

Table 37. Effect of tree, crop distance and direction on soil moisture content in agrihortisilviculture system (November, 1994-May, 1995)

Treat- ments	Season-II (November, 1994-May, 1995)													
	Wheat							Lentil						
	Nov	Dec	Jan	Feb	March	April	May	Nov	Dec	Jan	Feb	March	April	May
A) Tree														
T ₁	3.84	7.81	14.46	16.45	13.64	6.50	3.80	4.09	9.55	13.20	16.00	15.35	6.88	3.99
T ₂	3.41	7.50	13.34	14.30	13.06	5.85	3.70	4.05	8.03	12.80	14.70	14.21	6.06	3.73
T ₃	3.89	7.91	15.00	16.93	13.97	6.68	3.94	4.24	9.67	13.06	16.18	15.93	7.61	4.01
T ₄	3.96	7.94	15.10	16.75	14.31	6.90	4.01	4.34	9.70	13.34	16.74	16.67	7.77	4.03
T ₅	4.01	8.06	15.30	17.25	14.68	7.00	4.04	4.53	9.72	15.00	17.00	17.08	8.00	4.07
T ₆	4.27	8.19	15.45	17.74	15.47	7.06	4.07	4.58	9.79	15.58	17.22	17.69	8.30	4.16
CD(0.05)	NS	0.62	0.65	0.52	1.06	0.52	NS	NS	0.20	1.86	0.82	1.40	1.14	NS
B) Crop distance														
D ₁	3.74	7.60	13.71	15.08	12.08	5.91	3.04	4.01	8.91	12.33	15.27	14.33	6.72	3.71
D ₂	3.94	7.98	14.68	16.80	14.73	7.02	3.41	4.12	9.60	13.47	16.14	16.12	7.58	3.98
D ₃	4.01	8.12	15.92	17.83	15.76	7.07	4.83	4.29	9.73	15.69	17.52	17.95	8.02	4.31
CD(0.05)	NS	0.32	0.56	0.40	0.96	0.36	0.28	NS	0.18	1.05	0.74	1.28	0.72	0.52
C) Crop direction														
DR ₁	3.84	7.75	14.44	15.38	15.00	7.33	4.01	4.05	9.19	13.63	15.62	16.45	7.97	4.48
DR ₂	4.00	8.05	15.11	17.83	13.38	6.00	3.85	4.22	9.64	14.03	17.00	15.83	6.90	3.52
CD(0.05)	NS	0.24	0.46	0.38	0.86	0.28	0.20	NS	0.12	0.28	0.58	0.92	0.64	0.42

4.2.6 Per cent relative illumination (RI)

Table 38 shows per cent RI below the canopies of morus and peach in north and south direction of the trees. The observations have been taken just before the harvest of each field crop i.e. in the month of October, 1994 and May, 1995.

It is evinced from the data that during Kharif season per cent RI were more below the canopies of morus than that of peach. Below both the tree canopies it showed maximum value along with maize and on south direction of the tree as compared to soybean and north direction, respectively.

Table 38. Relative illumination (%) in agri-hortisilviculture system

Field crops	Morus		Peach	
	North of the tree	South of the tree	North of the tree	South of the tree
A) Season-I				
i) Maize	39	46	34	38
ii) Soybean	35	42	31	36
B) Season-II				
i) Wheat	63	66	52	58
ii) Lentil	59	65	50	54

In Rabi season also, the per cent RI exhibited the trend similar to Kharif season. Morus allowed more light to infiltrate below its canopy as compared to peach. However, under both the tree canopies, along with wheat and on south direction of the tree it had shown maximum value as compared to lentil and on north direction, respectively.

4.3 Comparative performance of different land use systems

Comparative performance of SC, AS, AH and AHS systems under the two cropping patterns used in these studies have been studied in terms of biomass productivity, nutrient dynamics and economic returns and described as under:

4.3.1 Biomass productivity^a

A) Cropping pattern-I

The data presented in Table 39 reveals that AS system recorded the highest productivity of $228.50 \text{ q ha}^{-1}\text{yr}^{-1}$ followed by AHS (207.29), AH (185.15) and SC (174.70), yielding 1.10, 1.23 and 1.31 fold higher than the latter three systems, respectively. In SC system, the field crops formed 100 per cent (34.41% grain + 65.69% straw) of the total productivity. Field crops also had major contribution to other land use systems, representing 85.77, 73.35 and 71.58 per cent of AH, AHS and AS systems, respectively. Morus also played a key role in the biomass productivity of AS and AHS systems contributing 28.42 and 15.57 per cent of the total, respectively. Peach contributed 14.23 per cent in AH and 11.08 in AHS systems productivity. However, the per cent contribution of morus was higher (15.57%) than the peach (11.08%) in AHS system.

B) Cropping pattern-II:

It is evident from the data presented in Table 39 that AS system recorded the highest productivity of $213.82 \text{ q ha}^{-1}\text{yr}^{-1}$ followed by AHS (196.61), AH (175.80) and SC (165.82), yielding 1.09, 1.22 and 1.29 fold higher than the latter three systems, respectively. In SC system, the field

Table 39. Biomass productivity ($t\ ha^{-1}\ yr^{-1}$) of different land use systems (1994-95)

Component	Cropping pattern-I												Cropping pattern-II											
	Sole cropping			Agrosilviculture			Agrihorticulture			Agrihortisilviculture			Sole cropping			Agrosilviculture			Agrihorticulture			Agrihortisilviculture		
	Maize	Lentil	Total	Morus + maize	Morus + lentil	Total	Peach + maize	Peach + lentil	Total	Morus+ peach+ maize	Morus+ peach+ lentil	Total	Soybean wheat	Soybean wheat	Total	Morus + soybean	Morus + wheat	Total	Peach + soybean	Peach + wheat	Total	Morus+ peach+ soybean	Morus+ peach+ wheat	Total
A) Field crops																								
Grain	42.17	17.95	60.12	39.21	15.38	54.59	38.50	13.14	51.64	37.47	12.05	49.52	19.85	35.19	55.07	18.91	30.59	47.50	18.52	28.63	47.15	18.75	27.51	46.26
Straw	70.34	44.24	114.58	66.19	40.79	106.98	68.07	39.09	107.16	66.53	35.99	102.52	50.45	60.30	110.75	43.84	55.81	99.74	47.63	55.54	103.17	40.34	50.71	91.05
Sub total	112.51	62.19	174.70	107.40	56.17	163.57	106.57	52.23	158.80	104.00	48.04	152.04	70.30	95.49	165.82	62.75	86.51	147.26	66.15	84.17	150.32	59.09	78.22	137.31
	(100%)	(100%)	(100%)	(62.32%)	(100%)	(71.58%)	(100%)	(66.47%)	(85.77%)	(76.31%)	(67.65%)	(73.35%)	(100%)	(100%)	(100%)	(47.72%)	(100%)	(66.65%)	(100%)	(77.65%)	(100%)	(80.22%)	(78.62%)	(71.55%)
B) Morus																								
Leaf	-	-	-	17.71	-	17.71	-	-	-	9.86	-	9.86	-	-	-	18.43	-	18.43	-	-	-	12.83	-	12.83
Branch	-	-	-	47.22	-	47.22	-	-	-	22.42	-	22.42	-	-	-	48.13	-	48.13	-	-	-	20.15	-	20.15
Sub total	-	-	-	64.93	-	64.93	-	-	-	32.28	-	32.28	-	-	-	66.56	-	66.56	-	-	-	32.98	-	32.98
				(37.68%)		(28.42%)				(23.69%)		(15.57%)				(52.28%)		(31.13%)				(36.77%)		(17.92%)
C) Peach																								
Fruit	-	-	-	-	-	-	-	17.00	17.00	-	16.12	16.12	-	-	-	-	-	-	-	14.80	14.80	-	13.46	13.46
Pruned-wood	-	-	-	-	-	-	-	9.35	9.35	-	6.85	6.85	-	-	-	-	-	-	-	9.38	9.38	-	7.00	7.00
Sub total	-	-	-	-	-	-	-	26.35	26.35	-	22.97	22.97	-	-	-	-	-	-	-	24.18	24.18	-	20.46	20.46
								(33.53%)	(14.23%)		(32.35%)	(11.08%)								(22.05%)	(13.75%)		(20.32%)	(16.42%)
Total	112.51	62.19	174.70	172.33	56.17	228.50	106.57	78.58	185.15	136.28	71.01	207.29	70.30	95.49	165.82	127.31	86.51	213.82	86.15	109.55	175.80	95.84	102.77	198.61

Figures in parentheses indicate the percentage of the total for each category

crops contributed 100 per cent (33.21% grain + 66.79% straw) of the total productivity. Whereas, their contribution were observed to be 77.95, 71.66 and 68.85 per cent in AH, AHS and AS system, respectively. It was further observed from the data that morus in AS and AHS system contributed 31.15 and 17.92 per cent of the total, respectively. Peach contributed 13.75 per cent in AH system whereas, 10.42 per cent in AHS system. However, the per cent contribution of morus was higher (17.92%) than the peach (10.42%) in AHS system.

4.3.2 Nutrient dynamics

4.3.2.1 Soil fertility status

The data pertaining to the effect of SC, AS, AH and AHS system on pH, organic carbon and available NPK in 0-30 cm soil layer studied under two cropping patterns before the sowing of first crop and after every harvest have been given in Table 40 and described as below:

A) pH

It is evident from the data that among the different land use systems, pH of the soil ranged between 7.31 to 7.38 in July, 1994 (before sowing of maize/soybean), 7.29 to 7.35 in October, 1994 (after harvesting maize/soybean) and 7.30 to 7.36 in May, 1995 (after harvesting wheat/lentil). The pH had shown a decrease after the harvest of maize/soybean whereas a slight increase in its values were observed after the harvest of wheat/lentil. In general, on all the sampling dates, SC system recorded higher pH followed by AS, AH and AHS system irrespective of the cropping patterns however, cropping pattern-II had shown higher values over cropping pattern-I.

B) Organic carbon

It is seen from the data (Table 40) that among the different land use systems, organic carbon content in soil ranged between 0.69 to 0.76 per cent in July, 1994 (before sowing of maize/soybean), 0.73 to 0.80 per cent in October, 1994 (after harvesting maize/soybean) and 0.70 to 0.80 per cent in May, 1995 (after harvesting wheat/lentil). The organic carbon content in soil had shown an increase after the harvest of maize/soybean whereas a slight decrease in its values were observed after the harvest of wheat/lentil. In general, AHS system had shown higher soil organic carbon content followed by AH, AS and SC system. Cropping pattern-I depicted higher values over cropping pattern-II.

C) Available NPK

It is evident from the data (Table 40) that available N, P and K was more in AHS system followed by AH, AS and minimum in SC system in all the sampling months irrespective of the cropping patterns. After harvesting maize/soybean in October, 1994, cropping pattern-I (maize-lentil) had shown higher values of available P and K over cropping pattern-II (soybean-wheat), whereas, for available N an opposite trend was observed. But after harvesting wheat/lentil in May, 1995, cropping pattern-I excel over cropping pattern-II for all the three nutrient elements. It was further deduced from the data that growing of cereals resulted into the depletion of soil reserves of available N, P and K but pulses had shown an increase in soil available N though they were also observed to be depletor of available P and K in soil. In general, the depletion of soil fertility was more severe in SC system followed by AS, AH and AHS system.

Table 40. Soil fertility status of different land use systems (1994-95)

Landuse systems	July 1994 (before sowing maize/soybean)					October 1994 (after harvesting maize/soybean)					May 1995 (after harvesting wheat/lentil)				
	pH	O.C. (%)	Available nutrient (kg ha ⁻¹)			pH	O.C. (%)	Available nutrient (kg ha ⁻¹)			pH	O.C. (%)	Available nutrient (kg ha ⁻¹)		
			N	P	K			N	P	K			N	P	K
A) Sole cropping															
1. Cropping patter-I (Maize-lentil)	7.35	0.72	442	34	358	7.32	0.74	432	30	351	7.35	0.72	440	26	348
2. Cropping pattern-II (Soybean-wheat)	7.38	0.69	438	32	350	7.35	0.73	444	27	347	7.36	0.70	435	22	341
B) Agrisilviculture															
1. Cropping pattern-I (Morus/maize-lentil)	7.33	0.73	444	35	361	7.31	0.75	435	32	356	7.33	0.73	445	29	354
2. Cropping pattern-II (Morus/soybean-wheat)	7.35	0.71	441	32	352	7.33	0.74	448	28	349	7.35	0.71	441	24	344
C) Agrihorticulture															
1. Cropping pattern-I (Peach/maize-lentil)	7.31	0.76	448	37	366	7.29	0.79	441	35	362	7.31	0.79	454	34	360
2. Cropping pattern-II (Peach/soybean-wheat)	7.33	0.75	445	35	357	7.31	0.79	453	33	356	7.32	0.78	449	30	354
D) Agrihortisilviculture															
1. Cropping pattern-I (Peach+Morus/maize/lentil)	7.31	0.76	449	38	367	7.29	0.79	442	35	364	7.30	0.80	455	34	363
2. Cropping pattern-II (Peach+Morus/soybean-wheat)	7.32	0.76	447	36	359	7.31	0.80	455	34	358	7.32	0.80	453	32	356

The values of N, P and K have been expressed as N, P₂O₅ and K₂O

4.3.2.2 Addition and removal of N, P and K

The data pertaining to the annual input and output trends of N, P and K under SC, AS, AH and AHS system in cropping pattern-I (maize-lentil) and II (soybean-wheat) have been tabulated in Table 41 and described as under:

A) Addition

It is evident from the data (Table 41) that N, P and K addition was higher in AH system closely followed by AHS and minimum in AS system following SC in both the cropping patterns. A further analysis of the data revealed higher N and P addition in cropping pattern-I compared to cropping pattern-II whereas, K addition had shown a reverse trend showing maximum values in cropping pattern-II than cropping pattern-I.

B) Removal

A critical examination of the data (Table 41) revealed that in both the cropping patterns removal of N, P and K was higher through AS system. However, in cropping pattern-I SC system for N and K and AHS system for P had shown minimum removal whereas, in cropping pattern-II AH system for N, AHS for P and, SC system for K removal registered minimum values. It was further deduced from the data that N removal was higher in cropping pattern-II than cropping pattern-I whereas, P and K removal was noticed to be higher in cropping pattern-I as compared to cropping pattern-II. In general, the pattern of nutrient removal was as follows: $N > K > P$.

4.3.2.3 Balance of N, P and K

It is evident from the data (Table 42) that in both the cropping patterns, all the four land use systems i.e. SC, AS, AH and AHS system had shown a net gain of available N in soil. However, AS system registered higher net gain followed by SC, AH and AHS system. Furthermore, cropping pattern-II (soybean-wheat) resulted in higher net gain of available N than cropping pattern-I.

The data further reveal that in both the cropping patterns, all the four land use systems proved to be exhaustive for available P. However, the net loss was more in AHS system closely followed by AH system whereas, minimum in AS system following SC system. Moreover, cropping pattern-I was found to be more exhaustive than cropping pattern-II.

A critical resume of the data further indicated that all of the four land use systems resulted in net gain of available K in soil, however, AH and AHS systems were found to be exhaustive in cropping pattern-II. It was further observed from the data that in cropping pattern-I, AS system had shown maximum net gain of available K followed by SC, AHS and AH system. But in cropping pattern-II, AS system proved to be more restorative over SC system whereas, AH system turned out to be more exhaustive than AHS system. In general, P was depleted in maximum quantity followed by K whereas, N have shown net gain.

4.3.3 Economic returns

4.3.3.1 Gross returns

Annual gross returns obtained from SC, AS, AH and AHS systems in

Table 42. Nutrient balance in different land use systems (1994-95)

Nutrient element	Cropping pattern-I							Cropping pattern-II						
	Initial status	Amount added	Total amount (initial+ added)	Cumulative removal by crops+trees	Expected balance	Actual balance	*Net gain or loss	Initial status	Amount added	Total amount (initial+ added)	Cumulative removal by crops+trees	Expected balance	Actual balance	*Net gain or loss
Available nitrogen (kg N ha^{-1})														
Sole cropping (maize-lentil)	442	106	548	252	296	440	+144	438	66	504	331	173	435	+262
Agrosilviculture (morus/maize-lentil)	444	103	547	277	270	445	+185	441	64	505	337	188	441	+273
Agrihorticulture (peach/maize-lentil)	448	158	606	252	354	445	+100	445	120	565	326	239	449	+210
Agrihortisilviculture (peach+morus/maize-lentil)	449	157	606	254	352	455	+103	447	189	636	330	306	453	+147
Available phosphorus ($\text{kg P}_2\text{O}_5 \text{ ha}^{-1}$)														
Sole cropping (maize-lentil)	34	90	124	36	88	26	-62	32	80	92	33	59	22	-37
Agrosilviculture (morus/maize-lentil)	35	87	122	38	84	29	-55	32	58	90	35	55	24	-31
Agrihorticulture (peach/maize-lentil)	35	112	147	36	111	34	-77	35	83	118	32	86	30	-56
Agrihortisilviculture (peach+morus/maize-lentil)	38	112	150	38	114	34	-80	36	83	119	31	88	32	-56
Available potassium ($\text{kg K}_2\text{O ha}^{-1}$)														
Sole cropping (maize-lentil)	358	44	402	126	276	348	+72	350	69	419	116	303	341	+38
Agrosilviculture (morus/maize-lentil)	361	43	404	152	252	354	+102	352	67	419	139	280	344	+84
Agrihorticulture (peach/maize-lentil)	368	108	474	133	341	360	+19	357	132	489	122	367	354	-13
Agrihortisilviculture (peach+morus/maize-lentil)	367	108	475	142	333	363	+30	359	132	491	132	359	356	-3

*Amount of nutrients retained in the non harvested tree components are not included since complete harvest of trees was not permissible

cropping pattern-I and II have been presented in Table 43 and described as under:

A) Cropping pattern-I

It is perused from the data given in Table 43 that AHS system furnished the highest annual gross returns amounting to Rs.48776 ha⁻¹ closely followed by AH system (Rs.48463 ha⁻¹), whereas, minimum gross returns were obtained from SC system (Rs.41143 ha⁻¹) preceded by AS system (Rs.43287 ha⁻¹). The gross returns from AHS system were 1.01, 1.13 and 1.19 times higher than the latter three systems, respectively. Field crops were the major contributors even in AHS system providing 65.44 per cent of the total returns mostly through their grains (89.32% of the crop). About 6.47 and 28.09 per cent of the total returns of the said system corresponded to fodder tree (morus) and fruit tree (peach), respectively. The fodder tree contributed major portion of its returns through branches (87.50% of the tree) while fruit tree showed maximum contribution through its fruits (94.10% of the tree). In AH system the contribution of field crops and fruit tree being 69.66 per cent and 30.34 per cent, respectively. In AS system field crops contributed 84.95 per cent while fodder tree 15.05 per cent of the total returns. In contrast, field crops solely formed 100 per cent of the total returns in SC system.

B) Cropping pattern-II

A critical resume of the data (Table 43) shows that AH system contributed the highest gross returns of Rs.46172 ha⁻¹yr⁻¹ closely followed by AHS system (Rs.45488 ha⁻¹yr⁻¹). SC system furnished minimum (Rs.36970

Table 43. Gross returns (kg ha⁻¹yr⁻¹) from different land use systems (1994-95)

Components	Cropping pattern-I												Cropping pattern-II											
	Sole cropping			Agrisilviculture			Agrihorticulture			Agrihortisilviculture			Sole cropping			Agrisilviculture			Agrihorticulture			Agrihortisilviculture		
	Maize	Lentil	Total	Morus	Morus	Total	Peach	Peach	Total	Morus+	Morus+	Total	Soybean	Wheat	Total	Morus	Morus	Total	Peach	Peach	Total	Morus+	Morus+	Total
				+	+		+	+		Peach+	Peach+					+	+		+	+		Peach+	Peach+	
				Maize	Lentil		Maize	Lentil		Maize	Lentil					soybean	Wheat		Soybean	Wheat		Soybean	Wheat	
A) Field Crops																								
Grain	15814	21540	37354	14704	18495	33199	14437	15768	30205	14051	14460	28511	15904	14076	29980	13528	12235	25764	14216	11932	26148	13408	11036	24444
Straw	2462	1327	3789	2387	1224	3611	2382	1173	3555	2329	1080	3409	1261	5729	6990	1096	5312	6408	1191	5286	6477	1098	5007	6105
Sub-total	18276	22867	41143	17091	19719	36810	16819	16941	33760	16380	15540	31920	17165	19805	36970	14624	17547	32172	16007	17218	33225	14506	16043	30549
	(100%)	(100%)	(100%)	(72.40%)	(100%)	(84.95%)	(100%)	(53.54%)	(69.66%)	(83.85%)	(53.14%)	(65.44%)	(100%)	(100%)	(100%)	(68.72%)	(100%)	(82.86%)	(100%)	(57.08%)	(71.96%)	(81.32%)	(58.02%)	(67.16%)
B) Morus																								
Leaf	-	-	-	708	-	708	-	-	-	394	-	394	-	-	-	737	-	737	-	-	-	484	-	484
Branch	-	-	-	5908	-	5908	-	-	-	2758	-	2758	-	-	-	5920	-	5920	-	-	-	2647	-	2647
Sub-total	-	-	-	6616	-	6616	-	-	-	3152	-	3152	-	-	-	6657	-	6657	-	-	-	3331	-	3331
				(27.60%)		(150.05%)				(16.14%)		(6.47%)				(31.28%)		(17.14%)				(18.68%)		(7.32%)
C) Peach																								
Fruit	-	-	-	-	-	-	-	13600	13600	-	12896	12896	-	-	-	-	-	-	-	11840	11840	-	10784	10784
Pruned wood	-	-	-	-	-	-	-	1103	1103	-	808	808	-	-	-	-	-	-	-	1107	1107	-	826	826
Sub-total	-	-	-	-	-	-	-	14703	14703	-	13704	13704	-	-	-	-	-	-	-	12947	12947	-	11610	11610
								(46.46%)	(30.34%)		(46.86%)	(28.09%)								(42.92%)	(28.04%)		(41.98%)	(25.52%)
Total	18276	22867	41143	23607	19880	43287	16819	31644	48483	19532	29244	48776	17165	19805	36970	21281	17548	38829	16007	30165	46172	17835	27653	45488

Table 44. Total cost and net returns from different land use systems (1994-95)

	Cropping pattern-I				Cropping pattern-II			
	Sole cropping	Agrisilvi-culture	Agrihorti-culture	Agrihorti-silviculture	Sole cropping	Agrisilvi-culture	Agrihorti-culture	Agrihorti-silviculture
A) Biomass productivity (g ha ⁻¹ yr ⁻¹)	174.70	228.50	185.15	207.29	165.82	213.82	175.80	196.61
B) Gross returns (Ps. ha ⁻¹ yr ⁻¹)	41143	43287	48463	48776	36970	38829	46172	45488
C) Total costs (Ps. ha ⁻¹ yr ⁻¹)	13230	14248	16521	17222	12656	13689	15977	16678
D) Net returns (Ps. ha ⁻¹ yr ⁻¹)	27913	29039	31942	31554	24314	25140	30195	28810

from SC system (Rs.27913 ha⁻¹yr⁻¹) following AS system (Rs.29039 ha⁻¹yr⁻¹), In cropping pattern-II also, AH system furnished higher (Rs.30195 ha⁻¹yr⁻¹) net returns followed by AHS (Rs.28810 ha⁻¹yr⁻¹), AS (Rs.25140 ha⁻¹yr⁻¹) and minimum in SC system (Rs.24314 ha⁻¹yr⁻¹). In general, cropping pattern-I was found to be more remunerative than cropping pattern-II.

Chapter 5

DISCUSSION

The results obtained from the present investigations entitled "Bio-economic appraisal of agroforestry land use systems" have been discussed in this chapter, establishing a cause and effect relationship wherever necessary or feasible, in the light of available literature, under the following heads:

5.1 Agrisilviculture System

- 5.1.1 Growth and yield performance of field crops and fodder tree
- 5.1.2 Nutrient content and uptake in field crops and fodder tree
- 5.1.3 Soil moisture content
- 5.1.4 Relative illumination

5.2 Agrihortisilviculture System

- 5.2.1 Growth and yield performance of field crops, fodder and fruit tree
- 5.2.2 Nutrient content and uptake in field crops, fodder and fruit tree
- 5.2.3 Soil moisture content
- 5.2.4 Relative illumination

5.3 Comparative performance of different land use systems

- 5.3.1 Biomass productivity
- 5.3.2 Nutrient dynamics
- 5.3.3 Economic returns

5.1 Agrisilviculture system

5.1.1 Growth and yield performance of field crops and fodder tree

A) Field crops

Growth and yield performance data of different field crops namely maize, soybean, wheat and lentil grown in association with morus i.e. under

agrisilviculture system have been recorded in Tables 1-8. The results thus obtained have been discussed as under:

It was observed from the data that growth attributes viz., plant height and number of plants m^{-2} increased with the decrease in number of morus trees per treatment. Distance of the crop from tree row also affected these characters significantly showing a decreasing effect with the increase in distance. However, direction of the crop from tree row depicted significantly higher values in the south as compared to north. Crop maturity was found to be delayed in the treatments having more number of trees whereas, the crops tended to mature in lesser number of days as the number of trees per treatment decreased. It was further deduced from the results that all the four field crops matured in longer time growing near to and in north direction of the tree row. However, the time taken by the field crops to mature was observed to be less with the increase in distance i.e. from distance D_1 to D_3 and in south direction.

Among the different field crops studied, it was inferred from the growth data that maize and soybean crops (Kharif season crops) were affected more adversely than wheat and lentil (Rabi season crops) due to morus tree association.

Yield attributes namely number of cobs/pods/spikes per plant, 1000 grain weight, grain yield, straw yield and harvest index of maize, soybean, wheat and lentil experienced effects similar to growth attributes viz. plant height and number of plants m^{-2} . Considering the grain yield of the different field crops under study it was inferred that wheat and soybean crops yield experienced comparatively higher depressing effect due to

number of morus trees per treatment, crop distance and direction as well. These were followed by lentil and maize crops. In general, distance of the crop from tree row exhibited more pronounced effect than the number of trees per treatment followed by direction of the crops.

The depressing effect of morus on the growth and yield of different field crops as discussed above may be due to higher competition for space, moisture, nutrients and light at the tree-crop interface, which is also evident from the present studies that the depressing effect of morus tree association on the growth and yield attributes decreased significantly with the decrease in number of trees per treatment as well as with the increase in distance. Additionally, the available soil moisture content in wheat plots during the month of April (Table 17), the stage of grain formation and ripening, fell below the available soil water limits (6-7%) which may have caused a higher reduction in its yield.

The results are in line with the findings of Yamoah *et al.* (1986), Huxley *et al.* (1989) and Krim *et al.* (1991) who reported lower crop growth and yield adjacent to hedgerow than in the centre of alley. Dhillon *et al.* (1979), Sharma (1992) have indicated increased crop growth and yield with the increase in distance from tree row. Whereas, Sheikh (1987) reported poor wheat crop yield on the northern side of *Acacia nilotica*.

B) Morus

An examination of the data in Table 9 and 10 have revealed that growth and yield parameters viz., height, diameter, crown spread, branch and leaf biomass of morus were found to be maximum in treatment T₃ (1 morus

tree) as compared to T_2 (2 morus trees) and T_1 (3 morus trees). Cropping pattern-II (soybean-wheat) was observed to be more compatible than cropping pattern-I (maize-lentil) for promoting morus growth and yield. The better performance of morus in treatment T_3 can be attributed to the ample light, soil moisture and nutrient availability. Likewise in cropping pattern-II wheat is the only exhaustive crop and its active growth period is different from morus. So, it may not have caused extra competition for the resources required to attain its optimum growth and development which resulted in better growth and biomass yield of morus. The results are in line with the findings of Maiti *et al.* (1993) who reported higher productivity of subabul when grown in fallow-rice-mustard sequence as compared to those grown in maize-cowpea-mustard and maize-sorghum-mustard sequences. Khybri *et al.* (1992) reported a yield of $1.28 \text{ t ha}^{-1}\text{yr}^{-1}$ of branches and $0.28 \text{ t ha}^{-1}\text{yr}^{-1}$ of leaves from *Morus alba* when intercropped with rice-wheat rotation.

5.1.2 Nutrient content and uptake in field crops and fodder tree

A) Field crops

The nutrient- (N,P,K) concentration and their uptake in grain and straw of maize, soybean, wheat and lentil (Tables 11 to 14) were found to differ significantly due to tree-crop treatments, distance and direction of the crops from tree row. Both nutrient content as well as uptake were found to be maximum in treatment T_4 i.e. open-control, distance D_3 (4 m) and direction DR_2 (south) however, P content in case of maize and soybean was found to be higher in DR_1 . The higher nutrient concentrations in treatment T_4 and at distance D_3 are obviously due to more availability of resources and less competition as the plants were away from tree-crop interface. The

effect of direction on the nutrient content may be due to the higher availability of light, temperature and faster mineralization as the trees have been planted in E-W direction thereby causing more light in south direction and shade in north direction. Higher nutrient uptake can be ascribed to the higher biomass yield at these positions.

All the above field crops responded differently to nutrient utilization capacity, grown in association with morus trees. Considering their respective N, P and K content in totality (grain+straw) obtained from open control versus morus associations, the following depressing trends were delineated. Nitrogen: maize >wheat >soybean >lentil; Phosphorus: maize >soybean >wheat >lentil; Potassium: maize >soybean >wheat >lentil. Distance and direction of the crop from tree row had more depressing effect on N P and K content in maize/soybean than wheat/lentil which indicates that Kharif season crops are more affected than rabi season crops due to tree-crop competition for these nutrients. The above trends may be due to the reason that maize and soybean crops require higher amount of N, P and K than wheat and lentil. Additionally, the active growth season to put in maximum biomass and utilization of nutrients for maize/soybean and morus is the same. Hence, these crops are liable to be affected more in comparison to wheat and lentil. Similar results have been reported by Yamoah *et al.* (1986a), Krim (1987) and, Hagggar and Beer (1993) who observed lower N content in maize growing next to the rows than in the middle of alley because of greater competition for light, water and/or nutrients near to trees. Dinssa (1993) reported lower N and P concentrations in soybean when intercropped with morus as compared to open control.

B) Morus

The N, P and K content in leaves and branches of morus did not differ significantly due to various tree-crop treatments however, significant variations were observed in their uptake under both the cropping patterns showing maximum value in treatment T₃ and minimum in T₁. It was also observed from the data that content of all the three nutrient elements especially nitrogen was slightly higher in the trees under cropping pattern-II (soybean-wheat). The significant differences in nutrient uptake in leaves and branches can be attributed to their higher biomass yield. However, slightly higher nutrient content under cropping pattern-II may have resulted because morus trees were growing in association with soybean during the period of sampling i.e. October, 1994 whereas, under cropping pattern-I (maize-lentil) maize was the associated crop. Maize being nutrient exhaustive and soybean nutrient replenishing, the latter may have rendered the nutrient pool available more to the morus. Similar observations in respect of nutrient content in morus leaves have also been reported by Pal *et al.* (1979), Debroy *et al.* (1980) and Khatta and Katoch (1983).

5.1.3 Soil moisture content

It is evident from the results given in Table 16 that soil moisture content in case of maize decreased significantly in treatment T₁ (3 morus trees) over the control during the months of June, September and October. Whereas during the months of July and August the variation in soil moisture content was non-significant. In case of soybean, the soil moisture content varied significantly between the aforesaid treatments, however, remained

statistically non-significant during the months of July and October. The non-significant changes during the month of July and August are obviously due to the peak period of rainy season. However, the non-significant changes in case of soybean during the month of October may be attributed to the reason that this crop may be utilizing lesser volumes of soil moisture than the maize crop. The above hypothesis is also corroborated from the findings that soil moisture increased with the increase in distance from the tree row throughout the growth season in both the crops. However, overall soil moisture content in case of soybean was higher during the entire growth season irrespective of distance and direction, especially in the month of October.

The variation in soil moisture content in wheat and lentil (Table 17) followed a trend similar to maize and soybean however, it had shown considerably lesser values. These results are quite discernible as wheat and lentil crops are cultivated in rabi season a period of scanty rainfall in the mid hills of H.P. Himalaya. It was further evinced from the results that soil moisture content in these two crops during the months of November, December, April and May reduced to the levels below the available soil water limits especially in treatments T₁ (3 morus trees) and T₂ (2 morus trees). This reduction in the soil moisture content can be attributed to the higher competition between the morus trees and the field crops. The results are in conformity with the findings of Connor (1983), Singh *et al.* (1989), Rao *et al.* (1990) and Srivastava *et al.* (1993) who reported poor moisture regime near the tree row.

5.1.4 Relative illumination (RI)

The data presented in Table 18 indicating the per cent relative illumination below the morus canopies revealed that in Kharif season the average illumination of incident radiation were lower under the trees growing with soybean as compared to maize. Likewise in rabi season, lentil plots have shown lower RI than the wheat growing plots. Directionally - plots in south depicted higher RI values over the north irrespective of the season. In general, RI was higher in rabi season.

The lower RI values under the trees growing with soybean and lentil may be due to higher crown spread of morus as compared to the trees growing with maize and wheat. This has also been evidenced from the crown development studies in the present case (Table 9). Higher RI values in south can be ascribed to the uninterrupted flow of radiations as the trees have been planted from east-west direction.

In rabi season higher RI was observed which may be due to smaller crown spread because in rabi season morus trees are still in their initial stage of crown development and could attain only small crowns because of complete lopping practices. The results are in line with the findings of Hazara and Tripathi (1986), Singh *et al.* (1989), Kaba (1993) and Jaiswal *et al.* (1993) who reported reduced light infiltration under the tree canopies.

5.2 Agrihortisilviculture system

5.2.1 Growth and yield performance of field crops, fodder and fruit trees

A) Field crops

The growth and yield behaviour of maize, soybean, wheat and lentil

studied in association with morus and peach under agrihortisilviculture system (Tables 19 to 26) have revealed that different growth attributes viz., plant height, number of plants m^{-2} and crop maturity were affected significantly due to different tree-crop treatments. However, results pertaining to number of plants m^{-2} in case of maize remained statistically non-significant. Furthermore, plant height and number of plants m^{-2} were found to increase with the increase in distance from tree row and displayed better performance in south direction. Similarly, crops took minimum time to mature with the increase in distance from tree row and in southern direction compared to north. It was further observed that growth characters namely plant height, number of plants m^{-2} and crop maturity in case of maize and soybean had higher depressing effect due to morus association than peach. However, wheat and lentil crops exhibited an opposite behaviour than maize and soybean.

The dominant suppressing effect of morus association on the growth attributes of maize and soybean may be explained as both components of the systems i.e. morus-soybean/maize have got same active growth period which may have caused competition for nutrients and other resources. Similarly, peach association have caused more suppressing effect on the growth attributes of wheat and lentil. The suppressing effect of peach on plant height may have occurred due to the reason that during the period of March and April when wheat and lentil attain maximum height the peach tree also becomes active, wherein flowering and fruit set starts. Such a situation may have resulted in severe competition between the two components of the system. The resulting competition may have caused an extended effect on the crop maturity also.

Yield attributes viz. number of cobs/pods/spikes per plant, 1000 grain weight, grain yield, straw yield and harvest index of maize, soybean, wheat and lentil were found to increase with the increase in distance from tree row. Significantly higher values were shown in south direction. This may have occurred due to decrease in competition between the tree and crops for space, moisture, nutrients and light with the increase in distance.

In general yield attributes were suppressed by different morus-peach treatments over control, however, considering the grain yield of above field crops it was inferred from the results that peach tree association had caused more reduction in the yield of maize, wheat and lentil. Whereas, soybean yield was suppressed more by morus association. Harvest index though have shown significant differences over control yet only marginal differences have been noticed due to different tree-crop treatments especially in maize, soybean and lentil. It showed significant and increasing trend with the increase in distance from the tree row for all the field crops, indicating that with the increase in distance the increase in grain yield was more than the straw yield as harvest index is a function of grain yield divided by grain plus straw yield.

The reduction in grain yield of soybean due to morus is obvious as it had influenced the growth and yield attributing characters of soybean markedly whereas, decreased maize grain yield under peach may be due to low light availability under peach canopies. Also maize is a C₄ plant and perform adversely in the shade. The lower wheat and lentil grain yield under peach can be ascribed to increase in tree-crop competition for site resources as both components of the system have similar active growth period.

In general, it would be deduced from the study that distance of the field crops from the tree row accounted for most of the experimental variability compared with tree-crop treatments or direction. Tree crop treatment was of greater importance than direction.

The results, lower crop growth and yield under trees compared to open plots are in line with the findings of Mittal and Singh (1985), Huxley *et al.* (1989), Lal (1989), and Maiti *et al.* (1993). The lower wheat and lentil yield due to peach can also be supported with the findings of Rao and Coe (1992). Many other workers have reported reduced field crops yield at closer proximity to the trees viz. Khan and Aslam (1974), Akbar *et al.* (1990), Khybri *et al.* (1992) and Sharma (1992). The higher crop yields on southern direction are well supported by the findings of Dhillon *et al.* (1984) and Puri and Bangarwa (1992).

B) Growth and yield performance of morus and peach

The results presented in Table 27 pertaining to the growth attributes viz., height, diameter and crown spread of morus under the two cropping patterns in season-I and season-II have shown that treatment T₅ (1 morus tree) gave the maximum values over all other treatments. Among the two cropping patterns, cropping pattern-II i.e. soybean-wheat was noticed to promote the growth attributes over the cropping pattern-I (maize-lentil). The leaf and branch yield of morus as is evident from Table 29 followed the trend similar to growth attributes.

The data presented in Table 28 indicating the effect of treatments, cropping pattern and season of the crop on the growth and development of

peach whereas the data given in Table 29 showing the effect of above factors on the peach yield have clearly indicated that treatment T₄ (1 peach tree) have given better and higher values for all the growth and yield attributing characteristics. The effect of cropping pattern and season on the peach was similar to that of morus. However, cropping pattern-I have shown better fruit yield than cropping pattern-II.

It is inferred from the above findings that growth and yield of morus and peach trees is higher in the treatments having single tree in either of the cropping pattern. Cropping pattern-II i.e. soybean-wheat has been found more conducive to their better growth and development in general. The adverse effects of cropping pattern-I over cropping pattern-II may be due to the reason that maize crop used in this cropping pattern is more exhaustive and competitive than the crops used in cropping pattern-II. The higher branch and leaf yield of morus in cropping pattern-II may^{be} due to the beneficial effects of soybean whereas the better fruit yield^{of} peach in cropping pattern-I can be ascribed to promoting effects of lentil. Similar observations have been reported by Gupta *et al.* (1982), Arora and Mohan (1986), Mittal (1988), Khybri *et al.* (1992), Maiti *et al.* (1993) and Kumar (1994).

5.2.2 Nutrient content and uptake

A) Field crops

An analysis of the data presented in Tables 30-33 have evinced that N, P and K content in the grain and straw of maize as well as soybean were found to be affected significantly due to different tree-crop treatments. It was deduced from the data that among the various tree-crop treatments

maximum N, P and K content was observed in treatment T₄ (1 peach tree) followed by T₅ (1 morus tree). It was interesting to note that treatments involving peach as an associated tree resulted in higher nutrient content in maize and soybean whereas, in case of wheat and lentil, treatments involving morus as an associated tree gave higher N, P and K content in grain and straw components. However, the highest values were observed under treatment T₆ i.e. open control.

It was further inferred from the data that the nutrient content in grain and straw components of all the field crops under study increased with the increase in distance from the tree row. Direction DR₂ (south) reflected higher nutrient content in grain and straw, irrespective of the crop however, P content was found to be higher in direction DR₁ (north) for maize and soybean. Nutrient uptake in all the field crops (Table 30-33) followed the trend similar to their content in grain and straw irrespective of treatment, distance and direction.

The increase in nutrient content of maize and soybean crops due to peach association can be explained to the effect that the peach trees have been supplied with additional amount of fertilizers and manures every year whereas, the morus trees are grown under natural conditions. The applied fertilizers and manures may not be available to the wheat and lentil crops because of dormancy and low temperature coupled with moisture stress during their maximum growth period. The supplementary effect of fertilizers and manures applied to the peach trees may have been utilized by the subsequent crops i.e. maize and soybean. The suppressing effect of morus on maize and soybean nutrient content may be due to the reason that the period of

maximum foliage production and crown development of morus coincides with the maximum vegetative growth period of maize and soybean which may have caused severe competition for nutrients and hence low availability to maize and soybean. The results are in line with the findings of Miler *et al.* (1987), Krim (1987), Haggar and Beer (1993) and Dinssa (1993).

B) Morus and peach

The N, P and K content in morus branch and leaf (Table 34); pruned wood and fruits of peach (Table 35) have shown marginal differences due to various tree-crop treatments but remained statistically non-significant under both the cropping patterns. However, N, P and K uptake was observed to be statistically significant which may be due to higher biomass yield. Almost similar nutrient content in morus and peach have been reported by Pal *et al.* (1979), Debroy *et al.* (1980), Verma (1986), Arora and Mohan (1986) and Azad *et al.* (1990).

5.2.3 Soil moisture content

The soil moisture content (Table 36 and 37) was found to be maximum in the open field (T_6), at farthest distance from tree row (D_3) and in south direction (DR_2), irrespective of cropping pattern and season of the crop. However, season-II, in the months of March, April and May have shown higher soil moisture content on north direction (DR_1) as compared to south direction (DR_2). In cropping season-I depletion of soil moisture was more under morus as compared to peach whereas in cropping season-II peach proved to be more exhaustive. In general, soil moisture content was more under soybean as compared to maize in cropping season-I and under lentil as

compared to wheat in cropping season-II with a few exceptions. The lower soil moisture under trees as compared to open may be due to higher evaporative demands of tree species and greater concentration of roots in the upper soil horizon. The pronounced effect of morus in cropping season-I may be due to the fact that during this period morus was in its active growth phase and may therefore, have extracted larger volume of soil water whereas in cropping season-II adverse effect of peach can be ascribed to the fact that trees after recovering from pruning attain more leaf area (as compared to morus) and therefore, exerted more pressure on limited soil moisture during dry season. More soil moisture under soybean as compared to maize and under lentil as compared to wheat may be due to the differences in phytomass and obviously the leaf area index. The results are in line with the findings of Corlett *et al.* (1989), Singh *et al.* (1989), Rao *et al.* (1990) and Shrivastava *et al.* (1993) who reported poor soil moisture in agroforestry combination as compared to sole cropping and establishes that as the distance from tree row increases it also shows an improvement.

5.2.4 Relative illumination(RI)

It was inferred from the data in Table 38 that the RI below peach canopies were lower as compared to morus irrespective of the cropping season. It showed higher values in south direction of the tree compared to north direction. In general, rabi season gave higher RI than the Kharif season.

The lower RI below peach canopies may be due to its spreading branching habit as well as more canopy depth towards the tree trunk. Its higher values in southern direction of the trees may be due to greater

availability of sun as the trees have been planted in east-west direction. In rabi season, its higher values can be ascribed to less foliage and crown development of morus and peach as they are still in their initial phase of growth and development. Almost similar results have been reported by Hazara and Tripathi (1986), Singh *et al.* (1989), Kaba (1993) and Jaiswal *et al.* (1993) with different tree species.

5.3 Comparative performance of SC, AS, AH and AHS systems

5.3.1 Biomass productivity

An analysis of the data in Table 39 indicating the total productivity of each systems have shown that overall biomass productivity was found to be higher in AS followed by AHS, AH and SC system irrespective of the cropping patterns. However, cropping pattern-I (maize-lentil) recorded higher biomass productivity than cropping pattern-II (soybean-wheat). The higher biomass productivity in AS system may be due to higher branch and leaf biomass of morus whereas its higher values in cropping pattern-I can be ascribed to higher grain and straw yield of maize.

The contribution of field crops to the total productivity was higher in SC followed by AH, AHS and AS system. The lowest contribution of field crops to the total productivity under AS system was due to the reason that peach fruit and pruned wood yield in AH whereas, morus leaf and branch wood coupled with peach fruit and pruned wood yield in AHS system contributed less to the total productivity over the morus leaf and branch wood yield in AS system.

Morus productivity was higher in AS over AHS system which is obviously due to the fact that under AHS peach an additional component is causing more competition for the limited site resources. ON the other hand, in AHS system, morus contributed larger proportion compared to peach because the total leaf and branch wood biomass of morus compared to total fruit and pruned wood yield of peach is considerably higher.

5.3.2 Nutrient dynamics

A) Soil fertility status

The soils of the experimental site (Table 40) in general, was slightly basic in reaction, medium in organic carbon, available N, P and K.

The pH was lower under agroforestry systems than sole cropping (Table 40). This may be ascribed to the substantial addition of organic matter to the soils under trees. The reduction in soil pH under tree may also be due to the root activities. Nakayama (1969) reported that under vegetative cover, the respiring roots raise the CO_2 concentration in soil atmosphere, which on dissolution in water produces carbonic acid (HCO_3). This acid would reduce the pH of the soil under vegetative cover. Similar observations were also reported by Singh and Lal (1969), Yadav and Singh (1970) and Aggarwal *et al.* (1975) who reported notable reduction in pH and increase in organic matter content in soil under tree covers. Lower soil pH values under agrihortisilviculture system compared to other land use systems maybe due to fertilization of peach trees, addition of leaf litter as well as more number of trees per unit area and hence more root activities.

The organic carbon accumulation under AHS systems was found to be higher closely followed by AH system and minimum under SC system following AS. This is a clear reflection of continuous addition of peach leaf litter as well as decomposition of dead and decaying roots of the trees in the AHS system. The results are in agreement with the findings of Singh and Lal (1969), Aggarwal *et al.* (1975), Kang *et al.* (1984) and Atta-Krah *et al.* (1985), who reported higher soil organic carbon under the trees as compared to open control.

The available N, P and K in soil were higher under agroforestry systems viz. AHS, AH and AS as compared to SC. This may be associated with the release of nutrients and their cycling by the tree species. The results are in line with Nair (1984), Lundgren and Nair (1985) and, Kang and Juo (1986) who reported efficient nutrient cycling under tree based systems than many other systems. Another mechanism involved in higher soil nutrients status under agroforestry systems compared to sole cropping are canopy capture of precipitation inputs (Kellman, 1979), minimum losses of nutrients by leaching (Agamuthu and Broughton, 1985). However higher available N P and K in soil under AHS system compared to other systems may be due to fertilization of peach trees and more number of trees per unit area resulting in higher organic matter addition and microorganisms activities. The results are in line with Gupta *et al.* (1982), Kang *et al.* (1984) and Toky *et al.* (1989b) who also revealed higher nutrient status under agroforestry systems than monocultures.

B) Addition and removal of available N, P and K

The data presented in Appendices II-III and Table 41 showing the

addition and removal of N, P and K revealed that their addition in soil was higher under AH system closely followed by AHS system and minimum in AS system following SC system. This trend is due to the fact that nutrients are being added to these systems through inorganic fertilizers, FYM and additionally due to organic matter added through peach leaf litter. The lower nutrient inputs in AS system compared to SC system is obvious due to less net cropped area in the former resulting in reduced amounts of fertilizers and manure applications.

It was further revealed by the data that N and P addition was higher under cropping pattern-I (maize-lentil) over cropping pattern-II (soybean-wheat) whereas, in case of K the trend was opposite. Higher inputs of N and P in cropping pattern-I may be due to higher application of nitrogenous and phosphatic fertilizers, whereas higher addition of K in cropping pattern-II are due to more addition of potassic fertilizers. Since in cropping pattern-I, the lentil crop was not fertilized with potassic fertilizers at all. Similar results have also been reported by Toky et al. (1989), Mazumdar (1991) and Jensen (1993).

Removal of available N, P and K through different harvested components was found to be maximum in AS system compared to other land use systems (Table 41). This is attributed to the removal of higher total harvest yield from AS system especially the branches and leaves of morus depleted a sizeable quantity of nutrients in comparison to AHS and AH systems. Among nutrient elements, N was depleted in maximum quantity followed by K and P, may be because of their mobility in the soil solution phase.

5.3.2 Balance of available N, P and K

The results pertaining to nutrient balance in soil achieved under each land use system in both the cropping patterns (Table 42) have revealed a higher net gain of available N in AS system followed by SC, AH and AHS system. However, cropping pattern-II (soybean-wheat) gave higher values over cropping pattern-I (maize-lentil). The higher net gain in the cropping pattern-II was due to less expected balance than the cropping pattern-I, however, the actual balance was almost equal in both the cropping patterns. The low expected balance in cropping pattern-II over cropping pattern-I was due to higher cumulative removal of available N, whereas, total amount added in both the cases was almost equal.

It was further deduced from the data that all the four land use systems depleted the soil P reserves. However, the depletion was more in AHS system closely followed by AH system and minimum in AS system following SC system. Net loss of available P was observed to be more in cropping pattern-I than cropping pattern-II. The negative balance of available P under both the cropping patterns is due to the reason that actual balance in the soil was lower than the expected balance. The higher expected balance is the result of total amount of P added to its initial values whereas, lower actual balance in the soil may have occurred due to the fact that only a part of the added P was utilizable rather recoverable in the soil system.

Available K balance in AH and AHS systems in cropping pattern-II resulted in net loss however, SC and AS system in cropping pattern-II and all the four land use systems in cropping pattern-I had shown net gain. In

cropping pattern-I AS system had shown maximum net gain of available K followed by SC, AHS and AH systems. However, in cropping pattern-II, AS system proved to be more restorative over SC system whereas, AH system turned out to be more exhaustive than AHS system. The negative balance in AH and AHS systems in cropping pattern-II may be because of the fact that total amount of K was more than the cumulative removal which has resulted into higher expected balance, whereas, the actual balance did not differ in the same proportion and reflected negative balance of available K in these two systems.

5.3.3 Economic returns

A) Gross returns

Data in respect of gross returns presented in Table 43 reveal, that agroforestry systems viz., AHS, AH and AS, in general, furnished higher gross returns over sole cropping (SC). However, field crops contributed major chunk of total income even in agroforestry systems besides being the sole contributor in sole cropping. The results are in consonance with the findings of Mittal and Sing (1989), Mazumdar (1991), Grewal *et al.* (1992) and Harsh and Tiwari (1993).

In cropping pattern-I, AHS system had provided higher gross returns closely followed by AH system whereas minimum by SC following AS system. In cropping pattern-II, AH system furnished higher gross returns closely followed by AHS whereas minimum by sole cropping following AS system. The higher gross returns of AHS system in cropping pattern-I are due to substantial contribution by morus and peach trees. While higher gross returns of AH system in cropping pattern-II are due to poor performance of

Chapter 6

SUMMARY AND CONCLUSION

The present investigations entitled "Bio-economic appraisal of agroforestry land use systems" comprising two agroforestry systems viz. agrisilviculture and agrihortisilviculture were carried out at the experimental farm of the Department of Silviculture and Agroforestry, Dr YS Parmar University of Horticulture and Forestry, Solan (HP), during 1994-95. The agrisilviculture as well as agrihortisilviculture systems were laid out in randomized block design. The agrisilviculture system had morus as a tree component grown in three different proportions each with maize, soybean, wheat and lentil as intercrops and had one pure crop plot. The agrihortisilviculture system involved peach a fruit tree, morus a fodder and maize, soybean, wheat and lentil as intercrops as in case of agrisilviculture system. It comprised of five peach/morus combinations along with one pure crop plot for each of the above mentioned field crops. Each combinations have been replicated thrice.

Two cropping patterns viz. maize-lentil the cropping pattern-I and soybean-wheat the cropping pattern-II were studied. In order to facilitate comparison between the different production systems, the various treatment combinations of aforesaid systems were grouped into four land use systems namely, sole cropping (SC), agrisilviculture (AS), agrihorticulture (AH) and agrihortisilviculture (AHS).

Observations were recorded on growth and yield performance of field crops, fodder and fruit trees. N, P and K content and their uptake in harvested plant parts viz. grain and straw of field crops, branch and leaf of morus and pruned wood and fruit of peach were determined at their

respective harvesting periods. Soil chemical properties viz. pH, organic carbon, available N, P and K before sowing and after harvest of each crop, total nutrient addition, removal and their balance were also worked out after the harvest of second successive crop i.e. wheat/lentil in May, 1995. Available soil moisture under each system was determined at monthly intervals during the crop growth season. In addition, relative illumination below morus and peach canopies was recorded in October, 1994 and May, 1995 i.e. just before the harvest of Kharif and Rabi crops, respectively. Annual total costs incurred in each land use system were worked out on the basis of net cropped area and number of trees ha⁻¹ that the system contained. On the basis of biomass productivity, gross returns were computed by fixing the prevalent local market rates of various outputs. Ultimately net returns were calculated by deducting the total costs from gross returns.

A) Agrisilviculture system

The study clearly showed that growth and yield attributes viz. plant height, number of plants m⁻², number of cobs/pods/spikes plant⁻¹, 1000 grain weight, grain yield, straw yield and harvest index were negatively affected by the presence of morus trees. All these characters have shown an increasing trend with the decrease in number of morus trees per treatment and increase in distance from the tree row especially in south direction. However, crop maturity exhibited an opposite trend. Among different field crops growth of maize and soybean was affected more adversely than wheat and lentil. Wheat and soybean experienced comparatively higher reduction in grain yield than maize and lentil. In general, distance of the crops from the row exhibited more pronounced effect than the number of trees per treatment followed by direction of the crop.

Growth and yield parameters viz. height, diameter, crown spread, branch and leaf biomass of morus were found to increase with the decrease in number of trees per treatment. Morus performed better in cropping pattern-II (soybean-wheat) than cropping pattern-I (maize-lentil).

Tree crop treatments, distance and direction of the crop from tree row significantly affected the N, P, K-content and uptake in grain and straw components of different field crops showing their maximum values in open control (T_4), distance D_3 and direction DR_2 , however, P-content was more in DR_1 over DR_2 in case of maize and soybean. Nutrient uptake showed direct relationship with the biomass yield and nutrient content irrespective of the field crop. Considering treatments effects on total (grain+straw) nutrient content in field crops the following depressing trends were observed. Nitrogen: maize >wheat >soybean >lentil; phosphorus: maize >soybean >wheat >lentil; potassium: maize >soybean >wheat >lentil.

The N, P and K content in morus branches and leaves did not differ significantly due to various tree-crop treatments however, significant variations were observed in their uptake showing maximum value in plots having single trees (T_3) and minimum in plots having three trees (T_1). Soil moisture content at 0-30 cm depth was more in open control than in tree-crop treatments and was found to increase with the increase in distance from the tree row. Kharif season (June-October, 1994) had shown comparatively higher values over Rabi season (November, 1994-May, 1995). In Kharif soil moisture content was higher in soybean compared to maize whereas, it had depicted maximum values in lentil over wheat in Rabi season.

Relative illumination (RI) under morus canopies was found to be more in maize than soybean in Kharif season and in wheat over the lentil in Rabi season. In general, R.I. was higher in Rabi season than Kharif season.

B) Agrihortisilviculture system

Growth and yield attributes namely plant height, number of plants m^{-2} , number of cobs/pods/spikes $plant^{-1}$, 1000 grain weight, grain yield, straw yield and harvest index were found to be more in open control (T_6) as compared to tree-crop treatments. Their values increased with the increase in distance and displayed better performance on south direction compared to north. Crop maturity exhibited minimum values in T_6 , D_3 and DR_2 . Kharif season crops i.e. maize and soybean growth parameters (plant height, number of plants m^{-2} and crop maturity) were influenced negatively due to morus association whereas, on Rabi season crops viz. wheat and lentil had a negative effect on their growth due to peach association. Regards grain yield; maize, wheat and lentil crops experienced more depressing effect due to peach association whereas soybean yield was affected more by morus association. With the increase in distance from tree row the increase in grain yield was found to be more over the straw yield. The distance accounted for most of experimental variability compared with treatment or direction.

Growth and yield of morus and peach trees was found to be higher in the treatments having single tree in either of the cropping patterns. Cropping pattern-II was found to favour their growth and yield, however, peach fruit yield was found to be higher in cropping pattern-I.

N, P and K content in grain and straw components of field crops was found to be more in treatment T_6 (open control) and at distance D_3 from the row. Direction DR_2 reflected higher N, P and K content. However, in case of maize and soybean P-content was found to be higher in direction DR_1 . Tree crop treatments involving peach as an associated tree resulted in higher nutrient content in maize and soybean whereas treatments having morus as an associated tree depicted higher nutrient content in wheat and lentil.

The N, P and K content in morus (branch and leaf) and peach (pruned wood and fruits) did not exhibit significant differences due to various tree-crop treatments, however, nutrient uptake was found to be influenced significantly. Treatments having single morus/peach tree depicted higher nutrient uptake values than involving two morus/peach trees.

Soil moisture content was found to be maximum in the open control(T_6), at farthest distance (D_3) and in south direction (DR_2) from tree row, irrespective of cropping pattern and season of the crop. Morus during cropping season-I and peach in cropping season-II depleted higher volumes of soil moisture. In general, soil moisture content was more under soybean compared to maize in cropping season-I and under lentil than wheat in cropping season-II.

Relative illumination (RI) was found to be more under morus canopies compared to peach irrespective of the cropping season. It showed higher values in south than north direction. Rabi season crops experienced higher RI than Kharif season.

C) Comparative performance of SC, AS, AH and AHS systems

Biomass productivity among the various land use systems studied followed the order AS >AHS >AH >SC. AS system yielded 1.10, 1.23 and 1.31 times in cropping pattern-I and 1.09, 1.22 and 1.29 times in cropping pattern-II, higher biomass than AHS, AH and SC, respectively. The contribution of field crops to the system's total productivity was in the order: SC >AH >AHS >AS. Morus contributed more in AS over AHS whereas, peach in AH than AHS system's productivity. On the other hand contribution of morus was higher than peach in AHS system. Cropping pattern-I depicted higher biomass productivity as compared to cropping pattern-II.

Results pertaining to the soil chemical changes under different land use systems have shown that soil pH followed an order of SC >AS >AH >AHS whereas, organic carbon and available N, P and K were found in the order: AHS >AH >AS >SC. However, cropping pattern-I depicted higher values over cropping pattern-II for all of these soil characteristics. Growing of cereals was found to be more exhaustive in respect of available N, P and K as compared to pulses. However, pulses had shown an increase in available N.

Addition of N, P and K to the soil through various sources such as manures, fertilizers and leaf litter was found in the order: AH >AHS >SC >AS system. N and P addition was found to be more in cropping pattern-I whereas, K addition had shown a reverse trend. AS system depicted higher removal of N P and K over all other land use systems. Removal of these nutrients followed the trend N >K >P.

Further, N and K had shown net gain whereas P depicted net loss in all the land use systems, however, AH and AHS systems resulted in net loss of K in cropping pattern-II.

Total costs incurred during 1994-95 in each land use system irrespective of the cropping pattern was found in the order: AHS >AH >AS >SC, however, cropping pattern-I was found to be more cost intensive than cropping pattern-II.

Gross returns in cropping pattern-I followed the order: AHS >AH >AS >SC whereas in cropping pattern-II it followed the order: AH >AHS >AS >SC system. Net returns on the other hand exhibited following trend: AH >AHS >AS >SC in both the cropping patterns. Cropping pattern-I furnished higher gross and net returns over cropping pattern-II.

CONCLUSION

Investigations on "Bio-economic appraisal of agroforestry land use systems" have revealed that field crops perform poorly under agrisilviculture and agrihortisilviculture system in comparison to pure crops. In agrisilviculture system wheat and soybean experienced comparatively higher reduction in grain yield than lentil and maize. In agrihortisilviculture system maize, wheat and lentil were influenced adversely by peach whereas soybean by morus. Morus and peach gave higher biomass yield in treatments having single tree which decreases with the increase in number of trees per treatment. The studies have further indicated that morus compete more strongly with maize and soybean (Kharif season) for moisture and nutrients whereas peach with wheat and lentil

$$\frac{186}{20} = 206$$

(Rabi season). Peach has been shown to cast more shade than morus in both the season. The distance of the crop from the tree row accounts for most of experimental variability compared with treatments or direction. Both the tree species suppressed crop growth and productivity significantly on the north side in comparison to south.

It is further deduced from the studies that soil fertility status was higher under AHS followed by AH, AS and SC system. Addition of nutrients was found in the order AH >AHS >SC >AS system whereas, AS system resulted in maximum removal. Among nutrient elements the pattern of removal was: N >K >P. In general, P was depleted in maximum quantity followed by K whereas, N have shown net gain.

AS system gave higher biomass productivity followed by AHS, AH and SC system, however, cropping pattern-I gave higher values over cropping pattern-II. Gross returns obtained from cropping pattern-I were higher and followed the order: AHS >AH >AS >SC whereas in cropping pattern-II the order was AH >AHS >AS >SC. Total cost depicted the following trend AHS >AH >AS >SC. Cropping pattern-I was found to be more cost intensive than cropping pattern-II. From net returns point of view AH system excels over all other land use systems (AH >AHS >AS >SC). Cropping pattern-I furnished higher net returns than cropping pattern-II. Based on a compromise between nutrient cycling, biomass productivity and net returns, different land use systems using cropping pattern-I can be recommended in the following order of preference for similar ecological conditions/sites AHS >AH >AS >SC.

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APPENDICES

APPENDIX-I

Meteorological data for the experimental site during the period of field studies (1994-95)

Months	Temperature(°C)			Sunshine (hr/day)	Wind speed (km/hr)	Rainfall (mm)	No.of rainy days	Relative humidity (%)	Evaporation (mm)
	Maximum	Minimum	Mean						
1994									
May	31.1	18.3	24.7	9.9	8.0	23.8	3	50.2	6.4
June	32.1	20.9	26.5	7.5	6.9	121.6	6	57.5	8.0
July	27.5	21.3	24.4	3.3	3.6	370.8	14	86.2	3.6
August	26.9	21.1	24.0	3.4	3.6	210.2	12	89.5	3.5
September	27.1	18.2	22.6	7.1	4.0	57.6	4	78.3	4.0
October	25.9	11.5	18.7	9.5	5.3	3.4	1	59.0	3.2
November	22.7	8.3	15.5	8.5	5.3	-	-	58.4	2.6
December	18.6	5.0	11.8	5.8	5.1	19.1	4	60.6	2.0
1995									
January	15.4	2.6	9.0	6.3	5.3	77.0	3	63.3	1.5
February	17.1	5.1	11.1	5.8	6.1	92.7	7	60.3	2.3
March	22.1	9.0	15.6	7.4	6.9	60.7	5	56.6	3.2
April	26.3	12.3	19.3	8.2	6.5	38.8	4	53.9	4.3
May	32.3	19.9	26.1	8.9	6.8	4.0	1	45.0	8.2
June	33.5	22.9	28.3	8.7	7.7	95.4	7	60.0	8.9
July	27.6	21.1	24.3	4.0	4.1	350.1	19	83.0	4.2

Source: Meteorological section, Department of Soil Science, Dr YS Parmar University of Horticulture and Forestry, Solan (HP)

APPENDIX-I

Total amount of nutrient added annually (kg ha^{-1}) to the soil in different land use systems (1994-95)

Landuse systems	Cropping pattern-I												Cropping pattern-II											
	N				P				K				N				P				K			
	Maize	Lentil	Peach	Total	Maize	Lentil	Peach	Total	Maize	Lentil	Peach	Total	Soybean	Wheat	Peach	Total	Soybean	Wheat	Peach	Total	Soybean	Wheat	Peach	Total
A)Sole cropping																								
Fertilizer	90	10	-	100	45	40	-	85	30	-	-	30	10	50	-	60	30	25	-	55	30	25	-	55
FYM	6	-	-	6	5	-	-	5	14	-	-	14	6	-	-	6	5	-	-	5	14	-	-	14
Total	96	10	-	106	50	40	-	90	44	-	-	44	16	50	-	66	35	25	-	60	44	25	-	69
B)Agri- Silviculture																								
Fertilizers	87	9.7	-	96.7	43.5	38.7	-	82.2	29	-	-	29	9.7	48.38	-	58.08	29	24.18	-	53.18	29	24.18	-	53.18
FYM	5.8	-	-	5.8	4.8	-	-	4.8	13.5	-	-	13.5	5.8	-	-	5.8	4.8	-	-	4.8	13.5	-	-	13.5
Total	92.8	9.7	-	102.5	48.3	38.7	-	87	42.5	-	-	42.5	15.5	48.38	-	63.88	33.8	24.18	-	57.98	42.5	24.18	-	66.68
C)Agrihorticulture																								
Fertilizers	85	9.5	50	144.5	42.5	37.8	25	105.3	28.35	-	60	88.35	9.45	47.25	50	106.70	28.35	23.63	25	76.98	28.35	23.63	60	111.98
FYM	5.7	-	1.2	6.90	4.7	-	1	5.7	13.23	-	3	16.23	5.67	-	1.2	6.87	4.73	-	1	5.73	13.23	-	3	16.23
Leaf litter	-	-	6.15	6.15	-	-	0.66	0.66	-	-	3.31	3.31	-	-	5.98	5.98	-	-	0.78	0.78	-	-	3.54	3.54
Total	90.70	9.5	57.33	157.55	47.2	37.8	26.66	111.66	41.58	-	66.31	107.89	15.12	47.25	57.18	119.55	33.08	23.63	26.76	83.47	41.58	23.63	66.54	131.75
D)Agrihorti- silviculture																								
Fertilizers	85	9.5	50	144.5	42.5	37.8	25	105.3	28.35	-	60	88.35	9.45	47.25	50	106.70	28.35	23.63	25	76.98	28.75	23.63	60	112.38
FYM	5.7	-	1.2	6.90	4.7	-	1	5.70	13.23	-	3	16.23	5.67	-	1.2	6.87	4.73	-	1	5.73	13.23	-	3	16.23
Leaf litter	-	-	5.19	5.19	-	-	0.53	0.53	-	-	3.30	3.30	-	-	5.12	5.12	-	-	0.62	0.62	-	-	3	3
Total	90.70	9.5	56.39	156.59	47.2	37.8	26.53	111.53	41.58	-	66.30	107.88	15.12	47.25	56.32	118.69	33.08	23.63	26.62	83.33	41.98	23.63	66	131.61

APPENDIX-III

Annual removal of nutrients (kg ha⁻¹) from different land use systems (1994-95)

	Sole cropping			Agrisilviculture			Agrihorticulture			Agrihortisilviculture		
	N	P	K	N	P	K	N	P	K	N	P	K
Cropping patter-I												
A) Crops												
Maize												
-Grain	74.01	14.28	11.64	66.38	11.75	9.30	66.71	12.49	9.79	63.65	11.53	9.11
-Straw	38.53	13.97	60.55	35.45	11.55	56.32	36.02	12.72	57.26	34.48	11.72	55.33
Lentil												
-Grain	66.30	4.27	22.42	56.52	3.48	18.92	50.73	3.13	16.86	44.15	2.62	14.65
-Straw	72.71	3.70	31.28	66.44	3.34	28.19	66.12	3.32	28.07	57.98	2.90	24.55
Sub-total	251.55	36.22	125.89	224.79	30.12	112.73	219.58	31.66	111.98	200.26	28.77	104.14
B) Trees												
Morus												
- Branch	-	-	-	35.12	6.64	29.13	-	-	-	16.23	2.94	13.39
- Leaf	-	-	-	17.09	1.40	10.52	-	-	-	9.41	0.72	5.81
Peach												
-Pruned wood	-	-	-	-	-	-	8.32	2.15	4.86	5.99	1.47	3.59
-Fruit	-	-	-	-	-	-	23.84	2.52	16.46	22.40	2.13	15.37
Sub-total	-	-	-	52.21	8.04	39.65	32.16	4.67	21.32	54.03	7.26	38.16
Total	251.55	36.22	125.89	277.00	38.16	152.38	251.74	36.33	133.30	254.29	36.03	142.30
Cropping pattern-II												
A) Crops												
Soybean												
-Grain	96.07	4.43	22.73	78.98	3.12	18.48	85.12	3.67	19.83	80.02	3.28	18.47
-Straw	167.80	3.72	36.52	144.30	2.96	28.62	153.00	3.18	32.54	145.07	2.98	30.52
Wheat												
-Grain	49.47	13.32	16.96	42.48	10.89	14.08	43.60	11.23	14.49	37.98	9.48	12.29
-Straw	17.47	11.57	40.04	15.23	9.58	36.76	15.60	9.98	36.64	13.76	8.27	33.48
Sub-Total	330.81	33.04	116.25	280.99	26.55	97.94	297.32	28.06	103.50	276.83	24.01	94.76
B) Trees												
Morus												
-Branch	-	-	-	37.41	7.23	30.51	-	-	-	17.07	3.11	13.98
-Leaf	-	-	-	18.31	1.48	11.04	-	-	-	11.56	0.89	7.14
Peach												
-Pruned wood	-	-	-	-	-	-	8.25	2.25	5.07	6.05	1.59	3.69
-Fruit	-	-	-	-	-	-	20.83	2.12	14.40	18.79	1.86	12.98
Sub-Total	-	-	-	55.72	8.71	41.55	29.08	4.37	19.47	53.47	7.45	37.79
Total	330.81	33.04	116.25	336.71	35.26	139.49	326.40	32.43	122.97	330.30	31.46	132.55

APPENDIX-IV
Prices of various inputs and outputs during 1994-95

Inputs	Rate	Outputs	Rate
1. Tractor charges	Rs.44/hr	1. Maize grain	Rs.375/q
2. Thresher charges	Rs. 8/hr	2. Maize stover	Rs. 35/q
3. Labour charges		3. Soybean grain	Rs.800/q
a)June 1994 to Dec.,1994	Rs.24/man day	4. Soybean straw	Rs. 25/q
b)Jan.1995 to March,1995	Rs.26/man day	5. Wheat grain	Rs.400/q
c)April 1995 to July 1995	Rs.45.75/man day	6. Wheat straw	Rs.95/q
4. Seed cost		7. Lentil grain	Rs.1200/q
a) Maize hybrid 3485	Rs.17/kg	8. Lentil straw	Rs.30/q
b) Soybean Punjab No.1	Rs.8/kg	9. Morus leaf fodder	Rs.40/q
c) Wheat S-308	Rs.4/kg	*10. Morus fuel wood	Rs.123/q
d) Lentil HPL-5	Rs.12/kg	11. Peach fruit	Rs.800/q
5. Fertilizers and manure		*12. Peach fuel wood	Rs.118/q
a) CAN	Rs.340.75/q		
b) SSP	Rs.288/q		
c) MOP	Rs.412/q		
d) FYM	Rs.250/t		
6. Weedicides			
a) Tafazine	Rs.220/kg		
b) Goal	Rs.910/lit		
c) 2,4-D	Rs.160/kg		
d) Lasso	Rs.230/lit		
7. Insecticides			
a) TSO	Rs.40/lit		
b) Metasystox	Rs.340/lit		
8. Fungicide			
a) Blitox	Rs.182/kg		
9. Lin seed oil	Rs. 55/kg		

* Computed values in terms of calorific value

Kerosene oil	=	Rs.2.62/lit
1 litre kerosene oil	=	9259 Kcal/lit
1 kg morus branch wood	=	4363 Kcal/kg
1 kg peach branch wood	=	4181 Kcal/kg

APPENDIX-V
Cost of cultivation of maize and lentil in different land use systems (1994-95)

Particulars	Maize				Lentil			
	Sole cropping	Agri-silviculture	Agrihorticulture	Agrihortisilvi-culture	Sole cropping	Agri-silviculture	Agrihorticulture	Agrihortisilvi-culture
	Operational Cost ^a input(ha ⁻¹) (Rs. ha ⁻¹)	Cost ^a (Rs.ha ⁻¹)	Cost ^a (Rs.ha ⁻¹)	Cost ^a (Rs.ha ⁻¹)	Operational Cost ^a input(ha ⁻¹) (Rs.ha ⁻¹)	Cost ^a (Rs.ha ⁻¹)	Cost ^a (Rs.ha ⁻¹)	Cost ^a (Rs.ha ⁻¹)
Seed	20 kg 340	329	321	321	30 kg 360	348	340	340
FYM	10 ton 2500	2419	2362	2362	-	-	-	-
CAN	360 kg 1224	1184	1156	1156	40 kg 136	132	128	128
SSP	281 kg 809	782	764	764	250 kg 720	695	680	680
MOP	50 kg 206	199	195	195	-	-	-	-
Tafazine	2 kg 440	425	415	415	-	-	-	-
Lesso	-	-	-	-	3 lit 690	668	652	652
One ploughing	5 hrs 220	212	208	208	5 hrs 220	212	208	208
Two harrowing and ploughing	7 hr 308	298	291	291	7 hrs 308	298	291	291
Sowing	12 man days 288	278	272	272	14 man days 364	352	344	344
FYM application	9 man days 216	209	204	204	-	-	-	-
Top dressing	1 man days 24	23	22	22	-	-	-	-
Weedicide appli.	6 man days 144	139	136	136	7 man days 182	176	172	172
Hand weeding	16 man days 384	372	362	362	8 man days 208	201	197	197
Earthing up	14 man days 168	162	158	158	-	-	-	-
Harvesting	16 man days 384	372	362	362	18 man days 824	797	778	778
Dehusking	9 man days 216	209	204	204	-	-	-	-
Shelling	18 man days 432	418	408	408	-	-	-	-
Threshing	-	-	-	-	20 days 915	885	865	865
Total	8303	8030	7840	7840	4927	4765	4655	4655

1 man day = 8 hours of single labour unit.

Net cropped area: a) Sole cropping = 10000 sq m
b) Agrisilviculture = 9675 sq m
c) Agrihorticulture = 9450 sq m
d) Agrihortisilviculture = 9450 sq m

^aCosts have been calculated on the basis of net cropped area

APPENDIX-VI
Cost of cultivation of soybean and wheat in different land use systems (1994-95)

Particulars	Maize				Lentil			
	Sole cropping	Agri-silviculture	Agrihorticulture	Agrihortisilviculture	Sole cropping	Agri-silviculture	Agrihorticulture	Agrihortisilviculture
	Operational Cost* input(ha ⁻¹) (Rs. ha ⁻¹)	Cost* (Rs.ha ⁻¹)	Cost* (Rs.ha ⁻¹)	Cost* (Rs.ha ⁻¹)	Operational Cost* input(ha ⁻¹) (Rs.ha ⁻¹)	Cost* (Rs.ha ⁻¹)	Cost* (Rs.ha ⁻¹)	Cost* (Rs.ha ⁻¹)
Seed	70 kg 560	542	529	529	120 480	464	453	453
FYM	10 ton 2500	2418	2362	2362	-	-	-	-
CAN	40 kg 136	132	128	128	200 kg 680	658	642	642
SSP	188 kg 541	523	511	511	156 kg 450	435	425	425
MOP	50 kg 206	193	194	194	42 kg 173	167	163	163
Urea	1 lit 910	880	860	860	-	-	-	-
2,4-D	-	-	-	-	1 kg 160	155	151	151
One ploughing	5 hrs 220	212	208	208	5 hrs 220	212	207	207
Two harrowing	7 hrs 308	298	291	291	7 hrs 308	298	291	291
and planking								
Sowing	14 man days 336	325	318	318	15 man days 390	377	368	368
FYM application	9 man days 216	209	204	204	-	-	-	-
Top dressing	-	-	-	-	1 man day 26	25	24	24
Weedicide appli.	7 man days 168	162	158	158	7 man days 182	176	172	172
Hand weeding	12 man days 288	278	272	272	8 man days 208	201	196	196
Harvesting	18 man days 432	417	408	408	22 man days 1006	973	950	950
Threshing	21 man days 504	487	476	476	18 man days 824	797	778	778
Thresher	-	-	-	-	28 hrs 224	216	212	212
Total	7325	7082	6919	6919	5331	5154	5032	5032

1 man day = 8 hours of single labour unit.

Net cropped area: a) Sole cropping = 10000 sq m
b) Agrisilviculture = 9575 sq m
c) Agrihorticulture = 9450 sq m
d) Agrihortisilviculture = 9450 sq m

*Costs have been calculated on the basis of net cropped area

APPENDIX-VII

Cost of maintenance of peach and morus trees and harvest of their produce (1994-95)

Particulars	Peach								Particulars	Morus							
	Sole cropping		Agri-silviculture		*Agri-horticulture		*Agri-hort-silviculture			Sole cropping		**Agri-silviculture		Agri-horticulture		***Agri-hort-silviculture	
	Operational Cost input(ha ⁻¹) (Rs.ha ⁻¹)		Operational Cost input(ha ⁻¹) (Rs.ha ⁻¹)		Operational Cost input(ha ⁻¹) (Rs.ha ⁻¹)		Operational Cost input(ha ⁻¹) (Rs.ha ⁻¹)			Operational Cost input(ha ⁻¹) (Rs.ha ⁻¹)		Operational Cost input(ha ⁻¹) (Rs.ha ⁻¹)		Operational Cost input(ha ⁻¹) (Rs.ha ⁻¹)		Operational Cost input(ha ⁻¹) (Rs.ha ⁻¹)	
Fertilizers & manures																	
CAN	-	-	-	-	200 kg	882	200 kg	882	Plant Protection chemicals								
SSP	-	-	-	-	155 kg	449	155 kg	449									
MGP	-	-	-	-	100 kg	412	100 kg	412									
FYM	-	-	-	-	2 tonnes	500	2 tonnes	500									
Plant protection chemicals																	
Blitox	-	-	-	-	500 gm	91	500 gm	91	Labour								
Lin seed oil	-	-	-	-	350 ml	19	350 ml	19									
Metesystox	-	-	-	-	250 ml	85	250 ml	85									
TSD	-	-	-	-	500 ml	20	500 ml	20									
Labour																	
Fertilizer application	-	-	-	-	4 mandays	104	4 mandays	104	Total1453701								
FYM application	-	-	-	-	10 mandays	260	10 mandays	260									
Blitox application	-	-	-	-	8 mandays	208	8 mandays	208									
Metesystox spray	-	-	-	-	6 mandays	156	6 mandays	156									
TSD spray	-	-	-	-	6 mandays	156	6 mandays	156									
Basin preparation	-	-	-	-	18 mandays	468	18 mandays	468									
Pruning	-	-	-	-	16 mandays	416	16 mandays	416									
Total40264026																	

1 manday = 8 hours of single labour unit

* 200 peach trees ha⁻¹

** 357 morus trees ha⁻¹

***200 morus trees ha⁻¹