TREE-CROP INTERACTION STUDIES IN AGRIHORTICULTURE SYSTEM

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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1999

AFFECTIONATELY
DEDICATED
TO
BABAJI AND NANUJI

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CERTIFICATE-I

This is to certify that the Thesis entitled "**Tree-crop interaction studies in Agrihorticulture System**", submitted in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE** in **AGROFORESTRY** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni-Solan is a bonafide record of research work carried out by **Ms. Rachita Sood** (F-97-17-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 has been fully acknowledged.

DATED : July 30, 1999.
PLACE: Nauni-Solan.

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Chairman,
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CERTIFICATE-II

This is to certify that the Thesis entitled **"Tree-crop interaction studies in Agrihorticulture System"** submitted by **Ms. Rachita Sood** (F-97-17-M) to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni-Solan, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE** in **AGROFORESTRY** has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the External Examiner.

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ACKNOWLEDGEMENTS

I would like to offer my prime heart felt salutations at the lotus feet of the "Supreme Being" for the unbroken vigour bestowed upon me, through out the span of my studies.

With great pride I seize this opportunity to express my deep sense of gratitude to Dr. K.S. Verma, Chairman of my advisory committee for his expert, invaluable, judicious and tireless guidance, keen interest, painstaking efforts, constant encouragement and swift executions during the course of present investigations. I shall always remain indebted to him for his benevolent patronage, affection and generosity bestowed on me without which I would never have been able to bring this manuscript to its present form.

I humbly express my loyal and heartiest thanks to the respected members of my Advisory Committee, Dr. V. K. Mishra, Dr. R.K. Nayital and Dr. J.N. Raina for their constant help during the entire course of study.

I would like to express my appreciation to the field, laboratory and office staff of the Department of Silviculture and Agroforestry for all the timely help and facilities provided.

I sincerely acknowledge the help, encouragement and cooperation received from my worthy seniors, adorable friends and companions.

Financial assistance from the University in the form of merit scholarship is duly acknowledged.

How can I forget Harshu, who has been a sister to me and has always helped in all my stressful moments. Thanks Harshu, for always being mine.

A formal acknowledgement of my emotions is hardly adequate to express my deep feelings for my Mummy and Papa who always believed in giving strong educational wings to their daughter. Their advice, affection and inspiring blessings will ever remain with soul and spirit as a memory and motto of my life.

It is with personal touch of emotions, that I express my deep feelings for my Bhai Arvind, Bhabi Meenakshi, adorable sister Ambika, loving nephew Triambik and all other relatives for their everlasting affection.

I solely claim all responsibilities for the short comings and limitations in this work.

Lastly but not the least, I owe a lot to the painstaking efforts of Mohanji, Jagdeepji, Assiji and Bansalji, for making this manuscript a beautiful piece of work.

PLACE : NAUNI (SOLAN)
DATED : 30th July, 1999.

(RACHITA SOOD)

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ACRONYMS

AH	=	Agrihorticulture
a.m.s.l.	=	above mean sea level
cm	=	centimeters
C.D.	=	Critical difference
E.C.	=	Electrical conductivity
F.Y.M.	=	Farm Yard Manure
g	=	gram
ha	=	hectare
H.I.	=	Harvest index
K	=	Potassium
Kg	=	Kilogram
m	=	meter
M.A.T.	=	Mean Annual Temperature
ml	=	milliliter
mm	=	millimeter
MoP	=	Muriate of Potash
N	=	Nitrogen
O.C.	=	Organic carbon
P	=	Phosphorus
q	=	quintal
R.I.	=	Relative illumination
Rs.	=	Rupees
S.E.	=	Standard Error
SSP	=	Single super phosphate
T.C.I.	=	Tree-crop interface
%	=	per cent

INTRODUCTION

1

INTRODUCTION

Land management systems which envisage combination of agriculture and forestry on the same land unit are though age old, but have lacked scientific input. The scanty information available regarding systematic studies on production of different agricultural crops under varied tree canopies and the interactions of the two reflects the positive response in some crops and inverse trend with other, when raised under tree species. These interactions take place through the media of soil and microclimate and exert a favourable or adverse effect on the crop. The nature of the interactions within and between species, therefore concern the ways in which plant can influence its neighbour by changing their environment either directly, by addition or substraction (e.g. nutrients) or indirectly (by encouraging insectivores) (Harper, 1977).

Goldberg and Werner (1983) reported that plant and its environment modify one another so that the environment causes a response in plant function and growth, and the plant then has an effect upon the environment by changing one or more of its factors. This shows that interactions between species are mediated by the environment through the "Response and Effect" principle.

Component interactions refer to the influence of one component of a system on the performance of the other components as well as the system as a whole (Nair, 1993). The interactions between components for growth factors absorbed through roots (nutrients and water) and those absorbed / intercepted through leaves (mainly radiant energy) are termed as "below ground" and "above ground" interactions. This provides a sound basis for studying the process involved as well as suggesting improved management options for components and the system as a whole. Component interactions can also be treated as positive (beneficial) and negative (harmful) interactions that occur at the tree-crop interface (TCI). The balance between these positive and negative effects determines the overall effect of the interactions on a given agroforestry combination.

In all types of vegetation, the ability of an individual to grow and reproduce depends on its success in capturing resources from its environment, often in competition with neighbours. When there is only one species in a stand with a uniform genetic base, resources appear to be shared equitably except when over crowding makes self-thinning unavoidable. In stands with more than one species, competition for limited resources is inevitable, both above and below ground. However, as in a free market economy, competition can increase production by the system as a whole or can help to stabilize outputs when the supply of resources is erratic (Monteith *et al.*, 1991).

In agroforestry system, there are both ecological and economical interactions between the different components. Ecological interactions between trees and crops are beneficial for three major reasons. First, leguminous trees have a beneficial effect on soil fertility through nitrogen fixation, greater organic matter production and recycling of nutrients (Young, 1986). Second, a combination of annual crops and trees raises biomass production because differences in rooting depth enable uptake of more water and nutrients (Huxley, 1983). Third, the presence of trees acts as a protective barrier against soil erosion or as wind breaks (Wiersum, 1984).

Conventional approach to agroforestry experimentation is difficult because of the possibility of too many combinations of factors and the requirement of large plots for trees. Another approach is to quantify yield at the tree-crop interface (TCI), where the tree and crop interact or compete for growth resources (Huxley, 1985). The key to the development of compatible tree-crop combinations in agroforestry depends on an understanding of the interaction at the tree-crop interface (Cannell, 1983). If the net effect at the tree-crop interface is advantageous or positive, planting arrangements which maximize the amount of interface would provide the greatest benefit. There is no particular advantage in modifying planting arrangements when the net effect of the TCI is neutral (Singh *et al.*, 1989). An understanding of the nature of tree and crop interactions at these interfaces should provide an important step for improving and designing new agroforestry systems. Tree-crop interfaces can be investigated in existing agroforestry situations or in specially designed treatments. The information generated at the interface can be used as a guide for extrapolation for different planting arrangements using the same tree and crop.

The challenge in agroforestry is to select species and varieties within a specie, design systems and, devise appropriate management regimes that will optimize environmental resource capture and resource use efficiency in a sustainable way, whilst fulfilling the farmer's objective. But to do this effectively requires a knowledge of the interactive response of the components in these woody-non woody intercrops (Huxley, 1996).

Wheat is the most important cereal crop of Himachal Pradesh and is sown throughout the state. Peach is also one of the most promising fruit tree in the mid hills. The present study intends to investigate the influence of above and below ground interactions on the resource utilization as well as the growth and yield productivity of different wheat varieties grown in association with peach with the following objectives :

1. Examine soil-plant nutrient use pattern as well as available soil moisture regimes and their impact on tree-crop growth and yield level in an agrihorticulture system.

2. The examination of soil-plant nutrient, available soil moisture and tree-crop productivity level during a crop season.

REVIEW OF LITERATURE

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. Systematic scientific information available in literature on competitive or complementary reciprocal effects of different components within the system are scanty.

Nevertheless, pertinent and accessible literature on the various aspects of Tree Crop Interaction studies in Agrihorticultural System have been reviewed under the following heads :

2.1 Plant growth and productivity

2.1.1 Field crops

2.1.2 Fruit trees

2.1.3 Root characteristics

2.2 Plant nutrient content and uptake

2.2.1 Field crops

2.2.2 Fruit crops

2.3 Soil properties

2.3.1 Soil moisture

2.3.2 Nutrient dynamics

2.4 Shade and relative illumination

2.5 Economic evaluation

2.1 Plant growth and productivity

2.1.1 Field crops

Field crops (cereals, pulses and oil seeds) as well as plantation crops respond differentially to the association of their woody components. The impact of adverse effects is greatest in the close vicinity of the trees and diminishes as the distance increases (Dhillon *et al.*, 1979; Yamoah *et al.*, 1986; Dwivedi, 1987; Sharma, 1987; Huxley *et al.*, 1989). Such effects have been observed on wheat crop using different tree species viz. poplar (Sheikh and Cheema, 1976); *Acacia nilotica* (Sharma, 1992); Eucalyptus, Albizia, Morus and Leucaena (Akbar *et al.*, 1990); *Azadirachta indica, Prosopis cineraria, Dalbergia sissoo* and *Acacia nilotica* (Puri and Bangarwa, 1992; Sheikh, 1978); Paulownia (Chirko *et al.*, 1996) and *Morus alba* (Kumar, 1996). The adverse effects of trees on wheat growth and yield were only upto 2 m distance from the tree trunk/row. In some situations, it extended upto 4m distance beyond which crop was affected the least.

Khan and Aslam (1974) quantified the reduction in wheat yield grown in association with Dalbergia tree (single tree). It was 30.88, 23.60 and 12.70 per cent at 3, 4.5 and 6m distance, respectively of the yield obtained at the center of the field. Trees being the dominant partners of agroforestry systems during the later growth stages, they cause consistent and progressive decrease in crop yields depending upon their planting geometry and growth phase. Wheat and paddy crops grown with Grewia, Morus and Eucalyptus (4x5m spacing) over a period of 13 years resulted into an average yield loss of 29, 29 and 28% in wheat and 28, 34 and 30 per cent in case of paddy (Khybri *et al.*, 1992).

Direction of planting the crop with respect to tree row too plays an important role in the growth and yield performance of a field crop. North - South direction causes least negative influence on crop yield than East - West as was reported by Dhillon *et al.* (1982) for rice, wheat and potato grown with eucalyptus. Similar results were obtained by them for wheat and paddy grown with *Dalbergia sissoo* and *Acacia nilotica* during 1984. Comparing the performance of maize, soybean, wheat and lentil sown in North and South direction of morus and grewia tree rows (Kumar, 1996) growth and yield of these crops was significantly better in South direction than North.

2.1.2 Fruit trees

Intercropping field crops with fruit trees in different agroforestry systems has shown vivid behaviour of fruit trees. Arora and Mohan (1986) showed that soybean and cowpea had no marked adverse effect on the height and crown diameter of the trees when compared to control (tree alone) upto seventh year. However, in the seventh year Sesame had shown a slightly inhibiting and soybean a slightly promoting effect on the tree height.

Gupta *et al.* (1982) reported that intercropping of kharif and rabi crops with five year old peach trees provide about 10-15 kg tree^{-1} of pruned wood and 10 kg leaf litter during November-December in Doon Valley of Uttar Pradesh. The mean fruit yield of peach per tree basis under pure orchard conditions varies with the age and cultivar used. An average yield of 20.667 kg (Sankhayan, 1969), 17.20-18.50 kg for 8 year old July Elberta trees (Jamir, 1985) and 34 kg plant^{-1} for 10-12 year old trees (Kumar, 1994) has been observed. Per tree yield of peach fruits increased when intercropped with Pine apple (40.1 kg) and turmeric (30 kg) which, however decreased on intercropping with lemon grass (14kg) compared to the control (24.6 kg) i.e. peach only (Arora and Mohan, 1986).

The improvement in the fruit yield due to the association of above crops may be due to their long duration nature. Association of short duration crops viz. cow pea (36kg) and sesame (34 kg) had no adverse effect on the fruit yield of seven year old peach trees as it was almost equal to the fruit yield (33 kg) from pure peach plantations.

2.1.3 Root characteristics

Knowledge of the structural development of root system is essential in understanding the ecological niche of a tree species and in management in order to optimize the productivity of trees in various agroforestry systems (Huxley, 1983; Toky *et al.* 1989).

Agroforestry tree species possess different structural patterns of the roots and hence influence the resource use vividly. Root system of various trees has been studied in agroforestry by different workers. Toky and Bisht (1992) showed that melia, morus and poplar have adventitious superficial roots mostly concentrated in the top 80cm of the soil profile. Albizia, morus, populus and zizyphus however, show asymmetrical spread with roots penetrating predominantly in one or two directions. In melia, azadirachta and leucaena a spread of 150cm was reported.

These authors also studied the spread of lateral roots in prosopis, eucalyptus and populus. Lateral roots exceeded 1.3 times the crown spread, Dhyani *et al.* (1990) also reported that in eucalyptus and bauhinia, lateral roots especially in the top layers of the soil mass exhibited a tendency of spreading parallel to the ground level but definitely showed a positive geotropism. The bulk of their roots was found near the surface, hence root competition was expected.

In Sharbati peach grafted on peach (12 years), maximum roots were present at 0-60cm radial distance from the trunk and at 0-25cm depth. The amount of fibrous roots was higher on the eastern side of the trunk compared to the western side (Godara, 1984). This was attributed to the temperature variation in two directions. At 60-120cm radial distance, the length of thin roots was lower by 65 per cent than at 0-60cm with a further decrease of

60 per cent at 120-180 cm distance. Roots beyond 240cm distance were negligible. Similarly, the root length at 50-75cm depth was 16 per cent lower than at 0-25cm depth. Most of the root production in peach trees occurs in spring with little or no root growth in summer even under frequent irrigation and favourable soil temperatures (Richards and Cockroft, 1975). They also reported double concentration of peach roots in the surface soil within a single season when frequently irrigated at 3-4 days interval than under normal interval of 12-16 days.

Nutrient level in the soil too affects root growth. In general, in regularly fertilized orchards more roots are found in the upper soil layers where higher levels of N, P, K and Mg occur (Robinson, 1976 and Bhutani *et al.*, 1978).

2.2 Plant nutrient content and uptake

Tree-crop components using same volume of soil are liable to be influenced due to one another's reciprocal effect. The amount of nutrients taken up by the plant primarily depends upon the concentration of nutrient in the close proximity to the root surface (Black, 1968 and Rusell, 1973).

2.2.1 Field crops

Yamoah *et al.* (1986) and Krim (1987) have reported that maize growing adjacent to the trees respond less to nitrogen fertilization than maize in the center of alleys presumably due to greater competition for light, water and/or nutrients near the tree row.

Field crops e.g. maize, soybean, wheat and lentil had more N, P and K content in grain and straw components beyond 3m distance of tree row and also in open control. N, P and K content in grain was well as straw was less near to the tree row upto 3m distance. Crop plants in South direction had higher N, P and K content. However, in case of maize and soybean more P content was found in North. The N, P and K content of wheat in grain varied from 1.68 - 1.75; 0.295-0.338 and 0.228-0.275, respectively in grains, while 0.514-0.547; 0.166-0.210 and 0.811-0.863, respectively in straw. The N, P and K concentration in grain as well as straw of maize under pure crop situation was 1.68, 0.32, 0.43 and 0.66, 0.08, 0.87 per cent respectively. N, P and K content in wheat grain was 1.66, 0.33, 0.36 and 0.43, 0.13 and 0.64 per cent in straw (Manuja, 1992).

2.2.2 Fruit trees

Shear and Faust (1980) reported N, P and K deficiency values to be < 1.7, < 1.1, < 0.75,respectively for peach plants while in normal range of these nutrients being 2.5-4.0, 0.14-0.40 and 1.5-2.0 per cent, respectively. Khera *et al.*(1981) reported 1.91-2.71, 0.14-0.17 and 1.02-1.23 per cent N, P and K, respectively as tentative critical levels for Sharbati peach. Verma and Bhandari (1990) in Rajgarh area (H.P.) found that N, P, K content in peach leaves varied from 1.5-2.6,0.15-0.28, 1.76-3.20 per cent, respectively.

Arora and Mohan (1986) observed N, P and K contents of peach 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 of control. Kumar (1996) observed N, P and K uptake in peach pruned wood when intercropped with wheat to be 8.32, 2.15 and 4.86 kg ha^{-1}, respectively. Fruit N, P and K uptake was recorded to be 23.84, 2.52 and 1.46 kg ha^{-1}, respectively.

2.3 Soil properties

2.3.1 Soil moisture

Higher evaporative demands of woody species cause a rapid depletion of water resources (Connor, 1983). Tree-crop systemshave been known to influence the availability and utilization of available moisture both horizontally as well as vertically in the field. Alley cropping experiments at ICRISAT, India and ICRAF, Kenya showed that though marked decrease in crop yield was observed when alley width was reduced below 5m, 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; Ong *et al.*, 1991).

Lal (1989) reported that soil moisture content in top 0-5cm layer in agroforestry systems was generally higher than that in the control during both wet and dry season. Competition for soil moisture caused approximately 30 per cent reduction in the yield of wheat and mustard growing at a distance less than 10m from the 3.5 year old *Eucalyptus tereticornis* (Malik and Sharma, 1990). For low yield of hedge row prunings (2-3 mg ha^{-1} yr^{-1}), competition of hedgerow for water has been one of the major reasons in water limited areas (Ong *et al.*, 1991; Rao *et al.*, 1991). Khybri *et al.* (1992) reported least soil moisture under eucalyptus followed by grewia, morus and control when grown with wheat and paddy. However, after harvest of eucalyptus, the lowest soil moisture was under grewia followed by morus, eucalyptus and highest was under control. This was due to grewia which remains green during growth of wheat. Burgess *et al.* (1996) reported reduced yield of wheat when grown in both side of poplars due to lack of readily available water towards the end of season when poplar was spaced at 10x6.4m by using mulched polythene strip of 1.5m width.

2.3.2 Nutrient dynamics

Nutrient cycling occurs to varying degree in all land use systems (Roswall, 1980). Agroforestry and other tree based systems are commonly seen with more efficient nutrient cycling and in turn a greater potential to improve soil fertility than many other systems because of presence of woody perennials in the system and their suggested beneficial effects on soil (Nair, 1984; Lundgren and Nair, 1985; Kang and Juo, 1986). In agroforestry systems, both short and long term effects are there on crops. The short term effects, which influence current season crops are governed by the nutrient release through mineralization of recently added prunings and root decay. The long term effects are changes in soil nutrient stocks that occur over the year from regular addition of pruning and root turn over.

Soils beneath the tree cover have been said to be 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 (Attah-Krah *et al.*, 1985). Enhancement of nutrient status beneath the tree canopies has been attributed to canopy capture (Kellman, 1979). Sanchez *et al.* (1985) examined the role of trees as tropical soil improves and summarized that some of the beneficial effects of trees on soil are expected when trees close their canopy. The main deleterious effects of the tree-crop on soil properties occurs during their establishment phase. Higher soil organic matter and organic forms of nutrients nearer the tree suggests that there could be increased mineralization and greater availability of plant available nutrients under trees than in open areas during the cropping season (Rhoades, 1995). Kater *et al.* (1992) reported more soil organic carbon, exchangeable Mg, Ca and K in soils in zone covered by the crowns of karite and near trees as compared to soils in the open.

Lal (1989) reported that over a period of six years, the relative rates of decline in the status of N, pH and exchangeable bases of the soil were much less under alley cropping than under non-alley cropping. N, P and K content in soil was appreciably reduced after growing of non-leguminous crops like maize, rice, sorghum and mustard. The reduction was greater under sole cropping system than under alley cropping system (Maiti *et al.*, 1993). Yamoah *et al.* (1986) reported that even without addition of prunings, maize performed better than those in middle of alleys, implying that there was transfer of nutrients by root turnover or some other means of below ground improvement.

Rao *et al.* (1998) reported that increase in soil fertility is due to nitrogen input into the system through biological nitrogen fixation, reduced soil erosion, reduced leaching of nutrients and uptake of nutrients from deep soil layers. Gupta *et al.* (1982) reported about 10 kg of leaf litter during November-December in peach when trees attained 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 $ha^{-1}yr^{-1}$. Toky *et al.* (1989) while studying the natural agroforestry systems in the mid hills of Himachal Pradesh, reported that in agrihortisilvicultural and agrihorticultural systems, considerable quantities of nutrients upto Nitrogen-169kg, phosphorus-14 kg and potassium-165kg 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 Hortiagriculture and maximum storage in Hortisilviculture system.

2.4 Shade and relative illumination

Light differs from other resources in that it cannot be regarded as a reservoir from which demands can be made as required (Donald, 1961). It is instantaneously available and has to be instantaneously intercepted for use in photosynthesis. It is also one of the most important factor when better temporal use of resources is achieved (Willey and Roberts, 1976). In any agroforestry system biomass production in understorey is a function of photosynthetic active radiation (PAR) falling on the ground surface (Hazara and Tripathi, 1986).

Srinivasan *et al.* (1990) while examining the resource sharing ability of multipurpose trees in an intercropping system reported reduced crop yields due to competition with the trees for light. Yield of wheat increased due to decrease in shade (Dadhwal and Narain, 1984).

Arora and Mohan (1986) in a study on agrihorticulture land use systems involving peach 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 declined to uneconomic levels due to shade effect of the trees.

2.5 Economic evaluation

Integration of trees with arable crops increase the overall productivity and the marginal fall in agricultural production is compensated through the general environmentally beneficial impacts. Riley (1986) suggested that it would be better to compare the biomass in terms of money to get a conclusive idea about the system. For individual farmers the financial returns from sale of wood compensates the reduction in agricultural yields (Chaturvedi, 1981) but the overall economics favour tree crop combinations (Harsh and Tewari, 1993).

Singh and Vishnumurthy (1990) found agrihorticultural system consisting of ber, guava and custard apple as fruit tree component alongwith arable crops viz. cow pea, green gram, and black gram very promising for stabilizing the income of farmers in semi-arid drylands. Majumdar (1991) showed that hortiagricultural system furnished the highest gross returns amounting to Rs. 91,557.20 annually which was about 6.6 and 31.5 fold higher than those of hortisilvipastoral and grassland systems, respectively. Grewal *et al.* (1992) reported that agrisilvihorticulture system could provide an average net returns of Rs. 17,066 ha^{-1} over a period of 4 years as compared to an average net return of Rs. 7852 from cropping alone. Kumar (1996) conducted a study on bio-economic appraisal of agroforestry systems in Himachal Pradesh and found that gross returns in maize-lentil cropping sequence followed the order AHS> AH > AS > SC. Net returns had shown the trend AH > AHS > AS > SC. Upadhaya (1998) conducted a study in Balh valley of Himachal Pradesh and reported that in marginal, small and medium group of farmers, more net returns were obtained from ASH system as compared to AS, PS, PSH and PH systems of agroforestry. Productivity and economics of 8 intercrops in 4 crop sequences indicated that the vegetable intercropping did not cause any adverse effect on the yield and income of eucalyptus (Singh *et al.*, 1998). However, yield of all intercrops reduced with the increase in the age of the trees. Colocasia proved to be most remunerative crop under open as well as shade conditions because of higher yield and remunerative price. Among the crop sequences faba bean - colocasia (Rs. 51,037) was the best followed by french bean - turmeric (Rs. 39,121), potato-onion (Rs. 37,861) and tomato-cowpea (Rs. 32,797).

MATERIALS AND METHODS

3

MATERIALS AND METHODS

The present investigations entitled **"Tree-crop interaction studies in Agrihorticulture System"** were conducted at the experimental farm of the Department of Silviculture and Agroforestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni-Solan, (H.P.), India during 1997-98. 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 Solan district of Himachal Pradesh at an elevation of 1250m a.m.s.l. It is located 15 km South east of Solan representing 30°51'N latitude and 76°11'E longitude (Survey of India Toposheet No. 55 F/1).

3.1.2 Climate

The climate of the area is sub-humid subtropical and subtemperate. There is 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 experience 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 1150mm, most of which is concentrated in the monsoon period (mid

June - mid August). The meteorological data for the experimental site recorded for the period under studies has been presented in Appendix-I.

3.2 Experimental Methodology

The experimental details and methods used are described as below :

Agroforestry system : Agrihorticulture

Structural components

Field Crop : Wheat (*Triticum aestivum* L.)

Fruit Crop : Peach (*Prunus persica* Batsch)

3.2.1 Planting Geometry

Peach has been planted in lines drawn from East to West 5m apart from plant to plant and 10m row to row in Randomized Block Design. Wheat was sown in the alley space or between the two tree lines.

3.2.2 Technical Programme

Response of four wheat varieties grown at three N-levels in an agrihorticulture system using peach as a fruit tree was studied.

A. Main plot treatments

Nitrogen levels : 3

N_1 : 25 per cent less (60kg) than recommended dose ha^{-1}

N_2 : Recommended (80 kg) dose ha^{-1}

N_3 : 25 per cent more (100kg) than recommended dose ha^{-1}

B. Sub plot treatments

Crop varieties	:	4
V_1	:	HD-2285
V_2	:	HD-2329
V_3	:	HD-2380
V_4	:	HS-240
C. System	:	2
S_1	:	Wheat with peach (Agrihorticulture system)
S_0	:	Wheat as sole crop (Sole crop system)
D. Direction	:	2
DR_1	:	North of peach row
DR_2	:	South of peach row
Design	:	Split plot

(Nitrogen was kept in main plot whereas varieties were in sub-plot)

Actual plot size	:	10x5m
Path area	:	0.5m in two sides both along the length and width.
Net utilizable Area for tree and crop	:	9x4m
Bund area	:	2x4m
Net cropped area	:	7x4m
Replication	:	3
Date of tree planting	:	01/1989
Date of sowing field crop	:	8-12-1997
Date of harvesting field crop	:	25-5-1998

3.3 Observations recorded

3.3.1 Plant

Growth and productivity

Fruit tree

Diameter 5cm above the graft union, Crown spread, Height, Number of fruits per tree and fruit yield, Total harvestable biomass.

Field crop

Germination per cent, Number of plants m^{-2}, Number of tillers $plant^{-1}$, Plant height, Number of spikes $plant^{-1}$, Thousand grain weight, Grain yield, Straw yield, Total biological yield and Harvest index.

Nutrient

Fruit tree	NPK concentration in leaves and fruits.
Field crop	N concentration and uptake in plants at tillering, spike initiation, milking and crop harvest.
	NPK concentration and uptake in grains and straw at maturity.

3.3.2 Soil

Soil moisture, pH, E.C., organic carbon, available N, P and K at tillering, spike initiation, milking and crop harvest stage of wheat.

Root distribution of peach tree in soil profile.

3.3.3 Light

Light interception by peach trees at pink bud , flowering, fruit set and fruit development stage.

3.3.4 Economic evaluation

Cost of cultivation

Gross returns

Net returns

3.4 Observational procedures

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

3.4.1 Peach

Diameter

Diameter was measured in centimeters at 5cm above the graft union 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 diameter. The measurements were made in December, 1997 and May, 1998, the sowing and harvesting time of wheat, respectively.

Crown spread

Crown spread was measured in meters 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 December, 1997 and May, 1998, the sowing and harvesting time of wheat, respectively.

Height

Tree height was measured in meters from ground level to the tip of main shoot with the help of properly graduated wooden rod. The measurements were made in December, 1997 and May, 1998, the sowing and harvesting time of wheat, respectively.

Number of fruits plant^{-1}

Fruits from a peach tree were harvested in June, 1998, counted and expressed as the average number of fruits plant^{-1}.

Fruit yield

The yield was recorded during harvesting season of 1997-98 (June, 1998) by weighing the total number of fruits on a single tree at the time of harvest and expressed in kg tree^{-1} on fresh weight basis.

Root distribution

The roots were excavated by the Skeleton Method (dry excavation), digging manually along the course followed by the roots in soil mass. Pick-axe, spade and small tools were used for digging the soil. During digging the horizontal spread of roots was measured.

Light interception

Solar radiation on a cloudy day were recorded below and outside the crown with a lux photometer (Blackman and Wilson, 1951). Radiation interception was expressed as percentage of radiation below and outside the canopy at pink bud , flowering, fruit set and fruit development stage

3.4.2 Wheat

For recording the observations on growth and yield attributes, 1m^2 sampling plots were laid out in each treatment in both the directions i.e. North and South of the tree row.

Germination count

After complete emergence, all the plants in 1m^2 area were recorded and percentage germination was worked out.

Number of tillers plant^{-1}

Number of tillers produced by 5 randomly selected plants were counted and expressed as number of tillers plant^{-1}.

Number of plants m^{-2}

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

Number of spikes plant^{-1}

Number of spikes produced by 5 randomly selected plants were counted and expressed as number of spikes plant^{-1}.

Plant height

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

Thousand grain weight

A random sample of grains from the produce of the sampling plot was drawn which was threshed and cleaned. The weight of the grains obtained was recorded and expressed in q ha^{-1}.

Grain yield

The weight of the total produce of the sampling plot was recorded and then threshed and cleaned. The weight of the grains obtained was recorded and expressed in q ha^{-1}, though the actual sown area for wheat was $7777.78 m^2$.

Straw yield

After deducting the weight of grain from weight of total produce the straw yield of the sampling plot was obtained and expressed in q ha^{-1}, though the actual sown area for wheat was $7777.78 m^2$.

Harvest index

Harvest index was calculated as per the following standard formula :

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Total biological yield (Grain+Straw)}} \times 100$$

Cultural schedule

The details about the cultural schedules adopted for wheat are as under :

Varieties :	HD-2285
	HD-2329
	HD-2380
	HS- 240
Date of sowing	8-12-1997
Seed rate	120 kg ha^{-1}
Spacing	22cm (R x R)

Manures and fertilizers applied

Entire quantity of phosphorus @ 40 kg ha^{-1} through SSP, 40 kg potassium ha^{-1} through MoP alongwith 1/2 dose of nitrogen was applied at the sowing time. The remaining half dose of nitrogen was top dressed after 45 days.

Weedicide application : 2,4-D @ 400g ha^{-1} in 750 lt water

3.4.3 Nutrient analysis

3.4.3.1 Plants

Collection of samples

Peach

Leaf samples were taken from the middle of the terminal shoots, on the periphery of the tree as recommended by Verma and Bhandari (1990) in the first fortnight of June.

Wheat

Whole plant except roots was taken at tillering, spike initiation, milking and crop harvest.

Preparation of samples

All the samples were washed serially with tap water, 0.1 N HCl and again with distilled water. The washed samples were first air dried and subsequently in oven at 60+5^{o}C for 48 hours.

Chemical analysis

For estimation of total N, 0.5g of plant material was digested in concentrated sulphuric acid, in the presence of a digestion mixture composed of

480g K_2SO_4, 20g $CuSO_4$, 1g Se powder and 3g HgO. 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 100ml. 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 (1957).

Nutrient uptake

Uptake of total N, P and K in different harvested components of wheat and peach was worked out by multiplying the concentration of each nutrient with respective dry matter yield using the following formula :

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

3.4.3.2 Soil

Collection and preparation of samples

Soil samples were collected from 0-30cm depth at all the four active growth stages of wheat viz. tillering, spike initiation, milking and crop harvest. Random samples were collected with the help of post hole auger, composited, plotwise, air dried, crushed, passed through 2mm sieve and analyzed for various chemical characters.

Chemical analysis of the soil

The following standard procedures have been used to analyze the chemical properties of the soil.

1. E.C.	Jackson (1957)
2. pH	1:2.5 soil water suspension with the help of digital pH meter (Jackson, 1957).
3. Organic carbon (%)	Walkley and Black (1934)
4. Available-N (kg ha^{-1})	Subbiah and Asija (1956)
5. Available-P (kg ha^{-1})	Olsen *et al.* (1954).
6. Available-K (kg ha^{-1})	Merwin and Peech (1951).

Soil moisture

Soil moisture was determined by gravimetric method. Soil samples were taken from the field and were dried in hot air oven at $105^{O}C$ until a constant weight was attained. The difference in weight between the wet and oven dry samples gave the moisture content.

3.4.4 Nitrogen use pattern

Nitrogen use pattern was calculated for wheat at tillering, spike initiation, milking and crop harvest as well as for wheat grain and straw.

Per cent response was worked out as follows :

$$\text{\% Nutrient uptake/ \% yield response} = \frac{\text{Nutrient uptake/yield In sole crop at } N_2 \text{ level} - \text{Nutrient uptake/yield in treated plots}}{\text{Nutrient uptake/yield in sole crop at } N_2 \text{ level}} \times 100$$

3.4.5 Nutrient addition and removal

Nutrient N, P and K added to peach and wheat were worked on per hectare basis (Appendix-XVII).

Nutrient removal was worked out by adding up the nutrients, removed through the harvested biomass (Appendix-XVIII).

3.4.6 Nutrient balance

After harvesting of wheat, the nutrient balance was calculated on the following assumptions :

a) Detailed considerations, such as loss of nutrients by leaching, weeds and the rate of release of slowly available forms of these nutrients to available forms were not considered.

b) Amount of nutrients retained by the non-harvested tree components were not included since complete harvest of the trees was not practicable.

c) Net gain or net loss of a particular nutrient in the soil was worked out by computing the difference between expected balance and actual balance of that nutrient in the soil.

Expected balance in soil was worked out as follows :

Expected balance = Initial status + Quantity added – Quantity removed by Field crops and trees in sequence.

3.4.7 Economic studies

Cost of cultivation

The cost of cultivation of the field crop as well as maintenance of the fruit tree and harvest of its produce was worked out on the basis of net cropped area and number of trees ha^{-1} (Appendices XX-XXI). 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-XIX). Cost of inputs such as fertilizers, seed, insecticide and weedicide were calculated based on the actual amounts applied to the land use system (Appendix-XX).

Gross returns

The prevailing local market prices were used to convert the yield of wheat and peach in rupees ha^{-1}. The market prices of the harvested products have been given in Appendix-XIX.

Net returns

Net returns were calculated by deducting total costs from the gross returns.

Net returns = Gross returns - Total costs.

3.4.8 Statistical analysis

The data obtained were subjected to statistical analysis using RBD for peach and Split Plot Design (Gomez and Gomez, 1984) for wheat. 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".

EXPERIMENTAL RESULTS

4

EXPERIMENTAL RESULTS

The experimental results obtained for the present studies are given in this Chapter under the following heads :

4.1 Field crop

4.1.1 Growth and yield of wheat

4.1.2 Foliar nutrient concentration and uptake

4.2 Tree species

4.2.1 Growth and yield

4.2.2 Foliar nutrient concentration and uptake

4.2.3 Root characteristics

4.3 Soil studies

4.3.1 Soil moisture

4.3.2 pH, E.C., organic carbon and available N, P, and K status of soils

4.4 Relative Illumination

4.5 Nutrient use pattern

4.6 Nutrient Balance

4.7 Economic Returns

Gross returns

Net returns

4.1 Field crop

4.1.1 Growth and yield of wheat

The influence of different nitrogen levels on four crop varieties grown in association with peach trees in an agrihorticulture system was studied. Data on growth and yield attributes wererecorded in two directions viz. North and South of the tree row.

4.1.1.1 Growth

The growth parameters studied were germination per cent, number of plants m^{-2}, number of tillers $plant^{-1}$ and plant height. The data on the parameters described below are tabulated in Table 1 and Appendix-II.

Germination per cent

Cumulative influence of nitrogen levels and varieties on germination per cent of wheat crop sown in A.H. system (S_1) as well as sole crop (S_0) was statistically non-significant both in North (DR_1) and South (DR_2) directions of peach tree row (Appendix-II).

Wheat varieties did not affect the per cent germination significantly (Table 1). The per cent germination due to direction and variety x direction was non-significant.

Influence of peach trees in A.H. system (S_1) on wheat when compared to sole cropped wheat (S_0) on per cent germination was significant. The germination was more at S_0 (83.40) compared to S_1 (80.76). Direction alone as well as interaction between system x direction did not show any significant influence on per cent germination (Table 1).

Table 1 ***Effect of N level, crop variety and system on the growth attributes* of wheat***

Direction	Germination per cent			No. of plants /m^2			No. of tillers /plant			Plant height (cm)		
	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean
(A) Nitrogen level												
N_1	83.12	84.08	**83.60**	54.54	58.71	**56.62**	3.84	4.28	**4.06**	74.93	75.75	**75.34**
N_2	82.29	83.79	**83.04**	59.12	62.83	**60.98**	4.17	4.30	**4.23**	76.46	80.08	**78.27**
N_3	79.54	79.67	**79.60**	59.46	61.62	**60.54**	4.04	4.62	**4.33**	78.06	81.22	**79.64**
Mean	**81.65**	**82.51**		**57.71**	**61.06**		**4.01**	**4.40**		**76.48**	**79.02**	
	S.E(d)±.		$CD_{(0.05)}$	S.E(d)±.		$CD_{(0.05)}$	S.E(d)±.		$CD_{(0.05)}$	S.E(d)±.		$CD_{(0.05)}$
N	1.22		N.S	1.44		N.S	1.11		N.S	0.56		1.56
DR	0.78		N.S	1.02		N.S	0.06		N.S	0.44		0.89
N x DR	0.95		N.S	1.24		N.S	0.085		N.S	0.55		1.09
(B) Variety												
V_1	83.22	84.00	**83.61**	63.17	66.83	**65.00**	3.91	4.08	**3.99**	71.43	73.34	**72.39**
V_2	82.28	83.78	**83.03**	54.33	54.61	**55.47**	3.85	4.22	**4.03**	72.87	71.89	**70.18**
V_3	79.83	81.06	**80.44**	52.78	54.44	**53.61**	4.03	4.49	**4.26**	94.06	95.49	**92.71**
V_4	81.28	81.22	**81.25**	60.56	66.33	**63.74**	4.27	4.81	**4.54**	75.90	75.34	**75.72**
Mean	**81.65**	**82.51**		**57.71**	**61.06**		**4.01**	**4.40**		**76.48**	**79.02**	
	S.E(d)±.		$CD_{(0.05)}$	S.E(d)±.		$CD_{(0.05)}$	S.E(d)±.		$CD_{(0.05)}$	S.E(d)±.		$CD_{(0.05)}$
V	1.10		NS	1.44		2.86	0.09		0.19	0.63		1.26
DR	0.78		N.S	1.02		N.S	0.06		N.S	0.44		0.89
V x DR	1.10		N.S	1.44		N.S	0.09		N.S	0.63		1.26
(C) System												
S_1	80.56	80.97	**80.76**	55.22	60.19	**57.83**	3.84	4.46	**4.15**	74.72	78.96	**76.84**
S_0	82.75	84.06	**83.40**	60.44	61.67	**60.93**	4.19	4.34	**4.26**	78.24	79.07	**78.66**
Mean	**81.65**	**82.51**		**57.71**	**61.06**		**4.01**	**4.40**		**76.48**	**79.02**	
	S.E(d)±.		$CD_{(0.05)}$	S.E(d)±		$CD_{(0.05)}$	S.E(d)±.		$CD_{(0.05)}$	S.E(d)±.		$CD_{(0.05)}$
S	0.78		1.55	1.02		2.03	0.06		N.S	0.44		0.89
DR	0.78		N.S	1.02		N.S	0.06		N.S	0.44		0.89
S x DR	0.78		N.S	1.02		N.S	0.06		N.S	0.44		0.89

DR_1 – North; DR_2 - South

* *Figures in (A) and (B) are the average values for land use system S_1 and S_0*

Number of plants m^{-2}

Number of plants m^{-2} was also not influenced significantly due to cumulative influence of nitrogen levels and varieties sown in two directions viz. North (DR_1) and South (DR_2) in A.H. system (S_1) and sole crop (S_0) (Appendix-II).

Wheat varieties affected the number of plants m^{-2} significantly. Variety V_1 showed the maximum number (65.00) followed by V_4 (63.74), V_2 (55.47) and V_3 (53.61) (Table 1).

Number of tillers plant^{-1}

The data in Appendix-II on combined effects of nitrogen levels, varieties, system and direction on number of tillers per plant have shown non-significant results. Similarly, N levels irrespective of variety and system did not alter the response of this character significantly (Table 1).

Wheat varieties affected the number of tillers plant^{-1} significantly. Among the varieties highest number was exhibited by V_4 (4.54) and lowest by V_1 (3.99). However, V_1 and V_2 were statistically at par with each other (Table 1).

Plant height

Plant height was statistically non-significant due to cumulative influence of different treatments (Appendix-II). The individual mean effects of N levels, varieties and system on plant height however, were significant (Table 1).

Plant height was maximum at N_3 level which was at par with N_2 followed by N_1. Their respective values were 79.64, 78.27 and 75.34 cm.

Height of the plants growing in direction DR_2 was significantly higher over DR_1. Their respective values were 79.02 and 76.48cm. Plant height due to system was also influenced significantly and showed its higher values in S_0 than S_1. Among the varieties maximum height of 92.71 cm was recorded in variety V_3 followed by V_4 (75.72), V_1 (72.39) and V_2 (70.18). All the varieties were statistically different from one another.

4.1.1.2 Yield

Yield attributes namely number of spikes plant^{-1}, thousand grain weight, grain yield, straw yield and harvest index of different wheat varieties grown at three nitrogen levels and recorded with the peach tree rows as well as without the peach tree rows in two directions i.e. DR_1 and DR_2 did not show any significant change in their values (Appendix-III). However, response of nitrogen and variety independent of each other was statistically significant for each yield attribute studied except harvest index in case of variety (Table 2). In case of system all the yield attributes responded significantly except number of spikes per plant. The details for each of the above yield attributes are described as below.

Number of spikes plant^{-1}

Highest number of spikes was recorded at N_2 level i.e. at recommended dose (80 kg ha^{-1}) of nitrogen level. However, it was statistically at par with N_3 level and significantly higher than N_1. The influence of direction and the interaction between nitrogen level x direction both were non-significant (Table 2).

Table 2 **Effect of N level, crop variety and system on the yield attributes* of wheat**

Direction	No. of spikes/plant			Thousand grain wt (g)			Grain yield (q ha^{-1})			Straw yield (q ha^{-1})			Harvest index (%)		
	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
(A) Nitrogen level															
N_1	3.24	3.33	3.29	33.09	33.83	33.46	18.06	19.17	18.61	51.71	52.71	52.21	25.82	26.70	26.26
N_2	3.48	3.43	3.45	33.77	34.68	34.22	19.29	20.96	20.12	56.69	57.77	57.23	25.28	26.56	25.92
N_3	3.41	3.47	3.44	35.30	36.03	35.67	20.04	21.54	20.79	60.67	62.00	61.33	24.46	25.88	25.17
Mean	3.38	3.41		34.05	34.85		19.13	20.56		56.35	57.49		25.18	26.38	
	S.E(d)±		$CD_{(0.05)}$	S.E(d)±		$CD_{(0.05)}$	S.E(d)±		$CD_{(0.05)}$	S.E(d)±		$CD_{(0.05)}$	S.E(d)±		$CD_{(0.05)}$
N	0.03		0.08	0.19		0.52	0.46		1.37	0.56		1.54	0.29		0.79
DR	0.04		N.S	0.09		0.19	0.16		0.32	0.30		0.60	0.16		0.33
N x DR	0.61		N.S	0.12		N.S	0.20		N.S	0.37		N.S	0.20		N.S
(B) Variety															
V_1	3.50	3.54	3.52	31.29	32.20	31.75	14.06	15.61	14.83	41.92	43.11	42.51	25.10	26.53	25.82
V_2	2.88	3.17	3.02	34.80	35.69	35.25	17.72	19.11	18.42	53.61	54.56	54.08	24.77	26.14	25.45
V_3	3.49	3.44	3.47	35.06	35.78	35.42	24.08	25.39	24.74	69.22	70.31	69.76	25.65	26.59	26.12
V_4	3.64	3.48	3.56	35.07	35.71	35.39	20.67	22.11	21.39	60.67	62.00	61.33	25.22	26.27	25.74
Mean	3.38	3.41		34.05	34.85		19.13	20.56		56.35	57.49		25.18	26.38	
	S.E(d)±		$CD_{(0.05)}$	S.E(d)±		$CD_{(0.05)}$	S.E(d)±		$CD_{(0.05)}$	S.E(d)±		$CD_{(0.05)}$	S.E(d)±		$CD_{(0.05)}$
V	0.07		0.14	0.14		0.28	0.23		0.45	0.43		0.85	0.24		N.S
DR	0.04		N.S	0.09		0.19	0.16		0.32	0.30		0.60	0.16		0.33
V x DR	0.07		N.S	0.14		N.S	0.23		N.S	0.42		N.S	0.23		N.S
(C) System															
S_1	3.06	3.11	3.09	34.14	34.45	34.29	17.08	19.03	18.06	53.40	54.87	54.14	24.12	25.79	24.96
S_0	3.69	3.71	3.70	33.97	35.24	34.61	21.18	22.08	21.63	59.31	60.11	60.11	26.25	26.97	26.61
Mean	3.38	3.41		34.05	34.85		18.06	21.63		56.35	57.49		25.18	26.38	
	S.E(d)±		$CD_{(0.05)}$	S.E(d)±		$CD_{(0.05)}$	S.E(d)±		$CD_{(0.05)}$	S.E(d)±		$CD_{(0.05)}$	S.E(d)±		$CD_{(0.05)}$
S	0.04		N.S	0.09		0.19	0.16		0.32	0.30		0.60	0.16		0.33
DR	0.04		N.S	0.09		0.19	0.16		0.32	0.30		0.60	0.16		0.33
S x DR	0.04		N.S	0.09		0.19	0.16		0.32	0.30		N.S	0.16		0.33

DR_1 – North; DR_2 - South

* *Figures in (A) and (B) are the average values for land use system S_1 and S_0*

Wheat varieties also had a significant effect on this parameter. Maximum number was observed under V_4 (3.56) and lowest under V_2 (3.02). Varieties V_1, V_3 and V_4 were statistically at par with each other.

Thousand grain weight

Thousand grain weight was significantly higher at N_3 level of nitrogen. A maximum of 35.42 was found in variety V_3 and minimum of 31.75 in V_1. System and direction of the crop from the tree row also had significant influence on this parameter. It was higher in S_0 (34.61) than in S_1 (34.29). Thousand grain weight was also affected by the direction of the crop. It was more in DR_2 (34.85) than in DR_1 (34.05). The interaction between system x direction was also found to be significant (Table 2).

Grain yield

Different levels of nitrogen showed significant differences in grain yield. The highest grain yield was observed at N_3 (20.79) followed by N_2 (20.12) and N_1 (18.61). However, yield at N_2 and N_3 levels was statistically at par.

Varietal effect on grain yield was also significant. It was maximum in variety V_3 (24.74) and minimum in V_1 (14.83). Direction of the variety sown too increased the grain yield in DR_2 over DR_1 significantly. However, interaction between V x DR was statistically non-significant (Table 2).

System had a significant influence on this character. System S_0 depicted higher grain yield over system S_1. The interaction effect between system and direction too was found to be significant.

Straw yield

Straw yield was maximum (61.33) at N_3 level followed by N_2 and N_1 showing their respective values of 57.23 and 52.21. All the N levels were statistically different from one another.

Among the wheat varieties V_3 gave the highest yield (69.76) and V_1 (42.51) the lowest. System S_0 depicted higher straw yield over system S_1. Directionally, straw yield was more in DR_2 over DR_1 whether due to N levels, variety or system. All the interaction effects viz. N x DR, V x DR and S x DR were found to be statistically non-significant.

Harvest index (H.I.)

Harvest index due to application of different N levels was highest (26.26) at N_1 level followed by N_2 and N_3. Levels N_2 and N_3 showing their respective values of 25.92 and 25.17 behaved statistically alike. Similarly, levels N_1 and N_2 were alike. Varieties used in the study, independent of N levels did not show any significant change in HI values.

Influence of peach trees on wheat studied in A.H. system S_1 compared to sole wheat (S_0) on harvest index in both North (DR_1) and South (DR_2) direction was found to be significant. System S_0 gave higher values over system S_1. Direction of crop sown influenced the H.I. significantly due to N levels, varieties and system (Table 2).

4.1.1.3 Comparative growth and yield performance of different wheat varieties under Agrihorticulture system and sole crop system

Growth and yield attributes (Table 3) of different wheat varieties were influenced significantly within a system as well as between the two systems except germination per cent and harvest index.

Table 3. Comparative growth and yield performance of wheat varieties under agrihorticulture and sole crop system

	Growth attributes				Yield attributes				
	Germination per cent	No. of plants /m^2	No. of tillers / plant.	Plant height (m)	No. of spikes / plant	Thousand grain wt. (g)	Straw yield (q ha^{-1})	Grain yield (q ha^{-1})	Harvest index (%)
Agrihorticulture									
V_1	82.78	58.33	3.78	70.34	3.14	31.27	38.17	12.06	24.02
V_2	81.11	52.44	3.61	67.56	2.55	34.91	50.56	15.67	23.64
V_3	78.89	51.11	3.85	85.27	3.28	35.05	66.89	22.17	24.72
V_4	79.44	59.00	4.11	75.73	3.29	35.32	58.00	18.44	24.11
Sole crop									
V_1	83.67	68.00	4.04	72.53	3.85	31.31	45.67	16.06	26.19
V_2	83.44	56.22	4.08	69.38	3.21	34.69	56.67	19.78	25.90
V_3	80.78	54.44	4.20	94.57	3.71	35.07	71.56	26.00	26.58
V_4	83.11	62.11	4.43	76.49	3.99	34.83	63.33	22.89	26.33
S.E(d)±.	1.10	1.44	0.09	0.63	0.07	0.14	0.42	0.20	0.23
$CD_{(0.05)}$	N.S	2.86	0.19	1.26	0.13	0.28	0.85	0.45	NS

Growth

Number of plants m^{-2} in A.H. system was maximum (59.00) in variety V_4 and minimum in V_3 (51.11). In sole crop system all the wheat varieties produced significantly higher number of plants m^{-2} than A.H. system. The maximum value was shown by V_1 (68.00) and minimum (54.44) by V_3. Number of tillers $plant^{-1}$ however, were found to be significantly higher in variety V_4 in A.H. and sole crop system. Plant height was maximum in variety V_3 and minimum in V_2 in both the systems. The values were however, higher in case of sole cropping (S_0) than the A.H. system (S_1).

Yield

In A.H. system highest number of spikes $plant^{-1}$ were observed in variety V_4 (3.29) followed by V_3 (3.28), V_1 (3.14) and V_2 (2.55). In sole crop also the highest number was recorded in V_4 (3.99) followed by V_1 (3.85), V_3 (3.71) and V_2 (3.21). Thousand grain weight too was maximum in variety V_4 (35.32) in A.H. system but in sole crop it was in variety V_3 (35.07). Both were statistically alike. Variety V_1 recorded the minimum weight both in A.H. System (S_1) and sole crop (S_0). (Table 3). Straw and grain yield was maximum in variety V_3 both in A.H. system as well as in sole crop followed by $V_4 > V_2 > V_1$ (Table 3; Fig. 1 and 2).

4.1.2 Nitrogen concentration and uptake in wheat during active growth stages

4.1.2.1 Concentration

Variation in nitrogen concentration in wheat plants due to variable doses of N, crop varieties and system in two different directions was studied at active growth stages of wheat and described below:

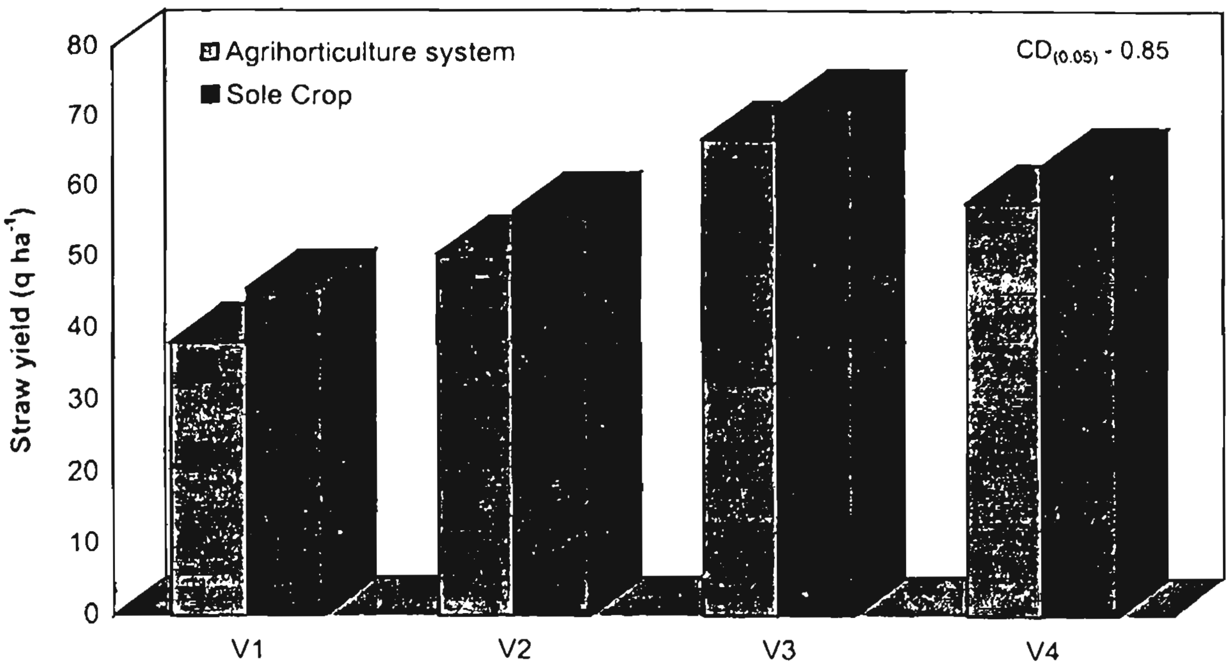


Fig. 1 Effect of varieties on straw yield (q ha^{-1}) of wheat

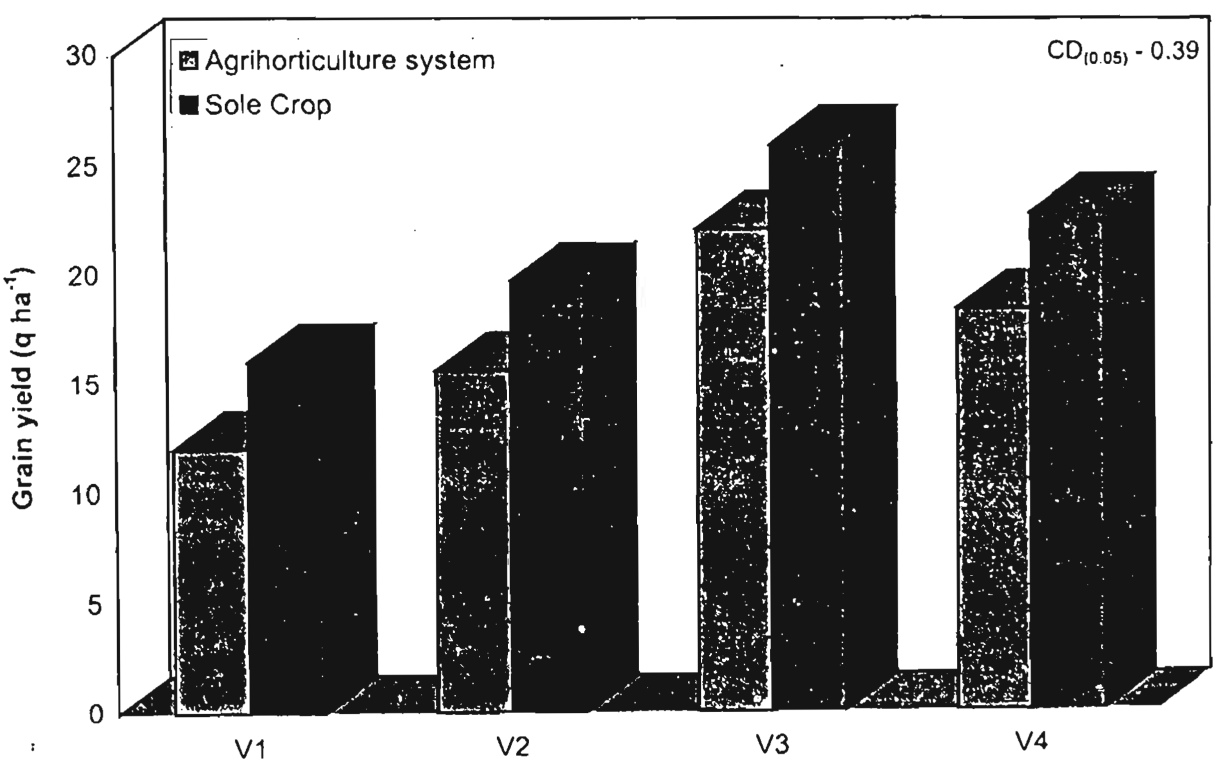


Fig. 2. Effect of varieties on grain yield (q ha^{1}) of wheat

Tillering

Application of nitrogen significantly affected the nitrogen concentration in wheat plants. It was maximum (2.41%) at N_3 level followed by N_2 and N_1. The later two levels have shown the values of 2.36 and 2.30 respectively (Table 4). Wheat varieties also influenced the N concentration significantly. Variety V_4 recorded the highest concentration (2.50).

System S_0 exhibited significantly higher N concentration over system S_1. The interaction between SxDR was also found to be significanl (Table 4).

The data on effect of nitrogen x variety x system x direction on per cent concentration of N in wheat at tillering stage (Appendix-IV) was non-significant.

Spike initiation

Application of nitrogen had a significant influence on N concentration in wheat plants at spike initiation stage. Highest concentration of N was observed in N_3 level (2.09) followed by N_2 (1.97) and N_1 (1.90). All the levels were statistically different from one another (Table 4). Wheat varieties differed significantly in their N concentration. Maximum concentration was observed in variety V_4 (2.17) and minimum 1.83 per cent in V_2.

A significantly higher N concentration was recorded in wheat plants growing without the peach tree row (S_0) as compared to those growing with the row (S_1). Direction however, showed no significant influence at this stage of plant growth. Interaction effects except in case of S x DR were statistically non-significant (Table 4). Influence of interaction between N x V x S x DR (Appendix-IV) concentration was also non-significant.

Table 4. ***Effect of nitrogen level, crop variety and system on nitrogen concentration (%)* of wheat during active growth stages***

	Tillering			Spike initiation			Milking			Crop harvest		
Direction	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean
A) Nitrogen												
N_1	2.30	2.31	**2.30**	1.89	1.91	**1.90**	1.80	1.82	**1.81**	0.87	0.89	**0.88**
N_2	2.36	2.37	**2.36**	1.97	1.98	**1.97**	1.85	1.91	**1.88**	0.95	0.98	**0.96**
N_3	2.41	2.42	**2.41**	2.08	2.10	**2.09**	1.95	1.98	**1.96**	1.03	1.06	**1.04**
Mean	**2.36**	**2.37**		**1.98**	**1.99**		**1.87**	**1.91**		**0.95**	**0.98**	
	S.E.(d)±		**C.D.(0.05)**	**S.E.(d)±**		**C.D.(0.05)**	**S.E.(d)±**		**C.D.(0.05)**	**S.E.(d)±**		**C.D.(0.05)**
N	0.001		0.005	0.001		0.006	0.007		0.003	0.003		0.013
DR	0.002		0.004	0.002		NS	0.004		0.008	0.003		0.006
NxDR	0.002		NS	0.002		NS	0.005		0.010	0.003		0.007
B) Variety												
V_1	2.27	2.28	**2.27**	1.92	1.94	**1.93**	1.83	1.83	**1.83**	0.98	0.98	**0.98**
V_2	2.20	2.22	**2.21**	1.82	1.84	**1.83**	1.74	1.82	**1.78**	0.95	0.98	**0.96**
V_3	2.46	2.47	**2.47**	2.00	2.03	**2.02**	1.89	1.93	**1.91**	0.95	0.99	**0.97**
V_4	2.49	2.51	**2.50**	2.16	2.18	**2.17**	2.02	2.04	**2.03**	0.99	0.99	**0.99**
Mean	**2.35**	**2.37**		**1.97**	**1.99**		**1.87**	**1.91**		**0.97**	**0.98**	
	S.E.(d)±		**C.D.(0.05)**	**S.E.(d)±**		**C.D.(0.05)**	**S.E.(d)±**		**C.D.(0.05)**	**S.E.(d)±**		**C.D.(0.05)**
V	0.002		0.004	0.003		0.006	0.006		0.011	0.004		0.008
DR	0.002		0.004	0.002		NS	0.004		0.008	0.003		0.006
VxDR	0.002		NS	0.003		NS	0.006		0.010	0.004		NS
C) System												
S_1	2.28	2.30	**2.29**	1.88	1.91	**1.89**	1.76	1.81	**1.79**	0.84	0.87	**0.85**
S_0	2.43	2.44	**2.44**	2.07	2.08	**2.07**	1.98	2.00	**1.99**	1.06	1.08	**1.07**
Mean	**2.36**	**2.37**		**1.98**	**1.99**		**1.87**	**1.91**		**0.95**	**0.97**	
	S.E.(d)±		**C.D.(0.05)**	**S.E.(d)±**		**C.D.(0.05)**	**S.E.(d)±**		**C.D.(0.05)**	**S.E.(d)±**		**C.D.(0.05)**
S	0.002		0.004	0.002		0.004	0.004		0.008	0.003		0.006
DR	0.002		0.004	0.002		NS	0.004		0.008	0.003		0.006
SxDR	0.002		0.004	0.002		0.004	0.004		0.008	0.003		NS

DR_1 – North; DR_2 – South

** Figures in (A) and (B) are the average values for land use systems S_1 and S_0*

Milking stage

The data in Table 4 showing the effect of N levels, varieties and system of crop independent of one another, influenced N concentration of wheat plants significantly.

Application of nitrogen increased the plant N concentration significantly at level N_3 (1.96%) followed by N_2 (1.88%) and N_1 (1.81%).

All the four varieties differed significantly in N concentration at milking stage. Variety V_4 gave highest value (2.03%) followed by V_3 (1.91%), V_1 (1.83%) and V_2 (1.78%).

System i.e. crop sown with the peach tree row (S_1) and without the peach tree row (S_0) also affected the concentration of N in wheat plants. Higher values were observed in plants growing without peach tree row (S_0) as compared to plants growing with peach tree row (S_1) (Table 5). Direction of the crop from peach tree row too influenced the N concentration significantly.

The interaction effects between S x DR (Table 4) as well as N x V x S x DR were statistically significant (Appendix-IV).

Crop harvest

Different doses of nitrogen, varieties and system of the crop resulted into significantly different N concentration in wheat plants at crop harvest. Nitrogen level N_3 increased the plant N concentration significantly over N_2 and N_1. Their respective values were 1.04, 0.96 and 0.88 per cent. In case of varieties highest concentration of N was recorded in variety V_4 (0.99%) and minimum in V_2 (0.96%).

Higher values of N were observed in wheat plants growing without peach tree row i.e. at S_0. South (DR_2) direction exhibited higher values over North (DR_1) (Table 4).

Interaction between N x DR was significant whereas V x DR and S x DR were non-significant (Table 4). The cumulative influence of nitrogen level and wheat varieties sown in two systems (S_1 and S_0)and in two directions (DR_1 and DR_2) was found to be statistically significant (Appendix-IV).

Grain and straw

In case of grains and straw besides N, concentration of P and K was also studied.

In grains cumulative effect of N x V x S x DR on the concentration of these nutrients (Appendix-V) shows statistically non-significant effects. However, influence of N levels, varieties and system independent of each other observed in North (DR_1) and South (DR_2) directions of peach tree row was statistically significant (Table 5) except for P in case of N levels only.

It is seen from Table 5 that level N_3 gave maximum value of N (1.56) and K (0.57) concentration whereas N_1 gave the minimum values for both the elements. P concentration remained statistically non-significant.

Varietal effect on grain N,P and K concentration have shown their maximum concentration in variety V_4 however, their minimum values occurred in different varieties.

Higher N, P and K concentration was observed in system S_0 (1.51, 0.42, 0.54) over S_1 (1.50, 0.41, 0.53) (Table 5) which were statistically significant.

Table 5. Effect of nitrogen level, crop variety and system on NPK concentration (%)* of wheat grain

Direction→	N			P			K		
	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean
A) NITROGEN LEVEL									
N_1	1.44	1.45	1.45	0.41	0.42	0.41	0.51	0.52	0.52
N_2	1.51	1.52	1.51	0.41	0.42	0.41	0.52	0.52	0.52
N_3	1.55	1.57	1.56	0.41	0.42	0.41	0.56	0.58	0.57
Mean	1.50	1.51		0.41	0.42		0.54	0.54	

Treatment	S.E.(d)± (N)	C.D. (0.05) (N)	S.E.(d)± (P)	C.D.(0.05) (P)	S.E.(d)± (K)	C.D. 0.05) (K)
N	0.0001	0.0006	0.0002	NS	0.0001	0.0006
DR	0.001	NS	0.0003	NS	0.0002	0.0003
NxDR	0.0002	NS	0.0003	NS	0.0002	NS

Direction→	N			P			K		
	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean
B) VARIETY									
V_1	1.38	1.39	1.39	0.31	0.32	0.32	0.20	0.20	0.20
V_2	1.32	1.33	1.32	0.31	0.31	0.31	0.78	0.78	0.78
V_3	1.59	1.61	1.60	0.31	0.31	0.31	0.19	0.20	0.20
V_4	1.72	1.73	1.72	0.33	0.33	0.33	0.97	0.97	0.97
Mean	1.72	1.51	1.61	0.31	0.31	0.31	0.54	0.54	

Treatment	S.E.(d)± (N)	C.D. (0.05) (N)	S.E.(d)± (P)	C.D.(0.05) (P)	S.E.(d)± (K)	C.D. 0.05) (K)
V	0.0002	0.0004	0.0003	0.0006	0.0002	0.0005
DR	0.0001	NS	0.0003	NS	0.0002	0.0003
VxDR	0.0002	NS	0.0003	NS	0.0002	NS

Direction→	N			P			K		
	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean
C) SYSTEM									
S_1	1.50	1.51	1.50	0.41	0.42	0.41	0.53	0.54	0.53
S_0	1.51	1.51	1.51	0.41	0.43	0.42	0.54	0.54	0.54
Mean	1.50	1.51		0.41	0.42		0.53	0.54	

Treatment	S.E.(d)± (N)	C.D. (0.05) (N)	S.E.(d)± (P)	C.D.(0.05) (P)	S.E.(d)± (K)	C.D. 0.05) (K)
S	0.001	0.0003	0.0003	0.0004	0.0002	0.0003
DR	0.001	NS	0.003	NS	0.0002	0.0003
SxDR	0.001	NS	0.0003	NS	0.0002	0.0003

DR_1 – North; DR_2 – South

* *Figures in (A) and (B) are the average values for land use systems S_1 and S_0*

Direction had a significant effect only on K concentration and direction DR_2 exhibited higher value (0.54) over DR_1 (Table 5).

All the interaction effects were found to be non-significant except SxDR for K concentration.

N, P and K concentration in wheat straw due to the joint effect of nitrogen level, wheat varieties sown in two systems (S_1 and S_0) in North (DR_1) and South (DR_2) direction of peach tree row was observed to be non-significant (Appendix-VI).

However, independently the above variables influenced the nutrient concentration significantly (Table 6). N, P and K concentration in wheat straw due to interactions between N x DR and S x DR was statistically non-significant except in case of P (Table 6).

System S_0 exhibited significantly higher values of N (0.34) and P (0.16) concentration over S_1. K concentration in wheat straw however did not change significantly due to system (Table 6). Direction of the crop influenced only P concentration in wheat plants significantly showing its higher value at DR_2 over DR_1. N and K concentration both remained statistically non-significant.

4.1.2.2 Uptake

Tillering

The uptake of N in wheat plants at tillering stage was not influenced by the joint effect of different levels of nitrogen, wheat varieties, system and direction (Appendix-VII). Nevertheless, sole effects of N levels, varieties and system recorded in North and South direction were statistically significant (Table 7).

Table 6. Effect of nitrogen level, crop variety and system on NPK concentration (%)* of wheat straw

	N			P			K		
Direction→	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean
A) NITROGEN LEVEL									
N_1	0.22	0.22	0.22	0.13	0.13	0.13	0.56	0.57	0.57
N_2	0.32	0.32	0.32	0.16	0.17	0.16	0.61	0.60	0.60
N_3	0.43	0.43	0.43	0.13	0.13	0.13	0.69	0.69	0.69
Mean	0.32	0.33		0.14	0.14		0.62	0.62	
Treatment	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. 0.05)
N	0.002		0.01	0.0002		0.0009	0.004		0.016
DR	0.002		NS	0.0001		0.0003	0.002		NS
NxDR	0.002		NS	0.0002		0.0004	0.002		NS
B) VARIETY									
V_1	0.30	0.30	0.30	0.14	0.14	0.14	0.42	0.42	0.42
V_2	0.32	0.33	0.32	0.13	0.14	0.14	0.42	0.42	0.42
V_3	0.34	0.34	0.34	0.13	0.13	0.13	0.41	0.42	0.42
V_4	0.33	0.34	0.34	0.17	0.17	0.17	0.43	0.43	0.43
Mean	0.32	0.33		0.14	0.14		0.43	0.43	
Treatment	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. 0.05)
V	0.002		0.005	0.0002		0.0004	0.003		0.006
DR	0.002		NS	0.0001		0.0003	0.002		NS
VxDR	0.002		NS	0.0002		NS	0.003		NS
C) SYSTEM									
S_1	0.30	0.31	0.31	0.12	0.12	0.12	0.43	0.43	0.43
S_0	0.34	0.34	0.34	0.16	0.17	0.16	0.43	0.43	0.43
Mean	0.32	0.33		0.14	0.14		0.43	0.43	
Treatment	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. 0.05)
S	0.002		0.003	0.0001		0.0003	0.002		NS
DR	0.002		NS	0.0001		0.0003	0.002		NS
SxDR	0.002		NS	0.0001		0.0003	0.002		NS

DR_1 – North *DR_2 – South*

** Figures in (A) and (B) are the average values for land use systems S_1 and S_0*

N uptake was significantly higher at N_3 level which was at par with N_2 level followed by N_1.Their respective values were 13.41, 13.39 and 11.94 kg ha^{-1}. In case of varieties maximum uptake of N (13.98) was exhibited by V_4, followed by V_3 (13.54), V_2 (13.42) and V_1 (10.72). The interaction of variety x direction was however, non-significant (Table 7).

Influence of system studied on wheat with (S_1) and without (S_0) the peach tree on N uptake was significant. The uptake was more in S_0 compared to S_1. Direction alone as well as interaction between system x direction also showed a significant effect on N uptake (Table 7).

Spike initiation stage

The cumulative effect of nitrogen levels and wheat varieties sown in two systems (S_1 and S_0) and in North (DR_1) and South (DR_2) direction had a non-significant effect on N uptake in wheat plants at spike initiation stage (Appendix-VII).

Sole effect of nitrogen levels on N uptake was significant in wheat plants at spike initiation stage as observed at tillering stage. The interaction effect between nitrogen x direction was however, non-significant (Table 7).

Wheat varieties also affected N uptake significantly. Variety V_4 gave a maximum value of 22.74 whereas, variety V_1 gave the minimum value of 16.86 kg ha^{-1}. The interaction between variety and direction was found to be non-significant.

A significantly higher N uptake was observed in plants without peach tree row (S_0) than in plants with the peach tree row (S_1). Direction alone

Table 7. **Effect of nitrogen level, crop variety and system on nitrogen uptake (kg ha^{-1})* by wheat during active growth stages**

	Tillering			Spike initiation			Milking			Crop harvest		
Direction	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean
A) Nitrogen												
N_1	11.72	12.17	**11.94**	17.47	17.84	**17.65**	20.49	21.01	**20.75**	20.98	21.58	**21.28**
N_2	13.15	13.63	**13.39**	19.63	20.49	**20.07**	23.54	24.15	**23.84**	24.18	25.28	**24.73**
N_3	13.15	13.68	**13.41**	21.54	22.31	**21.92**	25.47	26.35	**25.91**	26.09	27.49	**26.29**
Mean	**12.67**	**13.16**		**19.55**	**20.21**		**23.16**	**23.84**		**18.75**	**19.45**	
	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)
N	0.20		0.86	0.28		1.19	0.44		1.89	0.28		1.21
DR	0.10		0.21	0.15		0.31	0.19		0.38	0.13		0.27
NxDR	0.12		NS	0.19		NS	0.23		NS	0.16		NS
B) Variety												
V_1	10.45	10.99	**10.72**	16.53	17.20	**16.86**	19.22	19.84	**19.53**	21.91	22.76	**22.33**
V_2	13.17	13.67	**13.42**	19.13	20.06	**19.59**	22.57	23.77	**23.17**	20.81	23.36	**23.08**
V_3	13.30	13.77	**13.54**	19.95	20.67	**20.31**	23.84	24.32	**24.08**	24.07	24.80	**24.43**
V_4	13.77	14.20	**13.98**	22.58	22.91	**22.74**	27.02	27.43	**27.22**	26.20	26.89	**26.54**
Mean	**12.67**	**13.16**		**19.55**	**20.21**		**23.16**	**23.84**		**23.75**	**24.45**	
	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)
V	0.29		0.29	0.22		0.44	0.27		0.54	0.19		0.38
DR	0.10		0.21	0.15		0.31	0.19		0.38	0.13		0.27
VxDR	0.14		NS	0.22		NS	0.26		NS	0.19		NS
C) System												
S_1	11.45	12.50	**12.02**	17.90	19.02	**18.46**	20.73	21.72	**21.22**	20.74	21.96	**21.35**
S_0	13.67	13.82	**13.81**	21.19	21.41	**21.30**	25.60	25.95	**25.77**	26.76	26.94	**26.85**
Mean	**12.56**	**13.16**		**19.55**	**20.21**		**23.16**	**23.84**		**23.75**	**24.45**	
	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)
S	0.10		0.21	0.15		0.31	0.19		0.38	0.13		0.27
DR	0.10		0.21	0.15		0.31	0.19		0.38	0.13		0.27
SxDR	0.10		0.21	0.15		0.31	0.19		0.38	0.13		0.27

DR_1 – North; DR_2 – South

* *Figures in (A) and (B) are the average values for land use systems S_1 and S_0*

as well as interaction between system x direction also showed a significant change in N uptake values (Table 7).

Milking stage

N uptake in wheat plants at milking stage was observed to be uninfluenced by the interaction effect between nitrogen levels x varieties x system x direction (Appendix VII), though sole effects of N levels, variety and crop system followed the trend similar to uptake at spike intiation stage (Table 7).

Crop harvest

The cumulative influence of nitrogen levels, wheat varieties sown with the peach tree row (S_1) and without peach tree row (S_0) in North (DR_1) and South (DR_2) direction was statistically non-significant at this stage also (Appendix-VII). Data in Table 7 exhibiting the sole effects of N levels, varieties and system on N uptake in two directions, however, have shown statistically significant variations in N uptake. Maximum uptake was observed at level N_3 (26.29) followed by N_2 (24.73) and N_1 (21.28). Interaction between nitrogen level x direction (Table 7) was non-significant.

N uptake in wheat plants varied significantly due to the varietal effect. Highest value was observed in variety V_4 (26.54 kg ha^{-1}) and minimum (22.33 kg ha^{-1}) in V_1. Plants growing with the peach tree row (S_1) have shown significantly less N uptake than plants growing without the peach tree row i.e. S_0.

Influence of direction alone and the interaction between S x DR on uptake was significant (Table 7).

4.1.2.4 Grain and straw

Like nutrient concentration in wheat grain and straw, uptake of P and K besides N was also studied.

The data on sole effect of nitrogen (Table 8) have shown statistically significant difference due to N levels on N and K uptake in grains. However, interaction between N x DR was significant in case of N and P. Maximum N and K uptake in grains was observed at N_3 level and minimum at N_1 level. Varieties and system had significant effect on N, P and K uptake values. Variety V_3 gave the maximum N and P uptake whereas K was maximum in variety V_4.

System S_0 gave significantly higher N, P and K uptake values over S_1. Direction alone have influenced N and P significantly giving their higher values at DR_2. Interaction between S x DR also influenced N and P uptake only. The interaction effect of N x V x S x DR was observed to be non-significant for N, P and K uptake in wheat grains (Appendix-VIII).

Table 9 exhibiting the sole effects of N levels, varieties and system on N, P and K uptake in straw in two directions, has shown statistically significant variations in N, P and K uptake. However, interaction between NxDR and VxDR was observed to be significant only for N uptake. Maximum N, P and K uptake in straw was observed at N_3 level and minimum at N_1 level. Variety V_3 gave the maximum N, P and K uptake (Table 9).

System S_0 gave significantly higher N, P and K uptake values in straw over S_1. Direction has also influenced N, P and K uptake significantly giving their higher values at DR_2.

Table 8. Effect of nitrogen level, crop variety and system on NPK Uptake (kg ha^{-1})* by wheat grain

	N			P			K		
Direction→	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean
A) NITROGEN LEVEL									
N_1	23.25	24.54	23.89	8.20	8.28	8.24	8.46	9.01	8.73
N_2	25.29	26.93	26.11	8.49	8.72	8.60	8.98	8.73	8.93
N_3	29.61	30.80	30.20	8.63	8.75	8.69	10.81	11.48	11.14
Mean	26.05	27.42		8.44	8.58		9.42	9.79	
Treatment	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. 0.05)
N	0.10		0.44	0.10		NS	0.34		0.14
DR	0.06		0.12	0.04		0.09	0.20		NS
NxDR	0.07		0.14	0.05		0.11	0.25		NS
B) VARIETY									
V_1	17.51	19.09	18.30	4.86	5.51	5.18	3.12	3.80	3.46
V_2	20.75	21.92	21.33	6.31	6.92	6.61	11.44	11.14	11.29
V_3	33.53	34.86	34.19	11.85	12.56	12.20	4.94	5.47	5.21
V_4	32.41	33.81	33.11	10.15	10.95	10.55	18.17	18.75	18.46
Mean	26.05	27.42		8.78	8.82		9.41	9.79	
Treatment	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. 0.05)
V	0.08		0.17	0.07		0.13	0.29		0.59
DR	0.06		0.12	0.04		0.09	0.20		NS
VxDR	0.08		NS	0.06		NS	0.29		NS
C) SYSTEM									
S_1	25.27	27.19	26.23	6.78	8.13	7.45	8.77	9.36	9.07
S_0	26.83	26.75	27.24	9.80	9.83	9.82	10.06	10.22	10.14
Mean	26.05	27.42		8.29	8.98		9.42	9.79	
Treatment	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. 0.05)
S	0.06		0.12	0.04		0.09	0.20		0.41
DR	0.06		0.12	0.04		0.09	0.20		NS
SxDR	0.06		0.12	0.04		0.09	0.20		NS

DR_1 – North; DR_2 – South

Figures in (A) and (B) are the average values for land use systems S_1 and S_0

Table 9. Effect of nitrogen level, crop variety and system on NPK Uptake (kg ha^{-1})* by wheat straw

	N			P			K		
Direction→	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean
A) NITROGEN LEVEL									
N_1	10.73	11.54	**11.13**	6.35	6.84	**6.60**	28.38	28.63	**28.50**
N_2	16.10	18.01	**17.05**	6.75	7.34	**7.05**	31.69	32.05	**31.87**
N_3	24.18	24.92	**24.55**	7.76	8.45	**8.11**	39.00	39.39	**39.19**
Mean	**17.00**	**18.16**		**6.95**	**7.54**		**33.02**	**33.36**	
Treatment	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. 0.05)
N	0.09		0.38	0.04		0.18	0.11		0.49
DR	0.08		0.16	0.04		0.08	0.63		0.12
NxDR	0.98		0.19	0.05		NS	0.07		NS
B) VARIETY									
V_1	11.04	13.27	**12.15**	5.33	5.90	**5.61**	15.57	15.82	**15.69**
V_2	16.02	16.83	**16.42**	7.22	7.84	**7.52**	21.30	21.58	**21.44**
V_3	21.84	22.61	**22.22**	8.20	8.79	**8.49**	26.73	27.16	**26.94**
V_4	19.11	19.93	**19.52**	7.06	7.65	**7.36**	25.50	25.87	**25.68**
Mean	**17.00**	**18.16**		**6.95**	**7.54**		**22.27**	**22.60**	
Treatment	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. 0.05)
V	0.11		0.23	0.06		0.11	0.09		0.18
DR	0.08		0.16	0.04		0.08	0.63		0.12
VxDR	0.11		0.22	0.05		NS	0.89		NS
C) SYSTEM									
S_1	15.92	17.95	**16.93**	6.94	7.25	**6.67**	21.24	21.86	**21.55**
S_0	18.09	18.37	**18.23**	7.81	7.84	**7.82**	23.31	23.35	**23.33**
Mean	**17.00**	**18.16**		**6.95**	**7.54**		**22.27**	**22.61**	
Treatment	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. 0.05)
S	0.08		0.16	0.04		0.08	0.63		0.12
DR	0.08		0.16	0.04		0.08	0.63		0.12
SxDR	0.08		0.16	0.04		0.08	0.63		0.12

DR_1 – North; DR_2 – South

** Figures in (A) and (B) are the average values for land use systems S_1 and S_0*

Interaction between S x DR was significant for N, P and K uptake (Table 9). However, interaction between N x V x S x DR was observed to be significant for N uptake only (Appendix-IX).

4.2 Trees

4.2.1 Growth and yield

Peach tree growth and yield characteristics were studied at sowing as well as at harvest time of wheat crop. The pertinent data on growth attributes namely crown spread, height and diameter of the tree have been given in Table 10.

Crown spread at crop harvest (May, 1998) measured in all the four directions i.e. North, South, East and West was more towards South (1.77m) and East (1.61m) compared to North (1.54m) and West (1.49m). Average height of the trees was 3.03 m and diameter was 95.64 mm. The directional spread of the crown observed at crop harvest was similar as it existed at sowing time (December, 1997) of wheat.

Yield of the fruits was recorded as number of fruits tree^{-1} as well as on per hectare basis. The variations in fruit yield due to the nitrogen levels supplied to wheat and its varieties were statistically non-significant (Table 11). However, the average yield varied from 15.20 q ha^{-1} to 34.58 q ha^{-1}.

4.2.2 Nutrient concentration and uptake

4.2.2.1 Concentration (%)

The nutrient concentration in leaves and fruits was analyzed and the relevant data have been presented in Table 12.

Table 10. Growth and development of peach in Agrihorticulture system

Treatment	December, 1997						May, 1998					
	Crown spread (m)				Height (m)	Diameter (mm)	Crown spread (m)				Height (m)	Diameter (mm)
	North	South	East	West			North	South	East	West		
N_1	1.09	1.17	1.28	1.13	2.48	87.11	1.44	1.65	1.64	1.50	2.97	89.38
N_2	1.26	1.50	1.22	1.06	2.54	95.98	1.63	1.78	1.56	1.38	3.04	99.03
N_3	1.19	1.52	1.34	1.34	2.64	95.84	1.56	1.88	1.63	1.60	3.11	98.52
Mean	1.18	1.39	1.28	1.18	2.54	92.97	1.54	1.77	1.61	1.49	3.03	95.64
SE(d)±	0.16	0.14	0.16	0.18	0.21	8.7	0.16	0.23	0.17	0.20	0.23	8.8
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 11. Influence of crop association and its fertilization on fruit yield of peach

	No. of Fruits tree^{-1}					Fruit yield (q ha^{-1})				
	V_1	V_2	V_3	V_4	**Mean**	V_1	V_2	V_3	V_4	**Mean**
N_1	94.0	103.0	12.67	142.3	**88**	16.40	17.27	1.67	34.60	**17.48**
						(8.20)	(8.63)	(0.83)	(17.30)	**(8.74)**
N_2	242.7	42.0	231.7	170.0	**171.6**	62.00	7.33	65.93	40.04	**43.91**
						(31.00)	(3.67)	(37.96)	(20.20)	**(21.95)**
N_3	124.0	102.3	118.3	91.33	**109.0**	25.33	21.00	20.13	25.27	**22.93**
						(12.67)	(10.50)	(10.07)	(12.55)	**(11.45)**
Mean	**153.6**	**82.44**	**120.9**	**134.5**	-	**34.58**	**15.20**	**29.24**	**33.42**	-
						(17.29)	**(7.60)**	**(14.62)**	**(16.68)**	

Treatment	S.E.(d)±	C.D.(0.05)	S.E.(d) ±	C.D.(0.05)
Nitrogen level	28.98	NS	7.07	NS
Variety	33.47	NS	8.17	NS
Nitrogen level X variety	40.99	120.23	10.01	NS

Figures in parentheses indicate yield in kg tree^{-1}

Leaves

Application of nitrogen to different varieties of wheat influenced the leaf N and P concentration of peach trees significantly. K concentration however, remained statistically unaffected. Influence of N levels alone has shown maximum values of N and P at N_3 level whereas respective minimum concentration for these elements due to N levels was observed at N_1 level (Table 12).

Sole varietal effect on N concentration has exhibited its highest value at V_4 whereas lowest concentration was at V_1. The P and K concentration remained statistically non-significant.

The interaction between N x V was statistically significant both for N and P. Peach leaf N and P concentration was highest at N_3 combination with all the varieties than N_1 and N_2 combination.

Fruits

Applied levels of nitrogen in wheat crop were observed to influence N, P and K concentration in fruits significantly. N_3 level exhibited highest value for N and K concentration. Their respective values being 2.66 per cent and 1.74 per cent. Highest value (0.24) for P was exhibited at N_2 level (Table 12). Minimum concentration of N, P and K was shown by N_1, N_1 & N_3, and N_1 & N_2 respectively. Varietal effects on N concentration in fruits were non-significant.

Interaction between N x V was observed to be significant for N, P and K content in fruits (Table 12).

Table 12. **Leaf and fruit nutrient (NPK) concentration (%) of Peach in association with wheat grown at three nitrogen levels.**

	N					P					K				
	V_1	V_2	V_3	V_4	Mean	V_1	V_2	V_3	V_4	Mean	V_1	V_2	V_3	V_4	Mean
LEAVES															
N_1	2.14	2.14	2.15	2.24	**2.17**	0.40	0.40	0.40	0.40	**0.40**	3.03	3.03	3.04	3.03	**3.03**
N_2	2.67	2.73	2.75	2.73	**2.72**	0.45	0.45	0.45	0.45	**0.45**	3.03	3.03	3.03	3.03	**3.03**
N_3	2.87	2.86	2.83	2.85	**2.85**	0.50	0.50	0.51	0.51	**0.50**	3.04	3.03	3.03	3.03	**3.03**
Mean	**2.56**	**2.57**	**2.58**	**2.60**		**0.45**	**0.45**	**0.45**	**0.45**		**3.03**	**3.03**	**0.03**	**3.03**	
FRUITS															
N_1	2.54	2.52	2.52	2.54	**2.53**	0.23	0.23	0.23	0.24	**0.23**	1.73	1.73	1.74	1.73	**1.73**
N_2	2.59	2.58	2.60	2.58	**2.59**	0.24	0.24	0.24	0.23	**0.24**	1.73	1.73	1.73	1.73	**1.73**
N_3	2.65	2.67	2.66	2.66	**2.66**	0.23	0.23	0.23	0.24	**0.23**	1.74	1.73	1.74	1.74	**1.74**
Mean	**2.59**	**2.59**	**2.59**	**2.59**		**0.23**	**0.24**	**0.23**	**0.24**		**1.73**	**1.73**	**1.74**	**1.73**	

LEAVES

Treatment	N: S.E.(d) ±	N: C.D. (0.05)	P: S.E.(d) ±	P: C.D. (0.05)	K: S.E.(d) ±	K: C.D. (0.05)
Nitrogen Level	0.01	0.03	0.001	0.003	0.002	NS
Variety	0.01	0.03	0.001	NS	0.002	NS
Nitrogen Level x Variety	0.02	0.05	0.002	0.004	0.003	NS

FRUITS

Treatment	N: S.E.(d) ±	N: C.D. (0.05)	P: S.E.(d)±	P: C.D. (0.05)	K: S.E.(d) ±	K: C.D. (0.05)
Nitrogen Level	0.003	0.006	0.003	0.006	0.002	0.005
Variety	0.003	NS	0.004	0.007	0.003	0.006
Nitrogen Level x Variety	0.004	0.012	0.004	0.012	0.003	0.01

4.2.2.2 Uptake

Leaves

Nitrogen application to wheat could influence only N uptake in peach tree leaves, where maximum (42.61) and minimum (29.29) value was recorded at N_3 and N_1 level respectively. Contrary to N levels, varietal effects on N, P and K uptake though peach leaves were statistically significant. Variety V_1 gave the maximum uptake values of 42.54, 7.43, 50.49 kg ha^{-1} for N, P and K respectively. Interaction between N x V was significant but only in case of K uptake by leaves (Table 13).

Fruits

Nitrogen application to wheat influenced N, P and K uptake in peach fruits, where maximum (64.46, 5.81 and 43.04), and minimum (24.40, 2.24 and 16.66) values were recorded at N_2 and N_1 levels, respectively. Varietal effect for P uptake as well as interaction between N x V for N, P and K uptake in fruits was significant (Table 13).

4.2.3 Root characteristics

The horizontal root spread around the peach trees was studied by excavating the roots by skeleton method. The data presented in Fig. 3 indicated maximum length (6.20m) of the single longest root in South direction, followed by North (5.60m), West (4.70m) and East (4.20m). Looking into the spread of maximum root mass direction wise, East and West directions upto 2.5m radial system contained the maximum root mass. North and South directions had the least spread.

Table 13. **Nutrient uptake (kg ha^{-1}) by leaves and fruits of peach in association with wheat varieties grown at three nitrogen levels.**

N

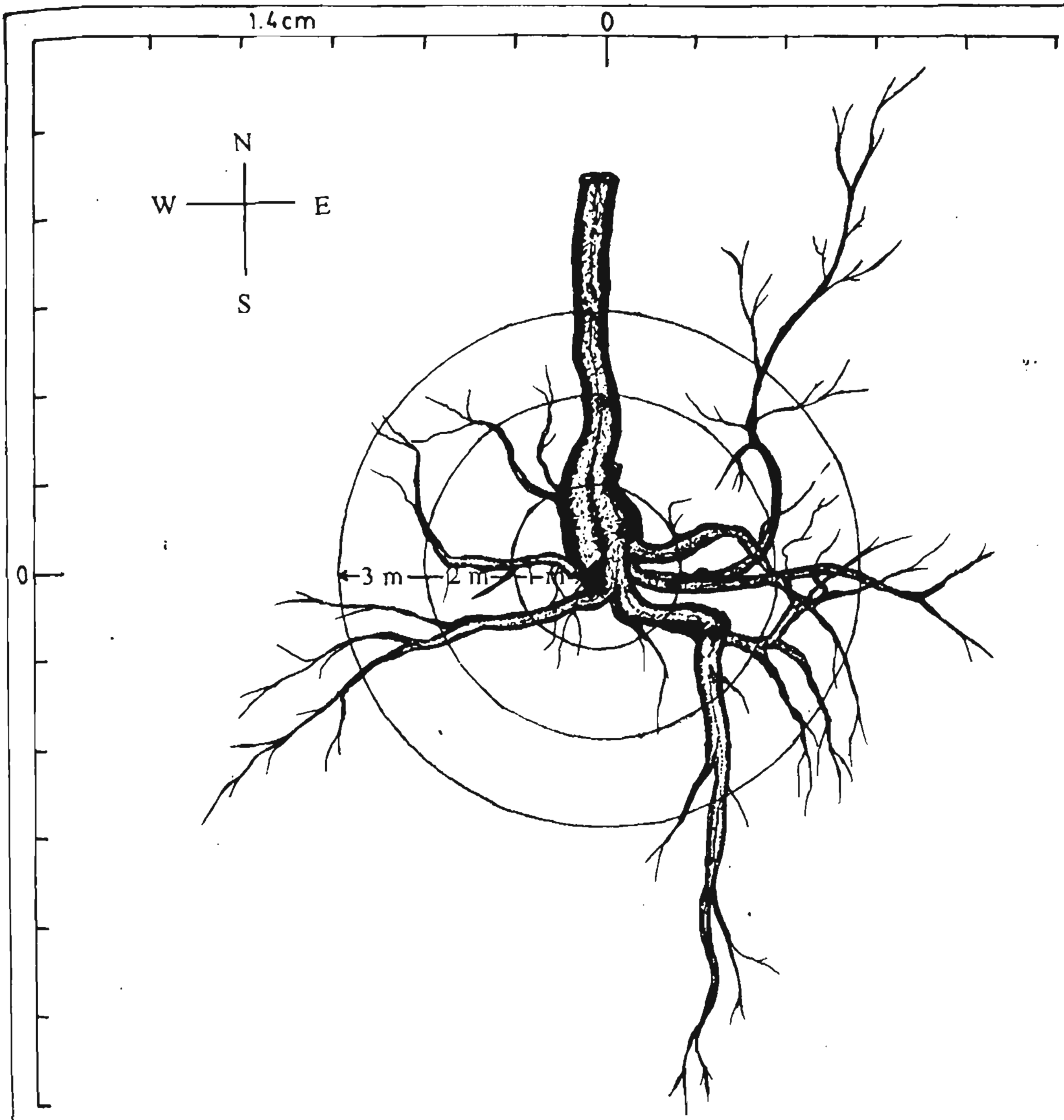
	V_1	V_2	V_3	V_4	Mean
LEAVES					
N_1	35.94	32.52	11.77	36.93	**29.29**
N_2	46.05	30.40	44.85	37.25	**39.64**
N_3	45.62	50.31	27.09	47.42	**42.61**
Mean	**42.54**	**37.74**	**27.90**	**40.53**	
Treatment		**S.E.(d) ±**	**C.D. (0.05)**		
Nitrogen Level		4.29	8.91		
Variety		4.96	10.29		
Nitrogen Level x Variety		6.08	NS		
FRUITS					
N_1	22.89	23.96	2.26	48.48	**24.40**
N_2	88.56	10.43	94.39	64.46	**64.46**
N_3	37.09	30.94	29.54	37.10	**33.67**
Mean	**49.51**	**21.78**	**42.06**	**50.01**	
Treatment		**S.E.(d) ±**	**C.D. (0.05)**		
Nitrogen Level		10.17	NS		
Variety		11.75	NS		
[illegible]n Level x Variety		14.39	41.63		

P

	V_1	V_2	V_3	V_4	Mean
LEAVES					
N_1	6.75	6.77	2.19	6.64	**5.59**
N_2	7.55	5.07	7.33	6.16	**6.53**
N_3	7.99	8.88	4.88	8.54	**7.57**
Mean	**7.43**	**6.91**	**4.80**	**7.11**	
Treatment		**S.E.(d) ±**	**C.D. (0.05)**		
Nitrogen Level		0.79	NS		
Variety		0.91	1.89		
Nitrogen Level x Variety		1.12	NS		
FRUITS					
N_1	2.07	2.26	0.21	4.45	**2.24**
N_2	8.52	0.97	8.72	5.07	**5.81**
N_3	3.31	2.67	2.60	3.47	**3.01**
Mean	**4.63**	**1.96**	**3.83**	**4.33**	
Treatment		**S.E.(d) ±**	**C.D. (0.05)**		
Nitrogen Level		0.89	1.85		
1.03		NS	0.007		
Nitrogen Level x Variety		1.27	3.66		

K

	V_1	V_2	V_3	V_4	Mean
LEAVES					
N_1	50.91	45.98	16.63	49.98	**40.87**
N_2	52.32	33.92	49.41	41.36	**44.25**
N_3	48.26	53.39	17.56	50.42	**42.41**
Mean	**50.49**	**44.43**	**27.87**	**47.25**	
Treatment		**S.E.(d) ±**	**C.D. (0.05)**		
Nitrogen Level		5.10	NS		
Variety		5.89	10.23		
Nitrogen Level x Variety		7.22	20.89		
FRUITS					
N_1	15.66	16.50	1.56	32.93	**16.66**
N_2	59.24	7.00	62.93	43.00	**43.04**
N_3	24.57	20.08	19.34	24.18	**22.04**
Mean	**33.16**	**14.53**	**27.95**	**33.37**	
Treatment		**S.E.(d) ±**	**C.D. (0.05)**		
Nitrogen Level		6.76	14.02		
Variety		7.81	NS		
Nitrogen Level x Variety		9.56	27.69		



East	-	4.20	m
West	-	4.70	m
North	-	5.60	m
South	-	6.20	m

Scale: 1.4 cm = 1 m

Fig. 3. Horizontal root spread of peach tree.

4.3 Soil studies

4.3.1 Soil moisture

Soil moisture was not significantly affected by different levels of nitrogen and wheat varieties (Fig. 4). However, system S_0 gave higher moisture per cent over system S_1 at tillering and spike initiation stage. Reverse trend was observed at milking and harvest stage. Direction DR_1 has shown significantly higher values (14.73, 8.28, 3.54%) over DR_2 (14.22, 8.22, 3.33%) at tillering, spike initiation and harvesting stage, respectively. While, direction DR_2 exhibited significantly higher value of 3.53 per cent over DR_1 (3.37%) at milking stage.

4.3.2 pH, E.C., Organic Carbon and available N, P and K status of soils

Effects of different nitrogen levels, wheat varieties and system in two directions (DR_1 - North, DR_2 - South) from peach tree row on pH, E.C., organic carbon and available N, P and K in soils were studied at all the four active growth stages of wheat. The relevant data is given in Appendix-XI-XVI.

pH

pH in soil was found to be significantly affected by system and direction. Slightly high pH was recorded at crop harvest as compared to tillering stage (Appendix-XI).

E.C.

Applied doses of nitrogen had no significant effect on E.C. values throughout the active growth phase of wheat. However, system was seen to influence E.C. to some extent. A slightly higher value was observed in system S_0 as compared to system S_1 (Appendix-XII).

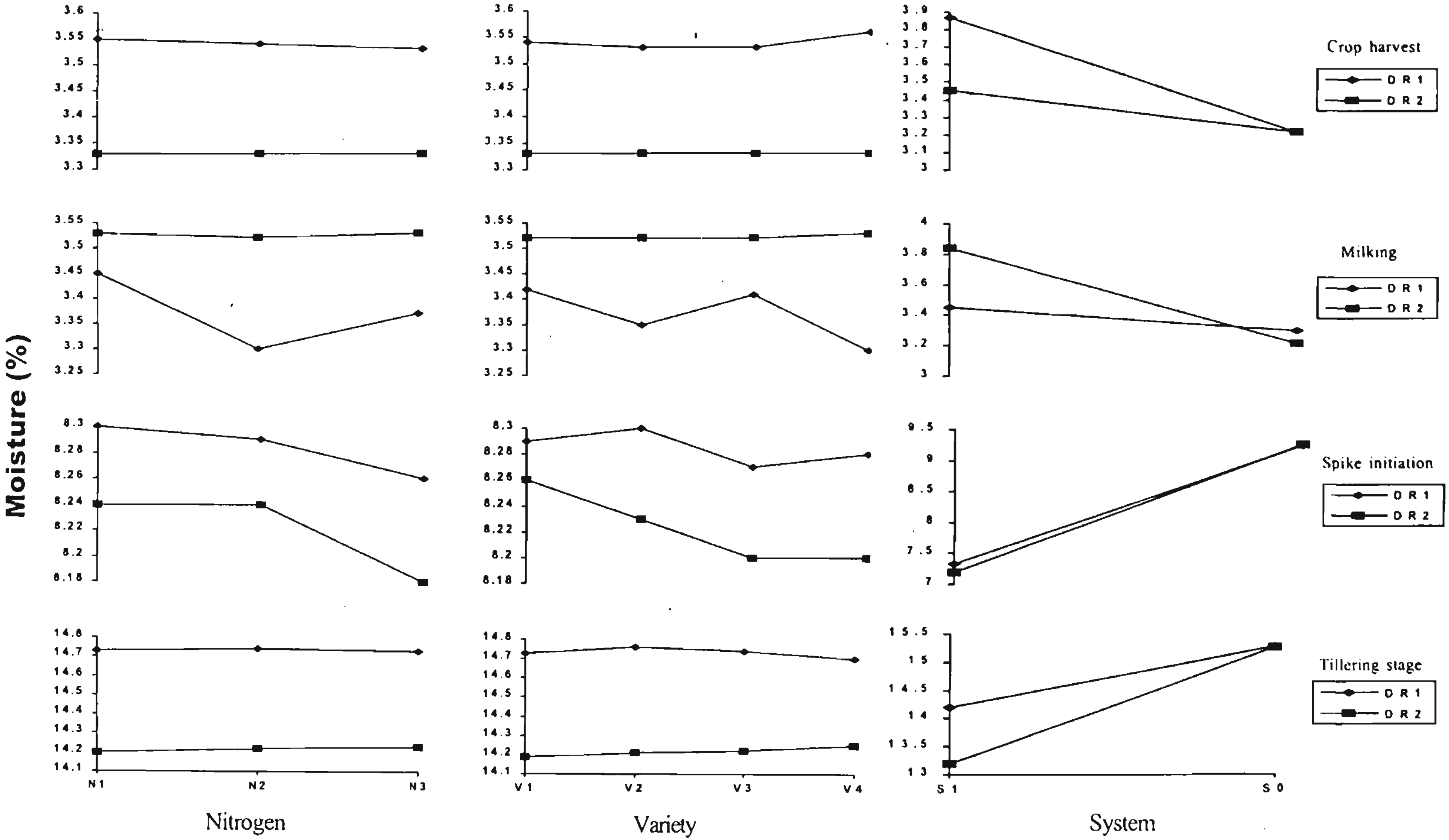


Fig. no. 4. **Effect of Nitrogen level, crop variety and system on soil moisture during the active growth stages of wheat**

DR_1- North ; DR_2 - South

Organic carbon

Organic carbon was significantly influenced in the soils with and without the peach tree rows and the direction of wheat crop sown (Appendix-XIII). A slightly higher organic carbon was recorded in soil near the peach tree rows. A significant decrease in its content was observed with increase in growing season i.e. advancement in crop development.

Available N, P and K

The change in available N, P and K elements in soils due to different nitrogen levels, wheat varieties and system was studied both in North (DR_1) and South (DR_2) direction of peach tree row (Appendix-XIV-XVI). Though the variations in the values for all the nutrient elements observed at each of the four active growth stages of wheat were statistically significant at some of the growth stage either due to the sole effects of N levels, varieties, or interaction between these treatments, yet in view of fertility management, the differences were negligible. This is true since N ranged from 514.8 to 547.6; P from 46.33 to 62.81 and K from 246.9 to 275.7 kg ha^{-1} irrespective of any particular treatment effect.

The pre-sowing values for pH, E.C., O.C., N, P and K of the soils were 6.82, 0.22, 1.29, 530.4, 50.60 and 270.7 (Appendix-X) for agrihorticulture system and 6.82, 0.22, 1.27, 525.9, 45.7 and 260.2 for sole crop.

4.4 Per cent relative illumination (RI)

Table 14 shows per cent RI below the canopy of peach in North and South direction of the trees. The observations have been taken during active growth stages of peach/wheat.

Table 14. Relative illumination (%) during active tree-crop growth stages in Agrihorticulture system

Growth Stage		Direction			
Peach	Wheat	North	South	S.E.m	C.D.(0.05`)
Pink bud	Tillering	98.51	99.39	0.19	0.39
Flowering	Tillering	70.38	75.49	0.12	0.24
Fruit Set	Spike initiation and Milking	51.43	56.45	0.05	0.09
Fruit development	Crop harvest	50.95	55.98	0.08	0.16

RI values were maximum at pink bud stage of peach crop when wheat plants entered the tillering stage. It declined steeply to a value of 70.38 per cent from 98.51 per cent during the same growth phase of wheat crop i.e. from pink bud to flowering. Fruit set matched with spike initiation and milking of wheat where RI dropped to lowest value of 51.43 and remained almost equal at crop harvest too. In general, RI was more in South of the trees than North.

4.5 Nitrogen use pattern

N use pattern and per cent response to variation in standard N level measured as its uptake as well as straw and grain yield in wheat were studied. The data given in Table 15 have been described as below.

4.5.1 Nitrogen uptake

Nitrogen uptake influenced significantly due to 25 per cent increase/decrease in N supply from the recommended standard dose i.e. N_2 level both in A.H. system as well as in sole crop of wheat. In A.H. system, the

Table 15. Nitrogen use pattern during active growth stages of wheat

	Uptake ($kg\ ha^{-1}$)				Yield ($q\ ha^{-1}$)	
	Tillering	Spike initiation	Milking	Crop harvest	Straw	Grain
AGRIHORTICULTURE SYSTEM						
N_1	10.06 (-28.65)	14.82 (-28.78)	16.77 (-35.02)	18.57 (-32.39)	48.83 (-18.72)	15.88 (-25.27)
N_2	12.20 (-13.47)	18.45 (-11.34)	21.27 (-17.59)	21.99 (-19.94)	53.29 (-11.30)	17.33 (-18.45)
N_3	12.38 (-12.19)	20.43 (-1.82)	24.15 (-6.43)	23.90 (-12.99)	58.08 (-3.32)	18.04 (-15.10)
SOLE CROP						
N_1	13.38 (-5.10)	20.12 (-3.31)	24.21 (-6.19)	24.40 (-11.17)	54.58 (-9.15;)	20.25 (-4.70)
N_2	14.10	20.81	25.81	27.47	60.08	21.25
N_3	13.92 (-1.27)	22.65 (+8.84)	26.79 (+3.79)	28.67 (+4.37)	63.25 (+5.27)	22.04 (+3.72)
S.E. (d)±	0.18	0.19	0.23	0.16	0.37	0.12
C.D. (0.05)	0.25	0.38	0.46	0.33	0.74	0.24

Figures in parentheses shows per cent change in response over N_2 level in pure crop decrease in N supply (N_1) caused reduction in uptake while increase in N supply (N_3) in equal magnitude caused significant increase in its uptake at all the growth stages viz. tillering, spike initiation, milking and crop harvest. The reduction, nevertheless was about twice the increase. In sole crop same pattern was observed except at tillering stage. Quantitatively the variation was about half the magnitude that occurred in A.H. system (Table 15).

Response of wheat to increase or decrease in recommended level of N expressed as percentage of the values obtained at N_2 level in sole crop (Table 15) was also calculated. It was negative at all levels in A.H. system and at each growth stage. The N uptake in wheat decreased by 13.47, 11.34, 17.59 and 19.94 per cent at tillering, spike initiation, milking and crop harvest stage respectively even with application of recommended nitrogen level in A.H. system. The decrease was further accentuated at N_1 level wherein 25 per cent less than the recommended dose of N was applied. The increase in applied nitrogen by 25 per cent over the recommended (N_3) improved the N uptake at all the growth stages. It was 12.19, 1.82, 6.43 and 12.99 per cent at tillering, spike initiation, milking and crop harvest stage, respectively. In sole crop, the decrease in level by 25 per cent resulted into the decrease in N uptake at all the growth stages, but in smaller magnitude than in A.H. system. The increase in N level however, resulted in an increase in per cent response to N uptake at spike initiation (8.84%), milking (3.79%) and crop harvest (4.37%). However, it was decreased by 1.27 per cent at tillering stage.

4.5.2 Total yield

The grain and straw yield varied significantly both in A.H. system and sole crop due to increase/decrease by 25 per cent in nitrogen supplied. In A.H. system, straw and grain yield at recommended level (N_2) was 53.29 and 17.33 q ha^{-1} which decreased to 48.83 and 15.88 q ha^{-1}, respectively by 25 per cent decrease (N_1) in N supply. An increase by 25 per cent of this nutrient (N_3) increased the straw (58.08) and grain yield (18.04). In sole crop respective straw and grain yield was 60.08 and 21.25 q ha^{-1} at N_2 level. These values were significantly higher than the values obtained at the same level in A.H. system. The variation in the yield levels due to increase or decrease in N supplied in sole crop too followed the trend similar to A.H. system.

In A.H. system the grain yield was reduced by 18.45 per cent at N_2 level and 25.27 per cent at N_1 level. But per cent reduction in yield was 15.01 per cent at N_3 level.

In sole crop system, the decrease in N supplied by 25 per cent (N_1) resulted into decrease in yield by 4.70 per cent and whereas increase (N_3) caused an enhancement in the yield by 3.72 per cent (Table 15).

4.6 Nutrient balance in soils

Nutrient balance in soils was calculated for N, P and K. The total amount of N, P and K added through FYM, fertilizer and leaf litter vis-a-vis their amounts removed through tree-crop harvests were taken as input/addition and output/removal during the crop season. The input and output data have been appended in Appendix-XVII and XVIII. Addition and removal of N, P and K have been calculated separately for agrihorticulture and sole crop system and are given in Table 16.

Addition

N, P and K addition was more in A.H. system than sole crop system (Table 16). In case of A.H. system total quantity of N, P and K added were 172.84, 75.59 and 151.93 kg ha^{-1}, respectively, whereas in sole crop the above values were 80, 40 and 40 kg ha^{-1}.

TABLE 16 Nutrient Balance in Agrihorticulture and Sole crop system calculated at optimum dose of N level

	Initial Status	Amount added	Total amount (initial + added)	Cumulative removal	Expected Balance	Actual Balance	Net Gain or Loss
AGRI HORTICULTURE SYSTEM							
Available N (kg ha $^{-1}$)	530.4	172.84	703.24	111.62	591.62	535.2	-56.42
Available P (kg ha $^{-1}$)	50.60	75.69	126.19	21.4	104.79	49.4	-55.39
Available K (kg ha $^{-1}$)	270.7	151.93	422.63	86.41	336.22	245.6	-90.62
SOLE CROP SYSTEM							
Available N (kg ha $^{-1}$)	525.9	80	605.9	43.53	562.37	533.0	-29.37
Available P (kg ha $^{-1}$)	45.7	40	85.7	16.86	68.84	47.7	-21.14
Available K (kg ha $^{-1}$)	260.2	40	300.2	42.28	257.92	255.6	-2.32

Removal

Like addition, removal of N,P and K through the harvested biomass was more in A.H. system than sole crop. The quantities of removed N, P and K in A.H. system were 111.62, 21.4 and 86.41 kg ha^{-1} whereas, in sole crop the values were 43.53, 16.86 and 42.28 kg ha^{-1} respectively (Table 16).

Balance

NPK addition/removal in A.H. system as well as sole crop had a negative balance at crop harvest. A net loss of 56.42, 55.39 and 90.62 kg ha^{-1} of N, P and K, respectively occurred in A.H. system. Sole crop also caused a net loss of N, P and K in soils amounting to 29.37, 21.14 and 2.32 kg ha^{-1}, respectively. Net loss in sole crop was less than A.H. system.

4.7 Economic returns

Gross returns

The gross returns calculated variety wise but at recommended N level of wheat only (Table 17) indicated that the gross returns from A.H. system were higher than for sole crop. Maximum gross returns in A.H. system and sole crop were with the use of variety V_3 followed by V_4, V_2 and V_1.

Net returns

Data from Table 17 shows that total costs incurred were more for agrihorticulture system (Rs. 12811.56) as compared to sole crop (Rs. 7392.95) yet the net returns were higher for A.H. System than the sole crop. In A.H

Table 17. Gross and net returns (Rs. ha^{-1}) from agrihorticulture system and sole crop using different wheat varieties.

A) Gross Returns (Rs ha^{-1})								
Components	Agrihorticulture system				Sole Crop			
	V_1	V_2	V_3	V_4	V_1	V_2	V_3	V_4
WHEAT*								
Grain	6915.00	8415.00	11500.00	9830.00	9165.00	10165.00	13165.00	11330.00
Straw	7687.50	13040.00	16352.50	14707.70	13000.00	15125.00	17.042.50	15375.00
Sub-Total	16602.50	21455.00	27852.50	24537.50	22165.00	25290.00	30207.50	26705.00
PEACH								
Fruits	25000.00	25000.00	25000.00	25000.00	-	-	-	-
TOTAL	41602.50	46455.00	52852.50	49537.50	22165.00	25290.00	30207.50	26705.00
B) NET RETURNS								
Gross Returns (Rs. ha^{-1})	41602.50	46455.00	52852.50	49537.50	22165.00	25290.00	30207.50	26705.00
Total Costs (Rs. ha^{-1})	12811.56	12811.56	12811.56	12811.56	7392.95	7392.95	7392.95	7392.95
Net Returns (Rs. ha^{-1})	28790.94	33643.44	40040.94	36725.94	14772.05	17897.05	22814.55	19312.05

* Wheat yield obtained at recommended level only have been used.

TABLE 18. Net returns (Rs. ha^{-1}) from agrihorticulture and sole crop system using different Wheat varieties.

	AGRI HORTICULTURE SYSTEM					SOLE CROP SYSTEM				
	V_1	V_2	V_3	V_4	MEAN	V_1	V_2	V_3	V_4	MEAN
N_1	26320.32	31780.32	38240.32	35990.32	33082.82	9749.37	15499.37	21829.37	20246.87	16831.24
N_2	28790.94	33643.44	40040.94	36725.94	34800.31	14772.05	17897.05	22814.55	19312.05	18698.92
N_3	30096.64	34549.14	43424.14	37216.64	36321.64	12919.73	17254.73	26879.73	20253.73	19326.98
Mean	28402.63	33324.30	40568.46	36644.30	34734.92	12480.38	16883.71	23841.21	19937.55	18285.71

system at N_2 level (Tables 17 and 18) the net returns were highest for variety V_3 (40040.94) followed by V_4 (36725.94), V_2 (33643.44) and V_1 (28790.94). The same trend was observed for sole crop also. The respective net returns from variety V_3, V_4, V_2 and V_1 were 22814.55, Rs. 19312.05, Rs. 17897.05 and Rs. 14772.05, respectively.

DISCUSSION

5

DISCUSSION

The effects emerged due to the use of different wheat varieties supplied with variable doses of nitrogen in an agrihorticulture system have been explained providing to each a scientific framework. Response of system components and the system as such in terms of growth, yield, nutrient use, soil moisture availability etc. has been explained in this chapter as under :

5.1 Field crop

5.1.1 Growth and yield of wheat

5.1.2 Foliar nutrient concentration and uptake

5.2 Tree species

5.2.1 Growth and harvested biomass

5.2.2 Foliar nutrient concentration and uptake

5.2.3 Root characteristics

5.3 Soil characteristics

5.3.1 Soil moisture

5.3.2 pH, E.C., Organic Carbon and available NPK

5.4 Relative illumination

5.5 Nitrogen use pattern

5.6 Nutrient balance

5.7 Economic returns

5.1 Field crop

5.1.1 Growth and yield performance of wheat

Growth

The growth attributes of wheat crop viz. germination per cent, number of plants m^{-2}, number of tillers $plant^{-1}$ and plant height of all the four varieties grown at three nitrogen levels in A.H. system were not influenced significantly due to the cumulative influence of N levels and varieties when compared to their values in sole crop system.

Considering each attribute separately,irrespective of the variety and N level influences in both the directions viz. North and South of tree row, per cent germination, number of plants m^{-2}, number of tillers $plant^{-1}$ and plant height had significantly higher values in sole crop (S_0) over A.H. system (S_1). Higher values in sole crop shows the competitiveness of peach association with wheat for growth resources. Varietal effects on these parameters except germination per cent were significant. Variety V_1 followed by V_4 showed the maximum number of plants m^{-2}. Number of tillers $plant^{-1}$ were significantly high in variety V_4 whereas plant height was more in V_3 followed by V_4. Nitrogen levels did not affect the above plant growth attributes except plant height, which was maximum at N_3 level.

The results have indicated that wheat varieties grown either at recommended N level or decrease/increase in N level by 25 per cent does not influence the germination per cent either in A.H. system (S_1) or sole crop (S_0) (Appendix-II). Per cent germination nevertheless,was significantly higher in sole crop over A.H. system (Table 1), irrespective of varieties used and their nitrogen supply. Although per cent germination in sole crop was significantly higher over A.H. system yet the differences were negligible ranging between 81.65-82.51 per cent.

Increase in number of plants m^{-2} and number of tillers $plant^{-1}$ due to variety and the plant height due to both variety and nitrogen is obvious because of the effect of varieties on growth characters. Nitrogen as a nutrient is basically responsible for the height growth of a plant and thus significant increase/decrease in plant height due to 25 per cent increase/decrease in recommended N level is understandable.

Yield

Wheat varieties and their nitrogen levels influenced the number of spikes $plant^{-1}$, thousand grain weight, grain yield, straw yield and harvest index significantly. Values from the above attributes were higher in South direction (DR_2) and in system S_0. However, harvest index was statistically non significant due to varietal influence. The higher yield in sole crop (S_0) over A.H. system (S_1) can be ascribed to the competitive association of peach trees with wheat crop. However, more values in South direction may be due to the relatively higher relative illumination (R.I.) (Table 4) and less root spread (Fig. 3) causing least competition for nutrients and moisture.

Comparative growth and yield performance of different wheat varieties have shown that varieties V_4 and V_3 gave higher values for each of the above growth and yield attributes over V_1 and V_2 in A.H. system. In A.H. system, the relative values for per cent germination, number of plants m^{-2}, number of tillers $plant^{-1}$, number of spikes $plant^{-1}$ and thousand grain weight were relatively higher in V_4. Plant height, straw and grain yield alongwith harvest index was more in V_3. It can be deduced that variety V_3 is better than remaining three to be grown with peach in an A.H. system providing about equal amount of yield in peach association (22.17q) as is produced by V_4 (22.89q) in pure crop which is highest among V_1, V_2 and V_4. V_3 variety nevertheless, produced 26.00q in sole crop (Table 3).

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), Maiti *et al.* (1993), and Rao and Coe (1992). Few other workers have also reported reduced field crop yield at closer proximity to the trees viz. Khan and Aslam (1974), Akbar *et al.* (1990), Khybri *et al.* (1992), Sharma (1992) and Kumar (1996). The higher crop yields in Southern direction are well supported by the findings of Dhillon *et al.* (1984), Puri and Bangarwa (1992) and Kumar (1996).

5.1.2 Nitrogen concentration and uptake in wheat

Nitrogen concentration (Table 4) in wheat was influenced significantly with the increase or decrease in the recommended standard N level at all the growth stages. At tillering, increase in N level by 25 per cent of the recommended dose (N_2) gave maximum N concentration in plants. Variety V_4 attained the highest concentration. During spike initiation, milking and crop harvest similar trend in concentration was observed i.e. at N_3 level, it was maximum and minimum at N_1.

A steady decrease in the concentration was observed from the advancement in growth stages from tillering to crop harvest at all the N levels and in each variety, showing their higher values in direction DR_2 i.e. South of the tree row. The difference between North and South direction were although significant, yet negligible to affect the crop growth and development. N concentration was more at S_0 over S_1 which implicitly explains that nitrogen concentration in wheat plants due to the peach association is decreased, may be through competition in soil or impeded supply in modified microclimatic conditions. Less relative light illumination can be one of the factor as is evident from the present study (Table 14).

Nitrogen uptake in wheat at different growth stages due to the increase or decrease in recommended N level followed the trend similar to its concentration during these stages. Trend in uptake by different varieties was also similar as variety V_4 showed maximum N uptake at tillering, spike initiation, milking and crop harvest.

In grain and straw besides N, P and K concentration was also determined. In grains increase in nitrogen levels by 25 per cent (N_3) increased its concentration significantly alongwith concentration of K. In case of varieties, N, P and K concentration was significantly high in V_4. The concentration of N, P and K was more in system S_0 than S_1. Values even being statistically significant their differences are too little to cause any resultant significant effect on grain yield (Table 5). In case of straw, N and K were significantly higher at N_3 level and phosphorus at N_2 level. Variety V_4 attained the maximum concentration in all the three nutrient levels. Wheat straw in system S_0 had more concentration of N and P over S_1 and the differences were considerably higher and significant (Table 6).

The above results show that increase or decrease by 25 per cent in the recommended N level (N_2) to the wheat causes almost equal proportionate increase or decrease in N concentration of grain and straw. P concentration in straw decreased significantly both by reducing or increasing the nitrogen supply from the recommended dose (N_2). Grain P content did not change either by increase or decrease in N content.

N, P and K uptake in grain and straw of wheat too reflected the pattern similar to their concentration due to increase or decrease in N levels. Nevertheless varietal response was quite inconsistent. In grain N and P uptake was highest in V_3 and K uptake was in V_4. However, N, P and K uptake in wheat straw was high in V_4.

5.2 Tree species

5.2.1 Growth and harvested biomass

The data on growth attributes viz. crown spread height and diameter at sowing and harvest of wheat as well as fruit yield have been presented in Table 13.

The crown spread was more in South and East direction compared to North and West. The tree rows extended from East to West along the sun direction. Whereas wheat crop was in North and South. South-east direction receives more sun light which may have increased the crown spread in this direction. The average height of the trees was 3.03m and the diameter at 5cm above the graft union at the time of harvest of wheat was 95.64mm. The average fruit yield varied from 15.20 to 34.58 q ha^{-1} which can partly be attributed to the size of the crown, fruit load etc.

5.2.2 Nutrient concentration and uptake

Nitrogen and phosphorus concentration in leaves was significantly higher at N_3 over N_2 and N_1. Similarly in fruits N and K concentration was significantly higher at N_3 level. Phosphorus at levels N_1 and N_3 was statistically alike. The increase in N concentration in leaves was due to its increase in N supply by 25 per cent over recommended level (N_2). This increased supply may have enhanced the K uptake in fruits too, though slightly. The similar response of leaf P as leaf N to increase or decrease in N levels applied, reveals its synergistic effect in the present case. However, fruit P concentration has given similar values at both increase/decrease in supplied N.

Applied levels of nitrogen affected only N uptake in leaves. It was higher at N_3 level over N_1 and N_2. Nevertheless, levels N_3 and N_2 were statistically alike. N uptake in fruits due to increase or decrease in N levels was non significant. However, P and K concentration was influenced significantly. The significant difference in uptake are attributed to significant differences in leaf and fruit biomass yields. Similar results were reported by Kumar (1996).

5.2.3 Root characteristics

The maximum length of the single longest root was in South direction. The maximum root mass was in East-West direction upto 2.5 m radial distance. However, longest root extended upto a distance of 6.20 m in South and 5.60 m in North. Towards East and West the longest root remained confined to a maximum distance of 4.20 and4.70 m, respectively. The majority of the root mass in East-West and least spread in North-South direction can be attributed to the regular disturbance of soils through continuous cultivation in North-South direction as the trees have been planted from East to West.

The root characteristics (Fig. 3) also indicated that horizontal spread of major/active roots was from 2.5 to 3m around the tree which forms the total below ground tree-crop interface (TCI) area. The distance of crop sown area from the tree trunk in the plot both sides was one meter, hence the net TCI was 2m.

The results presented in Table 10 for crown spread indicated the maximum crown spread upto 1.54 and 1.77m,in North and South direction, respectively. Since 1 m is the bund area, the effective TCI area was 0.54m and 0.77m respectively towards North and South. Hence correlating the crown spread with root spread, the effective TCI area above ground was 0.54m and 0.77m towards North and South i.e. cropped area, whereas belowground it was about 2m in each side. This indicates that below ground TCI area was about 2.5-3.5 times more than aboveground TCI area.

5.3 Soil characteristics

5.3.1 Soil moisture

The soil moisture content was found to be more in sole crop compared to A.H. system at tillering and spike initiation stage of wheat. The lower soil moisture under trees as compared to open may be due to higher evaporative demands of tree species at these stages of wheat as peach also enters its active growth phase during this time. Adverse effect of peach can also be ascribed to the fact that trees after pruning attain more leaf area and therefore, exert more pressure on limited soil moisture. The results are in line with the findings of Connor (1983). However, at milking and crop harvest higher moisture was recorded in A.H. system than sole crop. Better soil moisture with trees as compared to open field has been reported by Bronstein (1984) and Lal (1989). More soil moisture was observed in direction DR_1 (North) over DR_2 (South) except at milking stage.

5.3.2 pH, E.C., Organic Carbon and available NPK

The pH of the soil ranged between 6.81 and 6.85. A slightly higher pH was observed in North direction and in A.H. system. E.C. of the soils ranged from 0.20 to 0.22 dsm^{-1}. It was however, more under sole crop than A.H. system. Low E.C. values in A.H. system may be due to high O.C. content in these soils. It was 1.15 per cent in A.H. system and 1.11 per cent in sole crop. This can be attributed to increased mineralization under trees than in open. The results are in line with the findings of Kater *et al.* (1992) and Rhoades (1995).

Higher amount of available N and P were observed under A.H. system at all the active growth stages of wheat. Available K, however, was more in AH system during tillering and spike initiation stage. At milking and crop harvest, the available K content in soils was less in A.H. system. The above discussions though have shown statistically significant variations in N, P and K content of soils both in AH system or sole crop as well as between these two landuse systems (Appendix XIV-XVI), yet in view of fertility management differences were negligible.

The more nutrients in tree-crop combination may be due to the reason that respective association is either complimentary or supplementary in terms of nutrient sharing. This relationship is possible in the tree-crop systems influencing the nutrient cycles positively by way of litter deposition. Nutrient addition by the trees to soils have been reported amply in literature (Aggarwal, 1980; Nair, 1984; Toky *et al.*, 1989; Sanchez *et al.*, 1985; Kater, 1992).

5.4 Relative illumination

Per cent relative illumination (Table 14) was more in South direction as compared to North. 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 to West direction. Similar results have been reported by Hazara and Tripathi (1986), Singh *et al.* (1989), Jaiswal *et al.* (1993) and Kumar (1996).

With succeeding growth stages of peach, R.I. decreased in both directions. This can be attributed to the increasing canopy density. The decrease in R.I. values was from about 98 per cent to 50 per cent. This indicates significant adverse influence of R.I./crown development on associated wheat crop.

5.5 Nitrogen use pattern

Nitrogen use pattern and per cent response to variation with respect to standard N level under sole crop in terms of uptake as well as straw and grain yield in wheat was statistically significant. It was observed that in A.H. system with decrease of 25 per cent nitrogen (N_1) from the recommended dose the uptake of nitrogen decreased at each crop stage. However, the uptake improved significantly with 25 per cent increase in nitrogen. Same pattern was observed in sole crop too, except at tillering stage. The per cent response to variation in N levels gave negative values at all the stages in A.H. system. The uptake in wheat plants in A.H. system was less even when recommended dose of N was applied.

In case of grain yield it was significantly less in AH system over sole crop at N_2 level i.e. recommended dose. With the decrease in 25 per cent of standard N level, yield further reduced by about 1.45 q ha^{-1}. With the increase in 25 per cent N than recommended level, the yield increased by 0.71 q ha^{-1}. The above findings have revealed that the increase in yield by increasing the N dose by 25 per cent is just 50 per cent of the total decrease in yield if N application is decreased by same magnitude in A.H. system. In case of sole cropping the results are similar, however, the increase in yield was much higher i.e. about 79 per cent (Table 15). The above discussion indicates that N use is reduced by about 30 per cent in AH over sole crop system.

The over all decrease in yield in AH system over sole crop was about 18.45 per cent at standard N application which could be compensated by about 3.35 per cent by increasing the N dose by 25 per cent which is less than the yield improvement in pure crop i.e. 3.72 per cent.

Straw yield gave results more or less similar to grain yield. The decrease in grain yield by 18.45 per cent in A.H. system over sole crop, irrespective of the varieties at standard recommended N level can be ascribed to the above and below ground competition due to peach association in net cropped area of 7x4m. The average crown spread of peach towards the cropped area (North and South) was 1.65m. The reduction in wheat grain yield (Kumar, 1996) due to the association of peach was 20.16 per cent having net plot size of 6x4m and average crown spread of 1.34 m towards North and South i.e. the direction in which wheat crop was sown. The variation in the two studies may have occurred due to the different sampling procedure adopted in each case. In the present case, composite sampling procedure was adopted considering the actual plot area sown whereas, Kumar (1996) sampled the variation in yield separately at a distance of 1m, 2m and 4m of peach tree trunk.

5.6 Nutrient balance

5.6.1 Addition and removal of N, P and K

Addition of N, P and K was more in AH system as compared to sole crop. This was due to the additional supply of fertilizer and FYM to peach trees. In addition to above, leaf litter of peach has also contributed partly to the system. Removal of available N, P and K was also more in AH system which can be attributed to the higher total harvested biomass as compared to sole crop of wheat. It was about 98 quintal ha^{-1} in AH system and 81 q ha^{-1} in sole cropping.

5.6.2 Balance of N, P and K

N, P and K have shown depletion in their content both in AH system and sole crop. Depletion was more in AH system and less in sole crop. Results in Table 16 revealed that N removal in AH system was 2.56 times more than sole crop. Similarly P and K were removed to the tune of 1.27 and 2.04 times more. Overall the three nutrients have shown a -ve balance. The negative balance of these nutrients can be attributed to the reason that actual balance in soil was lower than expected balance. The higher expected balance was due to their high amount found initially in the soil.

5.7 Economic returns

Gross returns from mixture were higher than sole crop. This can be attributed to the additional income from peach fruits. Gross returns for different varieties showed a marked difference which can be ascribed to different yield levels in different varieties.

Net returns were higher under agrihorticulture system, though the total costs incurred were also more. This can be attributed to the additional income from peach fruits under agrihorticulture system. The results are in line with the findings of Majumdar (1991) and Kumar (1996) who reported higher gross and net returns from agrihorticulture system over sole crop system.

Variety V_3 gave highest net returns both in mixture as well as in sole cropping which was obviously owing to its higher yield levels in both the systems.

SUMMARY AND CONCLUSIONS

6

SUMMARY AND CONCLUSIONS

The present investigations entitled **"Tree-crop interaction studies in agrihorticulture system"** were carried out at experimental farm of the Department of Silviculture and Agroforestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, India during December, 1997 to June, 1998.

Studies involved four wheat varieties supplied with three nitrogen levels viz. recommended N level, 25 per cent less and 25 per cent more than recommended level and grown in association with peach trees as well as pure crop.

The experiment was laid in split plot design. The main plot treatments were three nitrogen levels viz. 25 per cent less than the recommended dose for wheat (N_1), recommended (80 kg ha^{-1}) dose (N_2) and 25 per cent more nitrogen than the recommended dose (N_3). In sub plots four wheat varieties were taken viz. HD-2285 (V_1), HD-2329 (V_2), HD-2380 (V_3) and HS-240 (V_4).

Growth and yield of wheat

The results revealed that increase or decrease in recommended N level by 25 per cent did not influence the germination per cent, number of plants m^{-2} and number of tillers $plant^{-1}$ of wheat crop. However, plants attained significantly lesser height when N supply was decreased by 25 per cent. The results are irrespective of variety and tree association. Influence of varieties alone also did not affect the germination per cent. However, the other growth attributes experienced statistically significant differences. Number of plants m^{-2}, number of tillers $plant^{-1}$ and plant height were maximum in V_1, V_4 and V_3, respectively. Peach tree association compared with sole crop influenced the above attributes negatively and significantly except number of tillers $plant^{-1}$.

Differential levels of nitrogen affected the yield attributes viz. number of spikes $plant^{-1}$, thousand grain weight, grain yield, straw yield and harvest index significantly and gave lesser values at N_1 level i.e. decrease by 25 per cent. However, at N_2 and N_3 level, values were more but at par with each other.

Different varieties differed in their yield attributes significantly, however, all had the same harvest index. Variety V_3 gave the maximum grain and straw yield. Whereas V_1 the minimum. In general, sole crop wheat plants (S_0) gave the overall higher values. South direction gave more thousand grain weight, straw and grain yield as well as harvest index. Comparing the grain yield of different varieties among the peach tree association versus sole crop i.e. S_1 and S_0, respectively variety V_3 produced the highest yield in S_1 which was statistically equivalent to the yield of V_4 in S_0 i.e. sole crop.

Concentration and uptake in wheat

The nitrogen concentration and uptake in wheat plants at tillering, spike initiation, milking and crop harvest was higher in sole wheat than in A.H. system. Highest concentration and uptake was at N_3 level (25% more nitrogen than the recommended). Variety V_4 gave the maximum N concentration and uptake values during each growth stage studied. N and K concentration in grains was affected significantly by the variation in nitrogen levels. The P concentration however, remained the same. Uptake of N, P and K was also influenced significantly. Among different varieties V_4 had the highest concentration of N, P and K in grains but the uptake was highest in V_3. In case of straw, highest N, P and K concentration as well as its uptake was at N_3 level. Variety V_4 had the highest concentration. Nevertheless, varieties V_3 showed the highest uptake value.

Tree species

The crown spread was more in South and East compared to North and West. Average height of the trees was 3.03m whereas diameter was 95.64mm. Average fruit yield varied between 15.20 and 34.58 q ha^{-1}. Increase or decrease in recommended N level resulted into significantly different concentration of N and P in leaves and of N, P and K in fruits. Varietal effects were however, only significant for N concentration in leaves and P and K concentration in fruits. Nitrogen levels influenced the uptake of N only in leaves and P and K in fruits significantly. On the other hand, uptake of N, P and K in leaves and P and K in fruits was influenced significantly due to varieties.

Root characteristics

The maximum root mass was in East and West direction upto 2.5m radial distance. However, longest root extended upto 6.20m in South and 5.60m in North. The horizontal spread of major/active roots was from 2.50 to 3.00m around the tree which formed the total below ground tree-crop interface (TCI) area. The below ground TCI area was about 2.5-3.5 times more than the aboveground TCI area.

Soil studies

Soil moisture was not significantly affected by increase or decrease in N levels and wheat varieties. It was higher in A.H. system at tillering and spike initiation stage of wheat and lower at milking and crop harvest as compared to sole crop of wheat. Moisture was more in North except at milking stage.

The pH of the soil ranged between 6.81 and 6.85. It was slightly higher in A.H. system in North direction. E.C. of the soils ranged from 0.20 to 0.22 dsm^{-1}. It was however, more under sole crop. The percentage of organic carbon was 1.15 per cent in A.H. system and 1.11 per cent in sole crop.

Higher amount of available N and P were observed under A.H. system at all the active growth stages of wheat. Available K however, was more in A.H. system during tillering and spike initiation stage. At milking and crop harvest the available K content in soils was less in A.H. system.

Relative illumination

Per cent R.I. was more in South than North. With succeeding growth stages of peach, R.I. decreased in both directions. The decrease in R.I. values was from about 98 to 50 per cent.

Nutrient use pattern

In A.H. system, the uptake of nitrogen decreased at each crop stage with decrease of 25 per cent nitrogen from the recommended dose. However, it was improved significantly with 25 per cent increase in nitrogen. Same pattern was observed in sole crop except at tillering stage. In A.H. system i.e. (S_1), the decrease in uptake of N, by 25 per cent decrease in N level was about twice the increase obtained due to increase in N level by 25 per cent of recommended level. In sole crop system the variation was of half the magnitude that occurred in A.H. system. The yield increased only by 50 per cent of the total decrease in yield due to reduction in N level by 25 per cent if N application was increased by same magnitude over the recommended dose.

In sole crop the increase in yield was however, about 79 per cent. This shows that N use is reduced by 30 per cent in A.H. system over sole crop. The overall decrease in yield in A.H. system over sole crop was 18.45 per cent at standard N application which could be compensated to the extent of about 3.35 per cent by increasing the N dose by 25 per cent. The improvement nevertheless, was smaller than the yield improvement in pure crop i.e. 3.72 per cent.

Nutrient balance

The addition of N, P and K was more in A.H. system than sole crop of wheat. N, P and K removal in A.H. system was 2.56, 1.27 and 2.04 times more than the sole crop of wheat. Overall, the three nutrients showed a negative balance.

Economic returns

The total cost incurred as well as gross returns were higher in A.H. system. The net returns were highest from variety V_3 followed by variety V_4 when 25 per cent more nitrogen than the recommended dose was applied.

CONCLUSIONS

Tree-crop interaction studies in agrihorticulture system evaluated the influence of peach tree association on four wheat varieties. Each variety was grown at three different N levels viz. 25 per cent less; 25 per cent more and at the recommended level as such. The influence and nature of association have been examined through determining the following : (i) nutrient use pattern (ii) tree-crop productivity (iii) soil moisture regimes and relative illumination during the crop season. From the details of investigations made, following inferences have been drawn :

- Growth and yield attributes of wheat have shown lesser values under A.H. system than the sole crop, irrespective of either nitrogen levels or variety. Peach tree association has decreased the wheat yield by 18.45 per cent over the sole crop despite being supplied with recommended levels of nitrogen in both the cases. The decrease in N supply of wheat by 25 per cent grown either in peach association or as sole crop causes reduction in the yield which could be improved by increasing the supply of N dose in equal amounts. Nevertheless, the improvement in the yield over its decrease under A.H. system is by 50 per cent only. In sole crop, the increase can be achieved to the extent of 79 per cent. This shows that response of wheat in association with peach to the application of nitrogen is less by about 30 per cent over the response obtainable under sole crop system. It can also be deduced from these findings that the nitrogen utilized by wheat crop in agrihorticulture system was about 30 per cent less than in sole crop system.

- Varietal response has depicted that in agrihorticulture system, use of variety HD-2380 would be a viable option to obtain higher grain and straw yield. Crown characteristics of peach trees and the root spread have shown that below ground tree-crop interface (TCI) area was about 2.5 to 3.5 times more than the above ground TCI. Relative illumination with the development of peach crown decreased by 50 per cent as the wheat crop attained the growth stages of spike initiation and milking. The R.I. value remained almost equal till crop harvest stage.

- Increase in the supply of nitrogen over the recommended level by 25 per cent; and use of variety HD-2380 to obtain higher yield (22 q ha^{-1}) equivalent to the second best variety (HS-240) found in sole crop are thus, the two important interventions identified to get increased overall total production from the existing resources using Wheat-Peach agrihorticulture system than available from wheat alone. In economic terms, net returns obtainable from A.H. System using the above two identified interventions were Rs. + 43,424.14. It was higher than the sole crop by Rs. 16,544.41.

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APPENDICES

APPENDIX - I

Meteorological data for the experimental site during the period of field studies

Month	Temperature (°C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
December, 1997	17.0	2.9	67.0	85.2
January, 1998	17.5	2.1	60.0	15.1
February, 1998	18.7	4.7	89.5	87.1
March, 1998	20.8	6.1	56.3	125.5
April, 1998	28.2	11.2	50.9	46.6
May, 1998	32.2	15.4	46.3	63.0
June, 1998	31.5	17.9	57.5	185.1

Source : *Meteorological Section, Department of Soil Science and Water Management, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni (Solan) H.P. 173 230.*

Appendix - II

Effect of nitrogen x variety x system x direction on growth attributes of wheat

	Germination Per cent				No of Plants / m^2				No. of tillers $plant^{-1}$				Plant height (cm)			
Direction	DR_1		DR_2		DR_1		DR_2		DR_1		DR_2		DR_1		DR_2	
System	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0
N – levels and variety																
N_1V_1	81.67	84.00	83.33	84.67	44.00	69.67	47.67	71.67	4.00	3.83	4.16	3.85	73.31	70.83	76.00	72.63
N_1V_2	85.00	84.33	83.33	86.00	41.33	53.67	50.67	54.67	3.33	3.63	3.88	4.82	72.90	70.53	72.00	72.20
N_1V_3	81.67	83.67	80.00	84.00	44.00	49.67	47.00	50.00	4.00	3.65	4.55	3.70	79.18	81.87	81.20	83.13
N_1V_4	80.00	84.67	85.00	86.33	64.33	69.67	77.33	70.67	4.31	3.96	4.93	4.33	75.82	74.97	73.33	75.50
N_2V_1	85.00	84.00	85.00	83.33	55.67	59.67	65.00	62.33	3.73	4.29	3.88	4.36	71.17	77.23	75.20	77.77
N_2V_2	81.67	84.33	83.33	87.00	60.33	61.00	58.33	62.67	3.96	4.33	4.00	4.33	64.40	67.97	77.60	69.27
N_2V_3	76.67	79.33	80.00	83.00	57.00	58.00	59.00	58.33	4.06	4.33	4.00	4.36	83.63	94.17	96.13	96.67
N_2V_4	83.33	84.00	85.00	83.67	61.33	60.00	73.33	63.67	4.15	4.50	4.93	4.56	75.80	77.30	77.20	70.80
N_3V_1	81.67	83.00	81.67	86.00	75.33	74.67	78.33	76.00	3.61	4.00	3.91	4.33	66.53	69.53	67.87	70.60
N_3V_2	76.67	81.67	80.00	83.00	55.67	54.00	57.00	56.33	3.55	4.30	3.93	4.36	65.37	69.53	69.00	71.30
N_3V_3	78.33	79.33	78.33	81.00	52.33	55.67	55.67	56.67	3.50	4.64	5.66	4.67	93.00	107.70	104.80	111.10
N_3V_4	75.00	80.67	66.67	80.67	51.33	56.67	56.00	57.00	3.88	4.83	5.73	4.36	75.57	77.20	77.17	78.03
	S.E(d)± 2.703		$CD_{(0.05)}$ N x V x S x DR - N . S.		S.E(d)± 3.533		$CD_{(0.05)}$ N x V x S x DR - N . S.		S.E(d)± 0.241		$CD_{(0.05)}$ N x V x S x DR - N . S.		S.E(d)± 1.557		$CD_{(0.05)}$ N x V x S x DR - N . S	

DR_1 - North, DR_2 - South

Appendix - III

Effect of nitrogen x variety x system x direction on yield attributes of wheat

Direction System	No. of spikes/plant				Thousand grain weight				Grain yield (q ha^{-1})				Straw yield (q ha^{-1})				Harvest Index(%)			
	DR_1		DR_2		DR_1		DR_2		DR_1		DR_2		DR_1		DR_2		DR_1		DR_2	
	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0
N- levels and variety																				
N_1V_1	3.11	3.75	3.36	3.80	30.11	30.53	30.39	32.57	10.50	14.67	12.33	15.33	32.33	37.00	33.67	38.33	24.52	28.40	26.81	28.57
N_1V_2	2.33	2.65	3.16	2.66	33.79	34.12	34.39	35.50	14.67	19.00	16.00	19.67	46.67	52.00	47.33	52.00	23.90	26.76	25.25	27.43
N_1V_3	3.44	3.48	3.00	3.51	33.91	34.53	33.97	35.00	20.67	25.00	22.33	25.33	59.67	65.33	61.33	66.00	25.72	27.67	26.69	27.75
N_1V_4	3.54	3.65	3.50	3.66	34.07	33.68	34.10	34.75	17.67	22.33	19.33	23.00	56.67	64.00	58.33	64.67	23.74	25.85	24.89	26.23
N_2V_1	3.16	3.82	2.83	3.83	31.17	31.30	31.48	32.53	13.00	17.67	14.67	19.00	38.17	51.67	39.33	52.33	25.20	25.47	27.15	26.66
N_2V_2	3.00	3.33	3.00	3.33	34.43	34.23	34.84	35.57	16.00	20.00	17.67	20.67	52.00	60.00	53.33	61.00	23.52	25.00	24.88	25.20
N_2V_3	3.40	3.82	3.50	3.83	34.50	34.79	35.74	35.85	22.00	25.33	24.00	27.33	65.00	67.67	65.83	68.67	25.30	27.21	26.76	28.49
N_2V_4	3.32	4.00	3.00	4.10	35.13	34.58	35.17	36.25	18.33	22.00	21.00	23.33	58.00	61.00	59.67	62.00	24.01	26.50	26.02	27.35
N_3V_1	3.16	4.00	3.50	3.95	32.53	32.10	32.94	33.30	12.67	15.83	14.67	17.67	44.00	48.33	46.00	49.00	22.33	24.68	24.14	25.87
N_3V_2	2.33	3.64	3.16	3.68	36.50	35.72	36.69	37.17	16:33	20.33	20.00	20.67	53.00	58.00	54.67	59.00	23.49	25.94	26.78	27.29
N_3V_3	3.00	3.82	3.00	3.84	36.73	35.88	36.81	37.30	23.83	27.67	25.00	28.33	76.00	81.67	77.67	82.33	23.15	24.86	24.34	25.52
N_3V_4	3.00	4.33	2.33	4.33	36.76	36.22	36.86	37.13	19.33	24.33	21.33	24.67	59.33	65.00	61.33	66.00	24.58	26.63	25.80	27.30
S.E.(d)±	0.17				0.34				0.56				1.05				0.58			
C.D.(0.05)	NS				NS				NS				NS				NS			

DR_1 - North ; DR_2 - South

APPENDIX - IV

Effect of Nitrogen x Variety x System x Direction on per cent concentration of nitrogen in wheat at its various growth stages

	Tillering				Spike initiation				Milking				Crop harvest			
Direction	DR_1		DR_2		DR_1		DR_2		DR_1		DR_2		DR_1		DR_2	
System	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0
Nitrogen levels and varieties																
N_1V_1	2.17	2.26	2.18	2.27	1.74	1.89	1.78	1.90	1.70	1.82	1.72	1.84	0.78	0.88	0.79	0.89
N_1V_2	2.04	2.18	2.08	2.19	1.65	1.78	1.67	1.78	1.39	1.87	1.41	1.88	0.69	0.98	0.76	0.88
N_1V_3	2.34	2.51	2.37	2.50	1.79	2.10	1.83	2.10	1.68	1.98	1.71	1.99	0.76	0.98	0.80	0.99
N_1V_4	2.37	2.50	2.37	2.51	2.01	2.12	2.05	2.12	1.90	2.07	1.96	2.08	0.77	0.90	0.81	0.93
N_2V_1	2.20	2.37	2.21	2.36	1.76	1.99	1.78	1.99	1.71	1.84	1.73	1.86	0.99	1.00	0.90	1.00
N_2V_2	2.08	2.29	2.11	2.28	1.69	2.00	1.70	2.01	1.50	1.98	1.85	1.99	0.80	1.13	0.83	1.15
N_2V_3	2.39	2.52	2.40	2.53	1.85	2.12	1.87	2.14	1.81	1.98	1.84	1.99	0.76	1.11	0.89	1.13
N_2V_4	2.41	2.59	2.44	2.60	2.09	2.22	2.11	2.23	1.90	2.08	1.93	2.09	0.81	0.95	0.83	0.96
N_3V_1	2.21	2.38	2.24	2.39	1.95	2.18	1.99	2.19	1.90	1.97	1.85	1.98	0.89	1.23	0.95	1.24
N_3V_2	2.21	2.39	2.21	2.40	1.81	2.00	1.83	2.01	1.74	1.94	1.79	1.99	0.90	1.19	0.95	1.20
N_3V_3	2.40	2.59	2.43	2.59	2.00	2.15	2.04	2.16	1.85	2.05	1.90	2.15	0.91	1.15	0.93	1.17
N_3V_4	2.51	2.60	2.52	2.60	2.20	2.30	2.22	2.31	2.01	2.13	2.02	2.15	0.91	1.07	0.93	1.08
SE(d)±	0.006				0.007				0.014				0.10			
NxVxSxDR C.D. $_{(0.05)}$	NS				NS				0.028				0.020			

DR_1 – North ; DR_2 – South

APPENDIX - V

Effect of Nitrogen x Variety x System x Direction on per cent concentration of NPK in wheat grain

	N				P				K			
Direction	**DR_1**		**DR_2**		**DR_1**		**DR_2**		**DR_1**		**DR_2**	
System	**S_1**	**S_0**	**S_1**	**S_0**	**S_1**	**S_0**	**S_1**	**S_0**	**S_1**	**S_0**	**S_1**	**S_0**
Nitrogen levels And varieties												
N_1V_1	1.30	1.31	1.31	1.31	0.31	0.31	0.32	0.32	0.19	0.20	0.20	0.20
N_1V_2	1.28	1.29	1.28	1.29	0.31	0.32	0.32	0.32	0.78	0.79	0.79	0.79
N_1V_3	1.50	1.51	1.51	1.52	0.30	0.31	0.31	0.31	0.19	0.19	0.19	0.19
N_1V_4	1.68	1.69	1.68	1.69	0.71	0.71	0.72	0.72	0.89	0.90	0.90	0.90
N_2V_1	1.42	1.42	1.42	1.42	0.31	0.31	0.32	0.32	0.19	0.20	0.20	0.20
N_2V_2	1.32	1.32	1.32	1.32	0.31	0.31	0.31	0.31	0.78	0.78	0.78	0.78
N_2V_3	1.61	1.61	1.61	1.62	0.31	0.31	0.31	0.31	0.20	0.20	0.20	0.21
N_2V_4	1.70	1.71	1.71	1.71	0.71	0.71	0.72	0.72	0.90	0.90	0.90	0.90
N_3V_1	1.42	1.43	1.44	1.44	0.31	0.32	0.32	0.32	0.20	0.21	0.21	0.21
N_3V_2	1.34	1.36	1.38	1.39	0.31	0.31	0.31	0.31	0.78	0.78	0.78	0.79
N_3V_3	1.64	1.65	1.68	1.68	0.31	0.31	0.31	0.32	0.19	0.19	0.19	0.19
N_3V_4	1.78	1.78	1.78	1.78	0.71	0.71	0.72	0.72	1.11	1.12	1.12	1.12
	S.E.(d) ±	C.D.$_{(0.05)}$			S.E.(d) ±	C.D.$_{(0.05)}$			S.E.(d)±	C.D.$_{(0.05)}$		
	0.218	NS			0.0008	NS			0.0006	NS		

DR_1 – North ; DR_2 – South

APPENDIX - VI

Effect of Nitrogen x Variety x System x Direction on per cent concentration of NPK in wheat straw

	N				P				K			
Direction	DR_1		DR_2		DR_1		DR_2		DR_1		DR_2	
System	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0
Nitrogen levels And varieties												
N_1V_1	0.20	0.22	0.20	0.22	0.13	0.15	0.13	0.15	0.41	0.42	0.42	0.42
N_1V_2	0.20	0.23	0.21	0.23	0.12	0.14	0.13	0.15	0.42	0.42	0.42	0.42
N_1V_3	0.21	0.25	0.22	0.25	0.11	0.14	0.12	0.14	0.41	0.42	0.42	0.42
N_1V_4	0.22	0.24	0.22	0.24	0.11	0.14	0.11	0.14	0.42	0.43	0.43	0.43
N_2V_1	0.21	0.33	0.22	0.33	0.13	0.15	0.14	0.15	0.41	0.42	0.42	0.42
N_2V_2	0.30	0.34	0.30	0.34	0.13	0.14	0.13	0.14	0.42	0.42	0.42	0.42
N_2V_3	0.33	0.36	0.33	0.36	0.12	0.14	0.12	0.14	0.41	0.41	0.41	0.42
N_2V_4	0.33	0.35	0.35	0.36	0.11	0.40	0.11	0.40	0.43	0.42	0.43	0.43
N_3V_1	0.41	0.44	0.37	0.44	0.13	0.15	0.13	0.15	0.42	0.42	0.42	0.42
N_3V_2	0.41	0.40	0.42	0.45	0.13	0.14	0.13	0.15	0.41	0.42	0.42	0.42
N_3V_3	0.42	0.47	0.42	0.47	0.11	0.14	0.12	0.14	0.41	0.42	0.42	0.42
N_3V_4	0.41	0.46	0.41	0.46	0.15	0.14	0.12	0.14	0.44	0.43	0.44	0.44
	S.E.(d) ±	$C.D._{(0.05)}$			S.E.(d) ±	$C.D._{(0.05)}$			S.E.(d) ±	$C.D._{(0.05)}$		
	0.006	NS			0.0005	NS			0.0007	NS		

DR_1 – North ; DR_2 – South

APPENDIX-VII

Effect of nitrogen x variety x System x direction on uptake (kg ha^{-1}) of nitrogen by wheat at its various growth stages.

	Tillering				Spike initiation				Milking				Crop harvest			
Direction	DR_1		DR_2		DR_1		DR_2		DR_1		DR_2		DR_1		DR_2	
System	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0
itrogen levels and varieties																
N_1V_1	6.97	11.44	8.07	11.46	10.02	17.24	10.90	17.24	11.97	20.28	13.05	20.30	15.25	22.95	16.64	22.96
N_1V_2	8.73	12.77	9.61	12.77	13.40	18.79	14.05	18.79	13.76	24.11	15.10	24.14	16.26	25.77	17.30	25.78
N_1V_3	10.00	13.00	11.31	13.55	15.00	20.41	16.30	21.41	17.21	23.63	17.85	23.64	17.71	24.23	18.53	24.25
N_1V_4	13.65	15.75	14.77	15.76	20.87	24.04	21.04	24.04	24.14	28.81	25.15	28.83	21.06	24.63	22.55	24.65
N_2V_1	9.13	10.24	10.10	10.26	13.11	18.47	14.26	19.47	15.30	21.58	16.50	21.60	19.75	23.25	21.02	24.26
N_2V_2	14.67	15.33	15.65	15.33	21.35	20.22	22.40	21.22	23.24	25.30	24.14	26.03	24.34	30.48	25.35	32.49
N_2V_3	13.00	15.00	14.25	15.86	18.34	20.42	19.50	21.02	21.99	27.39	23.04	27.43	20.07	29.25	21.05	30.26
N_2V_4	11.81	14.98	12.53	14.98	20.99	24.12	21.94	24.12	24.55	28.97	25.50	28.99	21.41	24.90	22.95	24.91
N_3V_1	12.00	12.00	13.10	12.92	19.07	21.28	20.05	21.28	22.72	23.51	24.08	23.54	22.42	27.85	23.80	27.86
N_3V_2	13.24	14.26	14.36	14.28	19.51	21.49	22.45	21.49	23.01	26.00	24.17	29.03	25.41	32.65	26.60	30.67
N_3V_3	14.00	15.00	15.00	15.16	22.02	23.51	23.44	23.51	24.90	27.94	25.94	27.99	22.91	30.24	24.45	30.26
N_3V_4	10.21	13.38	11.19	13.39	21.11	24.33	22.00	24.33	25.99	29.70	26.15	29.97	22.30	24.94	23.35	24.95
SE.(d)±	0.36				0.54				0.65				0.53			
C.D. (0.05)	NS				NS				NS				NS			

DR_1 – North ; DR_2 – South

APPENDIX - VIII

Effect of Nitrogen x Variety x System x Direction on uptake (kg ha^{-1}) of NPK by wheat grain

	N				P				K			
Direction	DR_1		DR_2		DR_1		DR_2		DR_1		DR_2	
System	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0
Nitrogen levels And varieties												
N_1V_1	12.05	19.25	14.52	19.77	2.92	7.06	3.48	7.07	1.86	2.87	2.16	2.89
N_1V_2	16.68	17.99	19.35	18.15	4.09	9.06	5.10	9.06	9.65	11.00	10.80	11.06
N_1V_3	28.61	29.61	30.40	30.75	10.22	14.73	11.25	14.79	3.85	4.88	4.80	5.49
N_1V_4	30.29	31.49	31.60	31.74	8.69	12.85	9.85	13.00	15.99	17.54	17.25	17.64
N_2V_1	17.62	18.63	19.65	19.66	3.87	5.55	4.95	5.56	2.27	3.28	3.54	3.60
N_2V_2	18.49	19.52	20.55	20.58	4.39	7.15	5.65	7.20	10.95	11.97	6.93	11.99
N_2V_3	32.29	32.99	34.34	34.39	10.55	13.15	11.65	13.16	4.09	5.80	5.15	5.18
N_2V_4	30.63	32.13	32.85	33.37	8.16	11.15	10.41	11.16	16.50	17.00	17.25	17.35
N_3V_1	18.50	19.02	20.40	20.53	3.57	6.15	5.81	6.16	3.60	4.85	4.80	5.80
N_3V_2	25.36	26.47	26.41	26.47	5.04	8.12	6.35	8.13	12.05	13.00	13.00	13.05
N_3V_3	38.28	39.35	39.64	39.65	11.19	11.25	13.20	11.28	4 47	6.55	5.65	6.55
N_3V_4	34.42	35.47	36.60	36.67	8.68	11.39	9.85	11.41	20.00	22.00	21.00	22.00
	S.E.(d)±	C.D.(0.05)			S.E.(d)±	C.D.(0.05)			S.E.(d)±	C.D.(0.05)		
	0.21	NS			0.16	NS			0.72	NS		

DR_1 – North ; DR_2 – South

APPENDIX - IX

Effect of Nitrogen x Variety x System x Direction on uptake (kg ha^{-1}) of NPK by wheat straw

	N				P				K			
Direction	DR_1		DR_2		DR_1		DR_2		DR_1		DR_2	
System	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0	S_1	S_0
Nitrogen levels And varieties												
N_1V_1	5.72	7.80	6.51	7.90	3.60	5.36	4.27	5.38	12.17	14.85	12.98	14.90
N_1V_2	8.78	11.43	9.85	12.95	5.39	7.31	6.41	7.31	18.15	20.85	18.54	20.90
N_1V_3	12.26	14.46	13.75	14.79	6.73	8.05	7.75	8.08	23.62	25.75	23.89	25.90
N_1V_4	11.69	13.65	12.94	13.67	6.5	7.85	7.61	7.90	12.29	13.35	12.50	13.45
N_2V_1	7.29	9.25	18.65	9.25	4.53	6.21	5.72	6.27	14.17	16.55	14.50	16.65
N_2V_2	14.80	16.46	15.55	16.52	6.19	8.15	7.29	8.21	19.77	21.85	20.00	21.85
N_2V_3	19.49	21.46	20.65	21.47	7.02	8.75	8.15	8.81	24.05	26.13	25.20	26.13
N_2V_4	19.00	21.05	20.45	21.57	5.95	7.20	7.10	7.20	21.55	23.47	22.56	23.48
N_3V_1	16.88	19.26	17.94	19.38	5.29	7.00	6.65	7.10	16.85	18.80	17.05	18.82
N_3V_2	21.21	23.45	22.27	23.85	7.03	9.25	8.55	9.26	22.45	24.70	23.47	24.71
N_3V_3	30.69	32.65	32.25	32.75	8.51	10.11	9.01	10.13	29.90	30.94	30.91	30.95
N_3V_4	23.14	26.11	24.60	26.35	6.41	8.45	7.65	8.47	39.87	42.45	40.70	42.50
	S.E.(d)±	C.D. $_{(0.05)}$			S.E.(d)±	C.D. $_{(0.05)}$			S.E.(d)±	C.D. $_{(0.05)}$		
	0.27	0.56			0.144	NS			0.218	NS		

DR_1 – North ; DR_2 – South

APPENDIX – X

Properties of the soil of study area before sowing of wheat

Particulars	Agrihorticulture system Depth (0-30 cm)	Sole crop system (Depth 0-30cm)
pH	6.82	6.82
E.C. (ds m^{-1})	0.22	0.22
O.C. (%)	1.29	1.27
Available N (kg ha^{-1})	530.40	525.90
Available P (kg ha^{-1})	50.60	45.70
Available K (kg ha-1)	270.70	260.2

Appendix - XI

Effect of nitrogen level, crop variety, and system on soil pH

	Tillering stage			Spike initiation stage			Milking stage			Crop harvest		
Direction	**DR_1**	**DR_2**	**Mean**	**DR_1**	**DR_2**	**Mean**	**DR_1**	**DR_2**	**Mean**	**DR_1**	**DR_2**	**Mean**
A: Nitrogen Level												
N_1	6.82	6.81	**6.81**	6.82	6.81	**6.82**	6.82	6.82	**6.82**	6.85	6.83	**6.84**
N_2	6.82	6.81	**6.81**	6.82	6.82	**6.82**	6.84	6.83	**6.84**	6.84	6.83	**6.84**
N_3	6.82	6.81	**6.82**	6.82	6.82	**682**	6.85	6.83	**6.84**	6.85	6.83	**6.84**
Mean	**6.82**	**6.81**		**6.82**	**6.81**		**6.84**	**6.83**		**6.85**	**6.83**	
	S.E.(d)±	C.D.(0.05)		S.E.(d)±	C.D. (0.05)		S.E.(d)±	C.D.(0.05)		S.E.(d)±	C.D.(0.05)	
N	0.003	NS		0.001	NS		0.001	0.005		0.002	NS	
DR	0.001	0.003		0.001	0.003		0.001	0.003		0.001	0.003	
NxDR	0.002	NS		0.002	NS		0.002	0.004		0.002	NS	
B: Crop variety												
V_1	6.82	6.80	**6.81**	6.82	6.81	**6.82**	6.83	6.82	**6.83**	6.85	6.82	**6.84**
V_2	6.82	6.81	**6.82**	6.82	6.82	**6.82**	6.83	6.83	**6.83**	6.85	6.83	**6.84**
V_3	6.82	6.81	**6.81**	6.82	6.81	**6.82**	6.84	6.83	**6.83**	6.85	6.83	**6.84**
V_4	6.82	6.81	**6.81**	6.82	6.81	**6.82**	6.85	6.82	**6.84**	6.85	6.83	**6.84**
Mean	**6.82**	**6.81**		**6.82**	**6.81**		**6.84**	**6.83**		**6.85**	**6.83**	
	S.E.(d)±	C.D.(0.05)		S.E.(d)±	C.D. (0.05)		S.E.(d)±	C.D.(0.05)		S.E.(d)±	C.D.(0.05)	
V	0.002	NS		0.002	NS		0.002	0.004		0.002	NS	
DR	0.001	0.003		0.001	0.003		0.001	0.003		0.001	0.003	
VxDR	0.002	NS		0.002	NS		0.002	0.004		0.002	NS	
C: System												
S_1	6.82	6.80	**6.81**	6.83	6.81	**6.82**	6.85	6.83	**6.84**	6.87	6.83	**6.85**
S_0	6.82	6.82	**6.82**	6.82	6.82	**6.82**	6.82	6.82	**6.82**	6.82	6.82	**6.82**
Mean	**6.82**	**6.81**		**6.82**	**6.81**		**6.84**	**6.83**		**6.85**	**6.83**	
	S.E.(d)±	C.D.(0.05)		S.E.(d)±	C.D. (0.05)		S.E.(d)±	C.D.(0.05)		S.E.(d)±	C.D.(0.05)	
S	0.001	0.003		0.001	0.003		0.001	0.003		0.001	0.003	
DR	0.001	0.003		0.001	0.003		0.001	0.003		0.001	0.003	
SxDR	0.001	0.003		0.001	0.003		0.001	0.003		0.001	0.003	

DR_1 – North; DR_2 South

Appendix - XII

Effect of nitrogen level, crop variety, and system on E.C. (dsm^{-1})

	Tillering stage			Spike initiation stage			Milking stage			Crop harvest		
Direction	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean
A: Nitrogen Level												
N_1	0.219	0.212	**0.215**	0.219	0.217	**0.218**	0.213	0.213	**0.213**	0.213	0.211	**0.212**
N_2	0.213	0.213	**0.213**	0.214	0.215	**0.215**	0.215	0.215	**0.215**	0.211	0.213	**0.212**
N_3	0.212	0.217	**0.215**	0.214	0.216	**0.215**	0.212	0.215	**0.213**	0.211	0.215	**0.213**
Mean	0.215	0.214		0.216	0.216		0.213	0.214		0.212	0.213	
	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)
N	0.0007		NS	0.002		NS	0.002		NS	0.003		NS
DR	.0.001		NS	0.001		NS	0.002		NS	0.001		NS
NxDR	0.002		0.003	0.002		NS	0.002		NS	0.001		NS
B: Crop variety												
V_1	0.214	0.214	**0.214**	0.218	0.219	**0.219**	0.216	0.217	**0.216**	0.212	0.213	**0.212**
V_2	0.216	0.215	**0.215**	0.217	0.220	**0.219**	0.211	0.214	**0.212**	0.212	0.213	**0.212**
V_3	0.213	0.212	**0.213**	0.214	0.212	**0.213**	0.213	0.213	**0.213**	0.214	0.212	**0.213**
V_4	0.216	0.215	**0.215**	0.213	0.213	**0.213**	0.214	0.214	**0.214**	0.209	0.214	**0.212**
Mean	0.215	0.214		0.216	0.216		0.213	0.214		0.212	0.213	
	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)
V	0.002		NS	0.002		0.004	0.002		NS	0.002		NS
DR	0.001		0.003	0.001		NS	0.002		NS	0.001		NS
VxDR	0.002		NS	0.002		NS	0.002		NS	0.002		NS
C: System												
S_1	0.207	0.203	**0.205**	0.210	0.206	**0.208**	0.204	0.206	**0.205**	0.202	0.204	**0.203**
S_0	0.222	0.225	**0.224**	0.221	0.226	**0.223**	0.223	0.223	**0.223**	0.222	0.222	**0.222**
Mean	0.215	0.214		0.216	0.216		0.213	0.214		0.212	0.213	
	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)
S	0.001		0.003	0.001		0.003	0.002		0.003	0.001		0.002
DR	0.001		NS	0.001		0.003	0.002		NS	0.001		NS
SxDR	0.001		0.003	0.001		0.003	0.002		NS	0.001		NS

DR_1 – North; DR_2 South

Appendix - XIII

Effect of nitrogen level, crop variety, and system on O.C. (%)

	Tillering stage			Spike initiation stage			Milking stage			Crop harvest		
Direction	**DR_1**	**DR_2**	**Mean**	**DR_1**	**DR_2**	**Mean**	**DR_1**	**DR_2**	**Mean**	**DR_1**	**DR_2**	**Mean**
A: Nitrogen Level												
N_1	1.23	1.33	**1.28**	1.16	1.23	**1.19**	1.17	1.21	**1.19**	1.15	1.07	**1.11**
N_2	1.27	1.30	**1.29**	1.25	1.29	**1.27**	1.19	1.23	**1.21**	1.17	1.11	**1.18**
N_3	1.27	1.33	**1.30**	1.21	1.25	**1.23**	1.19	1.22	**1.20**	1.19	1.07	**1.13**
Mean	**1.25**	**1.32**		**1.21**	**1.26**		**1.83**	**1.22**				
	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)
N	0.008		NS	0.006		0.017	0.006		NS	0.02		NS
DR	,0.009		0.02	0.006		0.012	0.006		0.011	0.09		0.19
NxDR	0.014		NS	0.007		NS	0.007		NS	0.011		NS
B: Crop variety												
V_1	1.26	1.33	**1.29**	1.19	1.24	**1.22**	1.17	1.22	**1.20**	1.16	1.08	**1.12**
V_2	1.23	1.32	**1.27**	1.18	1.25	**1.22**	1.21	1.23	**1.22**	1.20	1.09	**1.15**
V_3	1.29	1.32	**1.31**	1.22	1.26	**1.24**	1.17	1.20	**1.19**	1.15	1.07	**1.14**
V_4	1.24	1.32	**1.28**	1.24	1.27	**1.26**	1.18	1.21	**1.20**	1.16	1.09	**1.12**
Mean	**1.25**	**1.32**		**1.20**	**1.26**		**1.18**	**1.21**		**1.17**	**1.08**	
	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)
V	0.02		NS	0.009		0.017	0.008		0.016	0.01		NS
DR	0.009		0.02	0.006		0.012	0.006		0.011	0.09		0.19
VxDR	0.016		NS	0.009		NS	0.008		NS	0.01		NS
C: System												
S_1	1.39	1.31	**1.35**	1.20	1.29	**1.25**	1.24	1.31	**1.27**	1.23	1.06	**1.15**
S_0	1.32	1.33	**1.33**	1.21	1.22	**1.22**	1.13	1.13	**1.13**	1.11	1.11	**1.11**
Mean	**1.25**	**1.32**		**1.21**	**1.26**		**1.18**	**1.22**		**1.17**	**1.08**	
	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)
S	0.009		0.02	0.006		0.12	0.006		0.011	0.09		0.19
DR	0.009		0.02	0.006		0.012	0.006		0.011	0.099		0.19
SxDR	0.009		0.02	0.006		0.012	0.006		0.011	0.09		0.19

DR_1 – North; DR_2 South

Appendix - XIV

Effect of nitrogen level, crop variety, and system on available Nitrogen (kg ha^{-1}) in soils

	Tillering stage			Spike initiation stage			Milking stage			Crop harvest		
Direction	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean
A: Nitrogen Level												
N_1	542.7	546.4	**544.5**	520.3	541.2	**530.8**	534.8	536.8	**535.8**	534.0	534.0	**534.0**
N_2	545.2	547.6	**546.4**	543.4	543.8	**543.6**	535.5	536.4	**536.4**	533.9	534.4	**534.1**
N_3	543.5	546.1	**544.8**	542.4	547.2	**544.8**	535.5	537.4	**536.5**	534.7	535.1	**534.9**
Mean	**543.8**	**546.7**		**535.4**	**544.1**		**535.3**	**536.2**		**534.2**	**534.5**	
	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)
N	0.73		NS	8.28		NS	0.98		NS	1.74		NS
DR	0.43		0.85	11.85		NS	0.60		1.20	0.46		0.19
NxDR	0.52		NS	8.38		NS	0.74		NS	0.56		NS
B: Crop variety												
V_1	543.3	547.2	**545.2**	514.8	543.0	**528.9**	535.4	537.4	**536.4**	534.3	534.4	**534.4**
V_2	544.9	546.7	**545.8**	542.5	543.0	**542.7**	534.3	536.4	**535.4**	532.9	533.5	**533.2**
V_3	543.8	546.9	**545.4**	543.0	543.5	**543.2**	535.5	537.1	**536.3**	534.9	535.2	**535.1**
V_4	543.2	546.1	**544.6**	541.1	546.8	**544.0**	535.9	537.8	**536.9**	534.7	534.9	**534.8**
Mean	**543.8**	**546.7**		**535.4**	**544.1**		**535.3**	**537.2**		**534.2**	**534.5**	
	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)
V	0.61		NS	9.68		NS	0.85		NS	0.65		1.30
DR	0.43		0.85	11.85		NS	0.60		1.20	0.46		NS
VxDR	0.61		NS	9.67		NS	0.85		NS	0.65		NS
C: System												
S_1	544.6	549.7	**547.2**	530.3	546.7	**538.5**	536.7	539.2	**537.9**	535.4	536.0	**535.7**
S_0	542.9	543.7	**543.3**	540.4	541.4	**540.9**	533.9	535.2	**534.5**	533.0	533.0	**533.0**
Mean	**543.8**	**546.7**		**535.4**	**544.1**		**535.3**	**537.2**		**534.2**	**534.5**	
	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)
S	0.43		0.85	11.85		NS	0.60		1.20	0.46		0.92
DR	0.43		0.85	11.85		NS	0.60		1.20	0.46		NS
SxDR	0.43		0.85	11.85		NS	0.60		NS	0.46		NS

DR_1 – North; DR_2 South

Appendix - XV

Effect of nitrogen level, crop variety, and system on available Phosphorus (kg ha^{-1}) in soils

	Tillering stage			Spike initiation stage			Milking stage			Crop harvest		
Direction	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean
A: Nitrogen Level												
N_1	58.12	59.42	**58.77**	54.83	56.87	**55.85**	51.67	53.50	**52.58**	47.17	47.54	**47.35**
N_2	57.96	60.67	**59.31**	54.12	56.83	**55.48**	50.92	53.33	**52.12**	48.42	48.71	**48.56**
N_3	57.58	59.17	**58.36**	54.17	56.46	**55.31**	50.21	53.00	**51.60**	47.21	47.58	**47.40**
Mean	**57.89**	**59.75**		**54.38**	**56.72**		**50.93**	**53.28**		**47.60**	**47.94**	
	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)
N	0.35		0.41	0.39		NS	1.17		NS	2.10		NS
DR	0.20		0.41	0.26		0.53	0.59		1.19	0.91		NS
NxDR	0.20		0.49	0.32		NS	0.73		NS	1.11		NS
B: Crop variety												
V_1	57.89	59.72	**58.81**	54.39	56.61	**55.50**	51.00	53.28	**52.14**	47.94	48.44	**48.19**
V_2	47.67	59.89	**48.78**	53.56	56.22	**54.89**	50.89	53.33	**52.11**	47.33	47.78	**47.56**
V_3	57.67	59.78	**58.72**	54.50	56.78	**55.64**	50.78	53.22	**52.00**	48.78	48.89	**48.83**
V_4	58.33	59.61	**58.97**	55.06	57.28	**56.17**	51.06	53.28	**52.17**	46.33	46.67	**46.50**
Mean	**57.89**	**59.75**		**54.38**	**56.72**		**50.93**	**53.28**		**47.60**	**47.94**	
	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)
V	0.29		NS	0.38		0.75	0.85		NS	1.29		NS
DR	0.20		0.41	0.26		0.53	0.59		1.19	0.91		NS
VxDR	0.29		NS	0.37		NS	0.84		NS	1.29		NS
C: System												
S_1	59.69	62.81	**61.25**	54.75	58.69	**56.72**	51.69	55.56	**53.62**	47.78	48.47	**48.13**
S_0	56.08	56.69	**56.39**	54.00	54.75	**54.38**	50.17	51.00	**50.58**	47.42	47.42	**47.42**
Mean	**57.89**	**59.75**		**54.38**	**56.72**		**50.93**	**53.28**		**47.60**	**47.94**	
	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D. (0.05)	S.E.(d)±		C.D.(0.05)	S.E.(d)±		C.D.(0.05)
S	0.20		0.41	0.26		0.53	0.59		1.19	0.91		0.92
DR	0.20		0.41	0.26		0.53	0.59		1.19	0.91		NS
SxDR	0.20		0.41	0.26		0.53	0.59		1.19	0.91		NS

DR_1 – North; DR_2 South

Appendix - XVI

Effect of nitrogen level, crop variety, and system on available Potassium (kg ha^{-1}) in soils

	Tillering stage			Spike initiation stage			Milking stage			Crop harvest		
Direction	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean	DR_1	DR_2	Mean
A: Nitrogen Level												
N_1	272.7	275.4	**274.1**	267.2	267.2	**267.2**	255.2	257.0	**256.1**	259.0	251.2	**251.0**
N_2	273.3	275.9	**274.6**	266.9	266.1	**266.5**	254.8	256.3	**255.6**	250.4	250.9	**250.6**
N_3	272.0	275.4	**273.7**	266.4	266.2	**266.3**	254.3	256.8	**255.6**	249.2	251.4	**250.3**
Mean	**272.7**	**275.6**		**266.8**	**266.5**		**254.8**	**256.7**		**250.1**	**251.2**	
	S.E.(d)±	C.D.(0.05)		S.E.(d)±	C.D. (0.05)		S.E.(d)±	C.D.(0.05)		S.E.(d)±	C.D.(0.05)	
N	0.41	NS		0.21	0.58		0.94	NS		0.47	NS	
DR	0.47	0.95		0.18	NS		0.87	1.73		0.33	0.66	
NxDR	0.58	NS		0.23	NS		1.069	NS		0.40	NS	
B: Crop variety												
V_1	272.9	275.6	**274.2**	267.2	266.9	**267.0**	255.1	257.0	**256.0**	250.3	250.1	**250.7**
V_2	271.0	275.6	**273.3**	267.3	267.1	**267.2**	255.3	256.8	**256.0**	250.9	251.5	**251.2**
V_3	273.4	275.3	**274.3**	266.4	266.0	**266.2**	254.3	256.7	**255.5**	250.2	251.3	**250.7**
V_4	273.4	275.7	**274.6**	266.4	266.0	**266.2**	254.5	256.4	**255.4**	249.2	250.7	**250.0**
Mean	**272.7**	**275.6**		**266.8**	**266.5**		**254.8**	**256.7**		**250.1**	**251.2**	
	S.E.(d)±	C.D.(0.05)		S.E.(d)±	C.D. (0.05)		S.E.(d)±	C.D.(0.05)		S.E.(d)±	C.D.(0.05)	
V	0.68	NS		0.26	0.52		1.23	NS		0.47	NS	
DR	0.47	0.95		0.18	NS		0.87	1.73		0.33	0.66	
VxDR	0.67	NS		0.26	NS		1.23	NS		0.47	NS	
C: System												
S_1	276.8	280.8	**278.8**	271.5	269.9	**270.7**	250.9	253.7	**252.3**	245.9	247.9	**246.9**
S_0	268.6	270.3	**269.5**	262.2	263.1	**262.6**	258.7	259.7	**259.2**	254.4	254.4	**254.4**
Mean	**272.7**	**270.3**		**266.8**	**266.5**		**254.8**	**256.7**		**250.1**	**251.2**	
	S.E.(d)±	C.D.(0.05)		S.E.(d)±	C.D. (0.05)		S.E.(d)±	C.D.(0.05)		S.E.(d)±	C.D.(0.05)	
S	0.47	0.95		0.18	0.37		0.87	1.73		0.33	0.66	
DR	0.47	0.95		0.18	NS		0.87	1.73		0.33	0.66	
SxDR	0.47	0.95		0.18	NS		0.87	NS		0.33	0.66	

DR_1 – North; DR_2 South

APPENDIX-XVII

Total amount of nutrients added (Kg ha^{-1}) annually to the Soil.

	N		P		K	
AGRI HORTICULTURE SYSTEM	WHEAT	PEACH	WHEAT	PEACH	WHEAT	PEACH
Fertilizer	80	50	40	25.6	40	60
FYM	-	3.2	-	3.6	-	7.68
Leaf litter	-	39.64	-	6.39	-	44.25
Total	80	92.84	40	35.59	40	111.93
SOLE CROP SYSTEM						
Fertilizer	80	-	40	-	40	-
FYM	-	-	-	-	-	-
Leaf litter	-	-	-	-	-	-
Total	80	-	40	-	40	-

APPENDIX XVIII

Total amount of nutrients removed (kg ha $^{-1}$) annually from the soil.

AGRI HORTICULTURE SYSTEM	N	P	K
WHEAT			
Grain	25.80	7.45	8.33
Straw	16.98	6.49	30.97
PEACH			
Fruits	64.46	5.81	43.04
Pruned wood	4.38	1.65	4.07
TOTAL	111.62	21.4	86.41
SOLE CROP			
WHEAT			
Grain	26.40	9.26	9.52
Straw	17.13	7.60	32.76
TOTAL	43.53	16.86	42.28

APPENDIX - XIX

Prices of various inputs and outputs during 1997-98

	Inputs	**Rate (Rs.)**
1.	Tractor charges	155/hr
2	Thresher charges	9/hr
3.	Labour charges	45.75/manday
4.	Seed cost	8.30/kg
5.	Fertilizers and minerals	
	CAN	422/q
	Urea	266/q
	SSP	260/q
	MoP	270/q
	FYM	30/q
6.	Chemicals	
	2,4D	180/kg
	TSO	40/lit
	Metasystox	186/lit
	Outputs	
1.	Wheat grain	5/kg
2.	Wheat straw	2.50/kg
3.	Peach fruits	9/kg

APPENDIX - XX
Cost of cultivation of wheat

Particulars	Operational inputs (ha^{-1})	Agrihorticulture system (Rs.)	Pure Crop (Rs.)
Seed	120 kg	774.67	996.00
CAN	160kg	525.15	675.20
Urea	87.5 kg	181.03	232.75
SSP	250 kg	505.55	650.00
MoP	65 kg	136.50	175.50
2,4,D	1kg	140.00	180.00
Three ploughings	10 hrs	355.83	457.50
Two harrowings and plankings	7 hrs	249.08	320.25
Sowing	15 mandays	533.75	686.25
Weedicide application	6 mandays	213.50	274.50
Hand weeding	15 mandays	533.75	686.25
Harvesting	20 mandays	711.67	915.00
Threshing	25 mandays	889.58	1143.75
TOTAL		5750.06	7392.95

1 Mandays = 8 hours of single labour unit

Net cropped Area :

Mixture = 7777.78 m^2
Pure-crop = 10,000 m^2

APPENDIX - XXI

Cost of maintenance of peach

	Operational Input*	Cost (Rs.)
CAN	200 kg	844.00
SSP	160 kg	416.00
MoP	100	270.00
FYM	6 tonnes	1800.00
TSO	4 litres	160.00
Metasystox	1 lit	186.00
FYM application	10 mandays	457.50
Fertilizer application	5 mandays	228.75
TSO spray	7mandays	320.25
Metasystox spray	7mandays	320.25
Basin preparation	20 mandays	915.00
Fruit plucking	25 mandays	1143.75
Total		**7061.50**

* - Operational input for 200 trees.

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TITLE OF THESIS : Tree-crop Interaction Studies in Agrihorticulture System

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MAJOR FIELD	:	Agroforestry
MINOR FIELD(S)	:	i) Silviculture ii) Soil science
No.of pages in Thesis	:	87 + ix + XXI
No.of words in Abstract	:	310

ABSTRACT

Investigation on "Tree-crop interaction studies in agrihorticulture system" were carried out during December, 1997 - June, 1998. The infleunce and nature of association of peach tree with four wheat varieties HD-2285, HD-2329, HD-2380 and HS-240 at three different nitrogen levels viz. 25 per cent less; 25 per cent more and at recommended level was examined through determining tree-crop productivity levels, soil moisture regimes and nutrient use pattern during the crop season. The experiment was laid in split plot design.

Peach tree association decreased the wheat growth and yield attributes over the sole crop. Variety HD-2380 in association with peach produced yield equivalent to the yield produced by variety HS-240 in sole crop. In general, reduction in wheat yield due to peach association was 18.45 per cent over the sole crop. However, increase in nitrogen level by 25 per cent the yield also increased by 3.35 per cent which was 50 per cent more than the decrease in the yield obtained by reducing the N level by 25 per cent.

The maximum root spread was in East-West direction. The longest root however, extended in the South direction. Below ground tree-crop interface (TCI) area was 2.5 to 3.5 times more than the above ground TCI. Relative illumination (R.I.) decreased by 50 per cent at the crop harvest stage of wheat. Soil moisture was found to be more in sole crop at tillering and spike initiation stage of wheat.

Net financial returns were higher in case of variety HD-2380 in A.H. system. The findings evinced that increase in supply of nitrogen over the recommended level by 25 per cent and use of variety HD-2380 can be a better option to get increased overall total production from the existing resources using wheat-peach agrihorticulture system than from wheat alone.

Signature of Major Advisor   Signature of Student

COUNTERSIGNED

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