STUDIES ON CANOPY MANAGEMENT IN PEAR

Dissertation

Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY
in
HORTICULTURE (FRUIT SCIENCE)
(Minor Subject: Botany)

By

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(L-2014-A-42-D)

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CERTIFICATE I

This is to certify that the dissertation entitled, **"Studies on canopy management in pear"** submitted for the degree of **Doctor of Philosophy**, in the subject of **Fruit Science** (Minor subject: **Botany**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Sukhchain Singh (L-2014-A-42-D)** under my supervision and that no part of this dissertation has been submitted for any other degree.

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

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CERTIFICATE II

This is to certify that the dissertation entitled, **"Studies on canopy management in pear"** submitted by **Sukhchain Singh (L-2014-A-42-D)** to the Punjab Agricultural University, Ludhiana, in the partial fulfilment of the requirements for the degree of **Doctor of Philosophy**, in the subject of **Fruit Science** (Minor subject: **Botany**) has been approved by the Student's Advisory Committee after an oral examination on the same in collaboration with an External Examiner.

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ABSTRACT

The present investigations "Studies on canopy management in pear" were conducted at Fruit Research Farm, PAU, Ludhiana during the years 2016 and 2017. Pear plants (cvs. Patharnakh, Punjab Beauty, Punjab Soft) trained on Espalier, Cordon and Y-trellis training systems were evaluated for eco-physiological, fruit quality and production parameters. In 1st experiment, photosynthesis efficiency of leaves was high in plants trained on Espalier system with maximum PAR and followed by Y-trellis system. Efficiency of eco-physiological parameters in pear cultivars was higher in the upper and middle canopy portions as compared to lower canopy portions irrespective of various trellis training systems. Spur formation, flower bud density and relative pattern of fruiting were also higher in middle and upper canopy portions. Vegetative growth in terms of trunk cross sectional area was higher in plants trained on Espalier and Y-trellis system. Larger size fruits were harvested from plants trained on Cordon system but with less TSS, fruit acidity and firmness whereas highest TSS and fruit acidity was found under Espalier system. Smaller size fruits with maximum fruit firmness were found under Y-trellis system. Fruit yield and production efficiency was highest in plants trained on Espalier system of pear cv. Patharnakh. In pear cvs. Punjab Beauty and Punjab Soft, yield related parameters were alike under Espalier and Y-trellis system. In 2nd experiment, plant growth regulators; BA (400, 600, 800 ppm), BA (600 ppm) + GA_3 (200, 400, 600 ppm) and heading back treatments (60, 75 and 90 cm from ground level) were applied on one-year-old pear plants to promote feathering. Maximum feathering and mean crotch angle of feathers with main axis in pear cultivars were recorded with the application of BA (400 ppm and 600 ppm) whereas minimum feathering was recorded under headed plants at 90 cm. Vegetative growth and foliar nutrient status of pear plants improved by the application of plant growth regulators as compared to heading of plants at different heights.

Keywords: Photosynthesis efficiency, PAR, training systems, Plant growth regulators, Feathering, Pear.

Signature of the Major Advisor	**Signature of the Student**

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CONTENTS

LIST OF TABLES

CHAPTER – I

INTRODUCTION

Pear (*Pyrus spp.*) is an important fruit crop of temperate and subtropical climate. It is found globally distributed between 30^{o}-40^{o} latitude where strong light, clear skies, long season and warm temperature prevails. In India, its cultivation is confined to the temperate and sub-tropical regions of Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Punjab, Haryana, Uttar Pradesh, Tamil Nadu, North- Eastern states and Nilgiri hills of southern India due to availability of low chilling, hard, semi-soft and soft varieties of pear. Generally, pear cv. Patharnakh requires approximately 250 chilling hours, however in other pear cultivars, it may vary significantly under varied climate conditions. In India, Pear is grown on 40,000 ha area, producing 3,12,000 MT of fruits annually (*Anonymous* 2017). The area under pear is steadily increasing in north Indian states.

Punjab government has promoted the concept of Garden Colonies after partition in the early fifties, as a result, pear orchards were established in some regions of Amritsar, Patti, Jalandhar, SBS Nagar, Hoshiarpur and Ropar. Recently in year 2013, Punjab has announced policy for diversification of traditional crops with an emphasis on promotion of high value crops (Maize, soyabean, sugarcane, cotton etc.), fruits and vegetable crops. Horticulture is rising as one of the major growth engine in shifting area from wheat-paddy cycle to cultivation of fruits and vegetable crops in Punjab. Presently, fruit crops grown on area of 79,086 ha with production is 16,77,326 MT in Punjab. Major fruit crops grown on large area in Punjab are kinnow, guava, mango, pear, sweet orange, litchi, peach and ber. There is a good scope for expansion of area under fruit crops due to their high productivity per unit area basis. In Punjab, pear occupies an area of 2,879 hectares with production of 66,047 MT annually and it productivity is 22,941 kg/ha (*Anonymous* 2016). In Punjab, pears rank fourth after citrus, guava and mango in term of area. Its cultivation mainly confined to the central and north-western districts of the state. With the introduction of new encouraging semi-soft pear cultivars, the area under pear is likely to increase further in subtropical regions of the country. Area under this fruit crop is increasing in the state due to availability of suitable pear cultivars viz. Punjab Nakh, Punjab Beauty, Punjab Soft and Yali with higher returns on a unit area basis than other traditional crops.

Horticultural crops include fruits and vegetables are widely cultivated for their importance which provides essential food products viz. minerals, vitamins that are critical for human health for proper nutrition (Kwack 2007). Horticultural crop's production can be affected by various eco-physiological and agronomic parameters, whose interaction with other production resources characterized as complex system of production (Lentz 1998). Plant growth and developments are influenced by environmental factors like light interception, temperature, relative humidity, soil and rainfall (Schaffer and Andersen 1994), in order to achieve a goal successfully for cultivation of fruits beyond optimize limits also. It is essential to understand various environmental factors with regard to plant physiology, which affected the entire growth and development of plants viz. flowering, fruit set, relative pattern of fruiting, fruit quality, production efficiency etc. (Wien 1997). In this context, eco-physiology is the science that studies the interactions between plant's physiology and micro-climatic conditions within plant canopy or on the orchard level to optimize production efficiency of plants (Lambers *et al* 2008). Environmental physiology is also important to study the effect of various environmental stresses (shading, heavy metals, drought and salinity etc.) on growth and development of plants with regard to production efficiency under these conditions (Salisbury and Ross 1992). Plants compensate the detrimental effects of stress through various mechanisms like stress response, acclimation and adaptation (Taiz and Zeiger 2006). However, canopy modification in plants through architectural changes by the use of various training systems also important to optimize the climatic factors, which regulate the growth and development of plants in the form of fruit quality, yield and production efficiency.

1.1 EFFECT OF TRELLIS TRAINING SYSTEMS ON PRODUCTION AND FRUIT QUALITY

Pear is recommended to be planted at a distance of 7.5m×7.5m under conventional system but 8m×4m in a rectangular system and 4m×4m in a square system through canopy management techniques. But, there is always a scope to increase production and income from a unit land area by increasing plant population through various training systems. High density planting by canopy management techniques in temperate fruit plants has been an important practice in recent years leading to increased productivity, higher early yield and better income per unit area. Inter plant competition is quite obvious as plant density increases, which is likely to be reflected in the form of reproductive growth, yield potential and fruit quality of the plants. Photo-synthetically active radiation (PAR) is a key parameter for the production of biomass and its effect on fruit sugar, acid content, flesh firmness and colour development. In pear and apple, trellis training systems are appropriate choice for high density planting in pear cultivars rather than use of dwarfing rootstocks or cultivars. Various training systems like open vase, Espalier, Cordon, Palmette, Fusetto, Free Spindle, Y-trellis are used in pear and apple for quality production of fruits. The plants trained to various training systems show different patterns of light interception and distribution within the plant canopy. The fundamental aim of any training system should be optimizing canopy photosynthetic efficiency and regulates translocation of photo-assimilates to the growing fruits rather than vegetative growth. There is also a strong need for early production and accelerate maximum productivity in plants through canopy management techniques. This must be accomplished without impairing fruit quality, as the marketing of fruits depends mostly on quality of fruits like fruit size, TSS and colour. Dwarfed plant's structure affect light interception and distribution within the plant canopy, which plays an important role in photosynthesis efficiency, floral initiation, fruit set, relative pattern of fruiting, fruit growth & development and quality of fruits. Therefore, high density planting has consistently gained popularity and acreage particularly with small land holdings during the past few decades in the developing countries.

Eco-physiological parameters (photosynthesis, stomatal conductance and transpiration rate) and micro-climate characteristics (relative humidity, canopy temperature, soil temperature) with regard to quality production of fruits, essentially depends on the photo-synthetically active radiation interception within plant canopy. Plant canopy refers to its physical composition comprising of the stem, branches, lateral shoots and spread of plant. Canopy management defined as the modification of these canopy components for the development plant structure in relation to the plant size and shape for maximum light interception and ease to harvesting. So, these canopy structures decide the quality production of fruits and productivity per unit area. The basic concept of canopy management is to make the best use of eco-physiological and climatic factors in relation to plant physiology of fruit plants as dimensional approach. Plant vigour and micro-climate play a vital role in the quality production of fruits. Therefore, the crux of canopy management lays in the fact that best manipulation of plant vigour with PAR interception and micro-climate to study the relationship between photosynthetic efficiency and yield of plants under various training systems.

A major objective for designing orchard systems is to arrange and trained plants on various training systems for maximize PAR interception within plant canopies. In apple (*Malus*×*domestica* Borkh.), production efficiency is related to light interception in canopy of plants under various training systems (Robinson and Lakso 1991). To ensure the production of high quality fruits, light distribution throughout the plant canopy is optimized by various training systems. Light interception is extremely important within canopy for maximize formation of fruiting sites (spurs) with regard to optimum yield/plant. Similarly in the previous studies, Kappel and Neilsen (1994) observed that fruit size of 'Anjou' pear is positively correlated to light interception within plant canopy. To reach the goal of an efficient orchard design, canopy modification through various training systems is required to attain higher production efficiency than conventional methods of planting. At present, size-controlling rootstocks and cultivars are commercially available for pear planting only in developed countries. Presently in British Columbia, pear plants are trained to multiple leader system and modified central leader system on standard size rootstocks. However, pear plants grafted on dwarfing rootstocks are not suitable under these various training systems. Canopy architecture can be manipulated through various means like training, pruning, rootstocks, PGR's, moisture stress and nutrition. Basically, the training is a potential tool to manage the canopy architecture according to the required conditions.

Various environmental factors are known to effect growth and performance of plants through many vital physiological processes in plants. Physiological processes of these plants like photosynthesis efficiency, water use efficiency and carboxylation efficiency under shade conditions within canopy are important factors that affect the growth and development of plants. Production efficiency increased through canopy management by regulating eco-physiological parameters is not a new concept in the state and a lot of opportunities are available to extend the operational area under various training systems. The quality production of fruits in plants trained on various training systems, which is ecologically and economically viable. The interaction between various components viz. light, temperature, photosynthesis, photo-synthetically active radiation, relative humidity, nutrients and production efficiency is complex to comprehend. Similar findings by Dhillon *et al* (2007, 2010) who reported that growth variables like stock girth, scion girth and height of fruit plants were positively correlated with radiation flux, photo-synthetically active radiation (PAR), stomatal conductance, inter-cellular CO_2, transpiration rate and fruit yielding characteristics under various pear based agro-forestry systems. It was found that net photosynthesis rate decreased almost to zero during midday due to stress of high temperature, intense irradiation, reduction in stomatal conductance and supply of CO_2. The stomatal conductance was affected by atmospheric temperature and relative humidity (RH) within plant canopy. Under low light interception conditions, physiological processes of these plants are influenced, which ultimately affect the economic yield. These general relationships have importance to determine fruit growth and development under various canopy management techniques at the beginning and during the growing season. Therefore information regarding the fruit growth and development can improve orchard management techniques like irrigation, fertilizer application, planting density, agronomic operations and cultural activities at the various growth phases of plants during canopy management.

1.2 EFFECT OF HEADING AND PLANT GROWTH REGULATORS ON FEATHERING OF PLANTS

One of the main purposes of fruit plant nurserymen is improving lateral branching in plants. Growers require well branched maiden plants for planting intensive orchards as feathered plants with wide crotch angled lateral shoots are more efficient to improve fruiting sites during early years of planting. The presence of sufficient number of feathers is desirable for a high-quality plant because flower bud formation on lateral shoots enable the plants to bear fruiting in the early years of planting (Elfving 2010). Moreover, as feathered plants facilitate earlier canopy structure formation, pruning is consequently simplified and management cost reduced as compared to plants with few lateral shoots (Robinson 2007). Hormonal hypothesis suggests that auxins play a vital role in apical dominance of plants, which can be overcome by application of cytokinins under various plants (Cook *et al* 2001). In apple, gibberellic acid (GA) has positive effect on the lateral shoot growth as compared to the untreated plants (Bulley *et al* 2005). Similarly, Dorić *et al* (2015) confirmed that application of synthetic cytokinin (6-benzyl aminopurine) either alone or combined with gibberellins, plays an important role in overcoming apical dominance and formation of well-feathered plants in apple nursery.

Traditional techniques like heading back and removing shoot tip not always give satisfactory results for promotion of lateral branching, so treatment of plant growth regulators (PGRs) is important to promote lateral branching in plants (Csiszar and Buban 2004). In many countries, application of cytokinins (BA) alone or in combination with gibberellins (GA) has been used to overcome apical dominance and stimulate the development of lateral branching with positive results in canopy management (Jaumien *et al* 2002). The use of strong, well-branched nursery plants greatly contributes to early and abundant fruiting in plants and well feathered healthy plants are also important for canopy management of fruit plants (Bielicki *et al* 2003). However, sufficient number of laterals required to formation of proper plant crowns and insufficient number of laterals is a limitation in nursery production of plants. The branching of maiden plants may be influenced by cultural practices like rootstock used, propagation techniques, planting density, fertilization as well as the climatic conditions in minor range. However, the ultimate factor responsible for poor feathering is a strong apical dominance in plants, which is under genetic control of hormonal balance. The phenomenon of apical dominance in plants is controlled by the interaction of endogenous growth hormone's level, especially auxins and gibberellins. The easiest method to overcome the apical dominance in plants is by various mechanical techniques viz. removing the auxin production site (heading back treatments), disturb their transport (leader twisting method) or by changing the nutritional equilibrium between leaves and lateral buds (top leaf removal). However, all of these physical methods are thought to be less effective as they promote only a few uppermost buds to develop into vigorous laterals than the application of PGR's in plants (Gąstoł and Poniedziałek 2003),. The chemical stimulation of branching may be achieved by the application of PGR's most effective than heading treatments. In addition, BA and GA_3 mixtures efficiently depress apical dominance in plants and induce feathering. The most commonly used PGR branching agent, promalin is a mixture of 6-benzyl adenine (BA) and gibberellic acid (GA). However, the response of the cultivar to PGR's differs from one to another, especially as some of them show negative effects (growth retardation, phyto-toxicity effects). To know the rate, timing and combination of cytokinins, gibberellins and additional substances is crucial for feathering of plants under the best nursery production of fruit plants. Thus, many experiments on PGR's, their concentration, composition as well as number of treatments have been conducted in many countries to optimize the dose and plant growth stage for treatment (Magyar and Hrotko 2005; Çaglar and Mürüvvet 2009). The purpose of this experiment was to compare different mixtures of BA+GA_3 or BA+GA_{4+7} with/ without additives in promoting lateral branching in young nursery apple plants.

A first trial was conducted on pear cvs. Patharnakh, Punjab Beauty and Punjab Soft at Fruit Research Farm, Department of Fruit Science, PAU (Ludhiana). The present studies were conducted with the following objectives to identify best trellis training system of pear cultivars for quality production of fruits with increasing productivity under sub-tropical conditions of Punjab. However, a second experiment was conducted on pear cvs. Patharnakh and Punjab Beauty and various treatments of heading and application of PGR's are given to plants in first year of planting to achieve goal with following objectives.

a.) To study the effect of different plant canopy structures on growth, productivity and fruit quality in pear.

b.) To study the effect of trellis training systems on eco-physiological parameters of pear.

c.) To study the effect of heading and plant growth regulators on feathering of pear nursery plants.

CHAPTER II

REVIEW OF LITERATURE

The literature pertaining to the studies carried out on "Studies on canopy management in pear" is documented under the following heads and sub heads:

2.1 Effect of training systems on production and fruit quality

- 2.1.1 Eco-physiological parameters
- 2.1.2 Vegetative characters
- 2.1.3 Flower and fruiting characters
- 2.1.4 Fruit yield characters
- 2.1.5 Fruit quality parameters
- 2.1.6 Foliar nutrient status

2.2 Effect of heading and plant growth regulators on feathering of plants

2.1 EFFECT OF TRELLIS TRAINING SYSTEMS ON PRODUCTION AND FRUIT QUALITY

The consequent influences on photosynthesis efficiency, transpiration rate and temperature are discussed in relation to canopy management, productivity and quality (Trentacoste *et al* 2015). This conclusion must await further work on irradiance distribution within canopy of plants under various training systems in response to orientation and porosity. The inadequacy of the existing literature and the preliminary model analyses of training systems establish the need for determined efforts to define the micro-environment and how it can be related to measurable parameters of architecture structure to give new impetus to the analysis of separate and combined impacts of irradiance and temperature effects on physiological development, growth, fruit yield and quality. In horticultural canopy management systems there is much scope to advance understanding of irradiance-based responses by comparative studies of impacts of depth and width of canopies, row spacing, porosity, latitude, cloudiness on fruit yield and quality. The response of fruit quality (total soluble solids, titratable acidity and fruit colour) provides more opportunity to discriminate between micro-climatic impacts resulting from training system orientation. This review has approached the question of the importance of plant orientation to performance of plants trained to various training systems by analyzing the significant impact of orientation on radiation capture and seeking consequent correlated impacts on temperature, evaporative demand, photosynthetic assimilation, fruit development, fruit yield and quality. The starting point was that the commonly accepted proposition of greater productivity of north-south compared with training systems of other orientations derives from greater interception of radiation that is distributed equally, diurnally to seasonally, on both sides of the systems. To evaluate this proposition, we searched the literature for comparisons between plant orientations and found many partial analyses, mostly related to radiation capture, but no comprehensive analyses of training system microclimate and production response with which to provide focus for the discussion. However, inadequate data on the distribution of fruit and irradiance within canopy management systems. Existing models could explain the vertical distribution of yield and some quality components.

Training refers to the form and spatial arrangement of the plant as dimensional approach, while pruning is the main technique used to achieve and maintain the desired size and form of canopies according to the requirements (Ferree and Schupp 2003). In apple orchards, the ‘central leader’ training system, developed for apple orchards during the 1970’s, forms pyramid-shaped plants with tiers of branches spaced up the trunks. But the vigorous growth of the upper canopy causes excessive shading on lower canopy portions, thereby reducing productivity of the apple plants (Robinson 2007). Subsequently during 1990’s, the ‘super spindle’ system appeared as a further modification that utilizes very high densities (4,000-7,500 plants/ha) that in combination with dwarfing rootstocks offers advantage of earlier yield at both plant and orchard levels (Fallahi *et al* 2002), but shortens the productive lifespan of the orchard at later stages (Robinson 2003). A common impact of high density is greater interception of solar radiation in early years that increases precocity (Rosa *et al* 2007; Hampson *et al* 1997) and controls plant size (Policarpo *et al* 2006; Williamson *et al* 1992). Canopy management systems have been adopted in a wide range of crops such as pear (Wheaton *et al* 1978), grape (Smart *et al* 1990), stone fruits (DeJong and Doyle 1985), citrus (Piner 1988) and nut fruits (Beyhan 2007; Olesen *et al* 2007; Wood and Stahmann 2004). Among these fruit crops, apple and pear are more responsive to canopy management under various training systems.

Similar results found by Rodrigo (2000) that plant microclimate distribution within the canopy affected the fruit production on plant level. The subsequent changes in the plant’s architecture will, therefore, modulate local environmental conditions (e.g., light, temperature and relative humidity), which in turn, can influence carbon acquisition and production efficiency of plants. The productivity and sustainability of orchard plants depends on various growth processes. Growth is an integrative process controlled by environmental conditions and orchard management practices. Air temperatures are influenced by microclimate, topography and soil characteristics (Ball *et al* 1997; Blennow 1998; Blennow and Persson 1998). Therefore, organ temperature is driven by the surrounding microclimate, but is also modulated by the organ’s physiological state (Chelle 2005). The within-crown microclimate is highly variable spatio-temporally and changes according to plant architecture, structure of the surrounding vegetation, climate and pedo-climate on the orchard level.

Eco-physiology is the study of environmental effects on plant physiology; these conditions are of paramount importance for the success of any fruit crop during planting (Fischer and Orduz-Rodriguez 2012). Eco-physiological research is conducted to describe the physiological mechanisms during development and growth of plants that interact with physical and biotic environmental factors related to plants (Lambers *et al* 2008). An orchard is characterized by an environment composed of light, temperature, water, humidity, wind, various atmospheric gases, soil nutrient status and other conditions of the rhizosphere on orchard level. During the growth of plants, several climatic and stress related factors are influential at the same time for the crop, such as drought, heat, UV light, etc. (Mittler 2006), *i.e.* no climatic factor alone can decide the physiological performance of plants. For example, photosynthesis efficiency of plants depends not only on radiation, but also on temperature, CO_2, water and nutritional elements available to plants (Fischer and Orduz-Rodriguez 2012). Solar energy use efficiency also depends on the plant size, structure, orientation and spatial location of the foliar surface of plants in both directions (Croitoru 2008). The continuous increase of the foliage area decreased the amount of light inside the crown at the determination of photosynthetic efficiency within canopy on various levels (Deviatov 1989). The stomatal behavior of leaves in response to changing photon flux density (PFD) and temperature in pear plants was similar to that commonly found in other species (Leuning *et al* 1995; Roux *et al* 1999) and previously observed in apple (Warrit *et al* 1980; Pretorius and Wand, 2003). Similarly, Massonnet and co-workers (2007) showed that parameters of photosynthetic efficiency and stomatal conductance models differed between different apple cultivars and examines the consequences of these differences for leaf water use efficiency.

Ying and co-workers (2016) examined the effect of thinning on the efficiency of PAR (photo-synthetically active radiation), fruit quality and yield. They measured leaf area, solar radiation and leaf air exchange at different canopy levels and by fitting relevant photosynthetic models, vertical distribution characteristics of leaf photosynthetic potentials and PAR were analyzed in various levels within canopies in densely planted orchards. Intermediate thinning significantly improved the radiant environment inside the canopies. PAR distribution within the canopies in the intermediately planted orchard was better than in the densely planted orchards.

Srivastava (2002) determined the photosynthetic compensation point for sub-tropical fruit plants to be between 10-20 $\mu mol/m^2/s$. Leaves on the ‘tunnel’ trained plants (11.03 $\mu mol/m^2/s$) were therefore found to be at the lower limit for photosynthetic compensation and this was the effect of training systems on photosynthesis efficiency of plants. Under low PAR interception conditions, fruit plant species maintained low levels of cellular respiration and modified their carbon partitioning in order to increase their photosynthetic efficiency (Kozlowsky and Pallard 1997; Schaffer and Whiley 2003). Therefore, Krause and Weis (1991) proposed changes in canopy shape to enable some shoots to intercept more light. In this respect, the ‘tunnel’ training system had a greater number of vigorous shoots in the upper portions of the canopy compared to the open-centre vase training system, which compensated the low photosynthetic efficiency of leaves located in highly-shaded areas. Therefore, environmental conditions inside the canopy can be modified significantly by the plant training systems, which subsequently affected flowering, fruit set, fruiting pattern, fruit quality, production efficiency and yield of plants.

Consequently, this situation has stimulated the development and application of various training technologies adapting the location in order to improve micro-environment of grape under semi-arid conditions (Romero *et al* 2004; Baloch *et al* 2013). Similarly, Nan and co-workers (2014) observed eco-physiological characters of grapes (*Vitis vinifera* L.) under different training systems. Training systems ‘HYTEC’ and ‘Solen’ depressed plant growth compared to ‘Mikado’ and ‘spindle’. Plants of different grape cultivars trained on ‘Mikado’ system were most productive followed by ‘spindle’, ‘Solen’ and ‘HYTEC’ training systems. Fruit size was best from plants trained on ‘Mikado’ system. Light was more evenly distributed in plants of ‘Mikado’ and ‘HYTEC’ training systems (Buler *et al* 2001). This research would be helpful for developing improved and effective canopy management strategies in high-efficient pear training systems.

2.1.1 Eco-physiological parameters

Light is essential for photosynthesis as it depends upon the absorption of light by pigments in the leaves. The energy derived from light absorption is used to achieve the final result of sugar synthesis as these are the building blocks for new growth and they are also needed for plant maintenance. An adequate distribution of light within canopy of fruit plants is also very important for the fruit bud differentiation to occur and thus it affects fruit quality and yield parameters. Knowledge on the responses of horticultural crops to environmental factors viz. temperature, water availability, light and CO_2 concentration is useful to determine the effect of sub-optimal environmental conditions and to manage crops for maximum productivity of fruit plants (Schaffer and Andersen 1994). Sunlight is not only the energy source for photosynthesis, but also the most important factor affecting productivity in horticultural crops (Papadopoulos and Pararajasingham 1997; Gregoriu *et al* 2007). Carbon exchange rate (CER) is strongly dependent on irradiance, absorption and utilization of photon energy (Gregoriu *et al* 2007). Insufficient light penetration into the canopy influences CER directly by reducing photon energy utilization, thus decreasing productivity (Hampson *et al* 1996; Gregoriu *et al* 2007). Canopy management as a routine activity in horticultural crops is aimed at increasing light interception and productivity, stabilizing yield and improving fruit quality through canopy modification (Hampson *et al* 1996).

Leaf Area Index (LAI) and light interception under different training systems viz. ‘palmette’, ‘slender spindle’ and ‘full field’ was calculated by Palmer (1986) and the fraction of the total light intercepted was 53% for both palmette and slender spindle training systems whereas, 66% of light intercepted in full field. Carbonneau and Lespinasse (1989) reported that the penetration of light into the canopy is related to training systems and planting density under a particular training system. The ratio between canopy height, thickness and alley width must be taken into account to ensure adequate light levels inside the canopy (Corelli and Sansavini 1989). Canopy management techniques involve maximum utilization of light as it is most important component of fruit production. Light is known to influence flower bud differentiation, fruit set, fruit quality and productivity of plants (Jackson 1980). Given that they need sunlight for flowering and flower bud formation; fruit-plant crops keep a balance between light interception and light distribution within plant canopies (Huett 2004). Relationship between photosynthetic photon flux density (PPFD) and net photosynthesis rate provides basic information for canopy management concept (Hanson *et al* 1987); several studies have focused on photo-synthetically active radiation (PAR) interception into the plant canopies (Higgins *et al* 1992; Wood 1996; Lombardini 2006). Light interception modeling has also been important in the development of pruning and training techniques for optimizing yield and canopy management strategies aimed at improving orchard productivity (Garriz *et al* 1998; Huett 2004; Li and Lakso 2004; Lombardini *et al* 2006). Shading levels of 60% to 90% affects leaf morphology and anatomy, gas exchange and water relations (water use efficiency, stomatal conductance and thus photosynthesis efficiency) in horticultural crops (Atanasova *et al* 2003; Heuvel *et al* 2004; Gregoriu *et al* 2007). In addition, shade diminishes reproductive potential directly by decreasing flowering, fruit set and fruit size; and indirectly by reducing the vegetative growth that the plant needs to support reproductive sites (Hampson *et al* 1996). Temperature is also an important environmental factor influencing vegetative growth, flowering, fruit set and fruit ripening in horticultural crops (Sage and Kubien 2007; Ledesma *et al* 2008; Kositsup *et al* 2009). Both high and low temperatures beyond the optimum, be they temporary or constant, can induce morpho-anatomical, physiological and biochemical changes in plants, leading to profit reduction (Higuchi *et al* 1998; Wang *et al* 2003; Wahid *et al* 2007). High temperature induces the acclimation of photosynthesis by changing the photosynthetic efficiency of leaves (Sage and Kubien 2007; Wang *et al* 2007; Kositsup *et al* 2009) and the functioning of photosystem II (Camejo *et al* 2005). In citrus species, net CO_2 assimilation rate is reduced by partial decrease in both stomatal conductance and instantaneous carboxylation efficiency at temperatures beyond optimum range (Machado *et al* 2005). Hence, knowledge about temperature limits is useful in physiological research as well as horticultural crop production. Understanding the way this factor affects plant physiology is greatly desirable to avoid damages due to unfavorable temperatures during plant ontogeny (Wahid *et al* 2007).

Canopy light interception is related to productivity and fruit quality in plants (Wagenmakers and Tazelaar 1999). Therefore, optimum light interception is of strategic importance for growers. Up to 70% diffuse light interception, productivity of an apple or pear orchard increases without loss of fruit quality. Solar energy interception and light distribution within the canopy are strongly related to plant architecture which influences production efficiency, but structure and leaf distribution in fruit plants are primarily affected by training systems (Lackso 1994). The efficiency of training system may be evaluated in terms of 'light use' in plants (Robinson and Lakso 1991), that is the capacity to maximize the assimilate distribution into plants for obtaining higher fruit yield (Chalmers and Vaden 1989). Full-field and multi-row training systems intercepted more light than single rows (Jackson 1980; Oberhofer 1989; Wagenmakers 1991). Training system also affects quality production of fruits by altering light distribution within plant canopies (Corelli and Sansavini 1989; Jotic and Oakford 1989; Cloyton 1993). Fruit colour, total soluble solids (TSS) and fruit firmness also depended upon light distribution in plant canopies (Barritt *et al* 1987; Robinson and Lakso 1991). Similarly, Robinson and Lakso (1991) reported that efficiency of a training system can be evaluated in terms of 'light use' by the entire canopy of plant. In Y-shaped tress, branches were grown over the alley and less incident of light penetration to the ground leads to higher light interception by the foliage and efficient PAR distribution over the plant foliage. However, Wunsche *et al* (1996) reported that in production system of plants with vertical hedgerow and palmette, considerable light was lost by the plant due to the extensive and unproductive alleys developed between rows.

Peach fruit plants trained to Y-trellis system have advantage because they are distributed on shoots with optimum exposure of leaves to light, which improved fruit quality and yield parameters (Lannini *et al* 2002). Apple plants were trained on five different training systems viz. slender spindle, Geneva Y-trellis, modified solen, V-trellis and high density V-trellis systems (Chenyl *et al* 2002). The high density V-trellis training system intercepted more light (73%) as compared to slender spindle (53%). The two Y-shaped training systems had 11-14% greater cumulative yield/ha than the slender spindle, but did not intercept significantly more light within plant canopies. Similarly in apple, Y-shaped plants were 11-18% more productive than plants trained as slender spindle and palmette training systems, respectively. The difference in yield was related to PAR interception in lower canopy portions (Robinson, 1997). The relationship between leaf area index, PAR interception and light distribution within plant canopies trained to the 'spindle' and 'HYTEC' training systems was studied in apple orchards. 'Solen' and 'Mikado' training system was studied by Buler and Mika (2009) who reported that highest leaf area index (LAI) and PAR interception was observed in plants trained on the 'Mikado' system. The lowest PAR interception was in the 'HYTEC' and 'Solen' systems. In the other systems, light penetration to the inner and basal portion of plant canopy was obstructed. Each training system plays an important role in PAR interception and its distribution within the plant canopy. Light interception is an important factor in productivity of fruit plants. It influences the flower initiation process and has an impact on quality production of fruits. Maximum potential assimilation is realized by a canopy that absorbs all incoming light in optimum range (Wagenmakers 1995). Fruit yield per ground unit area is positively correlated with light interception within plant canopies (Palmer 1989). Insufficient light interception and exposition may reduce fruit size, colour, TSS and efficiency of plants to produce fruits (Robinson *et al* 1991; Palmer *et al* 1992).

The significant effects of location within plant canopy on both primary metabolites and secondary metabolites demonstrate the importance of light exposure on apple fruit quality (Feng *et al* 2014). Here, fruits collected from the outer canopy were heavier and had a higher total soluble solids (TSS) content than fruits from lower canopy portions. These findings are consistent with those reported for the 'Aroma' apple (Nilsson and Gustavsson 2007) as well as pear (Sanchez and Righetti 1990) and grapefruit (Syvertsen and Albrigo 1980). This suggests that fruits in outer portions of the canopy benefit from better light exposure because leaves in those positions have greater photosynthetic efficiency (Barritt *et al* 1987). The higher light interception within plant canopies of Y-trellis plants with higher yield supports the data of Robinson and Lakso (1991), Robinson *et al* (1991) and Hampson *et al* (1998) for apples. Robinson and Lakso (1991) reported that fruit yield was correlated with the level of PAR. In further studies, it would be of interest to determine how artificial spur extinction (ASE) modifies seasonal light interception of the canopy, plant carbohydrate status and to elucidate whether these factors explain the measurable enhancement of flowering, fruit set and fruit quality (Van Hooijdonk 2014). According to Caruso *et al* (2008) higher gas exchange and water use efficiency was observed in apple plants trained to Y-trellis system. Kappel and Brownlee (2001) investigated average fruit weight was significantly affected by various training systems. Robinson *et al* (1991) reported that fruit size of 'Empire' and 'Delicious' apple cultivars was inversely related to crop load and Sugar; Van Buskirk (1994) reported similar results for 'Bosc' and 'Comice' cultivars of pear.

Solar radiation also referred to as shortwave radiation, drives the processes of water demand (transpiration rate), growth (photosynthesis efficiency) and various photo-morphogenetic responses of plants. Evapo-transpiration responds to interception of energy in the entire solar spectrum (0-3 µm) but photosynthesis only to the visible component (0.4-0.7 µm). Photo-synthetically active radiation (PAR) comprises a constant enough proportion of solar radiation incepted by plant canopies under a wide range of atmospheric conditions. Incidence and interception of radiation by canopy structures have been studied in horticultural plants under various orchard related practices. Porosity is important to canopy ventilation and penetration of pesticide sprays inside the deep layers of plant canopy (Lazzaro *et al* 2008), it receives much greater attention for its effect on internal irradiance within plant canopies.

In addition to direct effects on photosynthesis and various photo-morphogenetic processes, solar radiation also heats soil, air and plant surfaces. Biochemical processes are sensitive to temperature (Tarara *et al* 2008) with rates that double for each 10^{o}C increase (i.e. Q^{10} =2). But where individual processes respond to both radiation and temperature, it is difficult to separate the individual effects because this requires direct manipulation of the two variables (Sadras *et al* 2012). Under field conditions, temperature varies diurnally increasing shortly after sunrise to a maximum in early afternoon, then decreasing to sunset and on through the night to a minimum shortly after dawn the next day. Daily maximum temperature occurs after solar noon i.e. after maximum irradiance, due to heat storage in the atmosphere and surface layers of the soil (Chen *et al* 1999). The temperature of individual plant organs fluctuates according to air temperature although interactions with neighboring organs and their surrounding micro-environment can create large deviations from air temperature (Saudreau *et al* 2011). For example, the difference between organ and air temperature increases with solar irradiance and decreases with wind speed (Bergqvist *et al* 2001; Dokoozlian and Kliewer 1996). In water stressed plants, this difference increases as a consequence of reduced transpiration rate mostly of leaves (Jones *et al* 2002; Sepulcre-Cantó *et al* 2006), but of other plant organs also. Other factors that determine organ temperature are characteristics of surface conductance to water vapour diffusion and overall canopy architecture of plants under various training systems (Saudreau *et al* 2011).

Various studies in individual horticultural plants have revealed that linear increase in net photosynthesis rate of leaves with irradiance from a low value (compensation point) to a level at which it saturates. For example, Higgins *et al* (1992) compared photosynthetic efficiency of seven horticultural crops (apples, almonds, peaches, Asian pears, grapes, figs and olives) in relation to different light responses. They found that grapes and almonds had highest photosynthesis rate (> 20 mol $CO_2/m^2/s$) and Asian pears had lowest Pn rate (less than 15 mol $CO_2/m^2/s$). Similarly, peaches reached light saturation level at lower irradiance (900 mol PAR/m^2/s) and had low compensation points (50 mol PAR/m^2/s). Based on these leaf responses, it would be expected that diurnal photosynthetic response of training systems to solar radiation would be directly related to those of canopy irradiance. It was described earlier suggesting that supply of photo-assimilates for vegetative and reproductive growth would respond greatly to different irradiance environments caused by plant orientation at leaf and whole canopy levels. Overall this limited data identify differences in photosynthetic behavior of plants between various training systems of extreme orientations and the range of additional measurements required to identify their causes. There is clearly an opportunity for detailed physiological studies of canopy management techniques that would be best undertaken along-side micro-meteorological measurements of this type reported by Martínez-Cob and Faci (2010) with attention to canopy microclimate. In the mean time, measurements of photosynthesis and transpiration rate of individual leaves (5-6 leaves/plant) used in photosynthesis efficiency measurements (Higgins *et al* 1992; Proietti and Famiani 2002) provide clues that are difficult to agglomerate, as in other crop studies, to responses of entire plant canopies (Giuliani *et al* 1997). Transpiration rate of leaves is a function of intercepted radiation, stomatal conductance and vapour-pressure deficient (VPD) in plant's microclimate (Williams and Ayars 2005); and canopy cover of plant's foliage (Goodwin *et al* 2006). Similary, Mature 'hedgerow' orchard system with equal dimensions and different orientation has similar ground cover fractions, have variation in patterns of PAR interception.

Fruit yield of apple plants is highly correlated with PAR interception during the growing season and accounts for most variation in yield attributed to various training systems (Robinson and Lakso 1991). Wünsche and Lakso (2000) also found in apple plants that intercepted fraction of PAR were curvilinear related to fruit yields and it was achieved maximum at 60% PAR interception. Canopies with greater interception were suffered from shading effects that reduces both flowering and fruit growth rate. Such detrimental effects of shading on spur formation, flowering, fruiting, production efficiency and fruit quality have been reported in various horticultural species (Ferree *et al* 2001; Hampson *et al* 1996; Marini and Sowers 1990). Cherbiy-Hoffmann *et al* (2012) related the variation of yield components within large N–S oriented hedge rows (height 5.5m and width 4.6m) to measured irradiance within the hedgerow's canopy. Connor *et al* (2012) observed a linear function between relative pattern of fruiting and autumn daily irradiance over the range of 3.7-12.3 mol PAR/m^2/day within plant canopies. The direct comparison among different studies is difficult, because Cherbiy-Hoffmann *et al* (2012) measured the horizontal variation of PAR within the hedgerow, while Connor *et al* (2009; 2012) estimated vertical gradients of PAR irradiance within plant canopy.

Crafts-Brandner and Salvucci (2000) highlights the importance of Rubisco activation as a determinant of photosynthetic performance. The upper portion of plant canopy intercepted maximum radiation than the middle and lower canopy portions, irrespective of planting distances. The size and weight of fruits harvested from the plants spaced at 6m×6m were found significantly higher than the plants spaced at 6m×5m and 6m×4m. However, the fruit yield/plant decreased with decrease in spacing between plants (Singh and Dhaliwal 2007).

2.1.2 Vegetative characters

Kappel and Brownlee (2001) conducted the study to determine how various training systems affected early growth and fruiting in 'Conference' pear (*Pyrus communis* L.) plants were trained to angled trellis, slender spindle, vertical axis and Y-trellis training systems. The plants trained to Y-trellis system had the greatest spread after five years. However, 'vertical axis' and 'slender spindle' plants were tallest as compared to plants trained on other systems. The Y-trellis trained plants had highest amount of light interception within canopies and had significantly higher fruit yields than other training systems. Average fruit weight was inversely related to crop load. Choi *et al* (2014) reported the effect of training systems on growth and fruit production in 'Niitaka' pear (*Pyrus pyrifolia* L.). The training systems included Y-trellis, T-trellis and Vase Pergola affected plant height, canopy area and number of new shoots, average length of new shoots and trunk cross sectional area as compared to those in other training systems under this study. Similar results were obtained by Sosna (2006) on 'Conference' and 'Komisówka' pear cultivars that training systems affected the growth and development of plants.

Canopy management comprised better accommodation of foliage on trellising systems and different means of reducing foliage during fruit set at pea-berry size stage of growth and development in grapes (Hunter 2000). Grapevine canopy's micro-climate affected the photosynthesis efficiency, yield and grape quality parameters (Hunter *et al* 1995); canopy management should be applied with great care and thorough consideration of the partitioning of assimilates between sites of production, accumulation and utilization in order to reach this goal. The photosynthetic activity of leaves as well as export of photo-assimilates increased as a result of improved canopy microclimate and lower source-sink ratio in plants (Candolfi-Vasconcelos and Koblet 1990; Hunter *et al* 1995; Koblet *et al* 1996).

Trunk cross sectional area (TCSA) was correlated to percentage of photo-synthetically active radiation intercepted within canopies and fruit yield (Robinson and Lakso 1991). These results are in line with Maimaiti *et al* (2013) who reported that branch bending significantly increased the leaf chlorophyll content and blade thickness in young 'Fuji' apple plants. Lepsis and Blanke (2006) concluded that the relation between cumulative yield and TCSA can be used for yield modeling in fruit plants. The relation between annual yield and TCSA or cumulative yield effectiveness dynamics cannot be exploited for yield modeling. The canopy volume, leaf area, yields and production efficiency increased gradually with increase in trunk cross sectional area of plants (Dalal and Brar 2012). They reported positive and significant correlation between trunk cross sectional area and yield. However, a positive but non-significant correlation was found between trunk cross-sectional area and growth parameters viz. TSS, leaf N and P contents; while acidity content showed a negative correlation. Trunk cross sectional area (TCSA) per hectare was greatest in plants trained to Y-trellis system and smallest with 'central leader' training system of plants (Robinson *et al* 1991). Therefore, yield was highly correlated to TCSA/ha in plants. The physiological basis for the higher yield could be related to angle of the trellis arm under various canopy management techniques. It is well known that as the limb angle of apple becomes more horizontal, flowering increases and apical dominance with extension growth decreases in plants. Radial growth, expressed using TCSA was closely correlated with plant density on the orchard level (Sosna 2017). The apple plants with 'Mikado' canopies were characterized by highest TCSA values; whereas the 'Güttingen-V' plants growing in higher density planting developed the thinnest trunks. Similarly, the planting distance with in-row may have even bigger influence on the plant vegetative growth such as TCSA (Widmer and Krebs 2001; Uselis 2003; Robinson 2007, Uselis *et al* 2007).

In a modern canopy management system, these descriptors should be now integrated with other parameters enabling a better description of the real differences induced by various training systems. For instance, new modelling systems allowing an accurate description of the plant architecture are now available providing useful information and ultimate guidance on the most appropriate management cultural techniques to be adopted in any region. Key factors in achieving high consistent accumulated returns were depend on planting density with combination of good light interception and precocity within plant canopies. A factor less clearly defined is physiological compatibility that match between vigorous and non-vigorous training systems with rootstock used (Elkins and Dejong 2011).

Similarly leaf area changes affect solar radiation interception, photosynthesis efficiency and extinction coefficient of an orange plant's upper canopies (Pilau and Angelocci 2015). Positive relationships were found between total leaf area/plant, LAI and light interception within plant canopies. Light distribution within plant canopy was the most beneficial in the 'Mikado' training system. In the other training systems, light penetration to the inner and basal portions of plant canopy was obstructed by over vegetative growth.

Summer pruning significantly improved light distribution within plant canopy by removing excessive growth which is not useful for production in plants (Buler and Mika 2009).

2.1.3 Flowering and fruiting characters

Ende (1994) stated that early fruiting in pear with higher production is achievable, if a large and efficient bearing area can be built quickly by using the canopy management techniques. This implies a requirement for plant vigour, but also for qualitative canopy development favouring branches which readily formed flowering spurs and maximize fruiting sites. Arzani *et al* (2008) investigated fruits of Asian pears and fruit diameter was measured in time interval until fruit harvest period. Results indicated that simple and complete fruit sigmoid curves existed for all genotypes even though the period of each phase of fruit growth was different in studied genotypes. Such results, it has been reported by many research workers in other fruit plant species (Bramardi *et al* 1998; Szabo *et al* 1998; Bertelsen 2002). Shoot bending and girdling caused an increase in spur formation percentage, fruit set and yield of ‘Le-Conte’ pear cultivar. Bending techniques reduce shoot growth and increase spur formation, fruit set and improve fruit quality of various deciduous fruits (Ahmed *et al* 2002 on apple; Said *et al* 2003 on apricot and Fayek *et al* 2004 on pear). While, it gave significant decrease in fruit firmness, acidity, leaf N content in the ‘Anna’ apple cultivars (Kandil *et al* 2006). Moreover, Khattab *et al* (2003) reported that winter shoot bending increased lateral shoot growth and number of flowering spurs in ‘Le-Conte’ pear plants. On other hand, Sharma and Kaur (2006) found that bending of branches in pear enhanced spur formation and precocity in inner portions of plant canopy. Also Kandil *et al* (2006) on apple and Chen Chung *et al* (1997) cleared that summer shoot bending in ‘Hosui’ pears was effective in promoting lateral bud formation at the end of the year. Mohammadi *et al* (2013) reported that flower bud density and vegetative growth increased by heading back treatment of apple plants under different canopy management techniques. George *et al* (1996) stated that sunlight distribution influences flower initiation and fruit set in peach. Moreover, Abd-El-Rahman (2002) and Mohamed (2012) reported that shoot bending and stem girdling increased fruit set percentage in ‘Le-Conte’ pear cultivar.

The effect of shading in horticultural crops can reduce photosynthesis efficiency, transpiration rate and stomatal conductance; and enhance flower abortion. Likewise, high temperatures beyond optimum range can affect pollen viability and germination, number of flowers and number of fruits/plant leading to yield reduction. Finally, eco-physiological information is a tool that can be used in horticultural programs to obtain improved cultivars, as well as in strategies of agricultural zoning and canopy management, thus enhancing productivity of well trained plants (Restrepo-Díaz *et al* 2010). Nasr *et al* (2015) investigated the horticultural practices (bending, girdling and heading) in pear plants and these results showed increased spur formation, shoot number and diameter, dry matter production, fruit set, fruit yield and improved fruit quality. Shoot bending may enhance flowering of young plants, encourage the development of flower buds and increase yield in apple plants (Wei 1987; Edwards and Notodimedjo 1987) and in pear cultivars (Lin *et al* 1990; Chen Chung *et al* 1997). Shoot bending treatments also caused a rapid increase the number of nodes in auxiliary buds of Japanese pear (*Pyrus Serotina* Rehd) plants and finally percentage of flower bud formation under control plants only reached to 15.2% as compared to treated shoots with 60% flowering bud formation (Banno *et al* 1985). Abd-El-Rahman (2002) also noticed that shoot bending enhancing vegetative growth, fruit quality and quantity in 'Le-Conte' pear cultivar. Moreover, shoot bending significantly increased C/N ratio of spur wood, which leads to flowering in plants. Jana (2015) noticed that shoot bending increase ethylene synthesis in damaged cells which influence early flower bud formation in pear plants.

Management of flowering and fruit set are of prime importance in order to obtain high yields in cherimoya (*Annona cherimola* Mill.) and this phenomenon is largely dependent on environmental conditions such as temperature, relative humidity and light intensity to achieve acceptable levels of fruit set and yield (Cautín *et al* 2010). The 'slender spindle' training system was proposed for high-density fruit orchards because it is highly productive (Perry 1998; Lauri and Lespinasse 2000). This system can affect the micro-climate inside the canopy, both in terms of light interception efficiency, changes in temperature and relative humidity. Klinac (1995) compared the different training systems according to spur formation and floral bud density. Bud development in 'Nijisseiki' pear was more evenly distributed over all wood ages, with significantly higher proportion of spurs than other cultivars. Spur production was lowest in 'Kosui' pear cultivar. Plant growth was most vigorous on Y-trellis system and least vigorous on pergola training system, but training systems did not consistently affect the mix of wood ages or bud development in plants. In general, these results were consistent with those reported in Japan (Kishimoto *et al* 1989) and New Zealand (White 1990) that training systems affected the growth and development of pear plants.

2.1.4 Fruit yield characters

To adapt fruit production to these new situations, a complete understanding of multiple effects of climate change on plant physiology is required (Swaminathan and Kesavan 2012). The visible solar radiation is essential as a source of energy for photosynthetic activity in plants (Koyama *et al* 2012) with its key role as an energy source for biomass production and finally fruit crop's yield (Rivas 2008). The density of plants and branches as well as the plant height and shape of the crown was regulated by various training systems and direction of planting according to the region. These were important aspects to maximize light interception in plant's canopy (Fischer and Orduz-Rodriguez 2012). Similarly, In passion fruit

(*Passiflora tripartite* var. mollissima) in areas of high incidence of mist, the training and pruning of plant canopy in a 45° Espalier system orientated to the east increases interception of light and therefore, fruit production (Miranda *et al* 2009). If radiation levels fall below 10-30% of the light within the canopy, compared to those out of the canopy, the flowers are not differentiated in many fruit species (Rom 1996) and production will occur only in the apical and lateral periphery of the plant (Sherman and Beckman 2003).

Robinson and Lakso (1989) compared the plant density, light interception and yield among four training systems. High yield and fruit quality come from good light distribution in the plant canopies. However 'slender spindle', 'vertical trellis' and 'Y-trellis' training systems provide good light distribution within the plant canopy resulting in high yields and production efficiency (Robinson *et al* 1991). Although maximum fruit yields are ultimately limited by light interception and distribution; economic fruit yield and quality are a function of efficiency of light use and light distribution within the plant canopies (Jackson 1980; Lakso *et al* 1989; Robinson *et al* 1983). The training systems in fruits depend on the basic concepts of biological, ecological and technological resources that govern the productivity of fruit plants (Balan and Cimpoies 2009). Apple plant density affects the early productivity of the orchard; higher the plant density, higher the yield of plants (Robinson *et al* 1991; Ystaas *et al* 1994; Hampson *et al* 1998). Wertheim and Wagenmakers (1984) showed that increasing plant density of 'Conference' pear on Quince-C rootstock increased yield/plant. The influence of several orchard systems involving plants trained to different leader numbers on growth, cropping and fruit quality of two apple cultivars (Sosna 2017). Fruit plant and orchard productivities have been investigated in relation to training systems, rootstocks and crop management practices (Costes *et al* 2003) and their interactions with other environment factors.

Asian pear (*Pyrus pyrifolia* Nakai) plants used to be trained mostly by 'pergola' system or 'open-center natural form' since 1906, but after the introduction of 'Y-trellis' training system in 1985, the 'Y-trellis' system is prevailing throughout Korea. However, the 'V-trellis' system with some modification from the original 'Tatura-trellis' system has been tried in commercial orchards. Training systems for apple and pear plants increases production efficiency per unit area (Kim *et al* 2008). Lauri (2002) presented research work on the 'Solaxe' system and 'Centrifugal' training systems for Korean apple growers and demonstrated the method of establishing the light-well by removing the small branches, fruits and leaves around the trunk for 'Centrifugal' training system. Similar results defined by Morgan (2005) that the 'V-trellis' has more promising results in the aspect of a smaller canopy, large number of fruits with even bigger fruit size resulting in significantly higher yield in pear plants. Tatura-trellis training system improves the productivity of pear plants and offers the possibility to obtain high quality yields (Stanica *et al* 2002). Pear production quality and quantity depends on canopy management, but also on pruning techniques (Corelli *et al* 1989). In high-density pear orchards, the Tatura-trellis were one of the most used training systems (Sansavini and Musacchi 1994), offering the highest potential for light interception. To simplify training of the branches, a special trellis that allows modifying the branch angle was designed (Stănică and Dumitraşcu 1999). Highest chlorophyll a and b contents were found in leaves of 'Abbé Fétel' and 'Passe Crassane' compact types which also exhibited higher photosynthetic efficiency and productivity in pear plants (Rotondi and Predieri 2002).

Apple plants were trained to various training system viz. slender spindle, Geneva Y-trellis, modified Solen and V-trellis training systems (Chenyl *et al* 2002). Who found that two Y-shaped training systems had 11-14% greater cumulative yield/ha, whereas no consistent difference was observed in relation to fruit size and colour development. Vercammen (2014) planted seven different planting systems for 'Conference' pear cultivar on 'quince Adams' rootstock was planted in the spring of year 2002. Over ten production years (2003-2012) the large size pear fruits were found in the 'V-trellis' and 'Candle-stick' training systems while the small size fruits were found on the long pruning of plants. Also the spindle plants had a somewhat lower average fruit weight. The difference in fruit size only can be partly explained by the difference in yield. Similar results showed by Sosna and Czaplicka (2008) that pear plants trained to 'V-Güttingen' training system gave higher yield per hectare.

Fruit production does not always increase with increased light interception. On a trunk cross sectional area basis, there were no significant differences in fruit production in any of the four training systems. However, training system is most appropriate for increasing light interception without increasing vegetative growth potential of plants (Grossman and Dejong 1998). Appropriate canopy and crop load management are therefore, required to obtain an adequate balance between the yield and fruit size in the fruit plants (Bennewitz *et al* 2011). These results were agreement with those reported by Whiting *et al* (2005) that increase of planting density in pear orchards can be achieved not only by the use of dwarfing quince rootstocks but also by the choice of proper training systems; in fact, especially, the V-trellis system (4,000-7,000 plants/ha) and the vertical-axis system (7,000-13,000 plants/ha) prove more suitable for use in high density planting of pear by canopy regulation (Musacchi 2008).

2.1.5 Fruit quality parameters

Growth in plants defined as irreversible increase in volume and size. Good fruit production largely depends on the knowledge of orchardists on fruit growth and development stages (Arzani *et al* 1999; Salisbury and Ross 1992). In addition, desired growth and development of fruit plants are related to the suitable environmental conditions that are light, temperature, water and nutrients availability etc. Also, different factors influence the fruit growth stages, such as ecological factors, genotypes, orchard management and canopy management systems (Salisbury and Ross 1992). Thus study on fruit growth and development under different climatic conditions is urgently needed to estimate the final fruit size, time of fruit ripening with relation to canopy management techniques (Nejatian 2001; Mattiuz *et al* 1997; Salisbury and Ross 1992). The need to develop training and pruning strategies that would better fit the natural growing and fruiting habits of the plant has become a challenging issue (Lauri 2009). Choice of orchard system is one of the major factors on which production and fruit quality depends. Various training systems are used for an improved light interception by the fruits. Orchard systems are being evaluated all around the world, including Australia (Shafiq *et al* 2014), North America (Robinson 2007), North Africa (Hassan *et al* 2010), Far East (Jung and Choi 2010), and Europe (Uselis 2003; Licznar- Małanczuk 2006). Robinson (2000) investigated the most popular V-shaped canopy systems, recommended as an alternative for orchards with high density planting, which allow the optimal light interception and promote good yield of high-quality fruits (Monney and Evéquoz 1999; Widmer and Krebs 2001; Hampson *et al* 2002; Buler and Mika 2007; Hassan *et al* 2010).

Singh and Kanwar (2004) while studying the effect of spacing and training systems on radiation regime and fruit quality of peach observed that plants trained to Y-shaped structure showed higher mean total radiation as compared to modified leader system. Y-shaped plants intercepted 52.50%, 12.90% and 9.70% of the total irradiance in the upper, middle and lower canopy portions, while plants trained to modified leader system intercepted 50.10%, 10.40% and 6.70% of the total irradiance in the upper, middle and lower canopy portions, respectively. Good quality fruits were obtained from Y-shaped as compared to modified leader system plants. Similarly, Dallabetta *et al* (2014) performed the study for the comparison between the two training systems 'Slender Spindle' and 'Bi-axis' and that were performed on two main cultivars of that region. Plant architecture description and fruit position in the canopy were monitored during the fruit maturation and ripening. Fruit quality was dependent upon cultivars, training systems and fruiting pattern in the plant canopies. In general, fruit harvested from 'Bi-axis' resulted more homogeneous fruit size and weight with regards to 'Spindle' training system.

A clear understanding of environmental factors and their interaction with physiological processes is extremely important for improving horticultural practices (e.g. irrigation, light management, mineral nutrition, greenhouse design etc.), optimizing photosynthetic carbon assimilation and increasing fruit productivity and quality (Restrepo-Díaz *et al* 2010). The reduction of light intensity affects the reproductive growth more than the vegetative growth of plants because it directly influences floral induction, flower bud differentiation and also fruit set; fruit size, fruit colour and organo-leptic fruit qualities (Fischer *et al* 2012). Thus in fleshy fruits, optimum solar radiation benefits fruit colour, synthesis of anthocyanin pigments, the refractive index (°Brix) and dry matter content, as well as increases the concentration of vitamin C in fruits (Fischer and Orduz-Rodriguez 2012; Fischer *et al* 2016). Castro (2015) confirmed that, in the Colombian highlands within the orchards of deciduous fruit plants located at 2,500m above sea level in Duitama (Boyaca), the high solar radiation produces apples of good coloration and quality.

The pattern of light intensity in open canopies, such as V-Güttingen, Mikado and Solen training systems promotes best fruit quality (Buler and Mika 2004). Good fruit quality from open plant form was obtained by Widmer and Krebs (2001) on 'Royal Gala' and 'Golden Delicious' apple cultivars and by Sosna (2004) on 'Elstar' and 'Jonagold' apple cultivars. Sharma (2014) found that fruit weight, diameter and total soluble solids (TSS) also increased with the increase in pruning intensities. However, non-significant difference was observed on fruit firmness and acidity of 'Starking delicious' apples.

Fruit quality characteristics generally depend on relative pattern of fruiting in plant canopy because this influences irradiance on fruits and their neighboring leaves (Farina *et al* 2005). He *et al* (2008) harvested peach from various canopy positions and found a positive correlation of soluble solids with canopy irradiance. Similarly, Marini *et al* (1991) in peach, Dokoozlian and Kliewer (1996), Hummell and Ferree (1998), Rojas-Lara and Morrison (1989) in grapes, Jifon and Syvertsen (2001) in grapefruit, Campbell and Marini (1992) in apple have all shown that fruits with greater exposure to solar radiation during late stage of fruit growth increased soluble solids (TSS) with slightly decreased or unchanged acidity of expressed juice. Similarly, The development of red skin colour in apple (Awad *et al* 2001; González-Talice *et al* 2013) and accumulation of skin flavonoid in grapes (Cortell and Kennedy 2006) have also been strongly correlated with irradiance. Exposures to high irradiance also increases fruit temperature that in turn increases fruit transpiration and respiration rate; and also sink activity in plants i.e. greater translocation of carbon and other assimilates into fruits (Génard and Bruchou 1993) as well as enzymatic activity of fruits (Marini *et al* 1991). In this way, fruit temperature is commonly associated with higher concentration of total soluble solids (Reynolds *et al* 1986) and yet excessively high fruit temperature has the potential to reduce total soluble solids (Bonora *et al* 2013) and anthocyanin content of fruits (Bergqvist *et al* 2001) through a change in fruit acid metabolism (Reynolds *et al* 1986 in grape). Furthermore, excessive temperature or irradiance has been related with increased fruit sunburn in apple and pear crops reducing that important (cosmetic) aspect of fruit quality (Khemira *et al* 1993). Based on irradiance patterns on canopies, it is reasonably expected that fruit quality characteristics would respond to canopy orientation. They were viewed the literature in horticultural systems in which records of fruit quality were available for individual training systems. The exception of this general trend is the work by Khemira *et al* (1993) who observed similar concentration of total soluble solids in fruits under different training systems.

The choice of training system is part of the whole orchard project and management, influencing planting distances, light interception and finally the success of the orchard in terms of obtained fruit quantity and quality (Robinson *et al* 1991; Palmer 1999). It is therefore essential to evaluate the training system not simply on the basis of total yield but also on the fruit quality traits which instead remain actually confined to the definition of empirical parameters such as average fruit weight and standard quality traits (total soluble solids content, acidity, flesh firmness and starch content).

2.1.6 Foliar nutrient status

Foliar nutrient status has complex effects which are mainly depends on fertilization that which nutrient is being supplied and when to the plants. Fertilization generally increases growth by increasing leaf area, light interception and transpiration rate of leaves in plants. Therefore, carbon allocation is shifted to the above ground plant parts, leaf coloration is delayed and bud burst is advanced (Thomas and Ahlers 1999; Nikula *et al* 2011; Forrester 2013). However, nitrogen (N) is critical for root system activity and for inducing root pressures that help the re-absorption of air bubbles and alleviation of embolism (Ewers *et al* 2001; Gloser *et al* 2007; Thitithanakul *et al* 2012). Phosphorus (P), which is involved in cell division, is also important for recovery of tissues after freezing damage or frost. Potassium (K) has a favorable effect on water regulation and photosynthesis efficiency of leaves in plants (Snyder *et al* 2005). Further research is needed, especially on the potential interactions between different nutrients, fruit production and canopy management techniques. However, many aspects are still unclear, especially regarding the potential interactions between the environment and physiology of plants. Based on this general framework, we are able to highlight factors by which various environmental conditions (temperature, light, flood, drought) and management practices (pruning, thinning, girdling, sheltering, water aspersion, irrigation, fertilization) influenced the fruit production (Charrier *et al* 2015). Similarly leaf analysis indicated that all cultivars of sweet cherry under high density planting had excessive levels of N and Cu; and in some cases P, whereas K, Ca, Mg, Fe, Mn, Zn and B were deficient (Milošević *et al* 2015).

Similar results obtained by Neilsen *et al* (2010) who reported that there was not any variation between cultivars in case of leaf N content and inconsistent differences in case of leaf P content. However, results of other research workers confirmed the great variability of leaf mineral composition due to genotype, planting year, rootstock and environmental variability (Ystaas 1995; Roversi *et al* 2008). Nagy *et al* (2008) reported that cherry cv. 'Germersdorfer' under Hungarian conditions contained higher levels of leaf K and Ca content as compared to other cultivars. A significant difference was observed in leaf N, P and K content due to various pruning levels at different planting densities of guava fields; the highest N, P and K content was recorded in leaves taken from plants subjected to severe pruning up to 60% removal of shoots followed by 40% and 20% removal of shoots as compared to leaves taken from un-pruned plant in guava systems (Singh *et al* 2017). The nitrogen, phosphorus and potassium content in leaves increased with decreasing plant density in many fruit crops. The N, P and K content was recorded maximum in leaves taken from plants at wider spacing and minimum in leaves taken from plants at closer spacing under HDP, which might be due to wider spacing responsible for higher uptake and translocation of nutrient from soil to aerial part of the plants. Similar findings of Kumar *et al* (2013) in apricot that foliar macro and micro nutrients status was significantly varied among different cultivars. Jiménez *et al* (2007) and Stochl *et al* (2008) also reported that cultivar differences of leaf micro nutrient content in different seasons were variable.

Han *et al* (2008) studied the effects of branch bending angle on physiological characteristics of 'Fuji' apple cultivars. They showed that there were no significant differences in leaf intercellular CO_2 concentration and leaf total nitrogen content. Solar radiation affects the N content in leaves located at different positions within plant canopy in order to acclimate environmental changes and to optimize the photosynthesis efficiency of plant at different canopy levels (Schoettle and Smith 1999; Genard *et al* 2000; Wilson *et al* 2000; Meir *et al* 2002; Han *et al* 2003; Zhang *et al* 2009). Leaf photosynthetic potential within plant canopy is related to nitrogen distribution pattern of leaves. PAR inside the canopy can alter N re-allocation of mature leaves within plant canopy and this represents another response to radiation changes (Brooks *et al* 1996). However, the acclimation mechanisms of the photosynthetic processes of plant canopies and variation of leaf N content are not well studied in relation to variable environmental factors (Medhurst and Beadle 2005). The relationship between the photosynthetic efficiency of leaves and the leaf nitrogen content was clear, as was the linear relationship between the leaf nitrogen content and PAR. Therefore, according to the vertical distribution of the relative leaf nitrogen content in plant canopies, the spatial distribution of the photosynthetic efficiency and relevant radiant flux density of the leaves can be quantified and this can play an important role in orchard management practices.

2.2 EFFECT OF HEADING AND PLANT GROWTH REGULATORS ON FEATHERING OF PLANTS

Auxin is mainly synthesized in the shoot apex in young leaves and is subsequently transported basipetally (Aloni 2007; Müller and Leyser 2011). The application of 6-benzylaminopurine (BA) affects the flow of auxins (Müller and Leyser 2011) and temporarily impedes the main shoot growth (Sazo and Robinson 2011), which helps to overcome apical dominance and creates favourable conditions for feather formation. For high-quality plants presence of a sufficient number of feathers is desirable because they form flowering buds in the second year of nursery production and enable the plant to bear fruiting in the first year following planting under field conditions (Robinson *et al* 2006; Sadowski *et al* 2007; Elfving 2010, Keserović *et al* 2012). Moreover, as feathered plant facilitate earlier canopy structure formation, pruning is consequently simplified and management costs are reduced (Robinson 2007). Nursery-grown apple cultivars vary greatly in their tendency to form feathers (Wertheim and Webster 2003). Some one-year-old apple cultivars exhibit poor feathering (Volz *et al* 1994; Hrotko *et al* 2000; Sazo and Robinson 2011). Important factors in feathering are nutrient availability (Tromp 1996), ecological conditions (Tromp 1996; Tromp and Boertjes 1996) and apical dominance (Volz *et al* 1994; Sazo and Robinson 2011). The terminal buds have apical dominance factor, which effect the development of lateral buds in plants (Cline 1997). Hormonal hypothesis suggests that auxins play a role in apical dominance, which can be overcome by application of cytokinins to the plants (Cline 2000; Cook *et al* 2001; Wang *et al* 1994).

Feather length is also important in determining the plant quality. According to Sadowski *et al* (2007), feather length and orchard plant productivity are linked. Apple cultivars are differ in their ability to form feathers in the nursery plants (Wertheim and Webster 2003; Cvetković 2010), whereby ‘Gala’ and ‘Jonagold’ apple cultivars tend to form longer feathers (Kviklys 2006; Cvetković 2010; Atay and Koyuncu 2013). As the main shoot and feathers are in competition for water and nutrients (Cline 1997), an increase in the number of feathers enables variation in mean feather length (Dorić *et al* 2013). These results are in accordance with earlier research findings, which confirmed that GA affects shoot elongation on apple plants (Volz *et al* 1994; Bulley *et al* 2005). It is very important aspect that the first spraying is performed at the right time and with appropriate concentrations of BA or BA+GA_{4+3}, so that the first feather formation at the right height, as this is indicative of the success of the first spraying treatments (Dorić *et al* 2013). Studies of apple plants have also established a significant effect of GA on the number and length of shoot internodes in plants under study (Bulley *et al* 2005).

In feathered nursery plants crown is formed from axillary buds of the main shoot, the emergence of which is governed by the auxin/cytokinin ratio (De Wit 2002; Watanabe *et al* 2008). Flow of auxin inhibits the growth of the axillary buds by limiting the amount of cytokinin entering the bud (Muller and Leyser 2011). In apple cultivars, synthetic cytokinin (6-benzyladenine) when applied either alone or in combination with gibberellins (GA_{4+7}) plays an important role in the production of well-feathered nursery plants and overcoming apical dominance (Hrotko *et al* 2000; Elfving 2010; Dorić *et al* 2013; Dorić *et al* 2014). However in some studies, BA spraying can adversely affect the plant height and trunk diameter (Hrotko *et al* 2000; Dorić *et al* 2013; Steiner *et al* 2013; Dorić *et al* 2014). In apple, GAs has positive influence on the lateral growth and shoots length (Rademacher 2000; Bulley *et al* 2005).

One-year-old apple (*Malus domestica* Borkh.), 'Boskoop' and 'Mutsu' cultivars showed strong apical dominance; however, increased branching potential was observed following the application of exogenous plant growth regulator mixtures like BA+GA_3 (Gastol *et al* 2012). In apple, synthetic cytokinin (BA) either alone or combined with gibberellins (GA_{4+7}) plays an important role in overcoming apical dominance and in the production of well-feathered apple nursery plants. Feather formation is strongly influenced by type and concentration of plant growth regulators. Increasing concentrations of BA and BA+GA_{4+7} led to a greater number of feathers, increased feather length and expanded branching zone. BA has a stronger effect compared to BA+GA_{4+7} on the growth rate of shoots resulting in a greater feather angle and a lower plant height, which can be eliminated by addition of GA_{4+7}. The treatments also had different effects on trunk diameter. In 'Gala' apple cultivar, a minor adverse effect of BA on trunk diameter was noted under some studies (Doric *et al* 2015).

Feathers initially emerge at a very sharp angle, which increases with further growth in the progressive season. This is preferable to wide angle branching as the resulting; these feathers bloom early and are more easily trained after planting on various trellis training systems (Warner 2011). By affecting apical dominance, PGR's (BA and BA+GA_{4+7}) have also impact on feather angles and plant height (Elfving and Visser 2005). Extant studies have shown that apple cultivars 'Idared' (Hrotko *et al* 2000) and 'Fuji' were negatively affected by BA application on one-year-old nursery plants and mean plant height was reduced (Sazo and Robinson 2011). When applied alone, cytokinins reduce plant height; while gibberellin sprays consistently increase plant height in pears (Palmer *et al* 2011). In 'Gala' apple cultivar, trunk diameter values measured following application of BA and BA+GA_{4+7} and these were found lower as compared to un-treated plants. In contrast, following their study of one year old 'Catarina' apples, Rossi *et al* (2004) found that increasing concentrations of BA+GA_{4+7} (250 to 750 µl/l) resulted in decrease of plant trunk diameter. Studies of some other fruit species, such as plum (Magyar and Hrotko 2002) and cherry (Magyar and Hrotko 2005) also confirmed that BA can result in decrease of plant trunk diameter to a certain degree, if higher concentrations of BA are applied. In pear, application of BA as a means of enhancing the formation of feathers did not affect the trunk diameter in plants (Palmer *et al* 2011).

The application of BA and BA+GA_{4+7} results in an increase in the number of feathers exceeding 10 cm in mean feather length, while in apple cv. Jonagold increase in number of feathers was also noted which were shorter than 10 cm length. Total feather length increased with PGRs (BA and BA+GA_{4+7}) concentrations during application. As GA_{4+7} have a significant positive effect on feather length and BA+GA_{4+7} treatments are more effective than BA treatments. The branching zone increased with PGRs (BA and BA+GA_{4+7}) concentrations. In addition to apical dominance, application of BA and BA+GA_{4+7} also affects plant height and feather angle of treated plants. Effects of BA and BA+GA_{4+7} on trunk diameter need to be further researched (Doric *et al* 2015). It is proved that heading and plant growth regulator (Arbolin) application improves feathering and length of lateral shoots on young sweet cherry plants, but Arbolin (PGR) applications were more effective than heading treatments. The number of lateral shoots enhanced with application of higher concentrations and repeated Arbolin treatments in both cultivars of cherry. Height of plants in Arbolin treatments was slightly more than control (un-treated) plants. Angle of laterals with application of Arbolin treatments was wider than heading treatments during the studies (Moghadam and Zamanipour 2013).

The branching effect was correlated with increases in rate of active ingredients which used for various treatments. BA+GA_3 based mixtures (Arbolin 36SL and Arbolin Extra) were better than BA+GA_{4+7} mixtures available for application on plants (Gąstoł and Poniedziałek 2003). Many researchers pointed out that heading alone had little effect on branching with either cultivar (Groene 1990; Poniedziałek and Porębski 1995). Removal of the shoot tips also caused production of lateral branches as it was in case of heading. However, the number of lateral shoot formation was insufficient (1.1-2.3 feathers/plant) to form proper plant crown. Moreover, these feathers had too narrow branch angles with main axis (Gąstoł and Poniedziałek 2003). The application of biochemical branching agents is thought to be more beneficial in promoting a more desirable branching for canopy development under various training systems (Basak and Soczek 1986). In all examined cultivars, found that the application of branching agents significantly reduced the apical dominance; both PGRs (Arbolins and Promalin) strongly affected branching of each cultivar as compared to control (un-treated) plants (Gąstoł and Poniedziałek 2003).

6-Benzyl adenine (BA) application had more significant effect on number and length of lateral shoots than heading treatments. Repeated application of BA treatments induced more number of lateral shoots than a single time treatment (Zamanipour *et al* 2012). BA application on plants induced the longest branches, most total branch growth and greatest branch crotch angles than applications involving a single BA+GA_{4+7} spray (Volz 1994). BA treatments showed some promise in increasing nursery plant quality over simultaneous applications of BA and GA_{4+7}; further stimulating to a lesser extent feather growth, increasing feather crotch angles and increasing feather formation. Studies were conducted to evaluate the impact of BA + GA_3 (Arbolin 36 SL) and BA + GA_{4+7} (Promalin 3.6 SL) in the form of lanolin paste on increasing the number of lateral shoots in maiden apple plants. The plant growth regulators were found to have a beneficial effect on the branching ability of the maidens of the studied cultivars (Kapłan 2010).

Whose confirm the average opinion in literature is that low BA concentration is optimal for good feathering of young plum plants; higher concentration caused the formation of short lateral branches may be due to phytotoxic effects on plum plants during treatments. The stem diameter of treated plants was observed to be reduced, which accounted for the transport of assimilates devoted to developing lateral shoots. The applied 600ppm and 800ppm BA concentrations reduced the terminal growth and had a phyto-toxic effect (burning, small-sized and deformed leaves; drying of tips of shoots at 800ppm BA treatment) on plum plants. It is important to note that due to the extremely wet weather of 1998 the growth of plants in the nursery was stronger than the average; therefore during the dry year period, treatments with higher BA concentrations (400-800ppm) might not give feathered plants of adequate quality (Magyar and Hrotko 2002).

CHAPTER III

MATERIAL AND METHODS

The present investigation entitled "Studies on canopy management in pear" was carried out during cropping year of 2016 and 2017 at Fruit Research Farm, Department of Fruit Science, Punjab Agricultural University, Ludhiana.

The experimental site represents a semi-arid and subtropical climate i.e. summers are very hot and dry followed by monsoon season from July to September and winters are cold. The mean maximum and minimum temperature show considerable fluctuations during summers and winters. The maximum air temperature rises above 40°C during summer months i.e. May-June while in winter months temperature falls down to less than 5°C occasionally accompanied by frost spells. The average annual rainfall of this area is about 885 mm. Out of this, 75% rainfall received during monsoon period i.e. July to September.

Experiment details

In this experiment studies were carried on pear cv. Patharnakh, Punjab Beauty and Punjab Soft trained according to Espalier, Cordon and Y-trellis training systems. Observations for various eco-physiological and morphological characters were recorded at fortnightly interval during fruit development period. The orchard soil was deep, well drained and sandy-loam. All the plants received similar cultural practices during the course of investigations. Fruit and leaf samples were analyzed in the PG Lab and Nutrition Lab of Department of Fruit Science, Punjab Agricultural University, Ludhiana (Punjab).

Site and Geographical location

The experiment was conducted at Fruit Research Farm of Department of Fruit Science, Punjab Agricultural University, Ludhiana, situated at latitude of 30.90^{o} N, longitude of 75.85^{o} E and at an altitude of 244 m above mean sea level.

Experiment No. 1

3.1 EFFECT OF TRELLIS TRAINING SYSTEMS ON PRODUCTION AND FRUIT QUALITY OF PEAR

a) Methodology

Observations on eco-physiological parameters and fruit growth rate were taken from fruit set to fruit maturity at fortnightly interval during both the years. Physico-chemical parameters of fruits were recorded at the time of harvest. Vegetative characters were recorded during dormant season in the month of January. Samples for nutrient status were taken from mature leaves in the month of July.

b) Treatment details

Training system = 3 viz.

I) Y- Trellis system

II) Cordon system

III) Espalier system

Cultivars = 3 viz. (Patharnakh, Punjab Beauty, Punjab Soft)

Replications per treatment = 7

Total number of experimental plants = 63

Observations of different pear cultivars trained on various training systems were made for the following eco-physiological, vegetative, flowering, fruiting, yield and fruit quality related physico-chemical traits:

3.1.1 Eco-physiological parameters

3.1.1.1 Photosynthesis parameters (μmol/m^2/sec)

Photosynthesis related observations i.e. photosynthesis rate (Pn), photo-synthetically active radiation (PAR), stomatal conductance (C) and transpiration rate (E) were recorded on clear sky days at morning (8-11 am), on fully expanded mature leaves during growth period of respective pear cultivars at fortnightly intervals by using a portable photosynthesis system (Model: CI-340, *CID Bio-Science, USA*).

3.1.1.2 Relative humidity (%)

Relative humidity (RH) was recorded midway in middle portions of the plant canopy with the help of Temp/RH/CO_2 Hand-Held Meter (Model: 3440, *Spectrum technologies, USA*) at morning (8-11 am). These observations were recorded on the day, when data for radiations and canopy temperature were recorded at fortnightly intervals.

3.1.1.3 Canopy temperature (^{o}C)

Canopy temperature was recorded midway in middle portions of the plant canopy with the help of Temp/RH/CO_2 Hand-Held Meter (Model: 3440, *Spectrum technologies, USA*) at morning (8-11 am) on the same day with other observations.

3.1.1.4 Soil temperature (^{o}C)

Soil temperature reading was taken at morning, during the course of study at fortnightly intervals. The soil thermometer was installed five cm deep in the soil underneath the canopy of marked plants. The mean diurnal soil temperature was calculated for analysis.

3.1.2 Vegetative parameters

3.1.2.1 Plant trunk cross sectional area (cm^2)

Plant trunk diameter in pear cultivars was measured at 5.0 cm above the ground with the help of Vernier's Calliper in mm. From this, plant trunk cross sectional area (TCSA) in pear was calculated with the help of following formulae.

$$\text{TCSA} = \pi\,(\text{Diameter}/2)^2$$

3.1.2.2 Shoot diameter (mm)

Shoot diameter (mm) of mature shoots in pear plants was measured with the help of Vernier's Calliper in lower, middle and upper canopy portions of plant.

3.1.2.3 Spur growth (mm)

Spur growth in pear cultivars was recorded in the form of spur diameter and length. Spur diameter and length (mm) were measured with the help of Vernier's Calliper in lower, middle and upper canopy portions of plant.

3.1.2.4 Extent of spur formation on shoots (spurs/meter)

Extent of spur formation on shoots in pear plants was recorded as number of spurs per meter shoot length before flowering and leaf emergence in lower, middle and upper canopy portions of plant.

3.1.2.5 Chlorophyll content

Chlorophyll content was measured in mature leaves of pear with the help of soil plant analysis development (SPAD) chlorophyll meter (Model: SPAD-502 plus chlorophyll meter, *Spectrum technologies, USA*).

3.1.2.6 Leaf area (cm^2)

Leaf area was measured from fully expanded mature leaves with the help of hand held Laser Leaf Area Meter (Model: CI-203, *CID Bio-Science, USA*).

3.1.2.7 Pruning wood weight (kg/plant)

Pruning wood weight was recorded from pear cvs. Patharnakh, Punjab Beauty and Punjab Soft with the help of platform weighing balance in kilogram per plant in the month of January.

3.1.3 Flowering and fruiting characters

3.1.3.1 Start of flowering

Date of initiation of flowering in pear cultivars was recorded when 5% flowers emerged on the pear plants.

3.1.3.2 Full bloom

Time of full bloom in pear cultivars was recorded when more than 75% flowers had opened on the pear plants.

3.1.3.3 End of flowering

End of flowering in pear cultivars was recorded when at least all the flowers >95% had opened on the pear plants.

3.1.3.4 Flower bud density (flowering spurs/meter)

Flower bud density on mature shoots was recorded as number of flowering spurs per meter shoot length at the time of full bloom period of flowering in various pear cultivars.

3.1.3.5 Fruit set (%)

Fruit set was recorded at pea stage of fruit growth in pear varieties on individual shoots and their average was taken for analysis.

Fruit set (%) = (Total no. of fruit set/Total no. of flowers) x 100

3.1.3.6 Relative pattern of fruiting in plant canopy

Relative pattern of fruiting in plant canopy was recorded as number of fruits on lower, middle and upper canopy portions of plant and calculated percentage distribution to the total fruiting in their respective canopy portions.

3.1.3.7 Fruit growth rate (mm)

Fruit growth rate was recorded in the form of fruit length and diameter (mm) in pear fruits with the help of digital Vernier's Calliper. Ten randomly selected fruits were used for recording data at fortnightly interval from fruit set to fruit maturity in pear cultivars and average data was taken for analysis.

3.1.4 Yield parameters

3.1.4.1 No of fruits per plant

Number of fruits/plant was counted in pear cultivars on lower, middle and upper canopy portions differently in the plants.

3.1.4.2 Yield (kg/plant)

Yield/plant was calculated in pear plants by multiply the total number of fruits on a plant with average weight/fruit under the present investigations.

Yield/plants = No. of total fruits/plant x average weight/fruit

3.1.4.3 Yield per hectare (tones)

Yield/hectare was calculated from pear orchards by multiply average yield/plant to the total number of plants/hectare. There are 1111 plants/ha under Espalier system at spacing of 2x3m, 2222 plants/ha under Cordon system at spacing of 2x1.5m and 1250 plants/ha under Y-trellis system at spacing of 3x2m, respectively. There is six meter wide space remained unplanted after six rows of fruit plants for proper orchard management operations.

Yield/ha (tones) = yield/plant x No. of plants/ha

3.1.4.4 Production efficiency (kg/cm^2)

Production efficiency per plant in various pear cultivars was calculated by the following formulae from the observations calculated that are yield/plant and trunk cross sectional area (TCSA) in pear plants.

Production Efficiency = yield per plant/TCSA

3.1.4.5 Crop load (cm^{-2})

Crop load per plant was calculated by the following formulae from the observations calculated that are number of fruits/plant and trunk cross sectional area (TCSA).

Crop load = Number of fruits per plant/TCSA

3.1.5 Fruit quality characters

Fruits were harvested from the experimental plants at physiological maturity stage during the cropping year of 2016 and 2017; during early hours in the morning. After collection, the fruits were immediately transferred to laboratory for analysis. The fruits were washed under running tap water, cleaned and dried with a piece of muslin cloth. After drying, the bruised and diseased fruits were sorted out, healthy and blemish free fruits were selected for analysis of various fruit quality characters.

3.1.5.1 Fruits length and diameter (mm)

Fruit length and diameter of pear fruits was measured with the help of digital Vernier's Calliper across the cheeks of ten randomly selected mature fruits and means were worked out for analysis.

3.1.5.2 Fruit weight (g)

Fruit weight of ten randomly selected mature pear fruits was recorded in grams with the help of electronic balance and the mean weight was worked out for statistical analysis.

3.1.5.3 Fruit firmness (lbf)

Fruit firmness of ten randomly selected mature pear fruits was recorded in pound-force with the help of stand mounted penetrometer (Model: FT 327, *EFFEGI, Italy*) and the mean fruit firmness was worked out for analysis.

3.1.5.4 Total soluble solids (^{o}Bx)

The juice of ten randomly selected fruits from each replication were extracted and stained through the muslin cloth immediately at the time of fruit analysis. TSS of pear fruits was measured with the help of digital refractometer (Model: Atago PAL-1, *Japan*) in terms of degrees Brix. The readings recorded with the help of Refractometer were then corrected to 20^o C with the help of temperature correction chart (AOAC 1990).

3.1.5.5 Titrable acidity (%)

The juice acidity was determined by titration 5 ml of juice against 0.1 N NaOH solution, using phenolphthalein as an indicator. The end point was observed at the appearance of light pink colour and the results were expressed in terms of maleic acid equivalent to fruit acidity. Then acidity percentage was calculated by following formula:

Juice acidity (%) = 0.0067 x 0.1 N NaOH used / Juice taken

(1 ml of 0.1 N NaOH = 0.0067 g maleic acid)

3.1.5.6 Total sugars (%)

The total sugars were estimated by extracting the carbohydrates in 80% ethanol, thereafter filtrate is used for sugar estimation with anthrone reagent. Twenty gram of fruit tissue was crushed to a fine pulp in a wearing blender and extracted in the same solvent on water bath for interval of two hours. The extract is filtered through Whatman's filter paper and the residue was re-extracted for 30 minutes using 25 ml of 80% ethanol. The process was repeated until no sugar could be checked in the filtrate with the help of anthrone reagent.

Then filtrate was taken in volumetric flask and volume is made to 100 ml with distilled water for sugar content estimation.

To the 10 ml of aliquot, some distilled water and 5 ml of saturated lead acetate was added and filtered through Whatman's filter paper, excess of lead acetate was removed by sodium oxalate solution till the precipitation was complete and then filtered, volume was made to 100 ml with distilled water. The one ml of diluted solution was taken in test tube and 10 ml of 0.2% antrone reagent was added. The test tubes were kept in boiling water for ten minutes and then cooled at room temperature. Optical density of dark green samples was taken at 630 nm on spectrophotometer. A standard curve was prepared by plotting the known concentration of glucose solution against OD value of each concentration. From standard curve, the amount of carbohydrates present in the sample was determined for sugar estimation.

3.1.5.7 Starch (%)

The residual obtained after extraction of water soluble carbohydrates was used for the estimation of starch content in fruits of pear. The residue was moistened with 10 ml H_2O and re-extracted with 13 ml 52% $HClO_4$ (Perchloric acid) at room temperature with constant stirring for fifteen minutes. Again 20 ml H_2O was added and centrifuged at 6,000 rpm for twenty minutes. Thereafter supernatant was collected in 100 ml volumetric flask to make 100 ml volume and filtered through Whatman's filter paper.

Two ml of filtered starch solution was diluted to 50 ml and 5 ml of diluted solution was taken in test tube and it was cooled in ice water. 10 ml of fresh anthrone reagent (0.2%) was added and test tubes were place in boiling water bath for ten minutes and cooled at room temperature. The optical density (OD) of coloured solution was measured at 630 nm wavelength for starch estimation. From the standard curve, the amount of glucose actually present in the sample was determined and starch content of pear fruit samples was calculated by multiplying the obtained value with correction factor (0.90).

3.1.6 Foliar nutrient status

3.1.6.1 Collection and preparation of leaf samples

For foliar nutrient status analysis, leaf samples were collected in the month of July from the mid-terminal shoots at random from all the sides of the plant. The leaf samples were washed with tap water by rubbing gently with hand to remove dust and other contaminants. Then leaves were rinsed in deionized water acidified with HCL (0.01 M) and final washing only with double distilled water. Thereafter leaves were dried in a hot air-oven at 65^oC for 48 hours. The dried leaf samples were ground in 'Wiley mill' with stainless steel blades to pass through 60 mesh size sieve and stored in butter paper bags, used later for analysis of various macro and micro-nutrients.

3.1.6.2 Nitrogen (%) determination

a) Digestion

For the determination of nitrogen (N), 0.5g leaf sample was digested in 8-9 ml concentrated H_2SO_4 along with digestion mixture in Semi-automatic Nitrogen Estimation System (*Pelican Equipments, India*). Powdered leaf sample with 4-5g catalyst mixture was put into digestion tube for digestion of leaf samples. Catalyst mixture is prepared by addition of 250g K_2SO_4 with 50g $CuSO_4$ and 5g metallic selenium in the ratio of 50:10:1. Digestion tube was heated in the digestion block upto temperature of 410^oC and the sample turns colourless or light green at the end point of digestion process.

b) Distillation

The tube containing digested leaf sample was then transferred to the distillation apparatus. It was diluted with distilled water and subsequently 40% NaOH was poured in distillation tube. In 150 ml conical flask, 10 ml 4% boric acid was taken out. In the distillation apparatus, the digested sample was heated by passing steam and the ammonia liberated due to the addition of alkali was collected in 4% boric acid. The boric acid consist of ammonia was taken for titration and estimation of nitrogen in the given leaf samples.

c) Titration

Distillate sample was taken in conical flask was titrated with 0.1N H_2SO_4 solution. The end point of titration was the change of colour from bluish green to permanent pale pink. Then percentage was calculated by using following formula:

$$N (\%) = \frac{14 \times \text{Titrate value} \times \text{Normality of acid}}{\text{Weight of sample} \times 1000} \times 100$$

3.1.6.3 Digestion of sample for P, K, Ca, Mg, Fe, Zn, Mn and Cu determination

For the estimation of phosphorus and potassium, 0.5g leaf sample with 10 ml of Di acid mixture, consisting of nitric acid (HNO_3) and perchloric acid ($HClO_4$) in the ratio of 4:1 were taken in the digestion test tube. Samples in test tubes could stand overnight and on the next day follow the digestion process. During digestion process, initially temperature was kept low and after that it was increased slowly. Digestion was completely in 3 hours when white fumes started emerging out of the tubes. Tubes were then removed from the digestion block and allowed to cool at room temperature. After cooling, the contents were diluted with distilled water and filtered. The volume was made to 100 ml with distilled water after filtration for the estimation of various nutrients.

3.1.6.4 Phosphorus (%) determination

Phosphorus (P) in pear leaf samples was determined with the help of vanadomolybdo phosphoric yellow colour method described by Chapman and Pratt (1961).

a) Nitric acid vanadate-molybdate reagent

Twenty five gram ammonium molybdate was dissolved with distilled water in a beaker. In another beaker, 1.25g ammonium metavanadate was dissolved with 300 ml boiling water. The solution was cooled to room temperature and 250 ml of concentrated nitric acid was added. Gradually molybdate solution was added to vanadate solution and final volume was made to one liter with distilled water, used for phosphorus estimation process.

b) Colour development

Plant digest (5 ml) was taken in a 25ml volumetric flask and one or two drops of 2,4 dinitrophenol indicator were added to it. Then 4N Na_2CO_3 solution was added dropwise till yellow colour appeared clearly. Thereafter 6N HCL was added drop wise till yellow colour disappeared in given sample. After this, 2 ml of 6N HCL was added to get required pH of 4.8 followed by addition of 5 ml of vanadate-molybdate reagent. Final volume was made to 25 ml with distilled water and allowed to stand for 30 minutes for colour development for P estimation.

c) Phosphorus standard curve

Small amount of distilled water was taken and 0.219g KH_2PO_4 was dissolved in distilled water to make final volume of one liter. This solution contains 50ppm phosphorus and 0.0ml, 0.5ml, 1.0ml, 1.5ml, 2.0ml, 2.5ml, 3.0ml, 3.5ml, 4.0ml, 4.5ml and 5.0ml of this solution were taken in eleven (25ml capacity) volumetric flasks and colour was developed in the same way as described above for the test leaf samples. Colour intensity of standard phosphorus solution was measured at 470 nm wavelength on a spectro-photometer (UV spectro-photometer) and standard curve was constructed on the graph paper. The colour intensity of test samples was measured and phosphorus concentration was estimated from the standard curve which expressed as P (%) according to the formula given below:

Phosphorus (%) = ppm x total dilution/10,000

3.1.6.5 Potassium (%) determination

Potassium (K) in pear leaf samples was determined with the help of Flame Photometer method described by Jackson (1973).

a) Potassium standard curve

KCI (1.907g) was dissolved in distilled water and final volume was made to one liter. From this solution, 10 ml solution was taken in a 100 ml volumetric flask to make 100 ml final volume with distilled water. This solution was 100 ppm stock solution to prepare different standard solutions for plotting standard curve. Out of this 100ppm stock solution; 1ml, 2ml, 4ml, 6ml, 8ml and 10ml were taken in 100 ml volumetric flask and volume was made up to mark with distilled water to get 1ppm, 2ppm, 4ppm, 6ppm, 8ppm and 10ppm solution, respectively. Distilled water was fed to atomizer of the flame photometer and reading of galvanometer was set to zero. Then 10ppm standard potassium solution was fed to atomizer and reading was adjusted to 100. Then other standard solution was fed and reading was noted. The flame photometer reading was plotted against concentration of standard solution to get a standard curve.

For determining potassium in the test leaf samples, 1 ml of plant extract was taken in 25 ml volumetric flasks and volume was made up to mark with distilled water. The leaf samples were fed to atomizer of the flame photometer, which had been adjusted with standard K solution and reading was noted. The concentration of K content present in the leaves was found from the plotted standard curve and expressed as K% according to the formula as given below:

Potassium (%) = ppm x total dilution/10,000

3.1.6.6 Calcium (%), Magnesium (%), Iron (ppm), Zinc (ppm), Copper (ppm) and Manganese (Mn) determination

Ca, Mg, Fe, Zn, Cu and Mn concentrations in the test leaf samples were determined using Atomic Absorption Spectro-photometer (AAnalyst 200, *Perkin Elmer, Shelton, CT, USA*). From these nutrients Ca and Mg are secondary macronutrients, whose concentration estimated as percentage. However Fe, Zn, Cu and Mn are micronutrients, whose concentration estimated as ppm. All the nutrient contents were expressed on dry matter basis.

Experiment No. 2

3.2 EFFECT OF HEADING AND PLANT GROWTH REGULATORS ON FEATHERING OF PEAR PLANTS

a) Methodology

One-year-old nursery pear plants were planted on the field in the month of January. Heading back treatments were given to plants at the time of planting. The subsequent, three sprayings of plant growth regulators (6-benzyladenine and GA_3) were conducted at 7 days intervals starting from the late spring. Vegetative characters were recorded at the end of the vegetative phase of plant growth.

b) Treatment details

Treatments = 9 viz.

I) BA (400 ppm)

I) BA (600 ppm)

III) BA (800 ppm)

IV) BA (600 ppm) + GA_3 (200 ppm)

V) BA (600 ppm) + GA_3 (400 ppm)

VI) BA (600 ppm) + GA_3 (600 ppm)

VII) Heading back at 60 cm

VIII) Heading back at 75 cm

IX) Heading back at 90 cm (Control)

Cultivars = 2 viz. (Patharnakh and Punjab Beauty)

Replications per treatment = 7

Total number of experimental plants = 126

Observations of the different pear cultivars under various heading and PGR treatments were made for the following vegetative growth and feathering parameters in first year of planting:

3.2.1 Plant vegetative growth parameters

Vegetative growth of experimental pear plants was recorded in terms of plant height, plant spread (East-West and North-South directions), stock girth, scion girth etc. at the end of vegetative growth phase. Mean plant height was measured by measuring tape in cm. Diameter of main stem below bud union and above bud union was recorded by Vernier's Caliper in mm. Spread of plant in both directions was measured by measuring tape in cm and mean was taken for analysis.

3.2.2 Feathering parameters

Total numbers of feathers/plant, number of feathers >50 cm and <50 cm were counted in each plant under various treatments and mean was taken for analysis of data. Number of buds and leaves on lateral shoots were counted on lateral shoots/100 cm length and mean value is used for data analysis. Mean diameter of feathers in pear plants under different treatments was measured by digital Vernier's Calliper in mm.

3.2.3 Crotch angles (Degree)

Crotch angle of feathers with respect to main stem was measured at the branch base with main axis in pear plants under different treatments. It was measured with the aid of transparent protractor in degree divergence from main axis and the mean was worked out for data analysis and results.

3.2.4 Leaf area (cm^2)

Leaf area was measured from fully expanded mature leaves with the help of hand held Laser Leaf Area Meter (Model: CI-203, *CID Bio-Science, USA*).

3.2.5 Foliar nutrient status

Nitrogen content (%) in the leaf samples was estimated by Pelican Semi-automatic Nitrogen Estimation System (*Pelican Equipments, India*). Phosphorus content (%) in the test sample was determined by Vanadomolybdo phosphoric yellow colour method described by Chapman and Pratt (1961). Potassium content (%) was determined by the Flame Photometer method described by Jackson (1973). Leaf Ca (%), Mg (%), Fe (ppm), Zn (ppm), Cu (ppm) and Mn (ppm) concentrations were determined by using Atomic Absorption Spectro-photometer (AAnalyst 200, *Perkin Elmer, Shelton, CT, USA*). All the nutrient contents were expressed on dry matter basis.

3.3 Statistical analysis

The experiment was laid out as randomized block design (RBD) with 7 replications per treatment. The data was subjected to analysis of variance (ANOVA) using statistical software package SAS 9.3 (*SAS Institute Inc., Cary, NC, USA*). The mean separations were done using least significant difference (Fisher's LSD) at ≤0.05 significance level.

CHAPTER IV

RESULTS AND DISCUSSION

The results of the present investigation entitled "Studies on canopy management in pear" are presented in this chapter. The results obtained on the various physical, biochemical and eco-physiological parameters of plants and fruits are presented in this chapter and discussed in the light of available literature under the suitable headings, sub-headings, after tabulation, statistical analysis and scientific references.

4.1 EFFECT OF TRELLIS TRAINING SYSTEMS ON PRODUCTION AND FRUIT QUALITY OF PEAR

4.1.1 Eco-physiological parameters

It was evident from the Tables 1-20 that training systems affect various eco-physiological parameters of pear plants during the years 2016 and 2017. The effect of different training systems on eco-physiological parameters was found to be significant irrespective of months. It was clear from the results that photo-synthetically active radiation interception by leaves was recorded higher in plants trained on Espalier system followed by Y-trellis and Cordon system. Photosynthesis is a physiological process that is affected by the environmental factors. The crops in general show daily changes in photosynthetic rate and midday depression of photosynthesis depending upon prevailing weather conditions during their growth period. Photosynthesis, stomatal conductance and transpiration rate was recorded maximum in the month of May-June and decreased thereafter irrespective of different cultivars. As photo-synthetically active radiation was depended on the radiation intercepted by the plants within canopy. However, photosynthesis, stomatal conductance and transpiration rate was inter-related with each other. Various training systems varied according to the radiation received by the plants at that particular time. The data pertaining to important meteorological parameters like air temperature and relative humidity was recorded within canopy of pear plants trained on various training systems. This showed the effect of training systems on microclimate within canopy of pear plants. The soil temperature was recorded lower under various training systems. It may be due to more availability of heat from sun light under open field condition as compared to trellis training systems.

4.1.1.1 Net photosynthesis rate (µmol/m$^{2/}$sec)

The data regarding the net photosynthesis rate (Pn) in the lower, middle and upper canopy under various training systems of pear cv. Patharnakh is presented in the Tables 1a, 1b and 1c, respectively. In lower canopy portions, the photosynthesis rate was higher during 1st fortnight of May under Espalier system, which was statistically at par with 2nd fortnight of May. Similar trend for photosynthesis rate was recorded under Cordon system. However under the Y-trellis system, photosynthesis rate was recorded higher during 1st fortnight of May. Under the various training systems, photosynthesis rate was decreased significantly after attaining maximum value in May month due to increasing effect of shade of the upper canopy during both the years (Table 1a). In the lower canopy portions, mean photosynthesis rate was recorded maximum under the Espalier system (4.28 µmol/m$^{2/}$sec**)** followed by Y-trellis system (3.98 µmol/m$^{2/}$sec) and Cordon system (3.90 µmol/m$^{2/}$sec). In the middle canopy portions, photosynthesis rate was recorded higher during 2nd fortnight of May under Espalier, Cordon and Y-trellis system during both the years (Table 1b). The mean maximum photosynthesis rate was recorded under the Espalier system (7.99 µmol/m$^{2/}$sec) followed by Y-trellis system (7.56 µmol/m$^{2/}$sec) and Cordon system (7.45 µmol/m$^{2/}$sec). In the upper canopy portions, the photosynthesis rate was recorded higher during 1st fortnight of June under Espalier, Cordon and Y-trellis training systems during both the years (Table 1c). The mean maximum photosynthesis rate was recorded under the Espalier system (8.40 µmol/m$^{2/}$sec) followed by Y-trellis system (8.05 µmol/m$^{2/}$sec) and Cordon system (7.93 µmol/m$^{2/}$sec). Under the various training systems, the trend of seasonal variation of photosynthesis rate was significantly higher during 1st fortnight of May, 2nd fortnight of May and 1st fortnight of June in lower, middle and upper canopy portions, respectively. Thereafter, photosynthesis rate was decreased towards the end of vegetative growth due to the again shading effect within canopy increased. The effect of shading on leaves was maximum in lower canopy portions followed by middle canopy and it was minimum in the upper canopy portions.

The data regarding the photosynthesis rate in lower, middle and upper canopy under various training systems of pear plants cv. Punjab Beauty is presented in the Tables 2a, 2b and 2c, respectively. A similar trend of photosynthesis rate was observed in lower, middle and upper canopy of pear plants trained on Espalier, Cordon and Y-trellis training systems as it was in the case of cultivar Patharnakh. However, the values of photosynthesis rate were different in pear cultivars and it was may be due to variation in plant growth rate and development. In lower canopy portions, the photosynthesis rate was significantly higher during 1st fortnight of May month during both the years. The mean maximum photosynthesis rate was recorded in plants trained on Espalier system (4.00 µmol/m$^{2/}$sec) followed by Y-trellis system (3.88 µmol/m$^{2/}$sec) and Cordon system (3.68 µmol/m$^{2/}$sec) in lower canopy portions. In middle canopy portions, the photosynthesis rate was significantly higher during 2nd fortnight of May month during both the years. The mean maximum photosynthesis rate was recorded in plants trained on Espalier system (6.67 µmol/m$^{2/}$sec) followed by Y-trellis system (6.54 µmol/m$^{2/}$sec) and Cordon system (6.45 µmol/m$^{2/}$sec) in middle canopy portions. In upper canopy portions, the photosynthesis rate was significantly higher during 1st fortnight of June month during both the years. The mean maximum photosynthesis rate was recorded in plants trained on Espalier system (7.37 µmol/m$^{2/}$sec) followed by Y-trellis system (7.21 µmol/m$^{2/}$sec) and Cordon system (7.08 µmol/m$^{2/}$sec) in upper canopy portions. Thereafter photosynthesis rate was decreased to minimum in the month of August towards the end of vegetative growth phase, because in pear cv. Punjab Beauty leaves falls in the month of August due to *Alternaria* disease under subtropical conditions of Punjab.

The data regarding the photosynthesis rate in lower, middle and upper canopy under different training systems of pear cv. Punjab Soft is presented in the Tables 3a, 3b and 3c, respectively. A similar trend of photosynthesis rate was observed in lower, middle and upper canopy of pear plants trained on Espalier, Cordon and Y-trellis training systems as it was in case of cultivar Punjab Beauty. In lower canopy portions, the photosynthesis rate was significantly higher during 1st fortnight of May month during both the years. The mean maximum photosynthesis rate was recorded in plants trained on Espalier system (3.93 µmol/m$^{2/}$sec) followed by Y-trellis system (3.86 µmol/m$^{2/}$sec) and Cordon system (3.68 µmol/m$^{2/}$sec) in lower canopy portions. In middle canopy portions, the photosynthesis rate was significantly higher during 2nd fortnight of May month during both the years. The mean maximum photosynthesis rate was recorded in plants trained on Espalier system (6.74 µmol/m$^{2/}$sec) followed by Y-trellis system (6.60 µmol/m$^{2/}$sec) and Cordon system (6.47 µmol/m$^{2/}$sec) in middle canopy portions. In upper canopy portions, the photosynthesis rate was significantly higher during 1st fortnight of June month during both the years. The mean maximum photosynthesis rate was recorded in plants trained on Espalier system (7.42 µmol/m$^{2/}$sec) followed by Y-trellis system (7.35 µmol/m$^{2/}$sec) and Cordon system (7.21 µmol/m$^{2/}$sec) in upper canopy portions. Thereafter photosynthesis rate was decreased to minimum in the month of August.

In our studies, the photosynthesis rate was recorded higher in the months of May-June and lower in the month of August during both the years. Similar results found by Fischer and Orduz-Rodriguez (2012) that photosynthesis efficiency depends not only on radiation, but also depends on temperature, CO_2, water, nutritional elements and plant physiology. Under various training systems, Pn rate was observed higher in upper canopy portions followed by middle and lower canopy, respectively. Similar observations were recorded by Deviatov (1989) who reported that the continuous increase of the foliage area decreased the amount of light interception inside the canopy and decreased the photosynthetic efficiency of leaves. Similarly, shading affects leaf morphology and anatomy which reduces photosynthesis efficiency in horticultural crops (Atanasova *et al* 2003; Heuvel *et al* 2004; Gregoriu *et al* 2007). The maximum photosynthesis rate was under the Espalier system followed by Y-trellis system and Cordon system under the upper canopy during both the years.

Table 1a: Seasonal variation in net photosynthesis rate (μmol/m^2/sec) in lower canopy portions of pear cv. Patharnakh plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	4.24^{bc}	4.55^{c}	4.39	3.99^{c}	4.45^{cd}	4.22	4.03^{cd}	4.61^{c}	4.32
	2nd	4.39^{bc}	5.05^{b}	4.72	4.22^{bc}	4.76^{bc}	4.49	4.41^{bc}	4.79^{bc}	4.60
May	**1st**	5.53^{a}	5.87^{a}	5.70	4.75^{a}	5.46^{a}	5.10	5.15^{a}	5.75^{a}	5.45
	2nd	5.35^{a}	6.00^{a}	5.62	4.61^{ab}	5.33^{ab}	4.97	4.60^{b}	5.14^{b}	4.87
June	**1st**	4.61^{b}	5.05^{b}	4.83	4.27^{bc}	4.99^{abc}	4.58	4.57^{b}	5.08^{b}	4.82
	2nd	4.58^{b}	4.71^{c}	4.64	4.25^{bc}	4.58^{c}	4.41	3.96^{d}	4.53^{c}	4.24
July	**1st**	3.90^{c}	4.49^{c}	4.19	3.53^{d}	3.89^{d}	3.71	3.53^{e}	4.08^{d}	3.80
	2nd	3.25^{d}	3.83^{d}	3.54	2.93^{e}	3.23^{e}	3.08	2.92^{f}	3.40^{e}	3.16
August	**1st**	2.71^{e}	2.90^{e}	2.80	2.31^{f}	2.59^{f}	2.45	2.17^{g}	2.74^{f}	2.45
	2nd	2.05^{f}	2.57^{f}	2.31	1.79^{g}	2.26^{f}	2.02	1.78^{h}	2.47^{f}	2.12
Mean		4.05	4.50	**4.28**	3.67	4.14	**3.90**	3.71	4.26	**3.98**
LSD		0.54	0.33		0.44	0.58		0.39	0.43	

[*]LSD indicates the least significant difference test at $p<0.05$.

[**]Values are means with a common letter are not significantly different at 5% level.

Table 1b: Seasonal variation in net photosynthesis rate (μmol/m^2/sec) in middle canopy portions of pear cv. Patharnakh plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
April	1st	6.95[de]	7.24[d]	7.09	6.04[ef]	6.53[e]	6.28	6.75[d]	7.14[de]	6.94
	2nd	7.57[cd]	8.05[c]	7.81	7.51[bc]	7.97[cd]	7.74	7.32[cd]	8.34[c]	7.83
May	1st	9.27[ab]	9.50[b]	9.38	8.73[a]	9.27[ab]	9.00	8.32[b]	9.13[ab]	8.72
	2nd	9.85[a]	10.42[a]	10.13	9.16[a]	9.71[a]	9.43	9.06[a]	9.66[a]	9.36
June	1st	9.70[ab]	9.63[b]	9.66	8.67[a]	9.03[b]	8.85	9.08[a]	9.54[a]	9.31
	2nd	8.99[b]	9.04[b]	9.01	7.94[b]	8.49[c]	8.21	8.10[b]	8.63[bc]	8.36
July	1st	7.96[c]	8.10[c]	8.03	7.02[cd]	7.75[d]	7.38	7.86[bc]	7.62[d]	7.74
	2nd	6.95[de]	7.35[d]	7.15	6.49[de]	6.92[e]	6.70	6.74[d]	6.74[e]	6.74
August	1st	6.17[e]	6.28[e]	6.22	5.70[f]	5.92[f]	5.81	5.89[e]	5.87[f]	5.88
	2nd	5.26[f]	5.54[f]	5.40	4.86[g]	5.40[f]	5.13	4.57[f]	4.92[g]	4.74
Mean		7.87	8.12	**7.99**	7.21	7.70	**7.45**	7.37	7.76	**7.56**
LSD		0.81	0.69		0.56	0.54		0.66	0.60	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Tables 1c: Seasonal variation in net photosynthesis rate (µmol/m^2/sec) in upper canopy portions of pear cv. Patharnakh plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	6.99^{e}	7.31^{de}	7.15	6.64^{ef}	7.38^{d}	7.01	6.81^{f}	7.39^{c}	7.10
	2nd	8.07^{d}	8.67^{c}	8.37	7.59^{d}	8.14^{bc}	7.86	7.67^{e}	8.41^{b}	8.04
May	**1st**	9.26^{bc}	9.67^{b}	9.46	8.84^{ab}	9.32^{a}	9.08	8.41^{cd}	9.31^{a}	8.86
	2nd	9.32^{b}	10.18^{ab}	9.75	8.98^{ab}	9.48^{a}	9.23	9.05^{ab}	9.68^{a}	9.36
June	**1st**	10.65^{a}	10.48^{a}	10.56	9.17^{a}	9.84^{a}	9.50	9.19^{a}	9.72^{a}	9.45
	2nd	9.74^{b}	9.50^{b}	9.62	8.36^{bc}	9.40^{a}	8.88	8.67^{bc}	9.57^{a}	9.12
July	**1st**	8.55^{cd}	8.64^{c}	8.59	7.69^{cd}	8.66^{b}	8.17	8.18^{d}	8.67^{b}	8.42
	2nd	7.90^{d}	7.96^{cd}	7.93	7.06^{de}	7.57^{cd}	7.31	7.41^{e}	8.14^{b}	7.77
August	**1st**	6.53^{e}	6.88^{ef}	6.70	6.37^{f}	6.99^{d}	6.68	6.51^{f}	7.08^{c}	6.79
	2nd	5.62^{f}	6.24^{f}	5.93	5.14^{g}	6.13^{e}	5.63	5.62^{g}	5.61^{d}	5.61
Mean		8.26	8.55	**8.40**	7.58	8.29	**7.93**	7.75	8.36	**8.05**
LSD		0.73	0.76		0.68	0.60		0.47	0.60	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 2a: Seasonal variation in net photosynthesis rate (µmol/m^2/sec) in lower canopy portions of pear cv. Punjab Beauty plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
April	1st	3.75^{cd}	4.29^{e}	4.12	3.77^{b}	4.30^{b}	4.03	3.76^{b}	4.40^{de}	4.08
	2nd	4.17^{bc}	5.22^{bc}	4.70	4.52^{a}	5.23^{a}	4.87	4.65^{a}	5.07^{bc}	4.86
May	1st	5.23^{a}	5.79^{a}	5.51	4.92^{a}	5.59^{a}	5.25	5.20^{a}	5.55^{a}	5.38
	2nd	4.73^{ab}	5.38^{ab}	5.06	4.50^{ab}	4.96^{b}	4.73	4.59^{ab}	5.37^{ab}	4.98
June	1st	4.44^{b}	5.17^{bc}	4.81	4.09^{b}	4.66^{b}	4.37	4.12^{b}	5.46^{ab}	4.79
	2nd	4.42^{b}	4.79^{cd}	4.61	3.91^{b}	4.35^{b}	4.13	3.92^{b}	4.77^{cd}	4.35
July	1st	3.63^{d}	4.44^{de}	4.04	2.91^{c}	3.48^{c}	3.19	3.60^{b}	3.97^{e}	3.79
	2nd	3.07^{e}	4.31^{e}	3.69	2.41^{c}	3.16^{c}	2.78	2.83^{c}	3.45^{f}	3.14
August	1st	1.78^{f}	2.45^{f}	2.12	1.80^{d}	2.32^{d}	2.06	1.81^{d}	2.41^{g}	2.11
	2nd	1.06^{g}	1.65^{g}	1.36	1.16^{e}	1.68^{e}	1.42	1.10^{e}	1.63^{h}	1.37
Mean		3.65	4.35	**4.00**	3.40	3.97	**3.68**	3.56	4.21	**3.88**
LSD		0.46	0.44		0.53	0.46		0.61	0.45	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 2b: Seasonal variation in net photosynthesis rate (µmol/m^2/sec) in middle canopy portions of pear cv. Punjab Beauty plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
April	1st	5.75[d]	6.19[c]	5.97	5.59[d]	6.32[de]	5.96	5.77[e]	6.01[c]	5.89
	2nd	6.88[c]	7.42[b]	7.15	6.53[c]	7.09[cd]	6.81	6.63[cd]	7.46[b]	7.04
May	1st	8.17[a]	9.06[a]	8.61	8.09[a]	8.98[a]	8.54	8.15[a]	8.59[a]	8.37
	2nd	8.75[a]	9.11[a]	8.93	8.11[a]	8.67[a]	8.39	8.21[a]	8.86[a]	8.54
June	1st	8.09[ab]	8.99[a]	8.54	7.74[ab]	8.54[ab]	8.14	7.49[ab]	8.37[a]	7.93
	2nd	7.29[bc]	7.89[b]	7.59	7.45[abc]	7.85[bc]	7.65	7.26[bc]	8.16[ab]	7.71
July	1st	6.90[c]	7.44[b]	7.17	7.06[bc]	6.92[d]	6.99	6.87[bcd]	7.51[b]	7.19
	2nd	5.77[d]	6.33[c]	6.05	5.26[d]	5.76[e]	5.51	6.07[de]	6.02[c]	6.05
August	1st	3.82[e]	4.40[d]	4.11	3.77[e]	4.34[f]	4.06	4.01[f]	4.31[d]	4.16
	2nd	2.28[f]	2.98[e]	2.63	2.18[f]	2.73[g]	2.46	2.16[g]	2.80[e]	2.48
Mean		6.37	6.98	**6.67**	6.18	6.72	**6.45**	6.26	6.81	**6.54**
LSD		0.82	0.81		0.92	0.77		0.84	0.82	

[*]LSD indicates the least significant difference test at p<0.05.

[**]Values are means with a common letter are not significantly different at 5% level.

Table 2c: Seasonal variation in net photosynthesis rate (μmol/m^2/sec) in upper canopy portions of pear cv. Punjab Beauty plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	5.77^{e}	6.52^{e}	6.14	5.63^{e}	6.39^{e}	6.01	5.87^{e}	6.21^{e}	6.04
	2nd	7.19^{cd}	7.70^{d}	7.44	7.07^{d}	7.36^{d}	7.21	6.87^{d}	8.04^{d}	7.46
May	**1st**	8.53^{ab}	9.05^{bc}	8.79	8.16^{bc}	8.66^{bc}	8.41	8.31^{bc}	8.74^{bcd}	8.52
	2nd	8.87^{ab}	9.62^{ab}	9.24	8.96^{ab}	9.26^{ab}	9.11	8.98^{ab}	9.54^{ab}	9.26
June	**1st**	9.30^{a}	10.10^{a}	9.70	9.23^{a}	9.77^{a}	9.50	9.46^{a}	9.76^{a}	9.61
	2nd	9.26^{a}	10.01^{a}	9.63	8.82^{abc}	9.38^{ab}	9.10	8.56^{bc}	9.43^{abc}	8.99
July	**1st**	8.02^{bc}	8.70^{c}	8.31	8.06^{c}	8.27^{c}	8.16	7.82^{c}	8.66^{cd}	8.24
	2nd	6.53^{de}	7.19^{de}	6.86	6.03^{e}	6.74^{de}	6.33	6.60^{de}	6.92^{e}	6.76
August	**1st**	4.34^{f}	4.82^{f}	4.58	4.15^{f}	4.71^{f}	4.38	4.26^{f}	4.57^{f}	4.41
	2nd	2.63^{g}	3.42^{g}	3.03	2.33^{g}	2.86^{g}	2.59	2.51^{g}	3.18^{g}	2.85
Mean		7.04	7.70	**7.37**	6.84	7.32	**7.08**	6.92	7.51	**7.21**
LSD		0.89	0.86		0.85	0.84		0.76	0.84	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 3a: Seasonal variation in net photosynthesis rate (µmol/m^2/sec) in lower canopy portions of pear cv. Punjab Soft plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	3.41^{d}	4.09^{d}	3.75	3.41^{ef}	4.00^{c}	3.70	3.45^{cd}	4.02^{d}	3.73
	2nd	3.94^{cd}	4.61^{c}	4.27	4.00^{cd}	4.43^{b}	4.21	3.93^{b}	4.63^{c}	4.28
May	**1st**	5.04^{a}	5.73^{a}	5.38	5.04^{a}	5.39^{a}	5.21	5.10^{a}	5.71^{a}	5.40
	2nd	4.74^{ab}	5.50^{ab}	5.12	4.50^{b}	5.24^{a}	4.87	4.73^{a}	5.34^{ab}	5.03
June	**1st**	4.95^{ab}	5.20^{b}	5.07	4.06^{c}	4.53^{b}	4.29	4.65^{a}	5.25^{b}	4.95
	2nd	4.41^{bc}	4.55^{c}	4.48	3.64^{de}	4.18^{bc}	3.91	3.88^{bc}	4.44^{c}	4.16
July	**1st**	3.64^{d}	3.77^{d}	3.65	3.01^{fg}	3.55^{d}	3.28	3.35^{d}	4.05^{d}	3.70
	2nd	2.81^{e}	3.17^{e}	2.99	2.64^{gh}	3.16^{e}	2.90	2.85^{e}	3.14^{e}	2.99
August	**1st**	2.37^{e}	2.74^{ef}	2.55	2.35^{h}	2.71^{f}	2.53	2.23^{f}	2.63^{f}	2.43
	2nd	1.61^{f}	2.34^{f}	1.97	1.64^{i}	2.15^{g}	1.89	1.69^{g}	2.18^{g}	1.93
Mean		3.69	4.16	**3.93**	3.43	3.93	**3.68**	3.59	4.14	**3.86**
LSD		0.56	0.44		0.42	0.39		0.45	0.39	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 3b: Seasonal variation in net photosynthesis rate (μmol/m^2/sec) in middle canopy portions of pear cv. Punjab Soft plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	4.71^{e}	5.25^{e}	4.98	4.73^{e}	5.35^{ef}	5.04	4.98^{e}	5.57^{e}	5.27
	2nd	6.50^{c}	7.13^{c}	6.81	6.41^{c}	6.94^{c}	6.67	6.75^{cd}	7.35^{c}	7.05
May	**1st**	7.52^{b}	7.95^{b}	7.73	7.39^{b}	7.79^{b}	7.59	7.17^{bc}	8.36^{b}	7.76
	2nd	8.80^{a}	9.37^{a}	9.08	8.52^{a}	9.21^{a}	8.86	8.61^{a}	9.01^{a}	8.81
June	**1st**	8.54^{a}	9.32^{a}	8.93	8.30^{a}	9.05^{a}	8.67	8.33^{a}	9.00^{a}	8.66
	2nd	7.72^{b}	8.22^{b}	7.97	7.44^{b}	7.85^{b}	7.64	7.74^{b}	8.13^{b}	7.93
July	**1st**	6.38^{c}	7.07^{c}	6.72	5.97^{d}	6.42^{d}	6.19	6.25^{d}	6.84^{d}	6.54
	2nd	5.73^{d}	6.33^{d}	6.03	5.08^{e}	5.67^{e}	5.37	5.16^{e}	5.77^{e}	5.46
August	**1st**	4.84^{e}	5.24^{e}	5.04	4.30^{f}	5.10^{f}	4.70	4.34^{f}	4.94^{f}	4.64
	2nd	3.94^{f}	4.31^{f}	4.12	3.63^{g}	4.28^{g}	3.95	3.67^{g}	4.20^{g}	3.93
Mean		6.47	7.02	**6.74**	6.18	6.77	**6.47**	6.30	6.92	**6.60**
LSD		0.43	0.48		0.40	0.47		0.57	0.50	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 3c: **Seasonal variation in net photosynthesis rate (µmol/m^2/sec) in upper canopy portions of pear cv. Punjab Soft plants trained on Espalier, Cordon and Y-trellis training systems**

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	5.09^{ef}	5.41^{ef}	5.25	4.91^{e}	5.41^{e}	5.16	5.04^{f}	5.70^{f}	5.37
	2nd	7.04^{c}	7.73^{cd}	7.38	7.08^{c}	7.59^{c}	7.33	7.11^{d}	7.72^{d}	7.41
May	**1st**	7.83^{b}	8.44^{b}	8.13	8.32^{b}	8.14^{c}	8.23	7.85^{c}	8.81^{c}	8.33
	2nd	9.11^{a}	9.92^{a}	9.51	8.60^{b}	9.37^{ab}	8.98	9.14^{ab}	9.52^{ab}	9.33
June	**1st**	9.21^{a}	10.02^{a}	9.61	9.52^{a}	9.65^{a}	9.58	9.37^{a}	9.94^{a}	9.65
	2nd	8.68^{a}	9.47^{a}	9.07	8.43^{b}	8.83^{b}	8.63	8.66^{b}	9.19^{bc}	8.92
July	**1st**	7.57^{bc}	8.12^{bc}	7.84	7.42^{c}	8.09^{c}	7.75	7.57^{cd}	8.10^{d}	7.83
	2nd	6.27^{d}	7.32^{d}	6.79	6.15^{d}	6.99^{d}	6.57	6.06^{e}	6.85^{e}	6.45
August	**1st**	5.39^{e}	5.90^{e}	5.64	5.19^{e}	5.68^{e}	5.43	5.60^{e}	5.84^{f}	5.72
	2nd	4.73^{f}	5.07^{f}	4.90	4.09^{f}	4.74^{f}	4.41	4.18^{g}	4.74^{g}	4.46
Mean		7.09	7.74	**7.42**	6.97	6.85	**7.21**	7.06	7.64	**7.35**
LSD		0.61	0.55		0.47	0.60		0.54	0.64	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Similar results were found by Trentacoste *et al* (2015) who reported that the consequent influences on photosynthesis were related to canopy management. The maximum photosynthesis rate was observed in pear cv. Patharnakh and minimum in cultivar Punjab Beauty. Our results are partially in accordance with the findings obtained by Higgins *et al* (1992), who compared photosynthetic light response of different horticultural crops and found that Asian pears had the photosynthetic rates less than 15 mol $CO_2/m^2/s$. Similarly, Srivastava (2002) determined the photosynthetic compensation point for sub-tropical fruit plants to be between 10-20 μmol/m^2/s. Similarly, Massonnet and co-workers (2007) showed that photosynthesis efficiency varied between different cultivars as it was in case of apple cultivars.

4.1.1.2 Photosynthetically active radiation (μmol/$m^{2/}$sec)

The data regarding the photosynthetically active radiation (PAR) interception in lower, middle and upper canopy of pear plants cv. Patharnakh trained on various training systems is presented in the Tables 4a, 4b and 4c, respectively. The results reveal that PAR interception was maximum during 1st fortnight of April in lower, middle and upper canopy portions. Thereafter, PAR interception decreased to minimum level in the month of August, which was statistically at par with the month of July. A similar trend of PAR interception was observed in pear plants trained on Espalier, Cordon and Y-trellis systems during both the years. In the lower canopy (Table 4a), the mean maximum PAR was received by leaves under the Espalier training system (86.42 μmol/$m^{2/}$sec) followed by Y-trellis system (81.86 μmol/$m^{2/}$sec) and Cordon system (71.67 μmol/$m^{2/}$sec). A similar trend of PAR interception was observed in middle and upper canopy portions as it was in case of lower canopy during both the years. In the middle canopy (Table 4b), the mean maximum PAR was received by leaves under the Espalier system (176.68 μmol/$m^{2/}$sec) followed by Y-trellis system (169.49 μmol/$m^{2/}$sec) and Cordon system (139.32 μmol/$m^{2/}$sec). In the upper canopy (Table 4c), the mean maximum PAR was received by leaves under the Espalier system (324.97 μmol/$m^{2/}$sec) followed by Y-trellis system (262.85 μmol/$m^{2/}$sec) and Cordon system (245.62 μmol/$m^{2/}$sec). The trend of seasonal variations of PAR interception in the lower, middle and upper canopy portions from maximum level in April to minimum level in August and it was due to increased effect of shade within the plant canopy.

The data regarding the PAR interception in lower, middle and upper canopy of pear plants cv. Punjab Beauty trained on various training systems is presented in the Tables 5a, 5b and 5c, respectively. The results reveal that PAR interception was maximum during 1st fortnight of April in lower, middle and upper canopy. Thereafter, PAR interception decreased to minimum level in the second fortnight of July month. A similar trend of PAR interception was observed in lower, middle and upper canopy of pear plants cv. Punjab Beauty as it was in case of pear cv. Patharnakh except the variation in the month of August during both the years. In the lower canopy (Table 5a), the mean maximum PAR was received by leaves under the Espalier system (106.94 µmol/m$^{2/}$sec) followed by Y-trellis system (103.30 µmol/m$^{2/}$sec) and Cordon system (92.65 µmol/m$^{2/}$sec). In the middle canopy (Table 5b), the mean maximum PAR was received by leaves under the Y-trellis system (239.34 µmol/m$^{2/}$sec) followed by Espalier system (230.04 µmol/m$^{2/}$sec) and Cordon system (203.49 µmol/m$^{2/}$sec). In the upper canopy (Table 5c), the mean maximum PAR was received by leaves under the Espalier system (338.70 µmol/m$^{2/}$sec) followed by Y-trellis system (316.25 µmol/m$^{2/}$sec) and Cordon system (305.17 µmol/m$^{2/}$sec). However, PAR interception varied between pear cultivars Patharnakh and Punjab Beauty, it was due to late initiation of leaves and early leaves fall in pear cv. Punjab Beauty. Thereafter, increasing trend of PAR interception was observed during the month of August in lower, middle and upper canopy of pear plants trained on various training systems. It was due to leaves fall of Punjab Beauty by *Alternaria* disease during the month of August under subtropical conditions of Punjab, which increased PAR interception.

The data regarding the PAR interception in lower, middle and upper canopy of pear plants cv. Punjab Soft trained on various training systems is presented in the Tables 6a, 6b and 6c, respectively. The results reveal that PAR interception was maximum during 1st fortnight of April in lower, middle and upper canopy. Thereafter, PAR interception decreased to minimum level in the month of August as it was in case of Patharnakh. A similar trend of PAR interception was observed in lower, middle and upper canopy of pear plants cv. Punjab Soft during both the years. In the lower canopy (Table 6a), the mean maximum PAR was received by leaves under the Y-trellis system (98.43 µmol/m$^{2/}$sec) followed by Espalier system (95.34 µmol/m$^{2/}$sec) and Cordon system (88.03 µmol/m$^{2/}$sec). In the middle canopy (Table 6b), the mean maximum PAR was received by leaves under the Espalier system (201.63 µmol/m$^{2/}$sec) followed by Y-trellis system (195.75 µmol/m$^{2/}$sec) and Cordon system (173.31 µmol/m$^{2/}$sec). Similarly in the upper canopy (Table 6c), the mean maximum PAR was received by leaves under the Espalier system (291.56 µmol/m$^{2/}$sec) followed by Y-trellis system (286.26 µmol/m$^{2/}$sec) and Cordon system (265.88 µmol/m$^{2/}$sec).

In our findings, the maximum PAR was received by leaves under the Espalier training system followed by Y-trellis system and minimum under Cordon system. Our results are partially in accordance with the observations obtained by Lackso (1994) who reported that solar energy interception and light distribution within the canopy are strongly related to canopy architecture which influences cropping efficiency, but structure and leaf distribution in fruit plants are primarily affected by training system. Similarly, the efficiency of training system may be evaluated in terms of ‘light use’ (Robinson and Lakso 1991).

Table 4a: Seasonal variation in photo-synthetically active radiation (μmol/m^2/sec) in lower canopy portions of pear cv. Patharnakh plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	181.43[a]	190.86[a]	186.14	166.14[a]	179.14[a]	172.64	189.14[a]	199.86[a]	194.50
	2nd	125.86[b]	145.86[b]	135.86	114.43[b]	124.43[b]	119.43	140.43[b]	157.29[b]	148.86
May	**1st**	107.71[bc]	116.71[bc]	112.21	104.57[bc]	103.29[bc]	103.93	111.86[bc]	111.00[c]	111.43
	2nd	79.29[cd]	98.43[cd]	88.86	80.71[cd]	89.86[cd]	85.28	92.86[c]	104.71[cd]	98.78
June	**1st**	66.00[de]	83.57[de]	74.78	61.00[de]	67.14[de]	64.07	69.14[d]	82.43[de]	75.78
	2nd	59.86[de]	74.86[def]	67.36	43.71[ef]	56.86[e]	50.28	48.57[de]	65.86[ef]	57.21
July	**1st**	48.71[e]	69.43[def]	59.07	27.57[f]	42.86[e]	35.21	35.86[e]	51.71[ef]	43.78
	2nd	43.14[e]	61.29[ef]	52.21	25.57[f]	39.43[e]	32.50	27.00[e]	42.57[f]	34.78
August	**1st**	42.14[e]	49.86[ef]	46.00	19.00[f]	36.43[e]	27.71	17.71[e]	36.29[f]	27.00
	2nd	34.00[e]	49.43[f]	41.71	16.57[f]	34.86[e]	25.71	17.29[e]	35.71[f]	26.50
Mean		78.81	94.03	**86.42**	65.93	77.43	**71.67**	74.99	88.74	**81.86**
LSD		32.99	33.87		31.00	32.95		32.93	32.96	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 4b: Seasonal variation in photo-synthetically active radiation (µmol/m^2/sec) in middle canopy portions of pear cv. Patharnakh plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	329.29[a]	338.86[a]	334.07	265.00[a]	284.43[a]	274.71	294.43[a]	366.00[a]	330.21
	2nd	291.71[b]	287.14[b]	289.42	226.00[b]	230.57[b]	228.28	270.43[b]	318.57[b]	294.50
May	**1st**	219.14[c]	236.00[c]	227.57	203.86[c]	197.71[c]	200.78	210.43[c]	240.86[c]	225.64
	2nd	211.14[d]	223.29[c]	217.21	187.00[c]	167.43[d]	177.21	195.00[c]	234.57[d]	214.78
June	**1st**	171.86[e]	187.71[d]	179.78	120.43[d]	129.43[e]	124.93	145.57[d]	188.43[e]	167.00
	2nd	117.29[f]	151.29[e]	134.29	94.43[de]	98.86[f]	96.64	130.00[de]	126.14[f]	128.07
July	**1st**	91.29[fg]	136.86[ef]	114.07	81.00[ef]	94.86[fg]	87.93	106.71[ef]	104.29[fg]	105.50
	2nd	80.29[g]	121.29[efg]	100.79	68.00[ef]	88.14[fg]	78.07	88.43[f]	95.29[fg]	91.86
August	**1st**	70.00[g]	103.86[fg]	86.93	55.43[f]	72.71[fg]	64.07	72.14[f]	90.29[g]	61.21
	2nd	64.86[g]	100.43[g]	82.64	52.57[f]	68.71[g]	60.64	69.57[f]	82.57[g]	76.07
Mean		164.69	188.67	**176.68**	135.37	143.29	**139.32**	158.27	184.70	**169.49**
LSD		36.27	34.61		30.92	26.45		38.06	32.64	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 4c: Seasonal variation in photo-synthetically active radiation ($\mu mol/m^2/sec$) in upper canopy portions of pear cv. Patharnakh plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	558.00^{a}	489.43^{a}	523.71	424.00^{a}	434.00^{a}	429.00	471.86^{a}	479.00^{a}	475.43
	2nd	391.71^{b}	462.57^{b}	427.14	342.86^{b}	346.29^{b}	344.57	393.43^{b}	410.14^{b}	401.78
May	**1st**	385.43^{b}	424.00^{c}	404.71	306.43^{bc}	316.14^{b}	311.28	378.86^{b}	375.00^{b}	376.93
	2nd	337.57^{c}	390.71^{d}	364.14	256.57^{d}	254.14^{c}	255.35	314.14^{c}	323.57^{c}	318.85
June	**1st**	318.14^{cd}	339.71^{e}	328.92	230.43^{de}	241.14^{c}	235.78	229.57^{d}	240.71^{d}	235.14
	2nd	294.00^{d}	309.43^{f}	301.71	200.43^{ef}	226.14^{cd}	213.28	190.43^{e}	187.29^{e}	188.86
July	**1st**	251.71^{e}	277.86^{g}	264.78	186.00^{fg}	198.29^{de}	192.14	179.86^{e}	180.00^{ef}	179.93
	2nd	228.14^{e}	239.00^{h}	233.57	162.57^{gh}	177.29^{ef}	169.89	158.00^{ef}	165.86^{ef}	161.93
August	**1st**	199.86^{f}	211.43^{i}	205.64	150.43^{h}	157.71^{f}	154.07	139.57^{f}	151.29^{f}	145.43
	2nd	189.29^{f}	201.57^{i}	195.43	144.57^{h}	157.14^{f}	150.85	137.71^{f}	150.86^{f}	144.28
Mean		315.39	334.57	**324.97**	240.42	250.83	**245.62**	259.34	266.37	**262.85**
LSD		25.50	21.19		35.36	32.52		35.30	35.32	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 5a: Seasonal variation in photo-synthetically active radiation (μmol/m^2/sec) in lower canopy portions of pear cv. Punjab Beauty plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	212.29[a]	244.00[a]	228.14	197.14[a]	209.86[a]	203.50	224.29[a]	250.71[a]	237.50
	2nd	178.43[b]	174.71[b]	176.57	122.00[b]	155.14[b]	138.57	161.00[b]	172.57[b]	166.78
May	**1st**	131.00[c]	125.86[cd]	128.43	113.14[bc]	126.71[bc]	119.92	113.00[c]	139.00[c]	126.00
	2nd	94.00[de]	98.86[de]	96.43	88.71[c]	102.86[cd]	95.78	99.86[c]	105.43[d]	102.64
June	**1st**	67.86[ef]	85.00[ef]	76.43	58.57[d]	73.43[de]	66.00	57.43[de]	72.00[ef]	64.71
	2nd	53.00[f]	72.43[ef]	62.71	37.43[de]	53.00[ef]	45.21	45.29[def]	61.57[ef]	53.43
July	**1st**	46.29[f]	62.86[f]	54.57	30.43[de]	41.43[f]	35.93	31.00[ef]	51.29[f]	41.14
	2nd	43.14[f]	56.00[f]	49.57	22.14[e]	41.40[f]	31.78	29.57[f]	46.86[f]	38.21
August	**1st**	66.14[ef]	78.14[ef]	72.14	50.29[de]	75.71[de]	63.00	64.29[d]	83.00[de]	73.64
	2nd	115.57[cd]	133.29[c]	124.43	117.57[bc]	136.14[b]	126.85	118.57[c]	139.29[c]	128.93
Mean		100.77	113.12	**106.94**	83.74	101.57	**92.65**	94.43	112.17	**103.30**
LSD		33.32	31.26		29.96	29.85		27.36	30.70	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 5b: Seasonal variation in photo-synthetically active radiation (μmol/m^2/sec) in middle canopy portions of pear cv. Punjab Beauty plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
April	1st	447.14^{a}	478.71^{a}	462.92	439.00^{a}	486.14^{a}	462.57	463.29^{a}	483.43^{a}	473.36
	2nd	358.71^{b}	406.29^{b}	382.50	319.14^{b}	320.71^{b}	319.92	396.14^{b}	404.71^{b}	400.42
May	1st	277.29^{c}	297.00^{c}	287.14	223.00^{d}	227.00^{c}	225.00	324.57^{c}	343.71^{c}	334.14
	2nd	190.43^{d}	226.57^{d}	208.50	183.71^{e}	157.00^{d}	170.35	215.71^{d}	219.86^{e}	217.78
June	1st	175.29^{d}	198.57^{d}	186.93	148.57^{f}	144.29^{de}	146.43	161.00^{e}	186.71^{ef}	173.85
	2nd	133.71^{e}	145.86^{ef}	139.78	104.43^{gh}	120.00^{ef}	112.21	141.57^{e}	159.14^{f}	150.35
July	1st	109.43^{ef}	127.29^{fg}	118.36	93.29^{h}	108.00^{f}	100.64	106.14^{f}	120.71^{g}	113.42
	2nd	88.14^{f}	102.71^{g}	95.42	78.14^{h}	95.57^{f}	86.85	85.00^{f}	104.57^{g}	94.78
August	1st	118.00^{ef}	159.57^{e}	138.78	133.00^{fg}	156.57^{d}	144.78	173.00^{e}	189.57^{ef}	181.28
	2nd	255.57^{c}	304.57^{c}	280.07	254.14^{c}	278.14^{b}	266.14	237.71^{d}	270.43^{d}	254.07
Mean		215.37	244.71	**230.04**	197.64	209.34	**203.49**	230.41	248.28	**239.34**
LSD		33.96	29.38		29.73	32.53		33.91	35.93	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 5c: Seasonal variation in photo-synthetically active radiation (μmol/m^2/sec) in upper canopy portions of pear cv. Punjab Beauty plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	550.29[a]	607.14[a]	578.71	530.29[a]	585.57[a]	557.93	564.71[a]	595.00[a]	579.85
	2nd	481.00[b]	460.86[b]	470.93	485.71[b]	440.14[b]	462.92	489.00[b]	502.09[b]	495.64
May	**1st**	404.86[c]	395.43[c]	400.14	351.71[c]	391.29[c]	371.50	405.00[c]	402.29[c]	403.64
	2nd	359.86[d]	358.00[d]	358.93	278.86[d]	270.29[d]	274.57	308.43[e]	320.57[d]	314.50
June	**1st**	301.14[e]	292.14[e]	296.64	214.43[ef]	223.71[ef]	219.07	225.57[f]	229.86[ef]	227.71
	2nd	252.14[f]	248.86[f]	250.50	204.43[fg]	199.00[fg]	201.71	191.71[fg]	193.86[fg]	192.78
July	**1st**	211.86[gh]	220.29[fg]	216.07	182.43[fg]	190.00[fg]	186.21	168.00[gh]	185.71[g]	176.85
	2nd	189.43[h]	202.43[g]	195.93	173.14[g]	181.57[g]	177.35	143.43[h]	159.86[g]	151.64
August	**1st**	225.57[fg]	279.57[ef]	252.57	230.14[e]	261.00[de]	245.57	219.57[e]	254.43[e]	237.00
	2nd	362.86[d]	370.43[cd]	366.64	355.71[c]	354.14[c]	354.92	365.00[d]	400.71[c]	382.85
Mean		333.90	343.52	**338.70**	300.69	309.67	**305.17**	308.04	324.46	**316.25**
LSD		35.60	36.80		36.03	41.24		43.93	37.73	

[*]LSD indicates the least significant difference test at $p<0.05$.

[**]Values are means with a common letter are not significantly different at 5% level.

Table 6a: Seasonal variation in photo-synthetically active radiation (μmol/m^2/sec) in lower canopy portions of pear cv. Punjab Soft plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	188.86[a]	215.43[a]	202.14	191.14[a]	207.00[a]	199.07	212.57[a]	228.14[a]	220.35
	2nd	162.43[b]	166.43[b]	164.43	155.86[b]	147.00[b]	151.43	167.57[b]	173.29[b]	170.43
May	**1st**	123.71[c]	132.29[c]	128.00	116.86[c]	123.57[c]	120.21	124.29[c]	139.00[c]	131.64
	2nd	93.43[d]	104.57[d]	99.00	107.57[c]	105.14[cd]	106.35	104.00[c]	115.14[cd]	109.57
June	**1st**	74.86[de]	83.57[de]	79.21	84.29[d]	87.00[de]	85.64	78.57[d]	95.00[de]	86.78
	2nd	63.14[ef]	71.43[ef]	67.28	61.86[e]	64.29[ef]	63.07	61.57[de]	74.57[ef]	68.07
July	**1st**	53.43[ef]	63.86[ef]	58.64	45.00[ef]	52.43[fg]	48.71	46.29[ef]	65.14[f]	55.71
	2nd	50.57[f]	61.43[ef]	56.00	34.14[f]	43.57[fg]	38.85	41.71[ef]	59.00[f]	50.35
August	**1st**	42.29[f]	57.57[f]	49.93	26.86[f]	43.43[fg]	35.14	38.86[ef]	58.57[f]	48.71
	2nd	41.29[f]	56.29[f]	48.79	23.00[f]	40.71[g]	31.85	33.71[f]	51.71[f]	42.71
Mean		89.40	101.29	**95.34**	84.66	91.41	**88.03**	90.91	105.96	**98.43**
LSD		23.09	24.26		22.26	23.05		24.25	24.69	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 6b: Seasonal variation in photo-synthetically active radiation (μmol/m^2/sec) in middle canopy portions of pear cv. Punjab Soft plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	377.71^{a}	417.71^{a}	397.71	365.71^{a}	403.00^{a}	384.35	402.14^{a}	442.71^{a}	422.42
	2nd	330.71^{b}	321.14^{b}	325.92	303.00^{b}	304.29^{b}	303.64	350.43^{b}	347.86^{b}	349.14
May	**1st**	246.14^{c}	267.57^{c}	256.85	235.71^{c}	243.29^{c}	239.50	263.29^{c}	280.71^{c}	272.00
	2nd	213.14^{d}	226.29^{d}	219.71	198.43^{d}	210.71^{d}	204.57	217.43^{d}	235.14^{d}	226.28
June	**1st**	174.29^{e}	186.71^{e}	180.50	152.71^{e}	136.43^{e}	144.57	175.86^{e}	191.86^{e}	183.86
	2nd	161.71^{ef}	157.43^{f}	159.57	120.71^{f}	112.86^{ef}	116.78	133.71^{f}	157.29^{f}	145.50
July	**1st**	137.86^{fg}	139.43^{f}	138.64	96.43^{fg}	100.43^{fg}	98.43	93.43^{g}	111.57^{g}	102.50
	2nd	122.29^{gh}	131.86^{fg}	127.07	78.57^{gh}	93.57^{fg}	86.07	78.29^{g}	94.43^{g}	86.36
August	**1st**	109.57^{h}	104.86^{gh}	107.21	70.14^{h}	85.71^{g}	77.92	78.00^{g}	93.43^{g}	85.71
	2nd	104.00^{h}	102.29^{h}	103.14	69.86^{h}	84.71^{g}	77.28	76.43^{g}	91.14^{g}	83.78
Mean		197.74	205.53	**201.63**	169.13	177.50	**173.31**	186.90	204.61	**195.75**
LSD		26.79	28.40		25.74	26.35		34.63	34.31	

[*]LSD indicates the least significant difference test at $p<0.05$.

[**]Values are means with a common letter are not significantly different at 5% level.

Table 6c: Seasonal variation in photo-synthetically active radiation ($\mu mol/m^2/sec$) in upper canopy portions of pear cv. Punjab Soft plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	535.00[a]	564.00[a]	549.50	544.14[a]	579.00[a]	561.57	522.14[a]	555.43[a]	538.78
	2nd	456.14[b]	462.29[b]	459.21	442.14[b]	475.57[b]	458.85	445.86[b]	459.00[b]	452.43
May	**1st**	360.57[c]	375.71[c]	368.14	372.00[c]	387.57[c]	379.78	350.14[c]	371.14[c]	360.64
	2nd	318.71[cd]	304.29[d]	311.50	309.71[d]	312.43[d]	311.07	305.29[cd]	314.29[d]	309.79
June	**1st**	288.43[d]	272.86[e]	280.64	247.43[e]	241.29[e]	244.36	268.43[de]	272.71[e]	270.57
	2nd	232.14[e]	245.86[ef]	239.00	190.86[f]	199.57[e]	195.21	222.57[ef]	232.57[ef]	227.57
July	**1st**	210.57[ef]	208.71[fg]	209.64	129.86[g]	151.43[f]	140.64	193.57[fg]	197.29[fg]	195.43
	2nd	176.00[fg]	172.43[gh]	174.21	115.86[g]	140.00[f]	127.93	181.29[fg]	185.86[g]	183.57
August	**1st**	156.86[g]	169.71[gh]	163.28	111.43[g]	129.43[f]	120.43	155.29[g]	170.00[g]	162.64
	2nd	156.71[g]	164.29[h]	160.50	110.43[g]	127.43[f]	118.93	153.29[g]	169.14[g]	161.21
Mean		289.11	294.02	**291.56**	257.39	274.37	**265.88**	279.79	292.74	**286.26**
LSD		42.76	42.55		47.92	47.64		47.05	46.05	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Canopy management as a routine activity in horticultural crops is aimed at increasing light interception and productivity, stabilizing yield and improving fruit quality (Hampson *et al* 1996). Light interception modeling has also been important in the development of training techniques for optimizing yield and canopy management strategies aimed at improving orchard productivity (Garriz *et al* 1998; Huett 2004; Li and Lakso 2004; Lombardini *et al* 2006). The maximum PAR was intercepted by leaves in upper canopy portions parts followed by middle canopy and lower canopy under all the training systems. Similar results found by Singh and Dhaliwal (2007) that upper part of plant canopy intercepted maximum radiation than the middle and lower canopy parts. Similarly, Ying and co-workers (2016) examined PAR at various levels within canopies in densely-planted orchards and observed maximum PAR was intercepted by upper canopy levels.

4.1.1.3 Stomatal conductance (mmol/m^2/sec)

The data regarding the stomatal conductance (C) in the lower, middle and upper canopy under various training systems of pear cv. Patharnakh is presented in the Tables 7a, 7b and 7c, respectively. In lower canopy portions, the results reveal that stomatal conductance was recorded highest during 1st fortnight of May under Espalier system, which was statistically at par with 2nd fortnight of May. Similar trend for stomatal conductance was recorded under Cordon system. However, stomatal conductance was recorded higher during 1st fortnight of May under the Y-trellis system. Under the all training systems, stomatal conductance was decreased significantly after attaining maximum level in May month due to increasing effect of shade of the upper canopy during both the years (Table 1a). In the lower canopy, the mean stomatal conductance was recorded maximum under the Espalier system (0.172 mmol/m^2/sec**)** followed by Y-trellis system (0.166 mmol/m^2/sec) and Cordon system (0.165 mmol/m^2/sec). In the middle canopy, stomatal conductance was recorded higher during 2nd fortnight of May under Espalier, Cordon and Y-trellis system during both the years, which was statistically at par with 1st fortnight of May and 1st fortnight of June (Table 7b). In the middle canopy, the mean maximum stomatal conductance was recorded under the Espalier system (0.226 mmol/m^2/sec) followed by Y-trellis system (0.215 mmol/m^2/sec) and Cordon system (0.209 mmol/m^2/sec). In the upper canopy, the stomatal conductance was recorded higher during 1st fortnight of June under Espalier, Cordon and Y-trellis system during both the years, which was statistically at par with 2nd fortnight of May and 2nd fortnight of June (Table 7c). In the upper canopy, the mean maximum stomatal conductance was recorded under the Espalier system (0.257 mmol/m^2/sec) followed by Y-trellis system (0.249 mmol/m^2/sec) and Cordon system (0.242 mmol/m^2/sec). Under the all training systems, the trend of seasonal variation of C was significantly higher during 1st fortnight of May, 2nd fortnight of May and 1st fortnight of June in lower, middle and upper canopy, respectively. Thereafter, stomatal conductance was decreased in the month of August towards the end of vegetative growth due to increased age of leaves and shading effect within canopy. The effect of shading on leaves was maximum in lower canopy portions followed by middle canopy and it was minimum in upper canopy portions.

The data regarding the stomatal conductance in lower, middle and upper canopy under various training systems of pear plants cv. Punjab Beauty is presented in the Tables 8a, 8b and 8c, respectively. A similar trend of stomatal conductance was observed in lower, middle and upper canopy of pear plants trained on Espalier, Cordon and Y-trellis training systems as it was in case of Patharnakh. However, the values of stomatal conductance were different due to different plant growth rate and development in case of pear cv. Punjab Beauty. In lower canopy portions, the stomatal conductance was significantly higher during 1^{st} fortnight of May month during both the years. The mean maximum stomatal conductance was recorded in plants trained on Espalier system (0.186 mmol/m^2/sec) followed by Y-trellis system (0.180 mmol/m^2/sec) and Cordon system (0.175 mmol/m^2/sec) in lower canopy portions. In middle canopy portions, the stomatal conductance was significantly higher during 2^{nd} fortnight of May month during both the years. The mean maximum stomatal conductance was recorded in plants trained on Espalier system (0.213 mmol/m^2/sec) followed by Y-trellis system (0.209 mmol/m^2/sec) and Cordon system (0.203 mmol/m^2/sec) in middle canopy portions. In upper canopy portions, the stomatal conductance was significantly higher during 1^{st} fortnight of June month during both the years. The mean maximum stomatal conductance was recorded in plants trained on Espalier system (0.235 mmol/m^2/sec) followed by Y-trellis system (0.225 mmol/m^2/sec) and Cordon system (0.221 mmol/m^2/sec) in upper canopy portions. Thereafter stomatal conductance was decreased to minimum level in the month of August towards the end of vegetative growth period, because in Punjab Beauty leaves falls in the month of August due to *Alternaria* disease under subtropical conditions of Punjab.

The data regarding the stomatal conductance in lower, middle and upper canopy under all training systems of pear cv. Punjab Soft is presented in the Tables 9a, 9b and 9c, respectively. A similar trend of stomatal conductance was observed in lower, middle and upper canopy of pear plants trained on Espalier, Cordon and Y-trellis training systems as it was in case of cultivar Punjab Beauty. In lower canopy portions, the stomatal conductance was significantly higher during 1^{st} fortnight of May month during both the years. The mean maximum stomatal conductance was recorded in plants trained on Espalier system (0.175 mmol/m^2/sec) followed by Y-trellis system (0.171 mmol/m^2/sec) and Cordon system (0.166 mmol/m^2/sec) in lower canopy portions. In middle canopy portions, the stomatal conductance was significantly higher during 1^{st} fortnight of June month during both the years.

Table 7a: Seasonal variation in stomatal conductance (mmol/m^2/sec) in lower canopy portions of pear cv. Patharnakh plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	0.169[b]	0.194[b]	0.181	0.163[b]	0.187[c]	0.175	0.167[b]	0.188[c]	0.177
	2nd	0.202[a]	0.216[a]	0.209	0.196[a]	0.212[ab]	0.204	0.198[a]	0.209[b]	0.203
May	**1st**	0.215[a]	0.232[a]	0.223	0.206[a]	0.228[a]	0.217	0.202[a]	0.230[a]	0.216
	2nd	0.196[a]	0.223[a]	0.209	0.192[a]	0.204[b]	0.198	0.187[ab]	0.221[ab]	0.204
June	**1st**	0.173[b]	0.195[b]	0.184	0.166[b]	0.189[c]	0.177	0.167[b]	0.185[c]	0.176
	2nd	0.171[b]	0.190[b]	0.180	0.160[b]	0.184[c]	0.172	0.166[b]	0.182[c]	0.174
July	**1st**	0.136[c]	0.161[c]	0.148	0.130[c]	0.149[d]	0.139	0.131[c]	0.156[d]	0.143
	2nd	0.124[cd]	0.157[cd]	0.140	0.126[c]	0.146[d]	0.136	0.121[c]	0.153[d]	0.137
August	**1st**	0.121[cd]	0.140[de]	0.130	0.119[cd]	0.133[de]	0.126	0.118[c]	0.130[e]	0.124
	2nd	0.101[d]	0.135[e]	0.118	0.093[d]	0.120[e]	0.106	0.094[d]	0.118[e]	0.106
Mean		0.161	0.184	**0.172**	0.155	0.175	**0.165**	0.155	0.177	**0.166**
LSD		0.023	0.019		0.022	0.017		0.021	0.017	

[*]LSD indicates the least significant difference test at $p<0.05$.

[**]Values are means with a common letter are not significantly different at 5% level.

Table 7b: Seasonal variation in stomatal conductance (mmol/m^2/sec) in middle canopy portions of pear cv. Patharnakh plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	0.179^{d}	0.198^{cd}	0.188	0.177^{d}	0.187^{d}	0.182	0.176^{de}	0.193^{de}	0.184
	2nd	0.232^{bc}	0.240^{b}	0.236	0.214^{bc}	0.223^{c}	0.218	0.219^{c}	0.224^{c}	0.221
May	**1st**	0.287^{a}	0.308^{a}	0.297	0.278^{a}	0.294^{a}	0.286	0.277^{a}	0.296^{ab}	0.286
	2nd	0.291^{a}	0.315^{a}	0.303	0.285^{a}	0.308^{a}	0.296	0.285^{a}	0.309^{a}	0.297
June	**1st**	0.255^{b}	0.297^{a}	0.276	0.244^{b}	0.254^{b}	0.249	0.252^{b}	0.281^{b}	0.266
	2nd	0.214^{c}	0.253^{b}	0.233	0.204^{c}	0.221^{c}	0.212	0.193^{d}	0.231^{c}	0.212
July	**1st**	0.183^{d}	0.216^{c}	0.199	0.162^{de}	0.186^{d}	0.174	0.167^{ef}	0.201^{de}	0.184
	2nd	0.175^{d}	0.199^{cd}	0.187	0.159^{de}	0.181^{de}	0.170	0.166^{ef}	0.189^{e}	0.177
August	**1st**	0.173^{de}	0.191^{de}	0.182	0.144^{ef}	0.165^{ef}	0.154	0.150^{fg}	0.186^{ef}	0.168
	2nd	0.152^{e}	0.180^{e}	0.166	0.140^{f}	0.157^{f}	0.148	0.142^{g}	0.171^{f}	0.156
Mean		0.214	0.240	**0.226**	0.200	0.218	**0.209**	0.203	0.228	**0.215**
LSD		0.023	0.019		0.022	0.018		0.020	0.018	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 7c: Seasonal variation in stomatal conductance (mmol/m^2/sec) in upper canopy portions of pear cv. Patharnakh plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	0.188^{d}	0.202^{e}	0.195	0.184^{d}	0.196^{d}	0.190	0.186^{d}	0.195^{d}	0.190
	2nd	0.238^{c}	0.252^{d}	0.245	0.226^{e}	0.240^{c}	0.233	0.237^{c}	0.243^{c}	0.240
May	**1st**	0.297^{ab}	0.310^{ab}	0.303	0.278^{ab}	0.292^{ab}	0.285	0.288^{ab}	0.292^{ab}	0.290
	2nd	0.298^{a}	0.313^{ab}	0.305	0.282^{ab}	0.293^{ab}	0.287	0.288^{ab}	0.302^{ab}	0.295
June	**1st**	0.303^{a}	0.318^{a}	0.310	0.293^{a}	0.303^{a}	0.298	0.297^{a}	0.312^{a}	0.304
	2nd	0.286^{ab}	0.300^{ab}	0.293	0.267^{b}	0.280^{ab}	0.273	0.278^{b}	0.293^{ab}	0.285
July	**1st**	0.275^{b}	0.292^{bc}	0.283	0.261^{b}	0.273^{b}	0.267	0.275^{b}	0.287^{b}	0.281
	2nd	0.241^{c}	0.272^{cd}	0.256	0.224^{c}	0.249^{c}	0.236	0.237^{c}	0.261^{c}	0.249
August	**1st**	0.192^{d}	0.209^{e}	0.200	0.173^{de}	0.187^{d}	0.180	0.178^{d}	0.188^{d}	0.183
	2nd	0.165^{e}	0.189^{e}	0.177	0.162^{e}	0.182^{d}	0.172	0.166^{d}	0.184^{d}	0.175
Mean		0.248	0.266	**0.257**	0.235	0.250	**0.242**	0.243	0.256	**0.249**
LSD		0.023	0.024		0.022	0.023		0.021	0.024	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 8a: Seasonal variation in stomatal conductance (mmol/m^2/sec) in lower canopy portions of pear cv. Punjab Beauty plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	0.105^{g}	0.138^{e}	0.121	0.102^{e}	0.129^{f}	0.115	0.109^{e}	0.134^{f}	0.121
	2nd	0.168^{e}	0.196^{c}	0.182	0.162^{d}	0.187^{d}	0.174	0.167^{d}	0.192^{de}	0.179
May	**1st**	0.221^{ab}	0.234^{b}	0.227	0.218^{ab}	0.222^{bc}	0.220	0.222^{ab}	0.232^{bc}	0.227
	2nd	0.252^{a}	0.276^{a}	0.264	0.231^{a}	0.257^{a}	0.244	0.237^{a}	0.269^{a}	0.253
June	**1st**	0.223^{ab}	0.247^{b}	0.235	0.217^{ab}	0.232^{b}	0.224	0.212^{b}	0.237^{b}	0.224
	2nd	0.207^{bc}	0.233^{b}	0.220	0.199^{bc}	0.212^{cd}	0.205	0.202^{bc}	0.213^{cd}	0.207
July	**1st**	0.195^{cd}	0.209^{c}	0.202	0.181^{cd}	0.201^{d}	0.191	0.188^{c}	0.204^{de}	0.196
	2nd	0.185^{de}	0.206^{c}	0.195	0.177^{d}	0.195^{d}	0.186	0.185^{cd}	0.192^{e}	0.188
August	**1st**	0.130^{f}	0.164^{d}	0.147	0.120^{e}	0.154^{e}	0.137	0.124^{e}	0.149^{f}	0.136
	2nd	0.058^{h}	0.078^{f}	0.068	0.052^{f}	0.069^{g}	0.060	0.059^{f}	0.076^{g}	0.067
Mean		0.174	0.198	**0.186**	0.166	0.186	**0.175**	0.171	0.190	**0.180**
LSD		0.020	0.022		0.021	0.019		0.020	0.020	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 8b: Seasonal variation in stomatal conductance (mmol/m^2/sec) in middle canopy portions of pear cv. Punjab Beauty plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	0.116^{f}	0.139^{g}	0.127	0.105^{f}	0.132^{f}	0.118	0.112^{g}	0.141^{g}	0.126
	2nd	0.174^{e}	0.191^{ef}	0.182	0.167^{d}	0.185^{d}	0.176	0.175^{e}	0.188^{ef}	0.181
May	**1st**	0.263^{b}	0.288^{c}	0.275	0.264^{ab}	0.286^{b}	0.275	0.266^{bc}	0.288^{b}	0.277
	2nd	0.282^{ab}	0.308^{ab}	0.295	0.280^{a}	0.302^{ab}	0.291	0.282^{ab}	0.307^{ab}	0.294
June	**1st**	0.294^{a}	0.322^{a}	0.308	0.282^{a}	0.312^{a}	0.297	0.295^{a}	0.318^{a}	0.306
	2nd	0.266^{b}	0.294^{bc}	0.280	0.247^{b}	0.283^{b}	0.265	0.253^{c}	0.287^{b}	0.270
July	**1st**	0.213^{c}	0.230^{d}	0.221	0.194^{c}	0.211^{c}	0.202	0.201^{d}	0.219^{cd}	0.210
	2nd	0.193^{d}	0.207^{e}	0.200	0.175^{d}	0.191^{d}	0.183	0.181^{e}	0.206^{de}	0.193
August	**1st**	0.161^{e}	0.175^{f}	0.168	0.140^{e}	0.165^{e}	0.152	0.145^{f}	0.172^{f}	0.158
	2nd	0.067^{g}	0.084^{h}	0.075	0.062^{g}	0.077^{g}	0.069	0.066^{h}	0.081^{h}	0.073
Mean		0.203	0.224	**0.213**	0.192	0.214	**0.203**	0.198	0.221	**0.209**
LSD		0.019	0.018		0.021	0.020		0.020	0.021	

*LSD indicates the least significant difference test at p<0.05.
**Values are means with a common letter are not significantly different at 5% level.

Table 8c: Seasonal variation in stomatal conductance (mmol/m^2/sec) in upper canopy portions of pear cv. Punjab Beauty plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	0.124^{g}	0.136^{f}	0.130	0.109^{f}	0.122^{f}	0.115	0.111^{f}	0.128^{g}	0.119
	2nd	0.199^{e}	0.204^{d}	0.201	0.170^{e}	0.193^{d}	0.181	0.183^{d}	0.201^{e}	0.192
May	**1st**	0.285^{c}	0.289^{b}	0.287	0.250^{c}	0.287^{b}	0.268	0.267^{b}	0.284^{c}	0.275
	2nd	0.308^{a}	0.326^{a}	0.317	0.292^{ab}	0.317^{a}	0.304	0.287^{ab}	0.313^{ab}	0.300
June	**1st**	0.311^{a}	0.328^{a}	0.319	0.299^{a}	0.321^{a}	0.310	0.298^{a}	0.325^{a}	0.311
	2nd	0.306^{ab}	0.318^{a}	0.312	0.293^{a}	0.302^{ab}	0.297	0.294^{ab}	0.310^{ab}	0.302
July	**1st**	0.287^{bc}	0.293^{b}	0.290	0.269^{bc}	0.285^{b}	0.277	0.275^{b}	0.290^{bc}	0.282
	2nd	0.227^{d}	0.231^{c}	0.229	0.215^{d}	0.227^{c}	0.221	0.217^{c}	0.234^{d}	0.225
August	**1st**	0.169^{f}	0.181^{e}	0.175	0.151^{e}	0.167^{e}	0.159	0.157^{e}	0.174^{f}	0.165
	2nd	0.087^{h}	0.093^{g}	0.090	0.074^{g}	0.086^{g}	0.080	0.076^{g}	0.095^{h}	0.085
Mean		0.230	0.240	**0.235**	0.212	0.231	**0.221**	0.217	0.235	**0.225**
LSD		0.021	0.021		0.024	0.025		0.023	0.024	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 9a: Seasonal variation in stomatal conductance (mmol/m^2/sec) in lower canopy portions of pear cv. Punjab Soft plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	0.120^{de}	0.139^{ef}	0.129	0.105^{ef}	0.127^{fg}	0.116	0.113^{ef}	0.138^{fg}	0.125
	2nd	0.177^{c}	0.198^{d}	0.187	0.172^{cd}	0.196^{cd}	0.184	0.176^{cd}	0.194^{cd}	0.185
May	**1st**	0.261^{a}	0.286^{a}	0.273	0.256^{a}	0.279^{a}	0.267	0.254^{a}	0.281^{a}	0.267
	2nd	0.217^{b}	0.252^{b}	0.234	0.215^{b}	0.242^{b}	0.228	0.214^{b}	0.248^{b}	0.231
June	**1st**	0.197^{b}	0.219^{c}	0.208	0.182^{c}	0.210^{c}	0.196	0.187^{c}	0.213^{c}	0.200
	2nd	0.166^{c}	0.191^{d}	0.178	0.156^{d}	0.182^{d}	0.169	0.163^{d}	0.188^{d}	0.175
July	**1st**	0.137^{d}	0.159^{e}	0.148	0.126^{e}	0.154^{e}	0.140	0.133^{e}	0.167^{e}	0.150
	2nd	0.132^{d}	0.156^{e}	0.144	0.123^{e}	0.145^{ef}	0.134	0.127^{ef}	0.152^{ef}	0.139
August	**1st**	0.116^{de}	0.147^{ef}	0.131	0.106^{ef}	0.132^{fg}	0.119	0.115^{ef}	0.143^{fg}	0.129
	2nd	0.103^{e}	0.129^{f}	0.116	0.097^{f}	0.115^{g}	0.106	0.107^{f}	0.125^{g}	0.116
Mean		0.163	0.188	**0.175**	0.154	0.178	**0.166**	0.159	0.185	**0.171**
LSD		0.025	0.023		0.023	0.025		0.021	0.024	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 9b: Seasonal variation in stomatal conductance (mmol/m^2/sec) in middle canopy portions of pear cv. Punjab Soft plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	0.137^{e}	0.166^{gh}	0.151	0.126^{fg}	0.149^{f}	0.137	0.130^{f}	0.158^{g}	0.144
	2nd	0.204^{d}	0.247^{e}	0.225	0.182^{e}	0.207^{e}	0.194	0.194^{d}	0.220^{e}	0.207
May	**1st**	0.275^{b}	0.298^{cd}	0.286	0.266^{c}	0.273^{c}	0.269	0.267^{b}	0.281^{c}	0.274
	2nd	0.312^{a}	0.326^{ab}	0.319	0.289^{ab}	0.308^{ab}	0.298	0.294^{a}	0.313^{ab}	0.303
June	**1st**	0.321^{a}	0.343^{a}	0.332	0.305^{a}	0.327^{a}	0.316	0.312^{a}	0.331^{a}	0.321
	2nd	0.278^{b}	0.314^{bc}	0.296	0.272^{bc}	0.290^{bc}	0.281	0.273^{b}	0.298^{bc}	0.285
July	**1st**	0.242^{c}	0.279^{d}	0.260	0.224^{d}	0.250^{d}	0.237	0.220^{c}	0.264^{d}	0.242
	2nd	0.190^{d}	0.220^{f}	0.205	0.178^{e}	0.202^{e}	0.190	0.181^{e}	0.194^{f}	0.187
August	**1st**	0.151^{e}	0.185^{g}	0.168	0.133^{f}	0.167^{f}	0.150	0.146^{f}	0.164^{g}	0.155
	2nd	0.111^{f}	0.145^{h}	0.128	0.109^{g}	0.115^{g}	0.112	0.104^{g}	0.131^{h}	0.117
Mean		0.222	0.252	**0.237**	0.208	0.229	**0.218**	0.212	0.235	**0.223**
LSD		0.020	0.021		0.019	0.020		0.019	0.019	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 9c: Seasonal variation in stomatal conductance (mmol/m^2/sec) in upper canopy portions of pear cv. Punjab Soft plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	0.144^{f}	0.166^{ef}	0.155	0.133^{f}	0.161^{f}	0.147	0.146^{f}	0.167^{f}	0.156
	2nd	0.224^{d}	0.241^{d}	0.232	0.213^{d}	0.238^{d}	0.225	0.224^{d}	0.241^{d}	0.232
May	**1st**	0.294^{bc}	0.309^{bc}	0.301	0.285^{bc}	0.300^{bc}	0.292	0.292^{b}	0.302^{bc}	0.297
	2nd	0.328^{a}	0.331^{ab}	0.329	0.304^{ab}	0.327^{a}	0.315	0.308^{ab}	0.320^{ab}	0.314
June	**1st**	0.331^{a}	0.345^{a}	0.338	0.324^{a}	0.337^{a}	0.330	0.324^{a}	0.340^{a}	0.332
	2nd	0.315^{ab}	0.328^{ab}	0.321	0.303^{ab}	0.319^{ab}	0.311	0.311^{ab}	0.323^{ab}	0.317
July	**1st**	0.274^{c}	0.287^{c}	0.280	0.264^{c}	0.279^{c}	0.271	0.262^{c}	0.278^{c}	0.270
	2nd	0.238^{d}	0.244^{d}	0.241	0.217^{d}	0.232^{d}	0.224	0.229^{d}	0.246^{d}	0.237
August	**1st**	0.179^{e}	0.188^{e}	0.183	0.169^{e}	0.182^{e}	0.175	0.172^{e}	0.189^{e}	0.180
	2nd	0.125^{f}	0.143^{f}	0.134	0.121^{f}	0.139^{f}	0.130	0.120^{g}	0.141^{g}	0.130
Mean		0.245	0.258	**0.251**	0.233	0.251	**0.242**	0.239	0.255	**0.246**
LSD		0.025	0.024		0.023	0.023		0.023	0.024	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

The mean maximum stomatal conductance was recorded in plants trained on Espalier system (0.237 mmol/m^2/sec) followed by Y-trellis system (0.223 mmol/m^2/sec) and Cordon system (0.218 mmol/m^2/sec) in middle canopy portions. In upper canopy portions, the stomatal conductance was significantly higher during 1st fortnight of June month during both the years. The mean maximum stomatal conductance was recorded in plants trained on Espalier system (0.251 mmol/m^2/sec) followed by Y-trellis system (0.246 mmol/m^2/sec) and Cordon system (0.242 mmol/m^2/sec) in upper canopy portions. Thereafter stomatal conductance was decreased to minimum level in the month of August during both the years.

In our studies, the stomatal conductance was recorded higher in the months of May-June and lower in the month of August. Under all training systems, stomatal conductance was observed highest in upper canopy portions followed by middle and lower canopy portions, respectively. The maximum stomatal conductance was observed under the Espalier training system followed by Y-trellis system and Cordon system. Similarly, the stomatal behavior of leaves in response to changing photon flux was similar to that commonly found in other species (Leuning *et al* 1995; Roux *et al* 1999) and previously observed in apple (Warrit *et al* 1980; Pretorius and Wand 2003). Our findings are partially in accordance with the results obtained by Massonnet *et al* (2007) who showed that stomatal conductance varied between different cultivars as it was in case of apple cultivars. Similarly, shading affects leaf morphology and anatomy, which reduces stomatal conductance in horticultural crops (Atanasova *et al* 2003; Heuvel *et al* 2004; Gregoriu *et al* 2007).

4.1.1.4 Transpiration rate (mmol/m^2/sec)

The data regarding the transpiration rate (E) in the lower, middle and upper canopy under various training systems of pear cv. Patharnakh is presented in the Tables 10a, 10b and 10c, respectively. In lower canopy portions, the transpiration rate was recorded higher during 1st fortnight of May under Espalier system, which was statistically at par with 2nd fortnight of May. Similar trend for transpiration rate was recorded under Cordon system. However, transpiration rate was recorded higher during 1st fortnight of May under the Y-trellis system. Under all training systems, transpiration rate decreased significantly after attaining maximum level in May month due to increasing effect of shade of upper canopy's growth during both the years (Table 10a). In lower canopy portions, the mean maximum transpiration rate was recorded under the Espalier system (1.458 mmol/m^2/sec) followed by Y-trellis system (1.435 mmol/m^2/sec) and Cordon system (1.388 mmol/m^2/sec). In middle canopy portions, transpiration rate was recorded higher during 2nd fortnight of May under Espalier, Cordon and Y-trellis system during both the years, which was statistically at par with 1st fortnight of May and 1st fortnight of June (Table 10b). The mean maximum transpiration rate was recorded under the Espalier system (2.001 mmol/m^2/sec) followed by Y-trellis system (1.915

mmol/m^2/sec) and Cordon system (1.885 mmol/m^2/sec). However in upper canopy portions, the transpiration rate was recorded higher during 1st fortnight of June under Espalier, Cordon and Y-trellis system during both the years, which was statistically at par with 2nd fortnight of May and 2nd fortnight of June (Table 10c). The mean maximum transpiration rate was recorded under the Espalier system (2.390 mmol/m^2/sec) followed by Cordon system (2.298 mmol/m^2/sec) and Y-trellis system (2.297 mmol/m^2/sec). Under the all training systems, the trend of seasonal variation of transpiration rate was significantly higher during 1st fortnight of May, 2nd fortnight of May and 1st fortnight of June in lower, middle and upper canopy portions, respectively. Thereafter, transpiration rate was decreased in the month of August towards the end of vegetative growth phase due to aging and shading effect within plant canopy. The effect of shading on leaves was maximum in lower canopy portions followed by middle canopy and it was minimum in upper canopy portions during both the years of studies.

The data regarding the transpiration rate in lower, middle and upper canopy under various training systems of pear plants cv. Punjab Beauty is presented in the Tables 11a, 11b and 11c, respectively. A similar trend of transpiration rate was observed in lower, middle and upper canopy of pear plants trained on Espalier, Cordon and Y-trellis training systems as it was in case of pear cv. Patharnakh. However, the values of transpiration rate were different due to variation in plant growth rate and development of various pear cultivars as it was in case of Punjab Beauty. In lower canopy portions, the transpiration rate was significantly higher during 1st fortnight of May month during both the years. The mean maximum transpiration rate was recorded in plants trained on Espalier system (1.501 mmol/m^2/sec) followed by Y-trellis system (1.458 mmol/m^2/sec) and Cordon system (1.410 mmol/m^2/sec) in lower canopy portions. In middle canopy portions, the transpiration rate was significantly higher during 2nd fortnight of May month during both the years. The mean maximum transpiration rate was recorded in plants trained on Espalier system (1.781 mmol/m^2/sec) followed by Y-trellis system (1.728 mmol/m^2/sec) and Cordon system (1.694 mmol/m^2/sec) in middle canopy portions. In upper canopy portions, the transpiration rate was significantly higher during 1st fortnight of June month during both the years. The mean maximum transpiration rate was recorded in plants trained on Espalier system (2.226 mmol/m^2/sec) followed by Y-trellis system (2.185 mmol/m^2/sec) and Cordon system (2.133 mmol/m^2/sec) in upper canopy portions. Thereafter transpiration rate decreased to minimum level in the month of August towards the end of vegetative growth period, because in cultivar Punjab Beauty leaves fall in the month of August due to *Alternaria* disease under subtropical conditions of Punjab.

The data regarding the transpiration rate in lower, middle and upper canopy under all training systems of pear cv. Punjab Soft is presented in the Tables 12a, 12b and 12c, respectively. A similar trend of transpiration rate was observed in lower, middle and upper canopy of pear plants trained on Espalier, Cordon and Y-trellis training systems as it was in case of Patharnakh. In lower canopy portions, the transpiration rate was significantly higher during 1st fortnight of May month during both the years. The mean maximum transpiration rate was recorded in plants trained on Espalier system (1.363 mmol/m^2/sec) followed by Y-trellis system (1.331 mmol/m^2/sec) and Cordon system (1.309 mmol/m^2/sec) in lower canopy portions. In middle canopy portions, the transpiration rate was significantly higher during 1st fortnight of June month during both the years. The mean maximum transpiration rate was recorded in plants trained on Espalier system (1.651 mmol/m^2/sec) followed by Y-trellis system (1.605 mmol/m^2/sec) and Cordon system (1.556 mmol/m^2/sec) in middle canopy portions. In upper canopy portions, the transpiration rate was significantly higher during 1st fortnight of June month during both the years. The mean maximum transpiration rate was recorded in plants trained on Espalier system (1.824 mmol/m^2/sec) followed by Y-trellis system (1.817 mmol/m^2/sec) and Cordon system (1.727 mmol/m^2/sec) in upper canopy portions. Thereafter, transpiration rate decreased to minimum level in the month of August as it was in case of Patharnakh.

In our studies, the transpiration rate was recorded higher in the month of May-June and lower in the month of August during both the years. Under all training systems, transpiration rate was observed higher in upper canopy portions followed by middle and lower canopy, respectively. Similar results were found by Williams and Ayars (2005) and Goodwin *et al* (2006) that canopy transpiration rate is a function of intercepted radiation, stomatal conductance and canopy cover. Similarly, shading affects leaf morphology and anatomy, which decreased stomatal conductance and transpiration rate in horticultural crops (Atanasova *et al* 2003; Heuvel *et al* 2004; Gregoriu *et al* 2007). The maximum transpiration rate was observed under the Espalier system followed by Y-trellis system and Cordon system, respectively. Our results are partially in accordance with the studies obtained by Trentacoste *et al* (2015) that consequent influences on transpiration rate were related to canopy management techniques.

Table 10a: Seasonal variation in transpiration rate (mmol/m^{2}/sec) in lower canopy portions of pear cv. Patharnakh plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
April	1st	1.159^{d}	1.326^{e}	1.242	1.149^{d}	1.274^{f}	1.211	1.139^{d}	1.399^{d}	1.269
	2nd	1.503^{b}	1.813^{b}	1.658	1.463^{b}	1.697^{b}	1.580	1.526^{b}	1.733^{b}	1.629
May	1st	1.759^{a}	1.990^{a}	1.874	1.664^{a}	1.877^{a}	1.770	1.681^{a}	1.929^{a}	1.805
	2nd	1.720^{a}	1.881^{a}	1.800	1.660^{a}	1.710^{b}	1.685	1.683^{a}	1.863^{a}	1.773
June	1st	1.549^{b}	1.729^{b}	1.639	1.514^{b}	1.593^{c}	1.553	1.491^{b}	1.650^{bc}	1.570
	2nd	1.384^{c}	1.623^{c}	1.503	1.256^{c}	1.499^{d}	1.377	1.276^{c}	1.627^{c}	1.451
July	1st	1.323^{c}	1.483^{d}	1.403	1.163^{d}	1.394^{e}	1.278	1.270^{c}	1.431^{d}	1.350
	2nd	1.177^{d}	1.386^{e}	1.281	1.097^{de}	1.371^{e}	1.234	1.167^{d}	1.429^{d}	1.298
August	1st	1.004^{e}	1.223^{f}	1.113	1.051^{e}	1.223^{fg}	1.137	1.034^{e}	1.284^{e}	1.159
	2nd	0.951^{e}	1.194^{f}	1.072	0.924^{f}	1.184^{g}	1.054	0.974^{e}	1.133^{f}	1.053
Mean		1.353	1.565	**1.458**	1.294	1.482	**1.388**	1.324	1.548	**1.435**
LSD		0.088	0.091		0.085	0.090		0.086	0.088	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 10b: Seasonal variation in transpiration rate (mmol/m^{2}/sec) in middle canopy portions of pear cv. Patharnakh plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	1.281^{f}	1.482^{g}	1.381	1.194^{f}	1.474^{e}	1.334	1.217^{f}	1.400^{e}	1.308
	2nd	1.851^{d}	1.973^{e}	1.912	1.763^{c}	1.904^{d}	1.833	1.780^{d}	1.943^{c}	1.861
May	**1st**	2.126^{c}	2.321^{c}	2.223	2.104^{b}	2.224^{c}	2.164	2.043^{c}	2.287^{b}	2.165
	2nd	2.606^{a}	2.837^{a}	2.721	2.527^{a}	2.713^{a}	2.620	2.547^{a}	2.794^{a}	2.670
June	**1st**	2.583^{a}	2.813^{a}	2.698	2.471^{a}	2.659^{a}	2.565	2.574^{a}	2.714^{a}	2.644
	2nd	2.247^{b}	2.584^{b}	2.415	2.081^{b}	2.421^{b}	2.251	2.146^{b}	2.529^{b}	2.337
July	**1st**	1.836^{d}	2.096^{d}	1.966	1.726^{c}	1.886^{d}	1.806	1.783^{d}	1.913^{c}	1.848
	2nd	1.833^{d}	1.993^{e}	1.913	1.524^{d}	1.823^{d}	1.673	1.661^{e}	1.794^{d}	1.727
August	**1st**	1.476^{e}	1.577^{f}	1.526	1.339^{e}	1.399^{ef}	1.369	1.337^{e}	1.339^{e}	1.338
	2nd	1.141^{g}	1.371^{h}	1.256	1.114^{f}	1.354^{f}	1.234	1.134^{f}	1.374^{e}	1.254
Mean		1.898	2.105	**2.001**	1.784	1.986	**1.885**	1.822	2.009	**1.915**
LSD		0.090	0.092		0.089	0.090		0.089	0.091	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 10c: Seasonal variation in transpiration rate (mmol/m^2/sec) in upper canopy portions of pear cv. Patharnakh plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	1.311^{g}	1.556^{g}	1.433	1.326^{f}	1.500^{g}	1.413	1.250^{h}	1.510^{g}	1.380
	2nd	1.934^{f}	2.097^{f}	2.015	1.906^{d}	1.989^{e}	1.947	1.937^{f}	1.947^{e}	1.942
May	**1st**	2.526^{d}	2.774^{d}	2.650	2.686^{b}	2.768^{c}	2.727	2.476^{d}	2.829^{c}	2.652
	2nd	2.830^{c}	3.217^{b}	3.023	2.899^{a}	3.191^{a}	3.045	2.717^{c}	3.207^{a}	2.962
June	**1st**	3.206^{a}	3.437^{a}	3.321	2.986^{a}	3.269^{a}	3.127	3.026^{a}	3.229^{a}	3.127
	2nd	2.957^{b}	3.179^{b}	3.068	2.534^{c}	3.087^{b}	2.810	2.873^{b}	2.989^{b}	2.931
July	**1st**	2.656^{c}	2.926^{c}	2.791	1.896^{d}	2.787^{c}	2.341	2.433^{d}	2.911^{b}	2.672
	2nd	2.239^{e}	2.469^{e}	2.354	1.514^{e}	2.427^{d}	2.970	2.159^{e}	2.379^{d}	2.269
August	**1st**	1.891^{f}	2.027^{f}	1.959	1.279^{f}	1.814^{f}	1.546	1.759^{g}	1.857^{f}	1.808
	2nd	1.261^{g}	1.313^{h}	1.287	1.150^{g}	1.230^{h}	1.190	1.184^{h}	1.274^{h}	1.229
Mean		2.281	2.440	**2.390**	2.018	2.406	**2.212**	2.181	2.413	**2.297**
LSD		0.091	0.092		0.088	0.091		0.089	0.088	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 11a: Seasonal variation in transpiration rate (mmol/m^2/sec) in lower canopy portions of pear cv. Punjab Beauty plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	0.896^{e}	1.026^{g}	0.961	0.874^{f}	1.004^{g}	0.939	0.886^{f}	1.043^{g}	0.964
	2nd	1.286^{d}	1.234^{e}	1.260	1.146^{e}	1.217^{f}	1.181	1.204^{e}	1.293^{e}	1.248
May	**1st**	1.824^{b}	1.986^{c}	1.905	1.684^{b}	1.840^{c}	1.762	1.799^{b}	1.746^{c}	1.772
	2nd	2.196^{a}	2.320^{a}	2.258	2.080^{a}	2.261^{a}	2.170	2.143^{a}	2.314^{a}	2.228
June	**1st**	1.822^{b}	2.093^{b}	1.957	1.776^{b}	1.954^{b}	1.865	1.726^{bc}	2.026^{b}	1.876
	2nd	1.656^{c}	1.984^{c}	1.820	1.584^{c}	1.813^{c}	1.698	1.690^{c}	1.944^{b}	1.817
July	**1st**	1.589^{c}	1.757^{d}	1.673	1.509^{c}	1.603^{d}	1.556	1.561^{d}	1.654^{c}	1.607
	2nd	1.306^{d}	1.489^{e}	1.397	1.247^{d}	1.334^{e}	1.290	1.251^{e}	1.416^{d}	1.333
August	**1st**	0.969^{e}	1.250^{e}	1.109	0.820^{f}	1.141^{f}	0.980	0.951^{f}	1.154^{f}	1.052
	2nd	0.593^{f}	0.757^{h}	0.675	0.571^{g}	0.753^{h}	0.662	0.593^{g}	0.779^{h}	0.686
Mean		1.414	1.590	**1.501**	1.329	1.492	**1.410**	1.380	1.537	**1.458**
LSD		0.094	0.095		0.093	0.093		0.093	0.094	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 11b: Seasonal variation in transpiration rate (mmol/m^2/sec) in middle canopy portions of pear cv. Punjab Beauty plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	0.921^{f}	1.189^{f}	1.055	0.909^{g}	1.139^{f}	1.024	0.907^{g}	1.166^{f}	1.036
	2nd	1.524^{d}	1.881^{d}	1.702	1.496^{e}	1.833^{d}	1.664	1.513^{e}	1.846^{d}	1.679
May	**1st**	1.923^{c}	2.289^{c}	2.106	1.929^{c}	2.119^{c}	2.024	1.967^{c}	2.246^{c}	2.106
	2nd	2.293^{b}	2.529^{b}	2.411	2.076^{b}	2.304^{b}	2.190	2.186^{b}	2.469^{b}	2.327
June	**1st**	2.743^{a}	2.914^{a}	2.828	2.583^{a}	2.873^{a}	2.728	2.673^{a}	2.844^{a}	2.758
	2nd	2.173^{b}	2.460^{b}	2.316	2.120^{b}	2.384^{b}	2.252	2.131^{b}	2.360^{b}	2.245
July	**1st**	1.840^{c}	1.974^{d}	1.907	1.706^{d}	1.857^{d}	1.781	1.773^{d}	1.827^{d}	1.800
	2nd	1.520^{d}	1.681^{e}	1.600	1.483^{e}	1.524^{e}	1.503	1.421^{e}	1.613^{e}	1.517
August	**1st**	1.110^{e}	1.269^{f}	1.189	1.029^{f}	1.244^{f}	1.136	1.019^{f}	1.251^{f}	1.135
	2nd	0.600^{g}	0.806^{g}	0.703	0.538^{h}	0.736^{g}	0.637	0.559^{h}	0.804^{g}	0.681
Mean		1.665	1.899	**1.781**	1.587	1.801	**1.694**	1.615	1.843	**1.728**
LSD		0.095	0.096		0.094	0.095		0.092	0.094	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 11c: Seasonal variation in transpiration rate (mmol/m^2/sec) in upper canopy portions of pear cv. Punjab Beauty plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	0.987^{g}	1.127^{g}	1.057	0.951^{g}	1.113^{g}	1.032	0.966^{g}	1.157^{g}	1.061
	2nd	1.769^{e}	1.968^{f}	1.868	1.723^{e}	1.774^{f}	1.748	1.723^{e}	1.891^{f}	1.807
May	**1st**	2.139^{d}	2.389^{e}	2.264	2.101^{d}	2.347^{e}	2.224	2.127^{d}	2.369^{e}	2.248
	2nd	2.726^{c}	2.940^{c}	2.833	2.647^{c}	2.791^{c}	2.719	2.699^{c}	2.840^{c}	2.769
June	**1st**	3.229^{a}	3.469^{a}	3.349	3.101^{a}	3.350^{a}	3.225	3.134^{a}	3.403^{a}	3.268
	2nd	3.014^{b}	3.274^{b}	3.144	2.914^{b}	3.156^{b}	3.035	2.973^{b}	3.249^{b}	3.111
July	**1st**	2.649^{c}	2.944^{c}	2.796	2.624^{c}	2.763^{c}	2.693	2.606^{c}	2.889^{c}	2.747
	2nd	2.177^{d}	2.684^{d}	2.430	2.054^{d}	2.481^{d}	2.267	2.123^{d}	2.587^{d}	2.355
August	**1st**	1.620^{f}	1.879^{f}	1.749	1.573^{f}	1.700^{f}	1.636	1.566^{f}	1.817^{f}	1.691
	2nd	0.620^{h}	0.923^{h}	0.771	0.643^{h}	0.866^{h}	0.754	0.693^{h}	0.907^{h}	0.800
Mean		2.093	2.360	**2.226**	2.033	2.234	**2.133**	2.061	2.311	**2.185**
LSD		0.096	0.094		0.094	0.096		0.094	0.093	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 12a: Seasonal variation in transpiration rate (mmol/m^2/sec) in lower canopy portions of pear cv. Punjab Soft plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	0.849^{g}	1.100^{e}	0.974	0.836^{g}	1.077^{g}	0.956	0.834^{h}	1.096^{f}	0.965
	2nd	1.187^{d}	1.304^{c}	1.245	1.074^{e}	1.236^{e}	1.155	1.187^{d}	1.297^{de}	1.242
May	**1st**	1.691^{ab}	1.799^{a}	1.745	1.557^{b}	1.776^{ab}	1.666	1.627^{a}	1.713^{b}	1.670
	2nd	1.769^{a}	1.819^{a}	1.794	1.694^{a}	1.843^{a}	1.768	1.674^{a}	1.814^{a}	1.744
June	**1st**	1.629^{b}	1.744^{a}	1.686	1.514^{b}	1.694^{b}	1.604	1.529^{b}	1.677^{b}	1.603
	2nd	1.370^{c}	1.614^{b}	1.492	1.292^{c}	1.477^{c}	1.384	1.323^{c}	1.589^{c}	1.456
July	**1st**	1.201^{d}	1.340^{c}	1.270	1.161^{d}	1.329^{d}	1.245	1.171^{de}	1.377^{d}	1.274
	2nd	1.127^{de}	1.296^{cd}	1.211	1.097^{de}	1.240^{e}	1.168	1.100^{ef}	1.270^{e}	1.185
August	**1st**	1.071^{e}	1.246^{d}	1.158	1.053^{e}	1.191^{f}	1.122	1.069^{f}	1.217^{e}	1.143
	2nd	0.971^{f}	1.137^{e}	1.054	0.927^{f}	1.114^{fg}	1.020	0.951^{g}	1.123^{f}	1.037
Mean		1.287	1.440	**1.363**	1.221	1.398	**1.309**	1.247	1.417	**1.331**
LSD		0.085	0.086		0.083	0.085		0.083	0.084	

*LSD indicates the least significant difference test at p<0.05.

**Values are means with a common letter are not significantly different at 5% level.

Table 12b: Seasonal variation in transpiration rate (mmol/m^2/sec) in middle canopy portions of pear cv. Punjab Soft plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	0.934^{g}	1.139^{f}	1.036	0.916^{g}	1.104^{e}	1.010	0.953^{g}	1.173^{g}	1.063
	2nd	1.266^{f}	1.434^{e}	1.350	1.186^{ef}	1.367^{d}	1.276	1.203^{f}	1.429^{f}	1.316
May	**1st**	1.749^{d}	1.894^{c}	1.821	1.669^{cd}	1.839^{b}	1.754	1.659^{d}	1.809^{d}	1.734
	2nd	1.887^{c}	1.989^{b}	1.938	1.726^{c}	1.899^{b}	1.812	1.694^{d}	1.957^{c}	1.825
June	**1st**	2.254^{a}	2.407^{a}	2.330	2.183^{a}	2.334^{a}	2.258	2.164^{a}	2.426^{a}	2.295
	2nd	2.144^{b}	2.314^{a}	2.229	1.953^{b}	2.254^{a}	2.103	2.054^{b}	2.324^{b}	2.189
July	**1st**	1.826^{cd}	1.966^{bc}	1.896	1.627^{d}	1.806^{b}	1.716	1.763^{c}	1.933^{c}	1.848
	2nd	1.393^{e}	1.634^{d}	1.513	1.210^{e}	1.477^{c}	1.343	1.300^{e}	1.569^{e}	1.434
August	**1st**	1.209^{f}	1.413^{e}	1.311	1.116^{f}	1.301^{d}	1.208	1.137^{f}	1.374^{f}	1.255
	2nd	0.994^{g}	1.190^{f}	1.092	0.979^{g}	1.187^{e}	1.083	0.993^{g}	1.191^{g}	1.092
Mean		1.566	1.738	**1.651**	1.457	1.657	**1.556**	1.492	1.719	**1.605**
LSD		0.085	0.087		0.084	0.086		0.084	0.085	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 12c: Seasonal variation in transpiration rate (mmol/m^2/sec) in upper canopy portions of pear cv. Punjab Soft plants trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	1.100^{g}	1.304^{f}	1.202	1.019^{f}	1.270^{g}	1.144	1.085^{g}	1.286^{f}	1.185
	2nd	1.347^{f}	1.544^{e}	1.445	1.218^{e}	1.479^{f}	1.348	1.303^{f}	1.586^{e}	1.444
May	**1st**	1.847^{d}	2.097^{c}	1.972	1.717^{c}	1.923^{d}	1.820	1.867^{d}	2.097^{c}	1.982
	2nd	2.189^{b}	2.376^{b}	2.282	2.139^{b}	2.313^{b}	2.226	2.177^{b}	2.316^{b}	2.246
June	**1st**	2.519^{a}	2.659^{a}	2.589	2.369^{a}	2.507^{a}	2.438	2.537^{a}	2.581^{a}	2.559
	2nd	2.269^{b}	2.436^{b}	2.352	2.179^{b}	2.400^{b}	2.289	2.229^{b}	2.499^{a}	2.364
July	**1st**	1.939^{c}	2.093^{c}	2.016	1.791^{c}	2.021^{c}	1.906	1.984^{c}	2.139^{c}	2.061
	2nd	1.679^{e}	1.804^{d}	1.741	1.501^{d}	1.647^{e}	1.574	1.643^{e}	1.744^{d}	1.693
August	**1st**	1.356^{f}	1.564^{e}	1.460	1.289^{e}	1.494^{f}	1.391	1.354^{f}	1.576^{e}	1.465
	2nd	1.063^{g}	1.290^{f}	1.176	1.029^{f}	1.239^{g}	1.134	1.049^{g}	1.296^{f}	1.172
Mean		1.731	1.917	**1.824**	1.625	1.830	**1.727**	1.723	1.912	**1.817**
LSD		0.086	0.0.088		0.084	0.086		0.084	0.083	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

4.1.1.5 Relative Humidity (%)

The data on the mean relative humidity (RH) in plant canopy under various training systems was recorded from the month of April to August has been presented in Tables 13-15. It reveals significantly higher relative humidity in the months of July and August. The lowest relative humidity was recorded in the month of April, when plant's vegetative growth at the initial stage. However among all the training systems, relative humidity was recorded highest under the Y-trellis system during all the months as compared to other training systems. The mean maximum relative humidity was recorded in pear cv. Patharnakh under the Y-trellis system (64.51%) followed by Cordon system (64.00%) and Espalier system (63.51%), respectively (Table 13). The relative humidity gradually increased with the progress of the season. The trend of seasonal variation in relative humidity was similar under different cultivars of pear viz. Patharnakh, Punjab Beauty and Punjab Soft. In pear cv. Punjab Beauty, the mean maximum relative humidity was recorded under the Y-trellis system (62.80%) followed by Cordon system (62.38%) and Espalier system (62.04%), respectively (Table 14). Similarly in pear cv. Punjab Soft, the mean maximum relative humidity was recorded under the Y-trellis system (62.90%) followed by Cordon system (62.67%) and Espalier system (62.39%), respectively (Table 15). With the advancement of the season, the plant canopy became denser and effect of shading on micro-climate increased within canopy, which resulted in low temperature and high relative humidity. Our findings are partially in accordance with the results obtained by Cautin *et al* (2010) who reported that high density tunnel system increased the relative humidity in 'cherimoya' orchards.

4.1.1.6 Canopy Temperature (^{o}C)

The data on the mean canopy temperature in pear plants under various training systems was recorded from the month of April to August has been presented in Tables 16-18. It is evident from the data that significantly higher canopy temperature within plant canopies was recorded in the month of June and it was noted lower in the month of April. The canopy temperature within the plant canopy gradually decreased after June month with the advancement of the season. However, the canopy becomes denser and relative humidity within plant canopy increased, which might have decreased canopy temperature. However among all the training systems, canopy temperature was recorded highest under the Espalier system in whole season of vegetative growth as compared to other training systems. In pear cv. Patharnakh, the mean maximum canopy temperature was recorded under the Espalier training system (34.23^{o}C) followed by Cordon system (34.05^{o}C) and Y-trellis system (33.77^{o}C), respectively (Table 16). The trend of seasonal variation in canopy temperature within plant canopy was similar under different cultivars (Punjab Beauty and Punjab Soft) as it was in case of Patharnakh. In pear cv. Punjab Beauty, the mean maximum canopy temperature was recorded under the Espalier system (32.94^{o}C) followed by Cordon system (32.75^{o}C) and Y-trellis system (32.48^{o}C), respectively (Table 17). Similarly in pear cv. Punjab Soft, the mean maximum canopy temperature was recorded under the Espalier training system (33.43^{o}C) followed by Cordon system (33.27^{o}C) and Y-trellis system (32.95^{o}C), respectively (Table 18). With the advancement of the season the canopy became denser and effect of shading increased within canopy, which might have reduced canopy temperature. Our results are partially in accordance with the studies obtained by Cautin *et al* (2010) who reported that high density tunnel system increased the relative humidity in 'Cherimoya' orchards, which resulted in lower canopy temperature.

4.1.1.7 Soil Temperature (^{o}C)

The data on the mean soil temperature underneath the canopy of pear plants under all training systems was recorded from the month of April to August has been presented in Tables 19-21. The significantly higher soil temperature was recorded in the month of June and lowest soil temperature was recorded in the month of April. The soil temperature shows a gradually decreasing trend after the June month during both the years. However, the canopy becomes denser and PAR interception within the plant canopies decreased, which resulted in lower soil temperature with the advancement of the season. Among all the training systems, soil temperature was recorded highest under the Espalier system in whole season of vegetative growth as compared to other training systems. In pear cv. Patharnakh, the mean maximum soil temperature was recorded under the Espalier system (26.18^{o}C) followed by Cordon system (26.05^{o}C) and Y-trellis system (25.95^{o}C), respectively (Table 19). The trend of seasonal variation in soil temperature was similar under various pear cultivars (Patharnakh, Punjab Beauty and Punjab Soft). In pear cv. Punjab Beauty, the mean maximum soil temperature was recorded under the Espalier system (26.99^{o}C) followed by Cordon system (26.90^{o}C) and Y-trellis system (26.74^{o}C), respectively (Table 20). Similar results were found in pear cv. Punjab Soft that the mean maximum soil temperature was recorded under the Espalier training system (26.64^{o}C) followed by Cordon system (26.52^{o}C) and Y-trellis system (26.34^{o}C), respectively (Table 21).

In our studies, the soil temperature was low underneath the various training systems as compared to open field conditions. However, it was may be due to less penetration of light and availability of heat underneath plant canopies as in case of Espalier, Cordon and Y-trellis training systems. Similar results were found by Rodrigo (2000) who reported that the subsequent changes in the plant's architecture were modulate local environmental conditions within the canopy such as temperature and relative humidity. Similarly, The air and soil temperature within plant canopy increased with solar irradiance (Bergqvist *et al* 2001; Dokoozlian and Kliewer 1996). Our results are partially in accordance with the observations obtained by Saudreau *et al* (2011) who reported that microclimate within plant canopy was characteristics of overall canopy architecture.

Table 13: Seasonal variation in relative humidity (%) within canopy of pear plants cv. Patharnakh trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1^{st}**	44.80^{h}	44.39^{g}	44.59	44.27^{h}	43.78^{g}	44.02	44.49^{h}	43.46^{g}	43.97
	2^{nd}	43.86^{h}	44.77^{g}	44.31	43.04^{h}	43.92^{g}	43.48	43.61^{h}	43.97^{g}	43.79
May	**1^{st}**	45.94^{g}	48.12^{f}	47.03	46.74^{g}	49.01^{f}	47.87	47.50^{g}	49.64^{f}	48.57
	2^{nd}	52.56^{f}	57.62^{e}	55.09	53.49^{f}	58.57^{e}	56.03	54.10^{f}	59.19^{e}	56.64
June	**1^{st}**	57.88^{e}	59.18^{d}	58.53	58.91^{e}	60.22^{d}	59.56	59.49^{e}	60.83^{d}	60.16
	2^{nd}	62.16^{d}	67.74^{c}	64.95	63.15^{d}	68.46^{c}	65.80	63.78^{d}	69.17^{c}	66.47
July	**1^{st}**	77.73^{c}	81.28^{ab}	79.50	78.75^{c}	82.39^{a}	80.57	78.83^{c}	82.99^{a}	80.91
	2^{nd}	78.28^{bc}	81.46^{ab}	79.87	79.22^{bc}	81.71^{a}	80.46	80.34^{b}	82.25^{a}	81.29
August	**1^{st}**	80.91^{a}	81.78^{a}	81.34	81.84^{a}	82.10^{a}	81.97	82.44^{a}	82.61^{a}	82.52
	2^{nd}	79.42^{b}	80.36^{b}	79.89	80.39^{b}	80.22^{b}	80.30	81.19^{ab}	80.37^{b}	80.78
Mean		62.35	64.67	**63.51**	62.98	65.04	**64.00**	63.58	65.45	**64.51**
LSD		1.32	1.32		1.42	1.28		1.34	1.28	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 14: Seasonal variation in relative humidity (%) within canopy of pear plants cv. Punjab Beauty trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	42.86^{g}	43.36^{h}	43.11	42.78^{g}	43.72^{h}	43.25	43.19^{h}	43.74^{h}	43.46
	2nd	43.02^{g}	45.00^{g}	44.01	42.32^{g}	43.30^{h}	42.81	42.75^{h}	43.83^{h}	43.29
May	**1st**	44.62^{f}	45.81^{g}	45.21	44.67^{f}	46.61^{g}	45.64	45.18^{g}	47.37^{g}	46.27
	2nd	50.24^{e}	55.34^{f}	52.79	51.27^{e}	56.18^{f}	53.72	51.88^{f}	56.84^{f}	54.36
June	**1st**	55.68^{d}	56.91^{e}	56.29	56.51^{d}	57.90^{e}	57.20	57.17^{e}	58.57^{e}	57.87
	2nd	59.91^{c}	65.49^{d}	62.70	60.88^{c}	66.41^{d}	63.64	61.54^{d}	67.04^{d}	64.29
July	**1st**	77.93^{b}	81.04^{a}	79.48	77.86^{b}	82.02^{a}	79.94	78.50^{bc}	82.63^{a}	80.56
	2nd	78.58^{ab}	80.44^{ab}	79.51	79.16^{a}	81.24^{a}	80.20	79.21^{ab}	82.06^{a}	80.63
August	**1st**	79.49^{a}	79.51^{b}	79.50	79.76^{a}	79.81^{b}	79.78	79.74^{a}	79.73^{b}	79.73
	2nd	77.81^{b}	77.89^{c}	77.85	77.99^{b}	77.37^{c}	77.68	77.74^{c}	77.36^{c}	77.55
Mean		61.01	63.08	**62.04**	61.32	63.46	**62.38**	61.69	63.92	**62.80**
LSD		1.40	1.16		1.28	1.08		1.20	1.10	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 15: Seasonal variation in relative humidity (%) within canopy of pear plants cv. Punjab Soft trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	43.23[h]	43.74[g]	43.48	42.93[h]	43.36[g]	43.14	43.07[h]	43.57[g]	43.32
	2nd	43.91[h]	45.92[f]	44.91	43.16[h]	44.23[g]	43.69	43.61[h]	44.11[g]	43.86
May	**1st**	45.06[g]	46.20[f]	45.63	44.99[g]	47.06[f]	46.02	45.13[g]	47.25[f]	46.19
	2nd	50.77[f]	55.71[e]	53.24	51.72[f]	56.71[e]	54.21	51.99[f]	56.95[e]	54.47
June	**1st**	56.01[e]	57.50[d]	56.75	56.99[e]	58.32[d]	57.65	57.24[e]	58.47[d]	57.85
	2nd	60.50[d]	65.88[c]	63.19	61.29[d]	66.86[c]	64.07	61.47[d]	67.15[c]	64.31
July	**1st**	77.32[c]	80.48[a]	78.90	77.45[c]	81.23[a]	79.34	77.55[c]	81.49[a]	79.52
	2nd	78.68[b]	80.66[a]	79.67	78.80[b]	81.05[a]	79.92	79.06[b]	81.07[a]	80.06
August	**1st**	80.24[a]	80.21[a]	80.22	80.23[a]	80.26[a]	80.24	80.48[a]	81.21[a]	80.84
	2nd	77.45[bc]	78.51[b]	77.98	78.26[bc]	78.67[b]	78.46	78.29[bc]	78.90[b]	78.59
Mean		61.32	63.48	**62.39**	61.58	63.78	**62.67**	61.79	64.02	**62.90**
LSD		1.24	1.32		1.28	1.18		1.16	1.10	

[*]LSD indicates the least significant difference test at $p<0.05$.
[**]Values are means with a common letter are not significantly different at 5% level.

Table 16: Seasonal variation in canopy temperature (^{o}C) of pear plants cv. Patharnakh trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		**Espalier system**			**Cordon system**			**Y-trellis system**		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	28.14^{f}	29.10^{f}	28.62	28.04^{f}	29.14^{f}	28.59	28.13^{e}	29.31^{g}	28.72
	2nd	32.03^{e}	33.42^{e}	32.72	31.86^{e}	33.29^{e}	32.57	31.54^{d}	33.28^{ef}	32.41
May	**1st**	34.44^{c}	35.69^{c}	35.06	34.25^{b}	35.52^{c}	34.88	33.92^{b}	35.16^{d}	34.54
	2nd	34.59^{b}	37.02^{a}	35.80	34.42^{b}	36.84^{a}	35.63	34.06^{b}	36.44^{b}	35.25
June	**1st**	36.09^{a}	37.34^{a}	36.71	35.60^{a}	37.14^{a}	36.37	35.32^{a}	36.78^{a}	36.05
	2nd	36.23^{a}	37.45^{a}	36.84	36.13^{a}	37.34^{a}	36.73	35.89^{a}	36.94^{a}	36.41
July	**1st**	34.20^{c}	36.43^{b}	35.31	34.02^{bc}	36.26^{b}	35.14	33.64^{b}	35.89^{c}	34.76
	2nd	34.11^{cd}	35.36^{c}	34.73	33.85^{c}	35.16^{e}	34.50	33.53^{b}	34.80^{d}	34.16
August	**1st**	33.65^{d}	34.13^{d}	33.89	33.46^{d}	33.92^{d}	33.69	33.11^{c}	33.42^{e}	33.26
	2nd	32.04^{e}	33.26^{e}	32.65	31.84^{e}	33.11^{e}	32.47	31.54^{d}	32.76^{f}	32.15
Mean		33.55	34.92	**34.23**	33.35	34.77	**34.05**	33.07	34.48	**33.77**
LSD		0.51	0.54		0.60	0.60		0.54	0.52	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 17: Seasonal variation in canopy temperature (°C) of pear plants cv. Punjab Beauty trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
April	1st	28.21^{e}	28.90^{f}	28.55	28.37^{e}	28.89^{f}	28.63	28.15^{f}	28.91^{f}	28.53
	2nd	30.79^{c}	32.39^{d}	31.59	30.55^{c}	32.11^{d}	31.33	30.21^{e}	31.81^{d}	31.01
May	1st	33.13^{b}	34.38^{c}	33.75	32.98^{b}	34.35^{c}	33.66	32.68^{c}	33.89^{c}	33.28
	2nd	33.41^{b}	35.72^{a}	34.56	33.28^{b}	34.86^{b}	34.07	32.82^{c}	35.21^{b}	34.01
June	1st	34.50^{a}	36.13^{a}	35.31	34.34^{a}	35.84^{a}	35.09	33.00^{b}	35.64^{a}	34.82
	2nd	35.13^{a}	36.27^{a}	35.70	34.97^{a}	36.35^{a}	35.66	34.60^{a}	35.74^{a}	35.17
July	1st	32.99^{b}	35.16^{b}	34.07	32.84^{b}	34.48^{c}	33.66	32.44^{c}	34.65^{b}	33.54
	2nd	32.86^{b}	34.08^{c}	33.47	32.68^{b}	34.00^{c}	33.34	32.32^{c}	33.57^{c}	32.94
August	1st	31.48^{cd}	31.99^{d}	31.73	30.92^{c}	32.26^{d}	31.59	30.86^{d}	31.43^{d}	31.14
	2nd	29.91^{d}	31.39^{e}	30.65	29.74^{d}	31.34^{e}	30.54	30.09^{e}	30.69^{e}	30.39
Mean		32.24	33.64	**32.94**	32.07	33.45	**32.75**	31.82	33.15	**32.48**
LSD		0.68	0.56		0.71	0.68		0.71	0.65	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 18: Seasonal variation in canopy temperature (^{o}C) of pear plants cv. Punjab Soft trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	28.09^{f}	29.18^{f}	28.63	28.12^{e}	29.00^{f}	28.56	28.42^{e}	28.77^{f}	28.59
	2nd	31.22^{e}	32.79^{d}	32.00	31.19^{d}	32.64^{d}	31.91	30.75^{d}	32.22^{d}	31.48
May	**1st**	33.43^{c}	34.66^{c}	34.04	33.25^{b}	34.51^{c}	33.88	32.91^{b}	34.14^{c}	33.52
	2nd	33.69^{c}	36.09^{ab}	34.89	33.50^{b}	35.95^{a}	34.72	33.20^{b}	35.59^{a}	34.39
June	**1st**	34.85^{b}	36.49^{a}	35.67	34.67^{a}	36.29^{a}	35.48	34.31^{a}	35.91^{a}	35.11
	2nd	35.60^{a}	36.64^{a}	36.12	35.39^{a}	36.47^{a}	35.93	35.01^{a}	36.10^{a}	35.55
July	**1st**	33.39^{cd}	35.56^{b}	34.47	33.19^{bc}	35.37^{b}	34.28	32.83^{b}	35.04^{b}	33.93
	2nd	33.15^{cd}	34.44^{c}	33.79	32.96^{bc}	34.29^{c}	33.62	32.66^{b}	33.94^{c}	33.30
August	**1st**	32.75^{d}	33.29^{d}	33.02	32.59^{c}	33.07^{d}	32.83	32.26^{c}	32.77^{d}	32.51
	2nd	31.32^{e}	31.99^{e}	31.65	31.24^{d}	31.84^{e}	31.54	30.89^{d}	31.47^{e}	31.18
Mean		32.75	34.11	**33.43**	32.61	33.94	**33.27**	32.32	33.60	**32.95**
LSD		0.65	0.69		0.66	0.69		0.69	0.66	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 19: Seasonal variation in soil temperature (^{o}C) underneath canopy of pear plants cv. Patharnakh trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	19.55^{h}	21.41^{g}	20.48	19.71^{g}	21.39^{h}	20.55	19.51^{h}	21.31^{h}	20.41
	2nd	23.01^{g}	24.04^{f}	23.52	22.89^{f}	23.78^{g}	23.33	22.79^{g}	23.66^{g}	23.22
May	**1st**	26.24^{e}	26.64^{d}	26.44	25.77^{d}	26.43^{e}	26.10	25.78^{e}	26.31^{e}	26.04
	2nd	26.87^{cd}	28.46^{b}	27.66	26.02^{c}	28.17^{b}	27.59	26.84^{bc}	28.08^{b}	27.46
June	**1st**	27.06^{c}	29.28^{a}	28.17	27.21^{b}	29.02^{a}	28.11	27.02^{b}	28.91^{a}	27.96
	2nd	27.68^{a}	28.37^{b}	28.02	27.52^{a}	28.12^{b}	27.82	27.43^{a}	28.00^{bc}	27.71
July	**1st**	27.33^{b}	28.31^{b}	27.82	27.29^{ab}	27.98^{b}	27.63	26.64^{cd}	27.91^{bc}	27.27
	2nd	26.64^{d}	27.41^{c}	27.02	26.76^{c}	27.50^{c}	27.13	26.42^{d}	27.83^{c}	27.12
August	**1st**	26.40^{e}	27.31^{c}	26.85	25.09^{d}	27.07^{d}	26.58	26.03^{e}	27.41^{d}	26.72
	2nd	25.67^{f}	25.90^{e}	25.78	25.56^{e}	25.79^{f}	25.67	25.41^{f}	25.89^{f}	25.65
Mean		25.65	26.71	**26.18**	25.58	26.52	**26.05**	25.39	26.53	**25.95**
LSD		0.24	0.28		0.26	0.24		0.24	0.24	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 20: Seasonal variation in soil temperature (^{o}C) underneath canopy of pear plants cv. Punjab Beauty trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	19.78^{g}	21.21^{h}	20.49	19.80^{g}	21.10^{g}	20.45	19.64^{h}	21.24^{g}	20.44
	2nd	23.56^{f}	24.46^{g}	24.01	23.40^{f}	24.35^{f}	23.87	23.21^{g}	24.11^{f}	23.66
May	**1st**	27.25^{d}	27.54^{e}	27.39	27.09^{d}	27.39^{e}	27.24	26.89^{e}	27.17^{e}	27.03
	2nd	27.64^{c}	29.36^{b}	28.50	27.49^{c}	29.19^{b}	28.34	27.67^{c}	29.00^{b}	28.33
June	**1st**	28.01^{b}	30.22^{a}	29.11	27.90^{b}	30.04^{a}	28.97	28.04^{ab}	29.88^{a}	28.96
	2nd	28.41^{a}	29.35^{b}	28.88	28.41^{a}	29.18^{b}	28.79	28.24^{a}	28.96^{b}	28.60
July	**1st**	28.00^{b}	28.88^{c}	28.44	28.30^{a}	28.81^{c}	28.55	27.76^{bc}	28.78^{b}	28.27
	2nd	27.96^{b}	28.68^{c}	28.32	27.99^{b}	28.61^{c}	28.30	27.31^{d}	28.35^{b}	27.83
August	**1st**	27.33^{d}	28.24^{d}	27.78	27.18^{d}	28.09^{d}	27.63	26.94^{e}	27.86^{c}	27.40
	2nd	26.70^{e}	27.36^{f}	27.03	26.57^{e}	27.20^{e}	26.88	26.31^{f}	27.53^{d}	26.92
Mean		26.46	27.53	**26.99**	26.41	27.40	**26.90**	26.20	27.29	**26.74**
LSD		0.26	0.24		0.28	0.26		0.28	0.24	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 21: Seasonal variation in soil temperature (°C) underneath canopy of pear plants cv. Punjab Soft trained on Espalier, Cordon and Y-trellis training systems

Fortnight Interval		Espalier system			Cordon system			Y-trellis system		
		2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
April	**1st**	19.81^{h}	21.27^{g}	20.54	19.72^{h}	21.21^{g}	20.46	19.64^{g}	21.20^{g}	20.42
	2nd	23.32^{g}	24.27^{f}	23.79	23.21^{g}	24.06^{f}	23.63	22.97^{f}	23.87^{f}	23.42
May	**1st**	26.84^{e}	27.14^{e}	26.99	26.70^{e}	27.00^{e}	26.85	26.49^{d}	26.77^{e}	26.63
	2nd	27.30^{cd}	28.95^{b}	28.12	27.14^{c}	28.84^{b}	27.99	26.95^{c}	28.63^{b}	27.79
June	**1st**	27.66^{b}	29.76^{a}	28.71	27.56^{b}	29.61^{a}	28.58	27.19^{bc}	29.42^{a}	28.30
	2nd	28.31^{a}	28.86^{b}	28.58	28.16^{a}	28.72^{b}	28.44	27.89^{a}	28.51^{b}	28.20
July	**1st**	27.56^{bc}	28.80^{b}	28.18	27.42^{b}	28.69^{b}	28.05	27.28^{b}	28.41^{b}	27.84
	2nd	27.14^{de}	28.31^{c}	27.72	26.99^{cd}	28.16^{c}	27.57	27.35^{b}	27.89^{c}	27.62
August	**1st**	26.89^{e}	27.77^{d}	27.33	26.77^{de}	27.69^{d}	27.23	26.71^{c}	27.41^{d}	27.06
	2nd	26.04^{f}	27.89^{e}	26.46	25.99^{f}	26.90^{e}	26.44	25.86^{e}	26.50^{e}	26.18
Mean		26.09	27.20	**26.64**	25.97	27.09	**26.52**	25.83	26.86	**26.34**
LSD		0.30	0.30		0.28	0.24		0.32	0.28	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

4.1.2 Vegetative characters

4.1.2.1 Plant trunk cross sectional area (cm^2)

It is evident from the data in Table 22 that maximum truck cross sectional area (TCSA) was higher in the year 2017 as compared to 2016 irrespective of training systems during the present studies. It was apparently due to growing age of plant within one year. Over a two years period, TCSA was recorded maximum in plants trained to Y-trellis system which was significantly more than the plants trained to Cordon system. It was closely followed by TCSA recorded in plants trained to Espalier system. However, the difference in plant girth of Y-trellis system and Espalier trained plants were statistically at par with each other. This general effect of training system on TCSA was true for year wise effects in 2016 and 2017 also. The mean maximum TCSA was recorded in pear cv. Patharnakh under Y-trellis system (59.41 cm^2) closely followed by Espalier system (58.20 cm^2) and minimum under Cordon training system (47.10 cm^2). This effect of training systems on TCSA in plants was similar for various pear cultivars (Patharnakh, Punjab Beauty and Punjab Soft), which is clear from the data presented in Table 22. In pear cv. Punjab Beauty, the mean maximum TCSA was recorded under Y-trellis system (52.81 cm^2) closely followed by Espalier system (52.07 cm^2) and minimum under Cordon system (42.37 cm^2). Similarly in pear cv. Punjab Soft, the mean maximum TCSA was recorded under Espalier system (40.44 cm^2) closely followed by Y-trellis system (39.96 cm^2) and minimum under Cordon system (27.44 cm^2).

In our results, the higher TCSA was found in plants trained to Espalier and Y-trellis training systems. These findings are in accordance with those of Choi *et al* (2014) who reported that maximum trunk cross sectional area in Tatura-trellis system as compared to Y-trellis and other training systems. Similarly, Rufato *et al* (2004) also found that girth of peach plants trained to Y-shaped structure were significantly lower than the plants trained to central leader system. Similar observations have been reported by Robinson *et al* (1991) in apple plants who reported that TCSA was affected by various training systems. These findings are supported by the results of Whiting and Lang (2004) who reported that trunk expansion is highly sensitive to competition from alternative sinks, whereas present results were contradiction with those of Rutkowski *et al* (2009) who stated that training system affected trunk cross-sectional area up to lesser extent in apple.

4.1.2.2 Shoot diameter (cm)

The data on this aspect presented in the Table 23 show that shoot diameter was higher in the year 2017 as compared to 2016 irrespective of training systems during the present studies. Shoot diameter increased with the growing age of plant within one year. Training systems had a significant effect on shoot diameter of pear plants during both the years. Mean maximum shoot diameter was recorded in Y-trellis system followed by Espalier system, which was statistically at par. Minimum mean shoot diameter was obtained in Cordon system which was significantly lower than the Espalier and Y-trellis training systems. This was apparently due to restriction of shoots in the plant canopy under the Cordon system. In pear cv. Patharnakh, the mean maximum shoot diameter was recorded under Espalier system (26.90 mm) followed by Y-trellis system (26.41 mm) and minimum under Cordon training system (21.83 mm).

This effect of training systems on shoot diameter in plants was similar for different pear vareities as it was in case of Pathranakh (Table 23). In pear cv. Punjab Beauty, the mean maximum shoot diameter was recorded under Y-trellis system (22.28 mm) followed by Espalier system (21.93) and minimum under Cordon system (19.22 mm). Similarly, the mean maximum shoot diameter was recorded in pear cv. Punjab Soft under Espalier system (21.43 mm) followed by Y-trellis system (20.24 mm) and minimum under Cordon system (18.80 mm). In our results, higher shoot diameter in plants trained on Espalier and Y-trellis training system, which confirm the average opinion in literature is that growth rate of shoots was higher under various training systems. Similar results were found by Choi *et al* (2014) who reported that average growth of shoots was higher in pear plants trained to Tatura-trellis training system.

4.1.2.3 Spur growth (mm)

The data regarding the spur growth presented in the Tables 24a and 24b show that spur length and diameter was higher in the year 2017 as compared to 2016 irrespective of training systems during the present studies. It was apparently due to growing age of spurs within one year. Training systems had a significant effect on spur growth of pear cv. Patharnakh and Punjab Beauty during both the years. Mean maximum spur length and diameter was recorded in Espalier system and it was closely followed by Y-trellis system, which was statistically at par with each other. Minimum mean spur length and diameter was obtained in Cordon system which was significantly lower than the Espalier and Y-trellis training systems. In pear cv. Patharnakh, the mean maximum spur diameter and length was recorded under Espalier system (7.58mm and 18.30mm) followed by Y-trellis system (7.23mm and 18.19mm) and minimum under Cordon system (6.69mm and 17.01mm). Similarly in pear cv. Punjab Beauty, the mean maximum spur diameter and length was recorded under Y-trellis system (5.25mm and 13.09mm) followed by Espalier system (5.23mm and 12.75mm) and minimum under Cordon system (4.68mm and 11.41mm). In pear cv. Punjab Soft, Training systems had a non-significant effect on spur growth (diameter and length) during both the years. This is true for year wise effects in 2016 and 2017 also. It was may be due to less formation of spurs in pear cv. Punjab Soft under subtropical conditions of

Punjab and this effect was similar under various training systems. Similar results were found by Choi *et al* (2014) in pear cultivars, who noted that spur growth and development was varied under the effect of various training systems.

4.1.2.4 Extent of spur formation

The data regarding the extent of spur formation presented in the Tables 25-27 showed the effect of different training systems on number of fruiting and vegetative spurs formation in the canopy of pear plants. Extent of spur formation was maximum in upper canopy portions followed by middle canopy, which was statistically at par with upper canopy during both the years. This effect was similar under the Espalier and Cordon training systems. Under the Y-trellis training system, extent of spur formation was maximum in the upper canopy portions, which was significantly higher than the middle and lower canopy portions. There was minimum spur formation in lower canopy portions due to increased effect of shading in lower canopy portion of plants. In pear cv. Patharnakh (Table 25), the mean maximum spur formation was recorded under Espalier training system (16.23 spurs/meter) followed by Y-trellis system (15.35 spurs/meter) and minimum under Cordon system (13.65 spurs/meter). This trend of spur formation was also similar for pear cultivars Punjab Beauty and Punjab Soft as it was in case of Patharnakh. In pear cv. Punjab Beauty (Table 26), the mean maximum spur formation was recorded under Espalier system (18.21 spurs/meter) followed by Y-trellis system (18.11 spurs/meter) and minimum under Cordon system (16.49 spurs/meter). Similarly in pear cv. Punjab soft (Table 27), the mean maximum spur formation was recorded under Espalier system (13.48 spurs/meter) followed by Y-trellis system (12.20 spurs/meter) and minimum under Cordon system (11.83 spurs/meter).

In our findings, extent of spur formation was higher in plants trained to Espalier training system followed by Y-trellis system and lower in plants trained to Cordon system for all three pear cultivars. Similarly, Klinac (1995) compared the various training systems according to spur formation. Our results confirm the average opinion in literature is that extent of spur formation was higher in upper and middle canopy portions. In general, these results were consistent with those reported in Japan (Kishimoto *et al* 1989) and New Zealand (White 1990). Shade diminishes reproductive potential directly by decreasing flowering, fruit set and fruit size; and indirectly by reducing the vegetative growth that the plant needs to support reproduction (Hampson *et al* 1996). Such detrimental effects of shading on extent of spur formation have been reported in various horticultural species (Hampson *et al* 1996; Ferree *et al* 2001).

4.1.2.5 Chlorophyll content of the leaves (SPAD)

The data on this aspect presented in Table 28 showed that various training systems had no significant effect on chlorophyll content of leaves in pear plants during the present investigations. The results showed that mean chlorophyll content was found to be varied under all training systems. But, their difference didn't attain a level of significance. A similar trend was observed in all pear cultivars viz. Patharnakh, Punjab Beauty and Punjab Soft during both the years. Similar findings have also been reported by earlier workers (Yakunina and Maslov 1978; Tanasev 1983; Shishkanu and Komarova 1988) who reported that chlorophyll content of leaves not affected by use of various training systems.

4.1.2.6 Leaf area (cm^2)

The perusal of the data in Table 29 reveals that leaf area was significantly different under various training systems during the present investigations. In pear cv. Patharnakh, plants trained to Cordon training system were recorded significantly highest leaf area over a two year period. However, the leaf area of pear plants trained to Espalier system and Y-trellis system were statistically at par during both the years. The mean maximum leaf area was recorded in pear cv. Patharnakh under Cordon system (56.35 cm^2) followed by Espalier system (54.76 cm^2) and Y-trellis system (54.49 cm^2). A similar trend was found in pear cv. Punjab Beauty as it was in case of Patharnakh during both the years and mean maximum leaf area was recorded under Cordon system (39.72 cm^2) followed by Espalier system (38.28 cm^2) and Y-trellis system (38.06 cm^2). However in pear cv. Punjab Soft, leaf area was not significantly affected by different training systems during the present studies. Similar findings were made by Carbonneau and Lespinasse (1989) who reported that angled canopies had best values for total leaf area in plants. These findings are in accordance with those of Pilau and Angelocci (2015) who reported that leaf area changes affect solar radiation interception by upper canopy portions in orange plants.

4.1.2.7 Pruning wood weight (kg/plant)

The data presented in Table 30 reveals that pruning wood weight increased from 2016 to 2017 under all training systems. It was apparently due to growing age of plants within one year and heavy pruning done in year 2017 to prevent intermingling of branches during our studies. Various training systems had a significantly effect on pruning wood weight during the present studies. It is evident from the data that significantly maximum pruning wood weight was obtained in pear plants cv. Patharnakh trained to Y-trellis system (9.42 kg/plant) followed by Espalier system (8.52 kg/plant). Minimum pruning wood weight was recorded in plants trained to Cordon system (4.70 kg/plant). Highest pruning wood/plant was recorded in Y-trellis system may be due to the vigorous growth of the shoots in terms of canopy volume and plant spread. A similar trend was found in other pear cultivars (Punjab Beauty and Punjab Soft) as it was in case of Patharnakh during both the years. In pear cv. Punjab Beauty, maximum pruning wood was recorded under Y-trellis system (10.98 kg/plant) followed by Espalier system (8.88 kg/plant) and Cordon system (4.11 kg/plant).

Table 22: Effect of training systems on trunk cross sectional area (cm^2) of pear plants cvs. Patharnakh, Punjab Beauty, Punjab Soft

Training System	Patharnakh			Punjab Beauty			Punjab Soft		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Espalier system	51.45[a]	64.95[a]	58.20	47.22[a]	56.93[a]	52.07	34.94[a]	45.95[a]	**40.44**
Cordon system	41.56[b]	52.65[b]	47.10	36.91[b]	47.84[b]	42.37	23.44[b]	31.44[b]	27.44
Y-Trellis system	52.83[a]	66.00[a]	**59.41**	47.95[a]	57.67[a]	**52.81**	34.56[a]	45.37[a]	39.96
LSD	2.54	2.35		2.47	1.86		1.78	2.48	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 23: Effect of training systems on shoot diameter (mm) of pear plants cvs. Patharnakh, Punjab Beauty, Punjab Soft

Training System	Patharnakh			Punjab Beauty			Punjab Soft		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Espalier system	23.99[a]	29.82[a]	**26.90**	19.36[a]	24.50[a]	21.93	19.35[a]	23.51[a]	**21.43**
Cordon system	18.98[b]	24.68[b]	21.83	17.20[b]	21.24[b]	19.22	16.72[b]	20.88[b]	18.80
Y-Trellis system	23.67[a]	29.16[a]	26.41	19.85[a]	24.72[a]	**22.28**	16.52[a]	23.96[a]	20.24
LSD	1.09	1.79		1.02	0.82		0.93	1.05	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 24a: Effect of training systems on spur diameter (mm) of pear plants cvs. Patharnakh, Punjab Beauty, Punjab Soft

Training System	Patharnakh			Punjab Beauty			Punjab Soft		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Espalier system	7.34[a]	7.83[a]	**7.58**	4.99[a]	5.48[a]	5.23	3.96[a]	4.51[a]	4.23
Cordon system	6.41[b]	6.98[b]	6.69	4.32[b]	5.05[b]	4.68	3.98[a]	4.40[a]	4.19
Y-Trellis system	7.02[a]	7.44[a]	7.23	4.96[a]	5.54[a]	**5.25**	4.08[a]	4.58[a]	**4.33**
LSD	0.50	0.39		0.56	0.46		NS	NS	

*LSD indicates the least significant difference test at p<0.05. **Values are means with a common letter are not significantly different at 5% level.

Table 24b: Effect of training systems on spur length (mm) of pear plants cvs. Patharnakh, Punjab Beauty, Punjab Soft

Training System	Patharnakh			Punjab Beauty			Punjab Soft		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Espalier system	17.91[a]	18.69[a]	**18.30**	11.96[a]	13.74[a]	12.75	12.72[a]	13.75[a]	**13.23**
Cordon system	16.36[b]	17.66[b]	17.01	10.95[b]	11.88[b]	11.41	12.28[a]	13.80[a]	13.04
Y-Trellis system	17.48[a]	18.90[a]	18.19	12.54[a]	13.64[a]	**13.09**	12.31[a]	13.72[a]	13.01
LSD	0.51	0.65		0.72	0.87		NS	NS	

*LSD indicates the least significant difference test at p<0.05. **Values are means with a common letter are not significantly different at 5% level.

Table 25: Effect of training systems and portion of the plant canopy on spur formation (fruiting and vegetative spurs/meter) of pear cv. Patharnakh

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	12.73^{b}	13.33^{b}	13.03	10.97^{b}	11.22^{b}	11.09	12.11^{c}	12.36^{c}	12.23
Middle	17.01^{a}	17.78^{a}	17.39	14.60^{a}	14.99^{a}	14.79	15.94^{b}	16.67^{b}	16.30
Upper	17.71^{a}	18.81^{a}	18.26	14.73^{a}	15.42^{a}	15.07	17.14^{a}	17.90^{a}	17.52
Mean	15.82	16.64	**16.23**	13.43	13.88	**13.65**	15.06	15.64	**15.35**
LSD	1.44	1.15		0.92	0.76		0.83	1.04	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 26: Effect of training systems and portion of the plant canopy on spur formation (fruiting and vegetative spurs/meter) of pear cv. Punjab Beauty

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	15.27^{b}	15.74^{b}	15.50	14.13^{b}	14.56^{b}	14.34	14.52^{c}	15.01^{c}	14.76
Middle	18.93^{a}	19.41^{a}	19.17	16.97^{a}	17.53^{a}	17.25	18.24^{b}	19.31^{b}	18.77
Upper	19.91^{a}	20.00^{a}	19.95	17.57^{a}	18.20^{a}	17.88	20.32^{a}	21.28^{a}	20.80
Mean	18.04	18.38	**18.21**	16.22	16.76	**16.49**	17.69	18.53	**18.11**
LSD	1.15	1.54		1.08	0.96		1.32	1.24	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 27: Effect of training systems and portion of the plant canopy on spur formation (fruiting and vegetative spurs/meter) of pear cv. Punjab Soft

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Lower	10.33[b]	11.17[b]	10.75	9.62[b]	9.67[b]	9.64	10.05[c]	10.21[c]	10.13
Middle	14.05[a]	15.27[a]	14.66	12.61[a]	12.83[a]	12.72	12.12[b]	12.68[b]	12.40
Upper	14.43[a]	15.62[a]	15.02	12.66[a]	13.63[a]	13.14	13.67[a]	14.49[a]	14.08
Mean	12.94	14.02	**13.48**	11.63	12.04	**11.83**	11.95	12.46	**12.20**
LSD	0.40	0.79		0.98	1.57		0.72	0.84	

*LSD indicates the least significant difference test at p<0.05. **Values are means with a common letter are not significantly different at 5% level.

Table 28: Effect of training systems on chlorophyll content (SPAD value) in leaves of pear plants cvs. Patharnakh, Punjab Beauty, Punjab Soft

Training System	Patharnakh			Punjab Beauty			Punjab Soft		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Espalier system	48.68[a]	49.80[a]	49.24	50.92[a]	52.18[a]	**51.55**	49.43[a]	50.53[a]	49.98
Cordon system	49.20[a]	49.45[a]	49.32	50.87[a]	51.80[a]	51.33	49.83[a]	50.75[a]	**50.29**
Y-Trellis system	49.14[a]	50.05[a]	**49.59**	50.45[a]	51.74[a]	51.09	49.59[a]	50.80[a]	50.19
LSD	NS	NS		NS	NS		NS	NS	

*LSD indicates the least significant difference test at p<0.05. **Values are means with a common letter are not significantly different at 5% level.

Table 29: Effect of training systems on leaf area (cm^2) of pear plants cvs. Patharnakh, Punjab Beauty, Punjab Soft

Training System	Patharnakh			Punjab Beauty			Punjab Soft		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Espalier system	54.54^{b}	54.98^{b}	54.76	37.69^{b}	38.88^{b}	38.28	36.80^{a}	37.26^{a}	37.03
Cordon system	56.23^{a}	56.48^{a}	**56.35**	39.21^{a}	40.23^{a}	**39.72**	37.77^{a}	37.82^{a}	**37.79**
Y-Trellis system	54.54^{b}	54.45^{b}	54.49	37.46^{b}	38.67^{b}	38.06	36.70^{a}	37.34^{a}	37.02
LSD	0.69	1.20		0.55	0.44		NS	NS	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 30: Effect of training systems on pruning wood (kg/plant) of pear plants cvs. Patharnakh, Punjab Beauty, Punjab Soft

Training System	Patharnakh			Punjab Beauty			Punjab Soft		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Espalier system	8.29^{b}	8.75^{b}	8.52	8.71^{b}	9.06^{b}	8.88	2.78^{b}	2.87^{b}	2.82
Cordon system	4.15^{c}	5.26^{c}	4.70	4.05^{c}	4.17^{c}	4.11	0.97^{c}	1.05^{c}	1.01
Y-Trellis system	9.28^{a}	9.56^{a}	**9.42**	10.87^{a}	11.09^{a}	**10.98**	3.84^{a}	3.88^{a}	**3.86**
LSD	0.42	0.58		0.35	0.32		0.26	0.24	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Similarly in pear cv. Punjab Soft, maximum pruning wood was recorded under Y-trellis system (3.86 kg/plant) followed by Espalier system (2.82 kg/plant) and Cordon system (1.01 kg/plant). Among all the training systems, pruning wood weight per plant was noted higher in Y-trellis system followed by Espalier system and lower under Cordon system for all three pear cultivars. Our results were partially in accordance with the observations obtained by Singh (2001) who reported that pruning wood weight over a two year period was maximum in Y-trellis shaped plants as compared to plants trained to modified leader system in peach.

4.1.3 Flowering and fruiting characters

4.1.3.1 Time of Flowering

The data regarding the flowering period presented in Tables 31-33 reveals that start of flowering, full bloom and end of flowering was affected by various training systems in pear cultivars during the present studies. Effect of different training systems on flowering period in pear cv. Patharnakh was recorded during both the years. In pear cv. Patharnakh (Table 31), the flowering period ranged from 2nd week of February to 1st week of March. In pear cv. Punjab Beauty (Table 32), the flowering period varied from 1st week of March to 3rd week of March. Similarly in pear cv. Punjab Soft (Table 33), the flowering period observed from 1st week of March to end of March month. Flowering in pear cultivars observed early (i.e. 2-3 days in Patharnakh and Punjab Soft; 2-5 days in Punjab Beauty) in plants trained to Cordon system than the Espalier system and Y-trellis training systems. A similar trend was observed in all three pear cultivars that flowering was early in plants trained to Cordon system. It was may be due to difference in translocation of assimilates to sinks in plants trained to Cordon system as compared to other training systems. Our results confirm the average opinion in literature is that the time of flowering was affected by various training systems in pear cultivars. Similar results were obtained by Abd-El-Rahman (2002) and Jana (2015) who observed that shoot bending in plants significantly increased C/N ratio of spur wood, which influences early flower bud formation in pear plants.

4.1.3.2 Flower bud density

The data presented in Tables 34-36 reveals that flower bud density (FBD) was significantly affected by different training systems in pear cultivars (Patharnakh, Punjab Beauty and Punjab Soft) during the present studies. Flower bud density was noted higher in the year 2017 as compared to 2016, irrespective of the training systems. In pear cv. Patharnakh (Table 34), plants trained to Espalier system recorded maximum FBD in middle and upper canopy portions and it was statistically at par during both the years. Plants trained to Cordon and Y-trellis system recorded maximum FBD in upper canopy portions followed by middle canopy, which was statistically varied from upper canopy during both the years. It was recorded significantly minimum in lower canopy portions under all three training systems. The mean maximum FBD was recorded under Espalier system (2.73 flowering spurs/meter) followed by Y-trellis system (2.61 flowering spurs/m) and Cordon system (1.95 flowering spurs/m).

In pear cv. Punjab Beauty (Table 35), plants trained to Espalier and Cordon system recorded maximum FBD in middle and upper canopy portions, which was statistically at par with each other. Plants trained to Cordon and Y-trellis system recorded maximum FBD in upper canopy portions followed by middle canopy, which was statistically different from upper canopy during both the years. FBD was recorded significantly minimum in lower canopy portions under all three training systems. The mean maximum FBD was recorded under Espalier system (2.30 flowering spurs/m) followed by Y-trellis system (2.23 flowering spurs/m) and Cordon system (1.43 flowering spurs/m). In pear cv. Punjab Soft (Table 36), a similar trend of FBD was observed in lower, middle and upper canopy portions of pear plants trained on Espalier, Cordon and Y-trellis training systems as it was in case of Punjab Beauty. The mean maximum FBD was recorded under Espalier system (1.58 flowering spurs/m) followed by Y-trellis system (1.49 flowering spurs/m) and Cordon system (1.38 flowering spurs/m).

In our findings, maximum FBD was observed under Espalier system, it was apparently due to proper distribution of light within middle and upper canopy portions, presence of thicker shoots and higher TCSA; which resulted in higher carbohydrate accumulation. Similarly, mean flower bud density was higher in upper canopy portions as compared to lower canopy parts under various training systems. It was due to comparatively reduced radiation interception within lower canopy parts. The present results are in accordance with those reported by Mika *et al* (1981) in apple; Ristevski (1982) in pear and Singh (2003) in guava. Heinicke (1963) reported that availability of proper sunlight to the lower branches of plant became a limiting factor thus it adversely affected flower bud differentiation. Environmental conditions inside the canopy can be modified significantly by the training systems, which subsequently affected flower bud density (Krause and Weis 1991). Our results were partially in accordance with the observations obtained by Huett (2004) who reported that canopy management techniques involve maximum utilization of light and keep a balance between light interception and light distribution within the plant canopy. It was most important component for flowering and flower bud formation in horticultural plants.

4.1.3.3 Fruit set (%)

The data presented in Table 37 reveals that the fruit set was not affected significantly in pear plants by various training systems under present investigations. The general effect of training systems on fruit set was true for both years. A similar trend was found in all pear cultivars viz. Patharnakh, Punjab Beauty and Punjab Soft. Among all the pear cultivars, fruit set was recorded highest in Patharnakh followed by Punjab Beauty and minimum fruit set was recorded in Punjab Soft. In our observations, the mean maximum fruit set was recorded under Espalier system in pear cultivars viz. Patharnakh (30.80%), Punjab Beauty (15.55%) and Punjab Soft (9.46%). It was due to better light distribution within canopy of pear plants trained on Espalier system. Similar results were found by Doud and Ferree (1980) who reported that significant reduction in light levels within plant canopies reduced fruit set. These findings are in accordance with those of Abd-El-Rahman (2002) and Mohamed (2012) who reported that shoot bending increased fruit set in pear cv. Le Conte than normal plants. However, it was not varied between various training systems.

4.1.3.4 Relative pattern of fruiting in plant canopy

The data presented in Tables 38-40 show that relative pattern of fruiting was higher within upper and middle canopy portions of pear plants trained to various training systems. Fruiting was recorded minimum in lower canopy portions under all three training systems over a two year period. In pear cv. Patharnakh (Table 38), mean maximum fruiting was recorded in middle canopy portions (45.27%) followed by upper canopy (40.72%) under Espalier system, which was statistically at par with each other. Similarly in plants trained to Cordon training system, mean maximum fruiting was recorded in middle canopy portions (47.34%) followed by upper canopy (42.07%) and it was significantly varied with each other. In plants trained to Y-trellis system, mean maximum fruiting was recorded in upper canopy portions (45.06%) followed by middle canopy (36.57%), which was also significantly different. However, minimum fruiting was recorded in the lower canopy portions under all training systems due to low light interceptions. In pear cv. Punjab Beauty (Table 39), mean maximum fruiting was recorded within the middle canopy (46.32% and 48.19%) closely followed by upper canopy (44.34% and 44.48%) under Espalier and Cordon system, respectively. It was not significantly different between middle and upper canopy portions. Similarly in plants trained to Y-trellis system, maximum fruiting was recorded in upper canopy portions (50.83%) followed by middle canopy (41.46%), which was significantly different from middle canopy. A similar trend was found in pear cv. Punjab Soft as it was in case of Punjab Beauty (Table 40). This is true for year wise effects in 2016 and 2017 also. However, minimum fruiting was recorded in the lower canopy portions irrespective of the effect of various training systems due to low light interception to lower canopy parts.

Table 31: Effect of training systems on time of flowering in pear plants cv. Patharnakh

Training System	Start of flowering		Full bloom		End of flowering	
	2016	2017	2016	2017	2016	2017
Espalier system	10 Feb.	16 Feb.	22 Feb.	28 Feb.	29 Feb.	6 March
Cordon system	8 Feb.	13 Feb.	21 Feb.	26 Feb.	26 Feb.	4 March
Y-Trellis system	10 Feb.	17 Feb.	23 Feb.	29 Feb.	28 Feb.	8 March

Table 32: Effect of training systems on time of flowering in pear plants cv. Punjab Beauty

Training System	Start of flowering		Full bloom		End of flowering	
	2016	2017	2016	2017	2016	2017
Espalier system	3 March	4 March	12 March	15 March	16 March	20 March
Cordon system	29 Feb.	1 March	8 March	10 March	12 March	18 March
Y-Trellis system	3 March	3 March	12 March	15 March	16 March	21 March

Table 33: Effect of training systems on time of flowering in pear plants cv. Punjab Soft

Training System	Start of flowering		Full bloom		End of flowering	
	2016	2017	2016	2017	2016	2017
Espalier system	6 March	11 March	17 March	20 March	21 March	28 March
Cordon system	4 March	9 March	15 March	18 March	19 March	25 March
Y-Trellis system	6 March	12 March	17 March	22 March	21 March	30 March

Table 34: Effect of training systems and portion of the plant canopy on flower bud density (flowering buds/meter) of pear cv. Patharnakh

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Lower	1.75^{b}	2.00^{b}	1.87	0.82^{c}	1.11^{c}	0.96	1.54^{c}	1.75^{c}	1.64
Middle	2.82^{a}	3.04^{a}	2.93	1.96^{b}	2.32^{b}	2.14	2.75^{b}	2.89^{b}	2.82
Upper	3.29^{a}	3.50^{a}	3.39	2.64^{a}	2.86^{a}	2.75	3.28^{a}	3.50^{a}	3.39
Mean	2.62	2.85	**2.73**	1.81	2.10	**1.95**	2.52	2.71	**2.61**
LSD	0.95	0.90		0.44	0.42		0.45	0.43	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 35: Effect of training systems and portion of the plant canopy on flower bud density (flowering buds/meter) of pear cv. Punjab Beauty

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Lower	1.52^{b}	1.63^{b}	1.57	0.45^{b}	0.49^{b}	0.47	1.45^{c}	1.56^{c}	1.50
Middle	2.38^{a}	2.66^{a}	2.52	1.63^{a}	1.91^{a}	1.77	2.13^{b}	2.16^{b}	2.14
Upper	2.70^{a}	2.91^{a}	2.80	1.95^{a}	2.16^{a}	2.05	2.95^{a}	3.16^{a}	3.05
Mean	2.20	2.40	**2.30**	1.34	1.52	**1.43**	2.18	2.29	**2.23**
LSD	0.56	0.47		0.54	0.48		0.57	0.47	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 36: Effect of training systems and portion of the plant canopy on flower bud density (flowering buds/meter) of pear cv. Punjab Soft

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	0.76[b]	1.01[b]	0.88	0.26[b]	0.51[b]	0.38	0.54[c]	0.83[c]	0.68
Middle	1.83[a]	1.79[a]	1.81	1.69[a]	1.94[a]	1.81	1.44[b]	1.51[b]	1.47
Upper	1.97[a]	2.11[a]	2.04	1.87[a]	2.04[a]	1.95	2.40[a]	2.26[a]	2.33
Mean	1.52	1.64	**1.58**	1.27	1.50	**1.38**	1.46	1.53	**1.49**
LSD	0.36	0.39		0.45	0.52		0.85	0.46	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 37: Effect of training systems on fruit set (%) of pear plants cvs. Patharnakh, Punjab Beauty, Punjab Soft

Training System	Patharnakh			Punjab Beauty			Punjab Soft		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Espalier system	29.75[a]	31.86[a]	**30.80**	15.23[a]	15.88[a]	**15.55**	10.42[a]	8.50[a]	**9.46**
Cordon system	29.17[a]	31.18[a]	30.17	14.63[a]	15.82[a]	15.22	9.82[a]	8.43[a]	9.12
Y-Trellis system	29.56[a]	31.48[a]	30.52	14.90[a]	16.00[a]	15.45	10.15[a]	8.14[a]	9.14
LSD	NS	NS		NS	NS		NS	NS	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 38: Effect of training systems and portion of the plant canopy on relative pattern of fruiting (%) of pear cv. Patharnakh

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Lower	13.97[b]	15.42[b]	14.69	10.68[c]	11.53[c]	11.10	18.45[c]	19.72[c]	19.08
Middle	45.40[a]	45.14[a]	**45.27**	47.31[a]	47.37[a]	**47.34**	36.95[b]	36.19[b]	36.57
Upper	41.41[a]	40.04[a]	40.72	42.48[b]	41.66[b]	42.07	45.39[a]	44.73[a]	**45.06**
LSD	6.82	6.32		4.77	4.02		5.92	5.12	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 39: Effect of training systems and portion of the plant canopy on relative pattern of fruiting (%) of pear cv. Punjab Beauty

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Lower	9.78[b]	10.54[b]	10.16	5.99[b]	9.32[b]	7.65	7.71[c]	8.42[c]	8.06
Middle	46.21[a]	46.44[a]	**46.32**	48.68[a]	47.71[a]	**48.19**	42.42[b]	40.51[b]	41.46
Upper	44.85[a]	43.83[a]	44.34	45.61[a]	43.36[a]	44.48	50.25[a]	51.41[a]	**50.83**
LSD	4.78	4.38		4.90	6.00		4.89	5.30	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 40: Effect of training systems and portion of the plant canopy on relative pattern of fruiting (%) of pear cv. Punjab Soft

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Lower	16.08[b]	12.97[b]	14.52	13.28[b]	11.42[b]	12.35	14.79[c]	13.44[c]	14.11
Middle	43.38[a]	43.59[a]	**43.48**	45.48[a]	43.48[a]	**44.48**	35.91[b]	37.25[b]	36.58
Upper	40.92[a]	44.66[a]	42.79	40.81[a]	45.42[a]	43.11	49.56[a]	49.11[a]	**49.33**
LSD	4.56	4.40		5.41	4.04		4.08	3.59	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

In our studies, relative pattern of fruiting was observed more uniformly in middle and upper canopy portions of pear plants trained to Espalier system due to well distribution of sunlight. Our results are partially in accordance with the observations obtained by Krause and Weis (1991) who reported that changes in canopy shape to enable shoots to intercept more light. Consequently, the goal of plant design is to intercept a high proportion of available light and to adequately expose the maximum number of fruiting sites by distributing the light uniformly within the plant canopy (Lakso *et al* 1989). Similar findings have also been reported by Hampson *et al* (1996) who noted that shade diminishes reproductive potential of plants. Therefore, the maximize light interception in plant canopies regulated by various training systems (Fischer and Orduz- Rodriguez 2012) and fruit distribution within plant canopies depend on this important aspect of canopy management.

4.1.3.5 Fruit growth rate

The data regarding the fruit growth rate is presented in Tables 41a-43b shows that fruit diameter and length was measured at fortnightly interval until fruit harvest during both the years under all the training systems. In pear cv. Patharnakh, fruit diameter increased significantly from 30 DAFS to 150 DAFS under all training systems (Table 41a). However, maximum fruit diameter was recorded under Cordon training system during harvest period. A similar trend was noted in fruit length as it was in case of fruit diameter (Table 41b). Higher fruit growth rate was recorded from 45 DAFS to 120 DAFS in pear fruits. Lower fruit growth rate was observed in plants trained to Y-trellis system as compared to other training systems. Similarly in pear cv. Punjab Beauty, fruit diameter increased significantly from 30 DAFS to 135 DAFS under all training systems, which was statistically at par with 150 DAFS. However, maximum fruit diameter and length was recorded in plants trained to Cordon system during harvesting period of fruits (Tables 42a and 42b). Similarly, higher fruit growth rate was recorded from 45 DAFS to 120 DAFS as it in case of Patharnakh. Lower fruit growth rate was observed in plants trained to Y-trellis system as compared to other training systems. Fruit diameter of pear cv. Punjab Soft was increased significantly from 30 DAFS to 120 DAFS under all training systems, which was statistically at par with 135 DAFS and 150 DAFS (Table 43a). However, maximum fruit diameter was recorded in plants trained to Espalier training system followed by Y-trellis system and minimum fruit diameter in plants trained to Cordon system during the period of fruit harvesting. A similar trend was recorded in case of fruit length (Table 43b).

Table 41a: Effect of training systems on fruit growth rate viz. fruit diameter of pear cv. Patharnakh

Days after fruit set (DAFS)	Espalier system			Cordon system			Y-trellis system		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
30	16.03^{i}	17.11^{i}	16.57	16.42^{i}	17.38^{i}	16.90	15.83^{h}	16.92^{h}	16.37
45	18.78^{h}	21.16^{h}	19.97	19.97^{h}	21.13^{h}	20.55	18.58^{g}	20.17^{g}	19.37
60	28.28^{g}	30.66^{g}	29.47	29.47^{g}	31.67^{g}	30.57	28.07^{f}	30.67^{f}	29.37
75	40.53^{f}	42.91^{f}	41.72	41.72^{f}	44.88^{f}	43.30	40.33^{e}	43.92^{e}	42.12
95	49.53^{e}	51.91^{e}	50.72	51.72^{e}	53.88^{e}	52.80	50.33^{d}	51.92^{d}	51.12
105	59.13^{d}	60.41^{d}	59.77	60.22^{d}	63.76^{d}	61.99	58.83^{c}	59.42^{c}	59.12
120	64.38^{c}	65.66^{c}	65.02	65.47^{c}	69.01^{c}	67.24	63.08^{b}	63.67^{b}	63.37
135	68.40^{b}	69.18^{b}	68.79	71.27^{b}	73.76^{b}	72.51	67.30^{a}	67.59^{a}	67.44
150	70.11^{a}	71.58^{a}	70.84	74.46^{a}	74.78^{a}	74.62	68.01^{a}	68.39^{a}	68.20
LSD	1.26	1.34		1.96	2.04		1.09	1.11	

[*]LSD indicates the least significant difference test at $p<0.05$. [**]Values are means with a common letter are not significantly different at 5% level.

Table 41b: Effect of training systems on fruit growth rate viz. fruit length of pear cv. Patharnakh

Days after fruit set (DAFS)	Espalier system			Cordon system			Y-trellis system		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
30	18.61[h]	20.13[h]	19.37	19.42[h]	20.67[h]	20.04	19.83[h]	20.23[h]	20.03
45	24.36[g]	26.88[g]	25.62	25.17[g]	27.42[g]	26.29	24.08[g]	26.48[g]	25.28
60	35.86[f]	38.38[f]	37.12	36.67[f]	38.92[f]	37.79	35.58[f]	37.98[f]	36.78
75	47.11[e]	50.63[e]	48.87	47.92[e]	50.17[e]	49.04	47.31[e]	49.80[e]	48.55
95	57.61[d]	59.13[d]	58.37	58.42[d]	60.67[d]	59.54	56.81[d]	58.73[d]	57.77
105	66.86[c]	69.38[c]	68.12	68.67[c]	69.92[c]	69.29	66.06[c]	68.98[c]	67.52
120	72.61[b]	75.13[b]	73.87	73.42[b]	75.27[b]	74.34	69.81[b]	71.73[b]	70.77
135	74.38[a]	76.75[a]	75.56	76.28[a]	78.79[a]	77.53	71.39[ab]	71.78[ab]	71.58
150	76.76[a]	76.99[a]	76.87	79.84[a]	80.17[a]	80.00	72.43[a]	72.42[a]	72.42
LSD	1.86	1.94		2.46	2.54		1.69	1.81	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 42a: Effect of training systems on fruit growth rate viz. fruit diameter of pear cv. Punjab Beauty

Days after fruit set (DAFS)	Espalier system			Cordon system			Y-trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
30	15.96[h]	16.82[h]	16.39	16.34[h]	17.28[h]	16.81	15.91[h]	16.68[h]	16.29
45	19.76[g]	21.02[g]	20.39	20.14[g]	22.48[g]	21.31	19.71[g]	21.88[g]	20.79
60	27.51[f]	28.77[f]	28.14	26.89[f]	29.23[f]	28.06	26.46[f]	29.36[f]	27.91
75	37.01[e]	38.27[e]	37.64	37.39[e]	38.73[e]	38.06	36.96[e]	39.13[e]	38.04
95	47.26[d]	48.52[d]	47.89	48.64[d]	49.98[d]	49.31	47.25[d]	49.38[d]	48.31
105	56.51[c]	58.77[c]	57.64	57.89[c]	59.23[c]	58.56	56.46[c]	58.63[c]	57.54
120	59.51[b]	62.23[b]	60.87	62.01[b]	64.57[b]	63.29	60.83[b]	61.12[b]	60.97
135	62.71[a]	63.61[a]	63.16	65.11[a]	65.98[a]	65.54	62.36[ab]	61.81[a]	62.08
150	62.86[a]	63.76[a]	63.31	65.26[a]	66.13[a]	65.69	62.51[a]	61.96[a]	62.23
LSD	1.36	1.12		1.58	1.44		1.12	1.32	

[*]LSD indicates the least significant difference test at $p<0.05$. [**]Values are means with a common letter are not significantly different at 5% level.

Table 42b: Effect of training systems on fruit growth viz. fruit length of pear cv. Punjab Beauty

Days after fruit set (DAFS)	Espalier system			Cordon system			Y-trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
30	21.21[g]	21.97[g]	21.59	20.95[h]	22.18[h]	21.56	21.35[g]	22.15[g]	21.75
45	26.01[f]	28.17[f]	27.09	26.45[g]	28.68[g]	27.56	26.15[f]	28.35[f]	27.25
60	37.76[e]	38.92[e]	38.34	37.22[f]	39.43[f]	38.32	36.91[e]	38.10[e]	37.50
75	47.51[d]	48.67[d]	48.09	47.97[e]	49.18[e]	48.57	46.66[d]	49.85[d]	48.25
95	57.76[c]	59.92[c]	58.84	59.22[d]	61.43[d]	60.32	58.91[c]	59.10[c]	59.00
105	67.01[b]	69.17[b]	68.09	69.47[c]	72.28[c]	70.87	66.61[b]	68.35[b]	67.48
120	72.78[a]	73.29[a]	73.03	73.46[b]	75.93[b]	74.69	72.56[a]	72.86[a]	72.71
135	74.11[a]	74.21[a]	74.16	76.61[a]	76.98[a]	76.79	73.28[a]	73.66[a]	73.47
150	74.23[a]	74.33[a]	74.28	76.73[a]	77.10[a]	76.91	73.40[a]	73.78[a]	73.59
LSD	1.96	1.72		2.08	1.94		1.82	2.02	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 43a: Effect of training systems on fruit growth rate viz. fruit diameter of pear cv. Punjab Soft

Days after fruit set (DAFS)	Espalier system			Cordon system			Y-trellis system		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
30	15.22[g]	16.03[g]	15.62	15.13[g]	15.78[g]	15.45	15.26[g]	16.18[g]	15.72
45	17.27[f]	19.48[f]	18.37	17.53[f]	20.88[f]	19.20	17.31[f]	19.63[f]	18.47
60	27.77[e]	29.98[e]	28.87	28.03[e]	30.38[e]	29.20	27.81[e]	30.13[e]	28.97
75	36.77[d]	38.98[d]	37.87	37.03[d]	39.38[d]	38.20	36.81[d]	38.13[d]	37.47
95	45.98[c]	48.98[c]	47.48	46.03[c]	47.38[c]	46.70	45.81[c]	47.13[c]	46.47
105	53.18[b]	55.40[b]	54.29	52.17[b]	52.68[b]	52.42	53.42[b]	55.55[b]	54.48
120	58.98[a]	59.42[a]	59.20	55.61[a]	55.79[a]	55.70	57.69[a]	57.92[a]	57.80
135	59.13[a]	59.57[a]	59.35	55.76[a]	55.94[a]	55.85	57.84[a]	58.07[a]	57.95
150	59.18[a]	59.62[a]	59.40	55.81[a]	55.99[a]	55.90	57.89[a]	58.12[a]	58.00
LSD	1.28	1.07		1.54	1.51		1.02	1.28	

*LSD indicates the least significant difference test at p<0.05. **Values are means with a common letter are not significantly different at 5% level.

Table 43b: Effect of training systems on fruit growth rate viz. fruit length of pear cv. Punjab Soft

Days after fruit set (DAFS)	Espalier system			Cordon system			Y-trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
30	19.02^{g}	19.83^{g}	19.42	19.21^{g}	20.08^{g}	19.64	19.37^{g}	20.01^{g}	19.64
45	24.07^{f}	26.28^{f}	25.17	23.83^{f}	25.96^{f}	24.89	24.32^{f}	26.46^{f}	25.39
60	33.57^{e}	35.78^{e}	34.67	32.33^{e}	33.46^{e}	32.89	33.82^{e}	35.96^{e}	34.89
75	44.57^{d}	47.78^{d}	46.17	44.33^{d}	46.46^{d}	45.39	45.86^{d}	47.96^{d}	46.91
95	54.26^{c}	57.08^{c}	55.67	54.35^{c}	55.46^{c}	54.90	55.78^{c}	56.96^{c}	56.37
105	62.82^{b}	65.02^{b}	63.92	60.30^{b}	62.66^{b}	61.48	63.20^{b}	65.44^{b}	64.32
120	67.56^{a}	67.98^{a}	67.77	63.87^{a}	64.21^{a}	64.04	67.00^{a}	67.34^{a}	67.17
135	67.68^{a}	68.10^{a}	67.89	63.99^{a}	64.33^{a}	64.16	67.12^{a}	67.46^{a}	67.29
150	67.73^{a}	68.15^{a}	67.94	64.04^{a}	64.38^{a}	64.21	67.17^{a}	67.51^{a}	67.34
LSD	1.88	1.67		2.04	2.01		1.72	1.98	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Our results further show that maximum fruit maturity period was recorded in pear cv. Patharnakh (150 days) followed by Punjab Beauty (135 days) and Punjab Soft (120 days). Our results confirm the average opinion in literature that fruit growth rate was showed simple sigmoid curve in pear cultivars. Similarly, Arzani *et al* (2008) investigated fruits of Asian pears and results indicated that simple and complete fruit sigmoid curves existed for all genotypes, even though the period of each phase of fruit growth was different in studied genotypes. Similar results reported by other research workers in fruits of some species (Bramardi *et al* 1998; Szabo *et al* 1998; Bertelsen 2002). Canopies with low light interceptions suffer from shading effect that reduced fruit growth and development whereas delay the fruit maturity. Such detrimental effects of shading on fruit growth rate have been reported in horticultural species (Ferree *et al* 2001; Hampson *et al* 1996; Marini and Sowers 1990).

4.1.4 Fruit yield characters

4.1.5.1 Number of fruits per plant

The data presented in Table 44 reveals that number of fruits/plant were significantly higher during the year 2017 as compared to 2016. It was may be due to maturity of plants over one year growth period. However, number of fruits/plant significantly affected by various training systems during the present investigations. In pear cv. Patharnakh, the significantly maximum numbers of fruits were recorded under Espalier system (87.43 fruits/plant) followed by Y-trellis system (79.85 fruits/plant). However, the minimum numbers of fruits were recorded in plants trained to Cordon training system (35.07 fruits/plant). In pear cvs. Punjab Beauty and Punjab Soft, the maximum numbers of fruits were recorded in plants trained to Espalier training system followed by Y-trellis system, which was statistically at par with each other. However, the minimum numbers of fruits were recorded in plants trained to Cordon system as it was in case of Patharnakh. The general effect of different training systems on number of fruits/plant was true for both the years. In pear cv. Punjab Beauty, the mean maximum numbers of fruits were noted under Espalier system (30.93 fruits/plant) followed by Y-trellis system (29.43 fruits/plant) and Cordon system (15.14 fruits/plant). Similarly, the mean maximum numbers of fruits were recorded under Espalier system (12.64 fruits/plant) closely followed by Y-trellis system (11.64 fruits/plant) and Cordon system (6.14 fruits/plant) in pear cv. Punjab Soft.

In our studies, results further show that lower number of fruits per plant was noted in plants trained to Cordon system, it was may be due to less number of bearing shoots on the arms of these plants. Whereas, Espalier system plants had higher canopy volume and more number of bearing shoots as compared to plants trained to other training systems. A similar trend was observed under all training systems of pear cultivars viz. Patharnakh, Punjab Beauty and Punjab Soft. Among all three cultivars of pear, maximum fruit number per plant was recorded in Patharnakh followed by Punjab Beauty and minimum fruit number per plant was recorded in Punjab Soft under various training systems. Loreti *et al* (1996) obtained maximum number of fruits under Tatura-trellis system in peach cv. July Elberta. Yield of nectarine plants increased with Y-shaped planting system due to proper distribution of fruits on shoots with optimum exposure of leaves to light (Lannini *et al* 2002). Our results were partially in accordance with the observations obtained by Fischer and Orduz-Rodriguez (2012) who reported that light interception in plant canopies regulated by different training systems and fruit distribution within plant canopies depends on this important aspect of fruiting.

4.1.5.2 Yield per plant (Kg)

The data presented in Table 45 reveals that yield/plant was higher during the year 2017 as compared to 2016. Yield per plant was significantly affected by various training systems during the present studies. Pear plants cv. Patharnakh trained to Espalier system recorded significantly maximum yield per plant (18.426 kg/plant) followed by Y-trellis system (15.717 kg/plant). The minimum mean yield per plant was recorded under Cordon system (7.848 kg/plant). However, pear cvs. Punjab Beauty and Punjab Soft trained to Espalier system recorded mean maximum yield per plant followed by Y-trellis system, which was statistically at par with each other. In pear cv. Punjab Beauty, the mean maximum yield/plant was noted under Espalier training system (4.583 kg/plant) followed by Y-trellis system (4.444 kg/plant)) and Cordon system (2.395 kg/plant). Similarly, the mean maximum yield/plant was noted under Y-trellis system (1.439 kg/plant) closely followed by Espalier system (1.409 kg/plant) and Cordon system (0.647 kg/plant) in pear cv. Punjab Soft.

Present results further show that mean minimum yield per plant was recorded under Cordon training system in all cultivars of pear. It was may be due to less number of bearing shoots on the arms of these plants. Whereas, Espalier training system plants had higher canopy volume and more number of bearing shoots. A similar trend was found under all training systems during both the years. Among all three cultivars of pear, maximum yield per plant was recorded in Patharnakh followed by Punjab Beauty and minimum yield per plant was recorded in Punjab Soft under subtropical conditions of Punjab. These results are in line with previous findings of Morgan (2005) in pear that the V-trellis has more promising results in the aspect of a smaller canopy and more number of fruits resulting in significantly higher yields. Similarly, fruit yield in apples is highly correlated with interception of radiation during the growing season and accounts for most variation in yield attributed to training systems

(Robinson and Lakso 1991; Wünsche and Lakso 2000). Various workers (Ahmed and Morad 2000; Lu *et al* 2003; Rufato *et al* 2004 in peach) also have suggested a close relationship between fruit yield and radiation intercepted in fruit crops. Similar results were found by Koyama *et al* (2012) and Rivas (2008) who reported that yield was directly related to photosynthetic efficiency of plants.

4.1.5.3 Yield per hectare (tonnes)

The data on yield/ha presented in Table 46 reveals that various training systems significantly affected yield per hectare. The mean maximum yield/ha was recorded in pear cv. Patharnakh plants trained to Espalier system (20.46 tonnes/ha) followed by Y-trellis system (19.64 tonnes/ha) during both the years. The minimum mean yield/ha was recorded under Cordon system (17.44 tonnes/ha). The general effect of training systems on yield/ha was true for both the years of our studies. However in pear cv. Punjab Beauty, the mean maximum yield/ha was noted under Y-trellis system (5.55 tonnes/ha) followed by Espalier system (5.09 tonnes/ha) and Cordon system (4.82 tonnes/ha), respectively. Similarly in pear cv. Punjab Soft, the mean maximum yield/ha was recorded under Y-trellis system (1.79 tonnes/ha) followed by Espalier system (1.56 tonnes/ha) and Cordon system (1.43 tonnes/ha). Whereas, the maximum yield/ha was recorded in pear cv. Patharnakh followed by Punjab Beauty and minimum in Punjab Soft.

These results are in accordance with those of Lavee and co-workers (2012) who observed that lower yield/ha in plants trained to Cordon system might be due to less number of bearing shoots and poor light interception due to dense canopy. Increased amount of light interception and more uniformly distribution of light within the plant canopy also increased yield of Y-trellis, V-trellis and Tatura-trellis training systems (Caruso *et al* 2008). These results are in accordance with the previous work of various workers (Nuzzo *et al* 2002; Chenyl *et al* 2002; Kiprijanovski *et al* 2009; Ramirez and Kallarackal 2015). Similar results showed by Sosna and Czaplicka (2008) that pear plants trained as a V-Güttingen training system gave higher yield per hectare.

4.1.5.4 Production efficiency (Kg per plant/trunk cross sectional area)

The data on production efficiency presented in Table 47 reveals that it was significantly affected by various training systems during the present investigations. Pear cvs. Patharnakh and Punjab Beauty plants trained to Espalier system recorded significantly highest production efficiency followed by Y-trellis system and attained a statistically significant difference. However, statistically minimum production efficiency was recorded in plants trained to Cordon training system. In pear cv. Patharnakh, the maximum production efficiency was noted under Espalier system (0.317 kg/cm^2) followed by Y-trellis system

(0.264 kg/cm^2) and Cordon system (0.165 kg/cm^2). In pear cv. Punjab Beauty, the maximum production efficiency was noted under Espalier system (0.086 kg/cm^2) followed by Y-trellis system (0.082 kg/cm^2) and Cordon system (0.054 kg/cm^2). However in pear cv. Punjab Soft, plants trained to Y-trellis system (0.035 kg/cm^2) recorded highest production efficiency followed by Espalier system (0.033 kg/cm^2), which was statistically at par with each other. The minimum mean production efficiency was recorded under Cordon training system (0.022 kg/cm^2).

In our studies, higher production efficiency was found in plants trained to Espalier system due to more number of bearing shoots as compared to plants trained to other training systems. A similar trend was observed in different training systems of pear cultivars viz. Patharnakh, Punjab Beauty and Punjab Soft. Among all three cultivars of pear, the maximum production efficiency was recorded in Patharnakh followed by Punjab Beauty and minimum in Punjab Soft. Similar findings were observed by Robinson *et al* (1991) who reported that higher light interception and light distribution within plant canopy was under Y-trellis system resulting in higher yield and cropping efficiency. Similar results were found by Kim and Co-workers (2008) who observed that various training systems for apple and pear cultivars have increased the production efficiency in plants. Our results were partially in accordance with the observations obtained by Arsov *et al* (2013) who reported that training systems significantly affected the yield efficiency in apple. Higher cumulative yield efficiency per plant was recorded in Vase Pergola training system as compared to Tatura-trellis in pear (Choi *et al* 2014).

4.1.5.5 Crop load (Number of fruits per plant/trunk cross sectional area)

The data regarding the crop load presented in Table 48 reveals that it was significantly affected by various training systems during the present studies. Pear plants cvs. Patharnakh and Punjab Beauty trained to Espalier system recorded significantly highest crop load in plants followed by Y-trellis system during both the years. In pear cv. Patharnakh, the mean maximum crop load was noted under Espalier system (1.514 cm^{-2}) followed by Y-trellis system (1.351 cm^{-2}) and Cordon system (0.744 cm^{-2}). In pear cv. Punjab Beauty, the maximum crop load was noted under Espalier system (0.588 cm^{-2}) followed by Y-trellis system (0.549 kg/cm^{-2}) and Cordon system (0.348 kg/cm^{-2}). However in pear cv. Punjab Soft, plants trained to Y-trellis system recorded highest crop load (0.307 cm^{-2}) closely followed by Espalier system (0.303 cm^{-2}), which was statistically at par with each other. The minimum crop load was recorded under Cordon training system (0.214 cm^{-2}) as it was in case of Patharnakh.

Table 44: Effect of training systems on fruit number/plant of pear cvs. Patharnakh, Punjab Beauty, Punjab Soft

Training System	Patharnakh			Punjab Beauty			Punjab Soft		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Espalier system	84.57^{a}	90.29^{a}	**87.43**	28.86^{a}	33.00^{a}	**30.93**	11.29^{a}	14.00^{a}	**12.64**
Cordon system	33.71^{c}	36.43^{c}	35.07	13.71^{b}	16.57^{b}	15.14	5.71^{b}	6.57^{b}	6.14
Y-Trellis system	77.00^{b}	82.71^{b}	79.85	27.29^{a}	31.57^{a}	29.43	11.00^{a}	12.29^{a}	11.64
LSD	1.88	2.47		1.70	2.07		1.41	1.81	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 45: Effect of training systems on yield/plant (kg) of pear cvs. Patharnakh, Punjab Beauty, Punjab Soft

Training System	Patharnakh			Punjab Beauty			Punjab Soft		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Espalier system	17.632^{a}	19.221^{a}	**18.426**	4.241^{a}	4.926^{a}	**4.583**	1.249^{a}	1.569^{a}	1.409
Cordon system	7.485^{c}	8.212^{c}	7.848	2.161^{b}	2.629^{b}	2.395	0.598^{b}	0.697^{b}	0.647
Y-Trellis system	15.057^{b}	16.378^{b}	15.717	4.106^{a}	4.783^{a}	4.444	1.365^{a}	1.513^{a}	**1.439**
LSD	0.842	0.940		0.298	0.361		0.174	0.241	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 46: Effect of training systems on yield/hectare (tonnes) of pear plants cvs. Patharnakh, Punjab Beauty, Punjab Soft

Training System	Patharnakh			Punjab Beauty			Punjab Soft		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Espalier system	19.58	21.35	**20.46**	4.71	5.47	5.09	1.38	1.74	1.56
Cordon system	16.63	18.25	17.44	4.30	5.34	4.82	1.32	1.54	1.43
Y-Trellis system	18.82	20.47	19.64	5.13	5.97	**5.55**	1.70	1.89	**1.79**

Table 47: Effect of training systems on production efficiency (kg/TCSA) of pear plants cvs. Patharnakh, Punjab Beauty, Punjab Soft

Training System	Patharnakh			Punjab Beauty			Punjab Soft		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Espalier system	0.341^{a}	0.294^{a}	**0.317**	0.088^{a}	0.085^{a}	**0.086**	0.034^{b}	0.033^{a}	0.033
Cordon system	0.177^{c}	0.154^{c}	0.165	0.056^{c}	0.053^{c}	0.054	0.024^{c}	0.021^{b}	0.022
Y-Trellis system	0.282^{b}	0.246^{b}	0.264	0.083^{b}	0.081^{b}	0.082	0.038^{a}	0.032^{a}	**0.035**
LSD	0.022	0.015		0.005	0.003		0.003	0.005	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 48: Effect of training systems on crop load (number of fruits per plant/TCSA) of pear plants cvs. Patharnakh, Punjab Beauty, Punjab Soft

Training System	Patharnakh			Punjab Beauty			Punjab Soft		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Espalier system	1.643^{a}	1.385^{a}	**1.514**	0.604^{a}	0.573^{a}	**0.588**	0.311^{a}	0.296^{a}	0.303
Cordon system	0.802^{c}	0.686^{c}	0.744	0.358^{c}	0.339^{c}	0.348	0.227^{b}	0.202^{b}	0.214
Y-Trellis system	1.454^{b}	1.248^{b}	1.351	0.558^{b}	0.540^{b}	0.549	0.332^{a}	0.283^{a}	**0.307**
LSD	0.087	0.046		0.029	0.020		0.031	0.040	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

In our findings, a similar trend was observed in different pear cultivars (Patharnakh and Punjab Beauty) under all training systems. Higher crop load was found in plants trained to Espalier system and it was may be due to more number of fruits per plant. Less crop load was observed during the year 2017 as compared to 2016, it was may be due to growth of plants in one year, therefore increases TCSA of plants. Among all three cultivars of pear, the crop load was recorded highest in Patharnakh followed by Punjab Beauty and lowest crop load in Punjab Soft. These results are agree with those reported by Whiting *et al* (2005) who observed that different training systems affect the TCSA and crop load per plants. Appropriate canopy and crop load management are therefore required to obtain an adequate balance between the yield and fruit size (Bennewitz *et al* 2011). Similar findings by Robinson *et al* (1991) who reported that fruit size of 'Empire' and 'Delicious' apple cultivars was inversely related to crop load. These results are in line with previous findings by Van Buskirk (1994) in pear cultivars 'Bosc' and 'Comice' who observed that crop load in plants influenced by various training systems.

4.1.4 Fruit quality parameters

4.1.4.1 Fruit weight (g)

Data presented in Tables 49-51 show that mean fruit weight was higher during 2017 as compared to 2016 irrespective of various training systems during the present studies. Patharnakh plants trained to Cordon training system recorded mean maximum fruit weight (221.09 g) over a two years period which was significantly higher than the plants trained to other training systems (Table 49). It was followed by Espalier system (209.87 g) and minimum mean fruit weight was recorded under Y-trellis system (195.21 g). Higher average fruit weight was recorded under Cordon system was apparently due to better translocation of assimilates towards sinks. A similar trend was noted in pear cv. Punjab Beauty (Table 50) as it was in case of Patharnakh and plants trained to Cordon system recorded mean maximum fruit weight (155.10 g) over a two years period which was significantly higher than the plants trained to other training systems. It was followed by Y-trellis system (149.07 g). However in pear cv. Punjab Soft (Table 51), plants trained to Y-trellis system recorded mean maximum fruit weight (111.88 g) over a two years period and It was closely followed by Espalier system (110.34 g). This is true for year wise effects in 2016 and 2017 also. Among all the pear cultivars, maximum fruit weight was recorded in Patharnakh followed by Punjab Beauty and Punjab Soft, respectively under sub-tropical conditions of Punjab.

As far as fruit weight in different plant canopy levels are concerned, the data in Table 49 show that fruit weight in upper canopy portions (225.25 g) was significantly highest and it was closely followed by middle canopy (221.59 g) under Espalier system in pear cv.

Patharnakh. It was statistically at par with middle canopy portions. The minimum fruit weight was recorded in lower canopy portions (182.86 g) under Espalier system. A similar trend was recorded in case of plants trained to Cordon training system. In Patharnakh plants trained to Y-trellis system was found that fruit weight in upper canopy portions (209.59 g) was significantly highest than the middle canopy (201.43 g) and lower canopy portions (174.60 g). A similar trend was found in pear cultivars viz. Punjab Beauty (Table 50) and Punjab Soft (Table 51) as it was in case of Patharnakh.

In our studies, an increase in fruit weight in the upper canopy portions may be due to the fact that this part was better exposed to solar radiation and had more efficient photosynthetic activity resulting in higher availability of photoassimilates which could be translated by the plant to produce higher fruit weight. Similar results were found by Wagenmakers and Callesen (1995) in apple cultivars, who reported that average fruit weight in plants was affected by the use of different training systems. These results are in accordance with those of Loreti *et al* (1989) and Singh (2003) who also observed that fruits harvested from the lower canopy portions of the plant weighed less than the fruit harvested from the upper parts in peach cultivars. This suggests that fruits in the outer-portions of the canopy benefit from better light exposure because leaves in those positions have greater photosynthesis efficiency (Barritt *et al* 1987). The significant effects of location within the canopy on both primary metabolites and secondary metabolites demonstrate the importance of light exposure on apple fruit quality such as fruit weight (Feng *et al* 2014). Similarly, Kappel and Brownlee (2001) investigated average fruit weight was significantly affected by training systems. These results are agreed with those reported by Dallabetta *et al* (2014) who reported that fruit quality (fruit weight) was dependent upon cultivar, training system and position in the canopy.

4.1.4.2 Fruit size (cm)

The data regarding the fruit size presented in Tables 52a-54b reveals that over the two years of study, different training systems had a significant effect on fruit size of pear cultivars. The mean maximum fruit size (diameter and length) was found in plants trained to Cordon system (72.79 mm and 77.67 mm) which was significantly highest than the plants trained to two other training systems. It was followed by Espalier system (69.47mm and 74.54 mm) and minimum fruit size was recorded under Y-trellis system (68.22 mm and 72.28 mm) in pear cv. Patharnakh (Tables 52a and 52b). Large fruit size in Cordon system was apparently due to better translocation of photoassimilates or less crop load. A similar trend was observed in pear cv. Punjab Beauty (Tables 53a and 53b) that plants trained to Cordon system recorded mean maximum fruit size (64.02 mm and 75.46 mm). However, in pear cv. Punjab Soft (Tables 54a and 54b), plants trained to Espalier system recorded mean maximum fruit size (57.00 mm and 65.76 mm) over a two years period. It was followed by Y trellis system (56.62 mm and 65.76 mm). The minimum fruit size was recorded under Cordon training system in case of pear cv. Punjab Soft. This is true for year wise effects in 2016 and 2017 also. Among all the pear cultivars, maximum fruit size (diameter and length) was recorded in Patharnakh followed by Punjab Beauty and Punjab Soft, respectively under sub-tropical conditions of Punjab.

Data in the Tables 52a-54b further show that fruit position in canopy also affected the fruit size significantly. Irrespective of training systems, fruits of upper canopy portions were bigger in size as compared to lower canopy parts. Fruit size (diameter and length) both in the upper and lower canopy portions was found to be maximum in plants trained to Cordon training system and minimum in Y-trellis system. In pear cv. Patharnakh, the mean maximum fruit size was found in upper canopy portions under Espalier system, which was statistically at par with middle canopy of plants (Tables 52a and 52b). A similar trend was noted under Cordon training system as it was in case of Espalier system. However under Y-trellis system, the maximum fruit size was recorded in upper canopy portions followed by middle canopy, which was significantly different from each other. Smaller sized fruits were distributed in lower portions of canopy due to comparatively reduced radiation penetration into deep layers of canopy. A similar trend for fruit size distribution within plant canopies was found in pear cultivars viz. Punjab Beauty (Tables 53a and 53b) and Punjab Soft (54a and 54b) under all three training systems in our studies.

These results are agreement with those reported by McDermott and Sherman (1989) who reported that upright and compact canopy interfered with light penetration during critical periods of fruit development resulting in smaller sized fruits. The adverse effects of lower light levels were due to the effects on both cell division and cell size (Jackson and Palmer 1977). Fruit size is the major component of fruit quality in pear. Similar results were obtained by Loreti *et al* (1980) who reported that fruit weights were 22-23% lower in crop harvested from lower third of the crown in peach cv. Suncrest. Similarly, Van Buskirk (1994) reported that fruit size was observed higher in upper and middle canopy portions in pear cultivars ‘Bosc’ and ‘Comice’. Our results are partially in accordance with the observations obtained by Farina *et al* (2005) who reported that different sized fruits were obtained from plants which were trained to various training systems had evenly distribution of fruits throughout the plant canopy. Thus study on fruit growth and development in different climatic conditions is urgently needed to estimate the final fruit size with relation to canopy management (Nejatian 2001; Mattiuz *et al* 1997; Salisbury and Ross 1992).

Table 49: Effect of training systems and portion of the plant canopy on fruit weight (g) of pear cv. Patharnakh

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	180.60[b]	185.13[b]	182.86	191.27[b]	196.06[b]	193.66	173.26[c]	175.94[c]	174.60
Middle	219.64[a]	223.54[a]	221.59	230.55[a]	234.01[a]	232.28	200.25[b]	202.62[b]	201.43
Upper	223.29[a]	227.22[a]	225.25	236.16[a]	238.50[a]	237.33	208.38[a]	210.81[a]	209.59
Mean	207.84	211.91	**209.87**	219.33	222.86	**221.09**	193.96	196.46	**195.21**
LSD	7.55	7.40		9.58	9.16		6.54	6.09	

*LSD indicates the least significant difference test at p<0.05. **Values are means with a common letter are not significantly different at 5% level.

Table 50: Effect of training systems and portion of the plant canopy on fruit weight (g) of pear cv. Punjab Beauty

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	125.72[b]	127.18[b]	126.45	132.37[b]	134.12[b]	133.24	129.80[c]	131.04[c]	130.42
Middle	152.24[a]	156.64[a]	154.44	162.53[a]	165.46[a]	163.99	153.55[b]	155.64[b]	154.59
Upper	156.71[a]	158.56[a]	157.63	167.58[a]	168.55[a]	168.06	161.77[a]	162.63[a]	162.20
Mean	144.89	147.46	**146.17**	154.16	156.04	**155.10**	148.37	149.77	**149.07**
LSD	5.60	5.08		5.91	6.14		5.28	5.16	

*LSD indicates the least significant difference test at p<0.05. **Values are means with a common letter are not significantly different at 5% level.

Table 51: Effect of training systems and portion of the plant canopy on fruit weight (g) of pear cv. Punjab Soft

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	85.73[b]	86.70[b]	86.21	85.33[c]	85.04[c]	85.18	86.32[c]	86.76[c]	86.54
Middle	119.55[a]	121.25[a]	120.40	105.94[b]	108.24[b]	107.09	120.96[b]	121.51[b]	121.23
Upper	124.09[a]	124.73[a]	124.41	112.32[a]	115.93[a]	114.12	127.83[a]	127.95[a]	127.89
Mean	109.79	110.89	**110.34**	101.19	103.07	**102.13**	111.70	112.07	**111.88**
LSD	6.83	7.32		4.12	4.62		6.57	6.35	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 52a: Effect of training systems and portion of the plant canopy on fruit diameter (mm) of pear cv. Patharnakh

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	65.50^{b}	66.72^{b}	66.11	67.92^{b}	69.01^{b}	68.46	64.47^{c}	65.81^{c}	65.14
Middle	70.17^{a}	71.72^{a}	70.94	74.19^{a}	75.22^{a}	74.70	68.46^{b}	68.93^{b}	68.69
Upper	71.01^{a}	71.75^{a}	71.38	74.72^{a}	75.69^{a}	75.20	70.37^{a}	71.30^{a}	70.83
Mean	68.89	70.06	**69.47**	72.28	73.31	**72.79**	67.77	68.68	**68.22**
LSD	2.14	2.36		3.35	3.38		1.44	1.67	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 52b: Effect of training systems and portion of the plant canopy on fruit length (mm) of pear cv. Patharnakh

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	69.34^{b}	70.51^{b}	69.92	71.91^{b}	73.39^{b}	72.65	68.08^{c}	69.16^{c}	68.62
Middle	76.46^{a}	77.05^{a}	76.75	79.07^{a}	80.16^{a}	79.61	72.10^{b}	72.76^{b}	72.43
Upper	76.37^{a}	77.54^{a}	76.95	80.00^{a}	81.54^{a}	80.77	75.25^{a}	76.35^{a}	75.80
Mean	74.06	75.03	**74.54**	76.99	78.36	**77.67**	71.81	72.76	**72.28**
LSD	3.09	3.43		3.27	3.98		2.11	2.95	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 53a: Effect of training systems and portion of the plant canopy on fruit diameter (mm) of pear cv. Punjab Beauty

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	58.81[b]	59.17[b]	58.99	59.65[b]	60.85[b]	60.25	58.77[c]	58.82[c]	58.79
Middle	62.15[a]	64.33[a]	63.24	65.07[a]	66.21[a]	65.64	62.48[b]	62.53[b]	62.50
Upper	63.06[a]	64.72[a]	63.89	66.24[a]	66.12[a]	66.18	63.99[a]	64.04[a]	64.01
Mean	61.34	62.74	**62.04**	63.65	64.39	**64.02**	61.75	61.83	**61.79**
LSD	1.24	1.17		1.71	1.76		1.22	1.32	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 53b: Effect of training systems and portion of the plant canopy on fruit length (mm) of pear cv. Punjab Beauty

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	70.48[b]	71.24[b]	70.86	71.90[b]	72.54[b]	72.22	70.60[c]	71.06[c]	70.83
Middle	73.25[a]	74.87[a]	74.06	76.42[a]	77.17[a]	76.79	73.13[b]	73.94[b]	73.53
Upper	74.41[a]	74.97[a]	74.69	76.86[a]	77.89[a]	77.37	75.18[a]	76.28[a]	75.73
Mean	72.71	73.69	**73.20**	75.06	75.87	**75.46**	72.97	73.76	**73.36**
LSD	1.30	1.41		1.31	1.48		2.03	2.21	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 54a: Effect of training systems and portion of the plant canopy on fruit diameter (mm) of pear cv. Punjab Soft

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	51.51[b]	52.18[b]	51.84	50.75[c]	51.72[c]	51.23	51.53[c]	52.09[c]	51.81
Middle	58.75[a]	59.88[a]	59.31	55.77[b]	56.40[b]	56.08	57.48[b]	58.28[b]	57.88
Upper	59.56[a]	60.14[a]	59.85	57.36[a]	58.27[a]	57.81	59.76[a]	60.61[a]	60.18
Mean	56.61	57.40	**57.00**	54.63	55.46	**55.04**	56.26	56.99	**56.62**
LSD	1.16	1.06		1.40	1.34		1.48	1.38	

*LSD indicates the least significant difference test at p<0.05. **Values are means with a common letter are not significantly different at 5% level.

Table 54b: Effect of training systems and portion of the plant canopy on fruit length (mm) of pear cv. Punjab Soft

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	60.51[b]	61.32[b]	60.91	59.42[c]	59.66[c]	59.54	60.54[c]	61.07[c]	60.80
Middle	67.39[a]	68.32[a]	67.85	63.49[b]	65.04[b]	64.26	66.96[b]	67.82[b]	67.39
Upper	68.16[a]	68.89[a]	68.52	65.51[a]	66.84[a]	66.17	68.52[a]	69.66[a]	69.09
Mean	65.35	66.18	**65.76**	62.81	63.85	**63.33**	65.34	66.18	**65.76**
LSD	1.58	1.69		1.42	1.65		1.43	1.83	

*LSD indicates the least significant difference test at p<0.05. **Values are means with a common letter are not significantly different at 5% level.

4.1.4.3 Fruit firmness (lbf)

The data presented in Tables 55-57 shows that fruit firmness was significantly affected by different training systems during the present studies. Mean maximum fruit firmness was recorded in plants trained to Y-trellis system (15.39 lbf) followed by Espalier system (15.21 lbf). Minimum fruit firmness was recorded under Cordon system (14.30 lbf) and it might be due to large sized fruits harvested from this system (Table 55). The general effect of training systems on fruit firmness was true for year wise affect also. Similarly, in pear cv. Punjab Beauty (Table 56), mean maximum fruit firmness was recorded under Y-trellis system (14.40 lbf) closely followed by Espalier system (14.34 lbf) and minimum fruit firmness was recorded under Cordon system (14.07 lbf). However in pear cv. Punjab Soft (Table 57), mean maximum fruit firmness was recorded in Cordon system (11.68 lbf) followed by Espalier and Y-trellis system (11.40 lbf). Among all pear cultivars, the maximum fruit firmness was found in Patharnakh followed by Punjab Beauty and Punjab Soft, respectively.

As far as the fruit firmness in different canopy portions was concerned, highest mean fruit firmness was observed in lower canopy portions as compared to upper and middle canopy levels. In pear cv. Patharnakh, fruit firmness was recorded highest in the lower canopy portions (14.64 lbf). It was recorded lesser in the middle (14.24 lbf) and upper canopy (14.14 lbf), which was statistically at par with each other under Espalier training system. A similar trend was noted under Cordon training system as in case of Espalier system. However, it increased from upper canopy to lower canopy levels under Y-trellis system (Table 55). Similar pattern for variation in fruit firmness was found in pear cultivars viz. Punjab Beauty (Table 56) and Punjab Soft (Table 57) under various training systems. Similarly, fruit firmness was recorded higher in lower canopy portions. It was recorded lower in middle and upper canopy parts, which was statistically at par with each other. This was true during both the years of study. Decrease of fruit firmness in upper canopy portions may be due to the reason that fruits are directly exposed to solar radiation which led to early maturity of fruits as compared to fruits harvested from lower canopy parts. These results are in line with the previous findings of Warrington *et al* (1996) who reported that greenest and firmest fruits of ‘Granny Smith’ apples harvested from inner canopy parts. Similar findings were observed by Deell *et al* (2001) and Sharma (2014) in apple that fruit firmness was affected by different training systems and fruit distribution within canopy portions.

4.1.4.4 Total soluble solids (°Brix)

It is evident from the Tables 58-60 that total soluble solids content of fruits was significantly affected by various training systems during both the years. In pear cv. Patharnakh, maximum fruit TSS content was recorded in plants trained to Espalier system (14.01°Brix) followed by Y-trellis system (13.91 °Brix). It was noted minimum in Cordon system (13.64 °Brix) may be due to large sized fruits in this system (Table 58). The general effect of training systems on fruit TSS was true for both the years of study. A Similar trend for fruit TSS was found in pear cultivars Punjab Beauty (Table 59) and Punjab Soft (Table 60) as it was in case of Patharnakh, when plants trained different training systems. As far as the fruit TSS in different canopy portions was concerned, highest mean fruit TSS was observed in upper canopy portions followed by middle canopy, which was statistically at par with each other. It was recorded minimum in fruits borne in lower canopy parts under different training systems. A similar trend was noted in pear cultivars viz. Patharnakh, Punjab Beauty and Punjab Soft, plants trained on various training systems (Tables 58-60). This was true during both the years of study. Among all three pear cultivars, maximum fruit TSS was found in Punjab Beauty followed by Patharnakh and Punjab Soft, respectively.

In our findings, fruit total soluble solids content was recorded highest in fruits harvested from upper canopy portions and it may be due to the reason that fruits were directly exposed to solar radiation which led to early maturity of fruits as compared to fruits harvested from lower canopy parts. Less TSS content in fruits harvested from lower canopy parts was due to the fact that low radiation interception during critical period of the fruit development; and affected the fruit quality in plants adversely. These results are in close conformity with those of other workers (Smart and Robinson 1991; Cortell and Kennedy 2006; Ristic *et al* 2007; Rahmani *et al* 2015) who also found that fruits in exposed portion of canopy exhibit higher concentration of sugars as compared to shaded fruits. Fruit soluble solids content decreased linearly from canopy top to bottom portions (Farina *et al* 2005). Here, fruits harvested from the outer-canopy had higher soluble solids content. These findings are consistent with those reported for the 'Aroma' apple (Nilsson and Gustavsson 2007) as well as pear (Sanchez and Righetti 1990). He *et al* (2008) harvested peach fruits from various canopy positions and found a positive correlation of soluble solids with canopy irradiance level. The significant effects of location within plant canopy on both primary metabolites and secondary metabolites demonstrate the importance of light exposure on apple fruit quality (Feng *et al* 2014).

4.1.4.5 Titratable acidity (%)

The data presented in Tables 61-63 reveals that fruit acidity was significantly affected by different training systems during the present investigations. In pear cv. Patharnakh (Table 61), maximum fruit acidity was recorded in plants trained to Espalier system (0.327 %) followed by Y-trellis system (0.324 %) and minimum fruit acidity (0.280 %) was recorded under Cordon training system. The general effect of various training systems on fruit acidity was true for year wise affects also. A similar trend was found in pear cv. Punjab Beauty as it was in case of Patharnakh (Table 62). Maximum fruit acidity was recorded in plants trained to Y-trellis system (0.253 %) closely followed by Espalier system (0.248 %) and minimum fruit acidity was recorded under Cordon training system (0.208 %). However in pear plants cv. Punjab Soft (Table 63), fruit acidity was recorded highest under Cordon system (0.168 %) due to small sized fruits and it was followed by Espalier system (0.164 %) and Y-trellis (0.163 %) training system, respectively.

As far as the fruit acidity in different canopy portions was concerned, highest mean fruit acidity was observed in lower canopy portions. Less fruit acidity was observed in middle and upper canopy portions, which was statistically at par with each other. A similar trend was found in all three pear cultivars viz. Patharnakh, Punjab Beauty and Punjab Soft, plants trained on different training systems (Tables 61-63). This general effect was similar during both the years of our studies. Among all three pear cultivars, maximum fruit acidity was observed in cv. Patharnakh followed by Punjab Beauty and Punjab Soft, respectively.

In our observations, higher level of fruit acidity was recorded in lower canopy portions and it may be due to the reason that fruits are under shade effect of upper canopy which led to late maturity of fruits as compared to fruits harvested from middle and upper canopy portions. The general effect of training systems on fruit acidity was true for year wise effect also. An increase in fruit acidity in the lower canopy portions may be due to reduced illumination which affected fruit quality adversely. Similar results were found by Sansavini *et al* (1980) who observed significant increase in acidity of apple fruits, harvested from lower plant's canopy portions. These findings are in close conformity with those reported by Rahmani *et al* (2015) in grapes and Mmoradiedigehsara *et al* (2015) in Kiwifruit whose observations are that canopy level of plants influenced fruit acidity under various training systems.

4.1.4.6 Total sugars (%)

The data regarding the total sugars presented in Tables 64-66 shows that it was significantly influenced by various training systems during both the years of studies. In pear cv. Patharnakh (Table 64), mean maximum total sugars were recorded in fruits harvested from Espalier system (11.18%) followed by Y-trellis system (11.15%) and minimum total sugars in fruits were recorded under Cordon training system (10.88%). Similar trend about total fruit sugars was found in pear cvs. Punjab Beauty (Table 65) and Punjab Soft (Table 66), plants trained on different training systems. As far as the total sugars content of fruits borne in different canopy portions were concerned, highest mean total sugars content was observed in fruits harvested from upper canopy portions (11.44%) followed by middle canopy (11.38%), which was statistically at par with each other. Minimum total sugars were noted in fruits harvested from lower canopy parts (10.73%). Similar results were found in pear cvs. Punjab Beauty and Punjab Soft as it was in case of Patharnakh, plants trained on different training systems. Among all three pear cultivars, maximum total sugars were found in fruits of pear cv. Punjab Beauty followed by Patharnakh and Punjab Soft, respectively.

In our studies, increase of sugars in fruits harvested from upper canopy portions may be due to the reason that fruits are directly exposed to solar radiation which led to early maturity of fruit as compared to fruits harvested from lower canopy parts. Reduced level of sugars in the fruits of lower canopy parts was due to reduction in radiation penetration with the depth of the canopy. These results are in accordance with those of Smart and Robinson (1991) who noted that fruit in exposed portions of the canopy generally exhibit higher concentrations of sugars as compared to shaded fruits. Similarly, an increase in sugar content of peach fruits harvested from upper parts of the canopy was also observed by Singh (2001). These results are in close conformity with those of other workers (Cortell and Kennedy 2006; Ristic *et al* 2007; Rahmani *et al* 2015) who also found that fruits in outer portion of canopy exhibit higher concentration of sugars as compared to fruits harvested from inner canopy portions due to the effect of shading within plant canopies.

4.1.4.7 Starch Content (%)

The data presented in Tables 67-69 shows that starch content of fruits was significantly affected by different training systems during the present studies in both the years. In pear cv. Patharnakh (Table 67), mean maximum starch content in fruits was recorded in plants trained to Y-trellis system (1.988%) followed by Espalier system (1.981%) and minimum starch content in fruits was recorded under Cordon system (1.881%). A similar trend about starch content in fruits was found in pear cv. Punjab Beauty as was observed in case of Patharnakh (Table 68). Fruit starch content was noted maximum in plants trained on Y-trellis system (1.554%) and minimum under Cordon training system (1.473%). However in pear cv. Punjab Soft (Table 69), maximum starch content in fruits were recorded under Espalier system (1.403%) closely followed by Y-trellis system (1.400%). As far as the fruit starch content in different canopy parts was concerned, highest mean starch content was observed in lower canopy portions (2.072%). In pear cv. Patharnakh, less starch content was recorded in fruits harvested from middle (1.948%) and upper (1.925%) canopy portions and it was statistically at par with each other (Table 67). Similar results were found in other cultivars of pear viz. Punjab Beauty and Punjab Soft trained on different training systems under study (Tables 68 and 69).

In our findings, an increase in fruit starch content in lower canopy portions may be due to reduced illumination, which affected fruit quality adversely. Similar results found by Singh and Kanwar (2004) while studying the effect of training system on radiation regime and fruit starch content of peach fruits. Similarly, Dallabetta *et al* (2014) performed the study for the comparison between the training systems and observed that plant architecture description and fruit position in the canopy were monitored during the fruit maturation and ripening. Our results were partially in accordance with the observations obtained by Feng *et al* (2014) who observed that fruit quality viz. starch content in fruits was dependent upon cultivars, training systems and position of fruits in plant canopies. The significant effects of location within the canopy on both primary metabolites and secondary metabolites demonstrate the importance of light exposure on apple fruit quality.

Table 55: Effect of training systems and portions of the plant canopy on fruit firmness (lbf) of pear cv. Patharnakh

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	15.29^{a}	15.85^{a}	15.57	14.88^{a}	15.43^{a}	15.15	15.42^{a}	15.96^{a}	15.69
Middle	14.79^{b}	15.35^{b}	15.07	13.58^{b}	14.23^{b}	13.90	15.12^{ab}	15.66^{ab}	15.39
Upper	14.69^{b}	15.25^{b}	14.97	13.50^{b}	14.17^{b}	13.83	14.79^{b}	15.40^{b}	15.09
Mean	14.93	15.49	**15.21**	13.99	14.51	**14.30**	15.11	15.68	**15.39**
LSD	0.26	0.27		0.34	0.35		0.31	0.32	

[*]LSD indicates the least significant difference test at $p<0.05$. [**]Values are means with a common letter are not significantly different at 5% level.

Table 56: Effect of training systems and portions of the plant canopy on fruit firmness (lbf) of pear cv. Punjab Beauty

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	14.37^{a}	14.91^{a}	14.64	14.12^{a}	14.70^{a}	14.41	14.31^{a}	14.93^{a}	14.62
Middle	13.97^{b}	14.51^{b}	14.24	13.62^{b}	14.20^{b}	13.91	14.11^{a}	14.73^{ab}	14.42
Upper	13.84^{b}	14.45^{b}	14.14	13.59^{b}	14.17^{b}	13.88	13.81^{b}	14.52^{b}	14.16
Mean	14.06	14.63	**14.34**	13.78	14.36	**14.07**	14.08	14.73	**14.40**
LSD	0.23	0.27		0.31	0.35		0.28	0.32	

[*]LSD indicates the least significant difference test at $p<0.05$. [**]Values are means with a common letter are not significantly different at 5% level.

Table 57: Effect of training systems and portions of the plant canopy on fruit firmness (lbf) of pear cv. Punjab Soft

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	11.38^{a}	12.02^{a}	11.70	11.64^{a}	12.27^{a}	11.95	11.33^{a}	11.99^{a}	11.66
Middle	10.98^{b}	11.62^{b}	11.30	11.31^{b}	11.87^{b}	11.59	11.03^{b}	11.79^{b}	11.36
Upper	10.86^{b}	11.52^{b}	11.19	11.20^{b}	11.80^{b}	11.50	10.85^{b}	11.49^{b}	11.17
Mean	11.08	11.72	**11.40**	11.38	11.98	**11.68**	11.07	11.73	**11.40**
LSD	0.24	0.21		0.32	0.29		0.29	0.26	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 58: Effect of training systems and portions of the plant canopy on fruit TSS (°Brix) of pear cv. Patharnakh

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	13.32^{b}	14.01^{b}	13.66	13.14^{b}	13.84^{b}	13.49	13.40^{b}	14.04^{b}	13.72
Middle	13.72^{a}	14.61^{a}	14.16	13.27^{ab}	14.09^{a}	13.68	13.60^{a}	14.36^{a}	13.98
Upper	13.75^{a}	14.68^{a}	14.21	13.33^{a}	14.14^{a}	13.73	13.66^{a}	14.41^{a}	14.03
Mean	13.59	14.43	**14.01**	13.25	14.03	**13.64**	13.55	14.27	**13.91**
LSD	0.25	0.23		0.18	0.21		0.20	0.28	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 59: Effect of training systems and portions of the plant canopy on fruit TSS (°Brix) of pear cv. Punjab Beauty

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	14.21^{b}	14.85^{b}	14.53	13.88^{b}	14.51^{b}	14.19	14.31^{b}	14.81^{b}	14.56
Middle	14.61^{a}	15.25^{a}	14.93	14.07^{ab}	14.79^{a}	14.43	14.73^{a}	15.21^{a}	14.97
Upper	14.67^{a}	15.32^{a}	14.99	14.14^{a}	14.85^{a}	14.49	14.76^{a}	15.35^{a}	15.05
Mean	14.49	15.14	**14.81**	14.07	14.75	**14.41**	14.60	15.12	**14.86**
LSD	0.37	0.33		0.25	0.21		0.42	0.38	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 60: Effect of training systems and portions of the plant canopy on fruit TSS (°Brix) of pear cv. Punjab Soft

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	12.26^{b}	12.89^{b}	12.57	12.17^{b}	12.79^{b}	12.48	12.26^{b}	12.86^{b}	12.56
Middle	12.66^{a}	13.29^{a}	12.97	12.47^{ab}	13.09^{ab}	12.78	12.56^{a}	13.26^{a}	12.91
Upper	12.72^{a}	13.36^{a}	13.04	12.53^{a}	13.14^{a}	12.83	12.61^{a}	13.33^{a}	12.97
Mean	12.54	13.18	**12.86**	12.39	13.00	**12.69**	12.47	13.15	**12.81**
LSD	0.23	0.22		0.31	0.30		0.28	0.27	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 61: Effect of training systems and portions of the plant canopy on fruit titrable acidity (%) of pear cv. Patharnakh

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	0.325[a]	0.367[a]	0.346	0.299[a]	0.337[a]	0.318	0.322[a]	0.366[a]	0.344
Middle	0.305[b]	0.347[b]	0.326	0.249[b]	0.290[b]	0.269	0.302[b]	0.346[b]	0.324
Upper	0.302[b]	0.341[b]	0.321	0.243[b]	0.284[b]	0.263	0.293[b]	0.336[b]	0.314
Mean	0.307	0.348	**0.327**	0.260	0.300	**0.280**	0.302	0.346	**0.324**
LSD	0.015	0.014		0.023	0.023		0.010	0.018	

[*]LSD indicates the least significant difference test at $p<0.05$. [**]Values are means with a common letter are not significantly different at 5% level.

Table 62: Effect of training systems and portions of the plant canopy on fruit titrable acidity (%) of pear cv. Punjab Beauty

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	0.246[a]	0.290[a]	0.268	0.224[a]	0.268[a]	0.246	0.248[a]	0.295[a]	0.271
Middle	0.216[b]	0.258[b]	0.237	0.175[b]	0.221[b]	0.198	0.229[ab]	0.278[ab]	0.253
Upper	0.211[b]	0.252[b]	0.231	0.170[b]	0.215[b]	0.192	0.213[b]	0.260[b]	0.246
Mean	0.227	0.270	**0.248**	0.186	0.231	**0.208**	0.230	0.277	**0.253**
LSD	0.026	0.027		0.024	0.025		0.021	0.022	

[*]LSD indicates the least significant difference test at $p<0.05$. [**]Values are means with a common letter are not significantly different at 5% level.

Table 63: Effect of training systems and portion of the plant canopy on fruit titrable acidity (%) of pear cv. Punjab Soft

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	0.164^{a}	0.201^{a}	0.182	0.162^{a}	0.211^{a}	0.186	0.165^{a}	0.198^{a}	0.181
Middle	0.144^{b}	0.179^{b}	0.161	0.142^{ab}	0.191^{b}	0.166	0.145^{ab}	0.178^{b}	0.161
Upper	0.140^{b}	0.177^{b}	0.158	0.139^{b}	0.186^{b}	0.162	0.142^{b}	0.175^{b}	0.158
Mean	0.146	0.182	**0.164**	0.144	0.192	**0.168**	0.147	0.180	**0.163**
LSD	0.014	0.024		0.022	0.017		0.020	0.019	

*LSD indicates the least significant difference test at p<0.05. **Values are means with a common letter are not significantly different at 5% level.

Table 64: Effect of training systems and portion of the plant canopy on fruit total sugars (%) of pear cv. Patharnakh

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	10.37^{b}	12.10^{b}	10.73	10.15^{b}	10.84^{b}	10.49	10.41^{b}	11.06^{b}	10.73
Middle	10.97^{a}	11.80^{a}	11.38	10.66^{a}	11.44^{a}	11.05	10.91^{a}	11.66^{a}	11.28
Upper	11.05^{a}	11.84^{a}	11.44	10.71^{a}	11.50^{a}	11.10	11.05^{a}	11.86^{a}	11.45
Mean	10.79	11.58	**11.18**	10.50	11.26	**10.88**	10.79	11.52	**11.15**
LSD	0.27	0.24		0.35	0.32		0.32	0.29	

*LSD indicates the least significant difference test at p<0.05. **Values are means with a common letter are not significantly different at 5% level.

Table 65: Effect of training systems and portion of the plant canopy on fruit total sugars (%) of pear cv. Punjab Beauty

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	10.94[b]	11.64[b]	11.29	10.74[b]	11.37[b]	11.05	10.96[b]	11.61[b]	11.38
Middle	11.44[a]	12.17[a]	11.80	11.14[a]	11.79[a]	11.36	11.41[a]	11.97[a]	11.69
Upper	11.50[a]	12.21[a]	11.85	11.19[a]	11.88[a]	11.43	11.61[a]	12.27[a]	11.94
Mean	11.29	12.00	**11.64**	10.96	11.62	**11.29**	11.36	11.98	**11.67**
LSD	0.39	0.37		0.37	0.35		0.34	0.32	

*LSD indicates the least significant difference test at p<0.05. **Values are means with a common letter are not significantly different at 5% level.

Table 66: Effect of training systems and portion of the plant canopy on fruit total sugars (%) of pear cv. Punjab Soft

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	9.71[b]	10.34[b]	10.02	9.65[b]	10.26[b]	9.95	9.65[b]	10.34[b]	9.99
Middle	10.11[a]	10.74[a]	10.42	10.00[a]	10.58[ab]	10.29	10.05[a]	10.64[a]	10.34
Upper	10.17[a]	10.79[a]	10.48	10.11[a]	10.68[a]	10.39	10.19[a]	10.84[a]	10.51
Mean	9.99	10.62	**10.30**	9.92	10.50	**10.21**	9.96	10.60	**10.28**
LSD	0.26	0.23		0.35	0.32		0.30	0.27	

*LSD indicates the least significant difference test at p<0.05. **Values are means with a common letter are not significantly different at 5% level.

Table 67: Effect of training systems and portion of the plant canopy on fruit starch content (%) of pear cv. Patharnakh

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	2.180^{a}	1.964^{a}	2.072	2.111^{a}	1.924^{a}	2.017	2.166^{a}	1.954^{a}	2.060
Middle	2.040^{b}	1.857^{b}	1.948	1.940^{b}	1.708^{b}	1.824	2.072^{b}	1.885^{b}	1.978
Upper	2.022^{b}	1.828^{b}	1.925	1.916^{b}	1.690^{b}	1.803	2.022^{b}	1.835^{b}	1.928
Mean	2.080	1.883	**1.981**	1.989	1.774	**1.881**	2.086	1.891	**1.988**
LSD	0.048	0.054		0.056	0.062		0.053	0.059	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 68: Effect of training systems and portion of the plant canopy on fruit starch content (%) of pear cv. Punjab Beauty

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**	**2016**	**2017**	**Mean**
Lower	1.754^{a}	1.514^{a}	1.634	1.762^{a}	1.495^{a}	1.628	1.723^{a}	1.540^{a}	1.631
Middle	1.549^{b}	1.314^{b}	1.431	1.532^{b}	1.293^{b}	1.412	1.656^{b}	1.464^{b}	1.560
Upper	1.528^{b}	1.294^{b}	1.411	1.508^{b}	1.252^{b}	1.380	1.573^{c}	1.374^{c}	1.473
Mean	1.610	1.374	**1.492**	1.600	1.346	**1.473**	1.650	1.459	**1.554**
LSD	0.038	0.048		0.046	0.056		0.043	0.053	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Table 69: Effect of training systems and portion of the plant canopy on fruit starch content (%) of pear cv. Punjab Soft

Canopy	Espalier system			Cordon system			Y-Trellis system		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Lower	1.427[a]	1.465[a]	1.546	1.627[a]	1.442[a]	1.534	1.596[a]	1.409[a]	1.502
Middle	1.427[b]	1.258[b]	1.342	1.418[b]	1.238[b]	1.328	1.489[b]	1.310[b]	1.399
Upper	1.406[b]	1.242[b]	1.324	1.412[b]	1.223[b]	1.317	1.388[c]	1.210[c]	1.299
Mean	1.486	1.321	**1.403**	1.485	1.301	**1.393**	1.491	1.309	**1.400**
LSD	0.051	0.055		0.059	0.063		0.056	0.060	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

4.1.6 Foliar nutrient status

4.1.6.1 Macronutrients (%)

The data regarding the foliar macronutrient status presented in Tables 70-72 showed that leaf macronutrient content (N, P, K, Ca and Mg) was affected significantly by various training systems during both the years of studies. Macronutrient level was found to be higher during the year 2016 as compared to 2017. This may be due to less crop load on the plants suggesting competition of nutrients due to high source and sink ratio during 2017. Mean maximum leaf N and Mg content was found in leaves of pear plants trained on Espalier system (2.46% N, 0.498% Mg) and Y-trellis system (2.41% N, 0.490% Mg); it was statistically at par with each other. Minimum leaf N and Mg content was found in leaves of pear plants trained to Cordon system (2.34% N, 0.466% Mg). P content in leaves of pear plants was not significantly affected by different training systems**.** However, mean K was higher in leaves of pear plants, trained to Espalier system (1.12%) in pear cv. Patharnakh (Table 70). Training system had non-significant effect on the Ca content during the present studies. A similar trend was observed in pear cultivars viz. Punjab Beauty (Table 71) and Punjab Soft (Table 72) as was observed in case of Patharnakh.

In our studies, variations in leaf nutrient contents were observed in pears cultivars (Patharnakh, Punjab Beauty and Punjab Soft) trained on different training systems. It may be due to the effect of cultivar or training system on foliar nutrient status. Our results are partially in accordance with the findings obtained by Neilsen *et al* (2010) who reported that there were no cultivar differences in leaf N content. However, results of others authors confirmed the great variability of leaf mineral composition due to genotype, year, rootstock and environment (Ystaas 1995; Roversi *et al* 2008). A large number of worker have reported that training systems had no significant effect on foliar P content in leaves (Kumawat *et al* 2014 in guava; Sidhu and Kaundal 2005 in plum; Wertheim 1985 in apple; Arora *et al* 1983 in Kinnow). Higher Ca and Mg content accumulated in modified central trained leader as compared to plants trained to spindle-bush system in apple cultivars (Sharma and Chauhan 1991). Training system had not significant effect on the Ca content during the present studies and similar results observed by Sidhu and Kaundal (2005) in plum plants.

4.1.6.2 Micronutrients (ppm)

The data on foliar micronutrient status presented in Tables 70-72 showed that leaf micronutrient content (Fe, Zn, Mn and Cu) was significantly influenced by the various training systems during both the years. In pear cv. Patharnakh (Table 70), mean maximum leaf Mn content (112.66 ppm) was found under Espalier system and maximum Fe content (117.29 ppm) was recorded under Cordon system. However, Zn and Cu content in leaves of pear plants was non-significantly different between various training systems. A similar trend was observed in pear cultivars viz. Punjab Beauty (Table 71) and Punjab Soft (Table 72) as was observed in case of Patharnakh.

Table 70: Effect of training systems on foliar nutrient status of pear plants cv. Patharnakh

Training System	N (%)			P (%)			K (%)		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Espalier system	2.32[a]	2.51[a]	2.41	0.182[a]	0.175[a]	0.178	1.12[a]	1.13[a]	1.12
Cordon system	2.27[b]	2.42[b]	2.34	0.185[a]	0.177[a]	0.181	1.10[b]	1.10[b]	1.10
Y-trellis system	2.38[a]	2.55[a]	2.46	0.187[a]	0.173[a]	0.180	1.09[b]	1.11[a]	1.10
LSD	0.03	0.05		NS	NS		0.02	0.02	
	Ca (%)			**Mg (%)**			**Fe (ppm)**		
Espalier system	2.81[a]	2.38[a]	2.59	0.470[a]	0.526[a]	0.498	120.97[b]	110.87[b]	115.92
Cordon system	2.76[a]	2.36[a]	2.56	0.434[b]	0.499[b]	0.466	122.73[a]	111.85[a]	117.29
Y-trellis system	2.78[a]	2.33[a]	2.55	0.462[a]	0.520[a]	0.491	118.77[c]	109.95[c]	114.36
LSD	NS	NS		0.025	0.019		0.80	0.54	
	Zn (ppm)			**Mn (ppm)**			**Cu (ppm)**		
Espalier system	14.89[a]	13.92[a]	14.40	116.61[a]	108.72[a]	112.66	7.87[a]	6.91[a]	7.39
Cordon system	14.73[a]	13.70[ab]	14.21	113.38[b]	106.19[b]	109.78	7.78[a]	6.85[a]	7.31
Y-trellis system	14.74[a]	13.61[b]	14.17	112.80[b]	103.77[c]	108.28	7.76[a]	6.33[b]	7.04
LSD	NS	0.30		1.28	1.53		NS	0.25	

[*]LSD indicates the least significant difference test at $p<0.05$. [**]Values are means with a common letter are not significantly different at 5% level.

Table 71: Effect of training systems on foliar nutrient status of pear plants cv. Punjab Beauty

Training System	N (%)			P (%)			K (%)		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Espalier system	2.46[a]	2.36[a]	2.41	0.178[a]	0.188[a]	0.183	1.13[a]	1.12[a]	1.12
Cordon system	2.42[b]	2.30[b]	2.36	0.175[a]	0.185[a]	0.180	1.10[b]	1.09[b]	1.09
Y-trellis system	2.48[a]	2.37[a]	2.42	0.176[a]	0.187[a]	0.181	1.14[a]	1.11[a]	1.12
LSD	0.03	0.05		NS	NS		0.03	0.02	
	Ca (%)			Mg (%)			Fe (ppm)		
Espalier system	2.67[a]	2.83[a]	2.75	0.496[a]	0.483[a]	0.489	128.94[b]	116.94[b]	122.94
Cordon system	2.61[a]	2.77[a]	2.69	0.464[b]	0.459[b]	0.461	135.15[a]	120.82[a]	127.98
Y-trellis system	2.64[a]	2.79[a]	2.71	0.492[a]	0.467[a]	0.479	121.96[c]	113.36[c]	117.66
LSD	NS	NS		0.025	0.019		1.76	1.47	
	Zn (ppm)			Mn (ppm)			Cu (ppm)		
Espalier system	14.79[a]	15.15[a]	14.97	103.97[a]	92.15[a]	98.06	7.54[a]	6.80[a]	7.17
Cordon system	14.63[a]	15.09[ab]	14.86	102.83[a]	88.92[b]	95.87	7.50[a]	6.74[a]	7.12
Y-trellis system	14.64[a]	14.84[b]	14.74	102.94[a]	91.82[a]	97.38	7.46[a]	6.81[a]	7.13
LSD	NS	0.39		NS	1.42		NS	NS	

[*]LSD indicates the least significant difference test at $p<0.05$. [**]Values are means with a common letter are not significantly different at 5% level.

Table 72: Effect of training systems on foliar nutrient status of pear plants cv. Punjab Soft

Training System	N (%)			P (%)			K (%)		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Espalier system	2.34[a]	2.53[a]	2.43	0.186[a]	0.177[a]	0.181	1.04[a]	1.08[a]	1.06
Cordon system	2.30[b]	2.47[b]	2.38	0.188[a]	0.175[a]	0.181	1.01[b]	1.05[b]	1.03
Y-trellis system	2.36[a]	2.57[a]	2.46	0.185[a]	0.176[a]	0.180	1.02[ab]	1.07[a]	1.04
LSD	0.03	0.06		NS	NS		0.03	0.02	
	Ca (%)			**Mg (%)**			**Fe (ppm)**		
Espalier system	2.42[a]	2.53[a]	2.47	0.487[a]	0.496[a]	0.491	115.35[b]	130.10[b]	122.72
Cordon system	2.38[a]	2.51[a]	2.44	0.455[b]	0.471[b]	0.463	120.94[a]	133.92[a]	127.43
Y-trellis system	2.41[a]	2.56[a]	2.48	0.483[a]	0.481[a]	0.482	112.34[b]	128.33[c]	120.33
LSD	NS	NS		0.026	0.020		3.91	2.05	
	Zn (ppm)			**Mn (ppm)**			**Cu (ppm)**		
Espalier system	13.41[a]	14.15[a]	13.78	103.38[a]	113.19[a]	108.28	6.84[a]	7.59[a]	7.21
Cordon system	13.02[a]	13.84[a]	13.43	100.46[b]	112.56[a]	106.51	6.41[b]	7.46[a]	6.93
Y-trellis system	13.29[a]	13.79[a]	13.54	101.33[ab]	111.65[a]	106.49	6.66[ab]	7.50[a]	7.08
LSD	NS	NS		2.01	NS		0.40	NS	

*LSD indicates the least significant difference test at $p<0.05$. **Values are means with a common letter are not significantly different at 5% level.

Variations in leaf nutrient contents were observed in pears cultivars (Patharnakh, Punjab Beauty and Punjab Soft) trained on different training systems and it may be due to effect of cultivars or different training systems. Our findings are partially in accordance with the results obtained by Ystaas (1995) and Roversi *et al* (2008) who confirmed the great variability of leaf mineral composition due to genotype, year, rootstock and environment in plants. These results are in line with previous findings of Kumar *et al* (2013) in apricot, Jivan and Sala (2014) in apple and Sidhu (1996) in Kinnow mandarin. Similarly to the macronutrients level, leaf micronutrients also significantly varied among different cultivars. Jiménez *et al* (2007) and Stochl *et al* (2008) also reported cultivar differences in leaf micronutrients content in different seasons were observed. Similarly leaf analysis indicated that all cultivars of sweet cherry under high density planting had excessive levels of Cu whereas Fe, Mn and Zn were deficient (Milošević *et al* 2015). This study also shows that foliar Mn levels were in the optimum range as suggested by Arnold and Crocker (1976).

4.2 EFFECT OF HEADING AND PLANT GROWTH REGULATORS ON FEATHERING OF PEAR PLANTS

4.2.1 Total number of feathers per plant

The data presented in Table 73 show that the total numbers of feathers/plant were affected significantly by different heading and plant growth regulator treatments during both the years of study. Number of feathers per plant found to be higher during the year 2016 due to more vegetative growth flush as compared to 2017. In pear cv. Patharnakh, higher number of feathers were recorded under treatment T2 (BA 600 ppm) followed by treatments T1 (BA 400 ppm) and T3 (BA 800 ppm). T1 treatment was statistically at par with T3 treatment. Minimum number of feathers/plant were recorded under treatment T9 (heading at 90cm). In pear cv. Punjab Beauty, higher number of feathers were recorded under treatment T4 (GA 200 ppm + BA 600 ppm) followed by treatment T3 (BA 800 ppm). Number of feathers was non-significantly different under application of PGR’s in pear cv. Punjab Beauty. However, significantly minimum number of feathers were recorded under treatment T9 (heading at 90cm). The general effect of heading treatments and plant growth regulators on number of feathers was true for both the years.

Similar findings by other workers that the application of 6-benzylaminopurine (BA) affects the flow of auxins (Müller and Leyser 2011) and temporarily impedes the main shoot growth (Sazo and Robinson 2011), which helps overcome apical dominance and creates favourable conditions for feather formation. Similarly, Dorić *et al* (2015) studied that synthetic cytokinin 6-benzylaminopurine (BA), either alone or combined with gibberellins (GA_{4+7}), plays an important role in overcoming apical dominance and in the production of well-feathered apple nursery plants. Similarly to heading, removal of shoot tip caused production of insufficient number of lateral branches to form proper plant crown (Gąstoł and Poniedziałek 2003). From our present studies, we observed that pear cv. Patharnakh was more responsive to the application of PGRs as compared to the Punjab Beauty. These studies are in line with the previous studies by various workers that apple cultivars differ in their ability to form feathers in the nursery (Wertheim and Webster 2003; Cvetković 2010).

4.2.2 Total number of feathers >50 cm and <50 cm per plant

It is evident from the Tables 74a and 74b that number of feathers >50 cm and <50 cm were significantly affected by the different heading and PGR treatments. In pear cv. Patharnakh (Table 74a), Highest number of feathers >50cm recorded under treatment T2 (BA 600 ppm). It was non-significantly different from treatments T1, T3, T4 and T5. Minimum number of feathers was recorded under control plants (heading at 90 cm). In pear cv. Punjab Beauty, a higher number of feathers >50 cm were recorded under treatments T5 (GA 200 ppm + BA 600 ppm) and T6 (GA 400 ppm + BA 600 ppm), which was statistically at par with treatments T1 and T3. However, significantly minimum numbers of feathers were recorded under control plants (heading at 90 cm). The general effect of treatments heading and plant growth regulators on number of feathers was similar during both the years. Similar results were recorded for the number of feathers <50 cm in pear cvs. Patharnakh and Punjab Beauty (Table 74b). In pear cv. Patharnakh, highest number of feathers <50 cm were noted under treatments T1 and T2, it was statistically at par. Similarly in pear cv. Punjab Beauty, highest number of feathers <50 cm were noted under treatment T3, it was statistically at par with treatments T2 and T4. However, minimum numbers of feathers were recorded under control plants (heading at 90 cm) in both pear cultivars.

These findings are in line with the previous results by Volz (1994) who observed that application of BA induced the longer branches than applications involving BA+GA_{4+7} combinations. The application of BA and BA+GA_{4+7} resulted in an increase in the number of feathers exceeding 10 cm in length; while in apple cv. 'Jonagold', increase was also noted in feathers shorter than 10 cm. Doric *et al* (2015) found that average feather length increased with BA and BA+GA_{4+7} concentration rates. However, apple cultivars differ in their ability to form feathers in the nursery plants (Wertheim and Webster 2003; Cvetković 2010), whereby cultivars 'Gala' and 'Jonagold' tend to form longer feathers (Kviklys 2006; Cvetković 2010; Atay and Koyuncu 2013).

4.2.3 Mean length (cm) and diameter (mm) of feathers

The data on mean length and diameter of feathers presented in Tables 75a and 75b shows that these parameters were significantly affected by the heading and PGR treatments during both the years of study. In pear cv. Patharnakh (Table 75a), maximum average length of feathers was recorded under treatment T9 i.e. control (heading at 90cm) followed by treatments T2 (BA 600 ppm) and T1 (BA 400 ppm), it was statistically at par with each other. However, minimum average length of feathers was noted under applications of all BA+GA treatments. Similar results were observed in pear cv. Punjab Beauty that maximum average length of feathers was recorded under heading treatments followed by BA application alone (T1, T2 and T3 treatments). The mean maximum feather length in control plants was due to less number of longer shoots at the top portion of plant. However, more number of longer shoots was found in application of BA alone than GA+BA combined applications. In pear cv. Patharnakh (Table 75b), higher average diameter of feathers was recorded under heading treatments (T7, T8 and T9) followed by treatments T1 (BA 400 ppm), T2 (BA 600 ppm) and T3 (BA 800 ppm), it was statistically at par with each others. However, minimum average diameter of feathers was recorded under treatments T5 (GA 400 + BA 600 ppm) and T6 (GA 600 + BA 600 ppm). A Similar trend was found in pear cv. Punjab Beauty that significantly higher average diameter of feathers was recorded under heading treatments followed by treatments of BA alone application during the studies. However, minimum average diameter of feathers was recorded under treatments of GA+BA combined applications.

In our studies, higher average length and diameter of feathers was observed in heading treatments was may be due to less number of longer shoots as compared to other treated plants. However, minimum average length and diameter of feathers was recorded under combined application BA+GA was may be due to more number of small shoots. The main shoot and feathers were in competition for water and nutrients, which affected the length and diameter of feathers (Cline 1997). Our results are partially in accordance with the findings by Dorić *et al* (2013) who reported that an increase in number of feathers enables variation in mean feather length and diameter. In apple plants, GA's has positive influence on the shoot growth rate (Rademacher 2000; Bulley *et al* 2005). Similar findings by Doric *et al* (2015) that application of BA alone has a stronger effect on the growth rate of lateral shoots as compared to combined application of BA+GA_{4+7} on plants.

4.2.4 Total Length of feathers per plant (cm)

The data presented in Table 76 reveals that total length of feathers/plant was found to be higher during the year 2016. It may be due to more vegetative growth in the year 2016 as compared to 2017. In pear cv. Patharnakh, highest total length of feathers/plant was recorded under treatment T2 (BA 600 ppm) followed by treatment T3 (BA 400 ppm) and these treatments were statistically at par. Total length of feathers/plant was noted lesser under treatments T7 (heading at 60cm) and T9 (heading at 90cm). In pear cv. Punjab Beauty, highest total length of feathers/plant was recorded under treatment T1 (BA 400 ppm) followed by treatments T2, T3, T4 and T5; these treatments were non-significantly different from T1 treatment during both the years. Lesser total length of feathers per plant was observed under heading treatments. However, higher total length of feathers per plant was recorded under application of BA alone than combination of GA+BA. The general effect of heading and PGR treatments on total length of feathers per plant was similar during both the years. In our studies, pear cv. Patharnakh was more responsive to the application of plant growth regulators as compared to the Punjab Beauty during both the years.

Studies of some other fruit species, such as plum (Magyar and Hrotko 2002) and cherry (Magyar and Hrotko 2005) also confirmed similar results that BA can result in more total feather length/plant. Application of BA on nursery plants enhancing the formation of more number of feathers per plant (Palmer *et al* 2011). Similar results found by Moghadam and Zamanipour (2013) the number of lateral shoots enhanced with application of higher concentrations and repeated Arbolin (BA+GA_3) treatments in apple plants. Higher total length of feathers per plant was recorded under application of BA alone than combination of GA+BA treatments. Our findings are partially in accordance with the results obtained by Doric *et al* (2015) in apple plants that total feather length/plant increased with BA and BA+GA_{4+7} concentration rates. However, BA has a stronger effect on the growth rate of lateral shoots as compared to BA+GA_{4+7} combined application.

Table 73: Effect of PGR and heading treatments on total number of feathers/plant of pear cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	**BA 400 ppm**	9.99[ab]	8.86[a]	9.43	9.54[a]	8.86[a]	9.20
T2	**BA 600 ppm**	10.33[a]	8.91[a]	**9.62**	9.67[a]	8.97[a]	9.32
T3	**BA 800 ppm**	9.78[ab]	8.28[ab]	9.03	9.81[a]	9.12[a]	9.47
T4	**GA_3 200 + BA 600 ppm**	9.00[bc]	8.24[ab]	8.62	10.10[a]	9.07[a]	**9.59**
T5	**GA_3 400 + BA 600 ppm**	8.57[c]	8.20[ab]	8.39	9.64[a]	9.06[a]	9.35
T6	**GA_3 600 + BA 600 ppm**	8.24[c]	7.65[b]	7.95	9.48[a]	9.07[a]	9.28
T7	**Heading at 60 cm**	3.29[de]	3.15[cd]	3.22	4.27[c]	4.18[b]	4.23
T8	**Heading at 75 cm**	4.05[d]	3.65[c]	3.85	5.00[b]	4.75[b]	4.88
T9	**Heading at 90 cm** (control)	2.79[e]	2.61[d]	2.70	4.30[bc]	4.16[b]	4.23
LSD		1.11	1.00		0.71	0.66	

[*]LSD indicates the least significant difference test at $p<0.05$.

[**]Values are means with a common letter are not significantly different at 5% level.

Table 74a: Effect of PGR and heading treatments on number of feathers >50cm/plant of pear cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	**BA 400 ppm**	7.11^{a}	6.17^{ab}	6.64	6.52^{ab}	5.79^{a}	6.16
T2	**BA 600 ppm**	7.65^{a}	6.69^{a}	**7.17**	6.33^{b}	5.22^{b}	5.78
T3	**BA 800 ppm**	7.66^{a}	5.91^{bc}	6.79	6.32^{b}	5.04^{b}	5.68
T4	**GA_3 200 + BA 600 ppm**	7.00^{a}	6.09^{b}	6.55	6.80^{ab}	5.30^{b}	6.05
T5	**GA_3 400 + BA 600 ppm**	7.12^{a}	6.58^{a}	6.85	6.89^{a}	5.99^{a}	**6.44**
T6	**GA_3 600 + BA 600 ppm**	6.53^{b}	5.57^{c}	6.05	6.83^{a}	5.84^{a}	6.34
T7	**Heading at 60 cm**	2.25^{c}	2.21^{de}	2.23	3.32^{d}	2.98^{c}	3.15
T8	**Heading at 75 cm**	2.84^{c}	2.71^{d}	2.78	3.84^{c}	3.29^{c}	3.57
T9	**Heading at 90 cm** (control)	2.04^{d}	1.88^{e}	1.96	3.21^{d}	3.12^{c}	3.17
LSD		0.76	0.56		0.48	0.47	

*LSD indicates the least significant difference test at p<0.05.

**Values are means with a common letter are not significantly different at 5% level.

Table 74b: Effect of PGR and heading treatments on number of feathers <50cm/plant of pear cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	**BA 400 ppm**	2.88^{a}	2.69^{a}	**2.79**	3.02^{bc}	3.07^{c}	3.05
T2	**BA 600 ppm**	2.68^{ab}	2.22^{a}	2.45	3.34^{ab}	3.75^{ab}	3.55
T3	**BA 800 ppm**	2.12^{bc}	2.37^{a}	2.25	3.49^{a}	4.08^{a}	**3.79**
T4	**GA_3 200 + BA 600 ppm**	2.00^{cd}	2.15^{ab}	2.08	3.30^{ab}	3.77^{ab}	3.54
T5	**GA_3 400 + BA 600 ppm**	1.45^{def}	1.62^{b}	1.54	2.75^{c}	3.07^{c}	2.91
T6	**GA_3 600 + BA 600 ppm**	1.71^{de}	2.08^{a}	1.90	2.65^{c}	3.23^{bc}	2.94
T7	**Heading at 60 cm**	1.04^{f}	0.94^{c}	0.99	0.95^{d}	1.20^{d}	1.08
T8	**Heading at 75 cm**	1.21^{ef}	0.94^{c}	1.08	1.16^{d}	1.46^{d}	1.31
T9	**Heading at 90 cm** (control)	0.75^{f}	0.73^{c}	0.74	1.09^{d}	1.04^{d}	1.07
LSD		0.66	0.69		0.47	0.55	

*LSD indicates the least significant difference test at p<0.05.

**Values are means with a common letter are not significantly different at 5% level.

Table 75a: Effect of PGR and heading treatments on mean length/feather (cm) of pear plants cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	**BA 400 ppm**	83.14^{ab}	74.74^{bc}	78.94	60.85^{bc}	55.38^{b}	58.12
T2	**BA 600 ppm**	84.43^{ab}	74.01^{bc}	79.22	59.84^{c}	53.18^{b}	56.51
T3	**BA 800 ppm**	80.29^{b}	73.70^{bc}	77.00	58.72^{c}	52.06^{b}	55.39
T4	**GA_3 200 + BA 600 ppm**	78.62^{bc}	67.48^{c}	73.05	55.51^{c}	50.81^{b}	53.16
T5	**GA_3 400 + BA 600 ppm**	70.13^{c}	65.43^{d}	67.78	55.04^{c}	50.03^{b}	52.54
T6	**GA_3 600 + BA 600 ppm**	70.00^{c}	65.13^{d}	67.57	53.13^{c}	48.64^{c}	50.89
T7	**Heading at 60 cm**	75.84^{bc}	72.98^{bc}	74.41	70.83^{b}	67.52^{a}	69.18
T8	**Heading at 75 cm**	78.91^{bc}	76.89^{b}	77.90	75.16^{ab}	71.04^{a}	73.10
T9	**Heading at 90 cm** (control)	92.97^{a}	88.17^{a}	**90.57**	85.60^{a}	77.93^{a}	**81.77**
LSD		10.24	7.80		10.59	7.62	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 75b: Effect of PGR and heading treatments on mean diameter/feather (mm) of pear plants cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	**BA 400 ppm**	8.84^{ab}	7.64^{ab}	8.24	8.51^{c}	7.68^{b}	8.10
T2	**BA 600 ppm**	9.51^{a}	7.69^{ab}	8.60	8.50^{c}	7.51^{bc}	8.01
T3	**BA 800 ppm**	8.76^{ab}	7.45^{b}	8.11	8.33^{c}	7.36^{bc}	7.85
T4	**GA_3 200 + BA 600 ppm**	8.45^{ab}	7.64^{ab}	8.05	8.03^{d}	7.53^{bc}	7.78
T5	**GA_3 400 + BA 600 ppm**	7.95^{b}	7.49^{b}	7.72	7.72^{e}	7.49^{bc}	7.61
T6	**GA_3 600 + BA 600 ppm**	7.79^{b}	7.47^{b}	7.63	7.56^{e}	7.28^{c}	7.42
T7	**Heading at 60 cm**	8.49^{ab}	8.77^{a}	8.63	9.25^{b}	8.47^{a}	8.86
T8	**Heading at 75 cm**	8.66^{ab}	8.82^{a}	**8.74**	9.53^{ab}	8.52^{a}	9.03
T9	**Heading at 90 cm** (control)	8.60^{ab}	8.80^{a}	8.70	9.67^{a}	8.62^{a}	**9.15**
LSD		1.21	1.05		0.29	0.33	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 76: Effect of PGR and heading treatments on total length of feathers/plant (cm) of pear cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	**BA 400 ppm**	830.56[ab]	662.19[a]	746.38	580.51[a]	490.67[a]	**535.59**
T2	**BA 600 ppm**	872.16[a]	659.43[a]	**765.80**	578.65[a]	477.02[a]	527.84
T3	**BA 800 ppm**	785.23[b]	610.24[b]	697.74	576.04[a]	474.78[a]	525.41
T4	**GA_3 200 + BA 600 ppm**	707.58[c]	556.04[c]	631.81	560.65[a]	460.85[a]	510.75
T5	**GA_3 400 + BA 600 ppm**	601.01[d]	536.53[cd]	568.77	530.59[a]	453.27[a]	491.93
T6	**GA_3 600 + BA 600 ppm**	576.80[d]	505.89[d]	541.35	503.67[b]	441.16[b]	472.42
T7	**Heading at 60 cm**	249.51[e]	229.88[f]	239.70	302.44[c]	282.23[d]	292.34
T8	**Heading at 75 cm**	319.59[e]	280.65[e]	300.12	375.80[c]	337.44[c]	356.62
T9	**Heading at 90 cm** (control)	259.39[e]	230.12[f]	244.76	368.08[c]	324.18[c]	346.13
LSD		72.24	31.93		74.76	41.08	

[*]LSD indicates the least significant difference test at p<0.05.

[**]Values are means with a common letter are not significantly different at 5% level.

4.2.5 Height of first feather from ground level (cm)

Data on this aspect presented in Table 77 shows that mean height of first feather from ground level was found to be significantly higher under treatment T9 (heading at 90cm) followed by treatments T8 (heading at 75cm) and T7 (heading at 60cm). In pear cv. Patharnakh, few shoots (i.e. 2-3 shoots/plant) were emerged under heading treatments (T7, T8 and T9) on the upper part of the plant therefore, mean height of first feather from ground level was found to be higher. Mean height of first feather from ground level was found to be lower under treatment T6 (GA 600 + BA 600 ppm) followed by treatments T5 (GA 400 + BA 600 ppm) and T4 (GA 200 + BA 600 ppm). However, with BA treatments mean height of first feather from ground level was observed intermediate between heading and GA+BA applications. Height of first feather from ground level decreased with the application of higher concentrations of PGRs in plants. A similar trend was found in pear cv. Punjab Beauty as was observed in case of Patharnakh plants. These findings are in line with the previous work done by Doric *et al* (2015) who reported that the branching zone increased with higher concentrations of BA and BA+GA_{4+7} treatments, decreases the mean height of first feather from ground level.

4.2.6 Diameter of main stem above bud union and below bud union (mm)

The data regarding the average diameter of main stem above bud union and below bud union presented in Tables 78a and 78b show that it was significantly affected by the different heading and PGR treatments during both the years. In pear cv. Patharnakh, average diameter of main stem above bud union (Table 78a) and below bud union (Table 78b) was found to be higher under treatment T1 (BA 400 ppm) followed by treatments T2 (BA 600 ppm) and T3 (BA 800 ppm). But differences were statistically non-significant. Stem diameter decreased with combined application of GA+BA in treatments T4, T5 and T6 during our studies. Lesser stem diameter was recorded under heading treatments (T7, T8 and T9) may be due to less radial growth of plant. A similar trend was found in pear cv. Punjab Beauty as was observed in case of Patharnakh plants and these results are described in Tables 78a and 78b.

Compared to BA+GA_{4+7} applications, BA has a stronger effect on the growth rate of lateral shoots and also had effect on growth rate of trunk diameter in plants. In contrast, following their study of one-year-old ‘Catarina’ apples, Rossi *et al* (2004) found that increasing concentrations of BA+GA_{4+7} resulted in the decrease of plant trunk diameter. Studies on some other fruit species, such as plum (Magyar and Hrotko 2002) and cherry (Magyar and Hrotko 2005) also confirmed that BA can result in decrease of plant trunk diameter to a certain degree, if higher concentrations of BA are applied to plants. In pear, application of BA as a means of enhancing the formation of feathers did not affect the trunk diameter (Palmer *et al* 2011). Our results confirm the average opinion in literature is that low BA concentration is optimal for good feathering of young plum plants and higher concentration may cause short laterals/feathers with phyto-toxic symptoms on plum plants. In case of stem diameter of plants, a decrease can be observed; all of these can be accounted for the transport of assimilates devoted to developing laterals (Magyar and Hrotko 2002).

4.2.7 Crotch angle of feathers (^{o})

Data on this important aspect presented in Table 79 shows that mean crotch angle of feathers was significantly affected by various heading and PGR treatments during the present studies. In pear cv. Patharnakh, mean maximum crotch angle of feathers was recorded under treatment T1 (BA 400 ppm) followed by treatment T2 (BA 600 ppm), which was statistically at par with treatment T1. The mean crotch angle of feathers was reduced under treatments of GA+BA combined applications with higher concentrations. Narrow crotch angles were recorded under treatments T9 (heading at 90cm), T8 (heading at 75cm) and T7 (heading at 60cm). A similar trend was found in pear cv. Punjab Beauty as was observed in case of Patharnakh plants. The general effect of heading and PGR treatments on mean crotch angle of feathers was true for year-wise studies.

From these results, we observed that pear cv. Patharnakh was more responsive to the application of BA alone. Mean crotch angle of feathers was found to be higher during the year 2016 due to more vegetative growth and spread of plants as compared to 2017. Angles of laterals with application of BA alone and GA+BA treatments were wider than heading treatments. These findings are conformity to the previous research work that application of PGRs (BA and BA+GA_{4+7}) also impact on feather angles by affecting apical dominance in treated plants (Elfving and Visser 2005). In the early studies, Volz (1994) found that BA application stimulates the growth of branches resulted in formation of longer branches with wide branch's crotch angles than applications involving a BA+GA_{4+7} combined application. Similar studies conducted by Doric *et al* (2015) that BA has a stronger effect on the growth rate of lateral branches, resulting in a greater feather angles as compared to BA+GA_{4+7} combined application. These results are in line with previous findings of Moghadam and Zamanipour (2013) that angles of lateral shoots with application of Arbolin (BA+GA_{4+7}) treatments were wider than heading treatments in nursery plants.

4.2.8 Spread of plant (cm)

It is evident from the Table 80 that mean plant spread in both directions was significantly affected by the different treatments viz. heading and PGR's. In pear cv. Patharnakh, highest mean spread of plant was recorded under treatment T1 (BA 400 ppm) followed by treatment T2 (BA 600 ppm), which was statistically at par with treatment T2. However in pear cv. Punjab Beauty, highest mean spread of plant was recorded under treatment T2 (BA 600 ppm) followed by treatment T3 (BA 800 ppm), which was statistically at par with each other. The mean spread of plant was reduced under higher concentrations of GA+BA combined application under treatments T4, T5 and T6. Minimum spread of plants was observed under heading treatments (T7, T8 and T9), may be due to narrow crotch angles in plants. From these results, we observed that mean crotch angle of feathers had direct effect on spread of plants in our studies during both the years.

Our findings are partially in accordance with the results obtained by Basak and Soczek (1986) who noted that the application of chemical branching agents were more beneficial in promoting a more desirable branching and canopy development in nursery plants. Similar results found by Doric *et al* (2015) that BA has a stronger effect compared to BA+GA_{4+7} on plant growth rate, resulting in a greater feather angles and spread of plants.

4.2.9 Mean plant height (cm)

The data presented in Table 81 show that the mean plant height was found to be higher under treatment T9 (heading at 90cm) followed by treatment T8 (heading at 75cm), which was statistically at par with each other. Less number of longer shoots (i.e. 2-3 shoots/plant) was emerged under heading treatments on upper part of the plant therefore; mean plant height was found to be higher. In pear cv. Patharnakh, mean plant height was found to be less under treatment T6 (GA 600 + BA 600 ppm) followed by treatment T5 (GA 600 + BA 600 ppm). However, mean under application of BA alone was observed intermediate between heading and GA+BA treatments and plant height decreased with higher concentrations of PGR's. A similar trend was found in pear cv. Punjab Beauty as was observed in case of Patharnakh plants. The general effect of heading and PGR treatments on mean plant height was similar during both the years of study.

These results are in line with the previous findings of Elfving and Visser (2005) that applications of PGRs (BA and BA+GA_{4+7}) also impact on plant height by affecting apical dominance in plants of horticultural species. There was contradiction between studies have shown that one-year-old apple nursery plant height (Hrotko *et al* 2000, Sazo and Robinson 2011) could be negatively affected by BA application. When applied alone, cytokinins reduce plant height, while gibberellin sprays consistently increase plant height in pears (Palmer *et al* 2011). However, BA spraying can adversely affect the plant height (Dorić *et al* 2013; Steiner *et al* 2013; Dorić *et al* 2014). BA has a stronger effect compared to BA+GA_{4+7} on the growth rate of lateral shoots, resulting in a greater feather angles and a lower plant heights. The branching zone increases with increased BA and BA+GA_{4+7} concentrations, decreases the mean plant height (Doric *et al* 2015).

4.2.10 Number of leaves (per 100 cm on feathers)

The data presented in Table 82 show that number of leaves were significantly affected by PGR's over heading treatments during both the years. In pear cv. Pathranakh, number of leaves/100cm shoot were found to be higher under treatments T4 (GA 200 + BA 600 ppm) and T5 (GA 400 + BA 600 ppm), which was statistically at par with each other. Similar results were found in pear cv. Punjab Beauty that numbers of leaves/100cm shoot were noted higher under treatments T3 (BA 800 ppm), T4 (GA 200 + BA 600 ppm) and T5 (GA 400 + BA 600 ppm), which were statistically at par to each other.

With the application of BA on plants, numbers of leaves/100cm shoot were lying intermediate between heading and GA+BA treatments. However, minimum numbers of leaves/100cm shoot were noted under treatments T7, T8 and T9 (i.e. heading treatments). In our studies, higher numbers of leaves were noted under PGR treatments may be due to growth of more number of lateral shoots and these plants have more number of vegetative buds on lateral shoots. A similar trend was found in pear cv. Punjab Beauty as it was in case of Patharnakh during both the years. These results are in line with the previous findings by Doric *et al* (2015) who observed that the branching zone increased with increased BA and BA+GA_{4+7} concentrations, which also increases number of buds and leaves per plant. Similar studies conducted by others research workers that PGR's increased the formation of buds on lateral shoots, which directly increased the number of leaves on shoots (Robinson *et al* 2006; Sadowski *et al* 2007; Elfving 2010).

4.2.11 Number of buds (per 100 cm on feathers)

The data presented in Table 83 show that number of buds were significantly affected by PGR's over heading treatments during both the years of study. In pear cvs. Pathranakh and Punjab Beauty, numbers of buds/100cm shoot were found to be higher under treatments T4 (GA 200 + BA 600 ppm), T5 (GA 400 + BA 600 ppm) and T6 (GA 600 + BA 600 ppm), which were statistically at par to each other. However, minimum numbers of buds/100cm shoot were noted under treatments T7 (heading at 60cm), T8 (heading at 75cm) and T9 (heading at 90cm). In our studies, the higher number of buds on lateral shoots was recorded under treatments of GA+BA application followed by BA application alone. Numbers of buds were observed less under control plants (heading at 90 cm) and other heading treatments at different heights. Our findings are partially in accordance with the results obtained by Doric *et al* (2015) that the branching zone increased with increased PGR concentrations, which also increases number of buds on lateral shoots. Similar studies conducted by others research workers that PGR's increased the formation of buds on lateral shoots in plants (Robinson *et al* 2006; Sadowski *et al* 2007; Elfving 2010).

4.2.12 Mean leaf area (cm^2)

Data on this aspect presented in Table 84 show that mean leaf area was significantly affected by various heading and PGR treatments during both the years of present studies. In pear cvs. Pathranakh and Punjab Beauty, mean leaf area was found to be higher under heading treatments i.e. T7 (heading at 60cm), T8 (heading at 75cm) and T9 (heading at 90cm), which was statistically at par with each other. However, mean leaf area was recorded intermediate under treatments T1 (BA 400ppm), T2 (BA 600ppm) and T3 (BA 800ppm) and these treatments have statistically non-significant differences. The minimum mean leaf area was noted under treatments T4 (GA 200 + BA 600 ppm), T5 (GA 200 + BA 600 ppm) and T6 (GA 200 + BA 600 ppm). Higher numbers of small sized leaves were found under treatments of GA+BA combined application followed by treatments BA alone application than heading treatments in plants. It was the main cause of less leaf area under PGR treatments in plants. The negative correlation was observed between number of leaves and leaf area in our studies during both the years. The branching zone increased with increased concentration of PGR applications on plants, which also influenced number of leaves/plant and decreased leaf area in plants (Doric *et al* 2015). Our results confirm the average opinion in literature is that low BA concentration is optimal for good feathering of young plum plants and higher concentration may cause short laterals or phyto-toxic symptoms on plum leaves (Magyar and Hrotko 2002).

Table 77: Effect of PGR and heading treatments on height of first feather from ground level (cm) of pear plants cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	**BA 400 ppm**	40.25^{d}	38.33^{d}	39.29	35.55^{d}	33.37^{d}	34.46
T2	**BA 600 ppm**	38.13^{de}	37.12^{d}	37.63	34.03^{d}	32.16^{d}	33.10
T3	**BA 800 ppm**	37.82^{e}	36.65^{de}	37.24	34.40^{d}	31.66^{d}	33.03
T4	**GA_3 200 + BA 600 ppm**	35.18^{f}	34.03^{ef}	34.61	33.18^{de}	31.30^{de}	32.24
T5	**GA_3 400 + BA 600 ppm**	34.17^{f}	32.93^{f}	33.55	31.06^{ef}	29.99^{de}	30.53
T6	**GA_3 600 + BA 600 ppm**	33.62^{f}	31.18^{f}	32.40	29.63^{f}	28.86^{e}	29.25
T7	**Heading at 60 cm**	44.48^{c}	42.94^{c}	43.71	40.96^{c}	38.67^{c}	39.82
T8	**Heading at 75 cm**	55.56^{b}	58.82^{b}	57.19	48.22^{b}	44.55^{b}	46.39
T9	**Heading at 90 cm** (control)	64.81^{a}	68.56^{a}	**66.69**	58.80^{a}	55.10^{a}	**56.95**
LSD		2.31	3.07		2.69	2.52	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 78a: Effect of PGR and heading treatments on diameter of stem above bud union (mm) of pear plants cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	**BA 400 ppm**	26.84^{a}	25.74^{a}	26.29	23.34^{a}	22.29^{a}	**22.82**
T2	**BA 600 ppm**	26.75^{a}	25.86^{a}	**26.31**	23.30^{ab}	22.23^{a}	22.77
T3	**BA 800 ppm**	26.39^{a}	25.40^{a}	25.90	23.23^{ab}	22.19^{a}	22.71
T4	**GA_3 200 + BA 600 ppm**	23.92^{b}	23.25^{b}	23.59	22.99^{ab}	21.23^{b}	22.11
T5	**GA_3 400 + BA 600 ppm**	23.80^{bc}	23.24^{b}	23.52	22.87^{abc}	21.15^{bc}	22.01
T6	**GA_3 600 + BA 600 ppm**	23.13^{c}	23.12^{b}	23.13	22.85^{abc}	21.08^{bc}	21.97
T7	**Heading at 60 cm**	22.08^{d}	22.50^{c}	22.29	22.92^{abc}	20.70^{c}	21.81
T8	**Heading at 75 cm**	22.07^{d}	22.37^{c}	22.22	22.80^{bc}	20.63^{cd}	21.72
T9	**Heading at 90 cm** (control)	22.18^{d}	22.58^{c}	22.38	22.43^{c}	20.49^{d}	21.46
LSD		0.69	0.54		0.51	0.50	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 78b: Effect of PGR and heading treatments on diameter of stem below bud union (mm) of pear plants cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	BA 400 ppm	27.15[a]	26.21[a]	**26.68**	24.18[a]	22.53[a]	**23.36**
T2	BA 600 ppm	26.81[a]	25.97[a]	26.39	23.79[ab]	22.43[a]	23.11
T3	BA 800 ppm	26.71[a]	25.99[a]	26.35	23.69[ab]	22.25[a]	22.97
T4	GA_3 200 + BA 600 ppm	24.53[b]	23.73[b]	24.13	23.29[bc]	21.37[b]	22.33
T5	GA_3 400 + BA 600 ppm	24.29[bc]	23.61[b]	23.95	23.11[cd]	21.29[b]	22.20
T6	GA_3 600 + BA 600 ppm	23.69[c]	23.55[bc]	23.62	23.10[cd]	21.22[bc]	22.16
T7	Heading at 60 cm	22.64[d]	23.08[cd]	22.86	23.19[cd]	20.99[bc]	22.09
T8	Heading at 75 cm	22.47[d]	22.97[d]	22.72	22.95[cd]	20.81[c]	21.88
T9	Heading at 90 cm (control)	22.93[d]	23.13[cd]	23.03	22.77[d]	20.79[c]	21.78
LSD		0.67	0.53		0.52	0.43	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 79: Effect of PGR and heading treatments on mean crotch angle/feather (^{o}) of pear plants cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	BA 400 ppm	57.98[a]	54.97[a]	**56.48**	58.18[ab]	57.00[a]	57.59
T2	BA 600 ppm	56.74[ab]	55.44[a]	56.09	58.96[a]	57.77[a]	**58.37**
T3	BA 800 ppm	56.14[b]	54.50[a]	55.32	58.34[ab]	56.82[b]	57.58
T4	GA_3 200 + BA 600 ppm	53.01[c]	50.04[b]	51.53	57.24[bc]	56.05[b]	56.65
T5	GA_3 400 + BA 600 ppm	52.81[c]	50.39[b]	51.60	56.94[c]	54.97[c]	55.96
T6	GA_3 600 + BA 600 ppm	52.05[c]	50.08[b]	51.07	56.16[c]	55.02[c]	55.59
T7	Heading at 60 cm	37.10[d]	35.77[c]	36.44	38.32[d]	36.37[d]	37.35
T8	Heading at 75 cm	36.92[d]	35.79[c]	36.36	38.59[d]	36.82[d]	37.71
T9	Heading at 90 cm (control)	33.68[e]	32.45[d]	33.07	36.38[e]	35.82[d]	36.10
LSD		1.65	0.97		1.32	0.78	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 80: Effect of PGR and heading treatments on mean spread of plants (cm) of pear cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	**BA 400 ppm**	43.33[a]	41.30[a]	**42.32**	38.64[a]	33.40[b]	36.02
T2	**BA 600 ppm**	42.55[a]	39.58[b]	41.07	38.88[a]	34.30[ab]	**36.59**
T3	**BA 800 ppm**	42.14[ab]	39.30[b]	40.72	37.42[ab]	35.25[a]	36.34
T4	**GA_3 200 + BA 600 ppm**	40.46[b]	39.18[b]	39.82	36.17[b]	34.02[ab]	35.10
T5	**GA_3 400 + BA 600 ppm**	38.07[c]	37.67[c]	37.87	36.12[b]	33.90[b]	35.01
T6	**GA_3 600 + BA 600 ppm**	38.16[c]	36.52[c]	37.34	36.06[b]	33.55[b]	34.81
T7	**Heading at 60 cm**	27.75[d]	25.10[d]	26.43	24.89[c]	23.33[c]	24.11
T8	**Heading at 75 cm**	27.83[d]	25.56[d]	26.70	24.87[c]	23.56[c]	24.22
T9	**Heading at 90 cm** (control)	27.21[d]	24.88[d]	26.05	23.23[c]	22.38[c]	22.81
LSD		2.02	1.11		1.90	1.28	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 81: Effect of PGR and heading treatments on mean height of plants (cm) of pear cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	**BA 400 ppm**	166.37[c]	160.68[c]	163.53	159.78[ab]	144.40[de]	152.09
T2	**BA 600 ppm**	165.45[c]	158.96[d]	162.21	159.27[ab]	142.78[d]	151.03
T3	**BA 800 ppm**	164.77[cd]	157.79[d]	161.28	157.92[bc]	142.09[de]	150.01
T4	**GA_3 200 + BA 600 ppm**	162.99[d]	148.97[e]	155.98	156.67[cd]	140.60[e]	148.64
T5	**GA_3 400 + BA 600 ppm**	158.94[e]	147.23[ef]	153.09	156.12[cd]	138.36[f]	147.24
T6	**GA_3 600 + BA 600 ppm**	157.90[e]	146.13[f]	152.02	155.23[d]	138.35[f]	146.79
T7	**Heading at 60 cm**	162.74[d]	158.09[d]	160.42	156.52[cd]	151.18[c]	153.85
T8	**Heading at 75 cm**	173.75[b]	167.68[b]	170.72	158.81[b]	155.78[b]	157.30
T9	**Heading at 90 cm** (control)	180.76[a]	173.11[a]	**176.94**	160.40[a]	158.78[a]	**159.59**
LSD		3.14	1.75		1.89	2.02	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 82: Effect of PGR and heading treatments on number of leaves (per 100 cm on feathers) of pear plants cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	BA 400 ppm	18.54^{c}	17.85^{c}	18.20	28.54^{c}	27.65^{b}	28.10
T2	BA 600 ppm	19.08^{c}	18.26^{c}	18.67	29.78^{b}	28.40^{ab}	29.09
T3	BA 800 ppm	18.95^{bc}	18.22^{c}	18.59	30.10^{b}	28.43^{ab}	29.27
T4	GA_3 200 + BA 600 ppm	19.76^{b}	18.41^{bc}	19.09	31.52^{a}	29.54^{a}	30.53
T5	GA_3 400 + BA 600 ppm	20.74^{a}	19.29^{a}	**20.02**	31.60^{a}	29.66^{a}	**30.63**
T6	GA_3 600 + BA 600 ppm	20.60^{ab}	19.01^{ab}	19.81	31.34^{a}	29.47^{a}	30.41
T7	Heading at 60 cm	11.97^{d}	10.07^{d}	11.02	23.11^{d}	21.60^{c}	22.36
T8	Heading at 75 cm	11.52^{d}	10.21^{d}	10.87	22.94^{d}	21.52^{c}	22.23
T9	Heading at 90 cm (control)	11.37^{d}	10.16^{d}	10.77	22.62^{d}	21.38^{c}	22.00
LSD		0.89	0.83		1.07	1.49	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 83: Effect of PGR and heading treatments on number of buds (per 100 cm on feathers) of pear plants cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	BA 400 ppm	8.11^{c}	8.48^{b}	8.30	10.06^{b}	11.67^{c}	10.87
T2	BA 600 ppm	8.63^{c}	9.08^{b}	8.86	10.25^{b}	11.86^{bc}	11.06
T3	BA 800 ppm	8.99^{bc}	9.51^{b}	9.25	10.81^{b}	11.97^{bc}	11.39
T4	GA_3 200 + BA 600 ppm	10.14^{ab}	11.01^{a}	10.58	12.41^{a}	13.24^{ab}	12.83
T5	GA_3 400 + BA 600 ppm	10.29^{a}	11.11^{a}	10.70	12.59^{a}	13.42^{ab}	13.01
T6	GA_3 600 + BA 600 ppm	10.33^{a}	11.15^{a}	**10.74**	12.93^{a}	13.78^{a}	**13.36**
T7	Heading at 60 cm	2.72^{d}	3.11^{c}	2.92	3.67^{c}	4.25^{d}	3.96
T8	Heading at 75 cm	2.65^{d}	3.08^{c}	2.87	3.37^{c}	3.94^{d}	3.66
T9	Heading at 90 cm (control)	2.55^{d}	2.51^{c}	2.53	3.21^{c}	3.71^{d}	3.46
LSD		1.22	1.33		1.44	1.66	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 84: Effect of PGR and heading treatments on mean leaf area (cm^2) of pear plants cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	**BA 400 ppm**	52.23[b]	51.22[b]	51.73	35.80[c]	34.79[b]	35.30
T2	**BA 600 ppm**	52.04[b]	51.03[b]	51.54	35.63[c]	34.68[b]	35.16
T3	**BA 800 ppm**	51.78[b]	50.76[b]	51.27	35.49[c]	34.52[b]	35.01
T4	**GA_3 200 + BA 600 ppm**	50.64[c]	49.49[c]	50.07	34.41[d]	33.17[c]	33.79
T5	**GA_3 400 + BA 600 ppm**	50.50[c]	49.35[c]	49.93	34.74[d]	33.12[c]	33.93
T6	**GA_3 600 + BA 600 ppm**	50.21[c]	49.06[c]	49.64	34.56[d]	33.05[c]	33.81
T7	**Heading at 60 cm**	53.86[a]	52.29[a]	53.08	37.14[b]	36.26[a]	36.70
T8	**Heading at 75 cm**	53.92[a]	52.36[a]	53.14	37.39[ab]	36.37[a]	36.88
T9	**Heading at 90 cm** (control)	54.05[a]	52.49[a]	**53.27**	37.60[a]	36.56[a]	**37.08**
LSD		1.07	1.06		0.42	0.58	

[*]LSD indicates the least significant difference test at $p<0.05$.

[**]Values are means with a common letter are not significantly different at 5% level.

4.2.13 Nutrient status

4.2.13.1 Macronutrients (%)

Data on this aspect presented in Tables 85a-85e show that leaf macronutrient contents (N, P, K, Ca and Mg) in leaves of treated plant were significantly affected by heading and PGR treatments during both the years of present studies. In pear cvs. Patharnakh and Punjab Beauty, leaf N (Table 85a), P (Table 85b), K (Table 85c), Ca (Table 85d) and Mg (Table 85e) contents were recorded maximum under treatment T3 (BA 800 ppm) followed by treatment T2 (BA 600 ppm), which was statistically at par with each other. However, minimum leaf macronutrient contents were noted under control plants (heading at 90cm) and other heading treatments (T7 and T8) at different heights.

Our results confirm the average opinion in studies that higher macronutrient contents were found under BA treatments (T1, T2 and T3) followed by GA+BA treatments (T4, T5 and T6). It was may be due to more translocation of macronutrients in plants by the application of plant growth regulators, which increased vegetative growth viz. higher number of feathers, total length of feathers and spread of plant than the control plants. In our observations, leaf macronutrient contents were significantly higher under application of BA alone followed by GA+BA combinations during studies. Similarly, Tromp (1996) confirmed that important factors in feathering are nutrient availability and similar results were found in our study. All of these can be accounted for the transport of assimilate devoted to developing laterals and nutrient status of leaves increased (Magyar and Hrotko 2002).

4.2.13.2 Micronutrients (ppm)

Data on this aspect presented in Tables 86a-86d show that leaf micronutrient contents (Fe, Zn, Mn and Cu) in leaves of plants were significantly affected by the different heading and PGR treatments during both the years. In pear cvs. Patharnakh and Punjab Beauty, leaf Fe content (Table 86a) was noted higher under treatment T6 (GA 600 ppm + BA 600 ppm) followed by treatment T5 (GA 400 ppm + BA 600 ppm), which was statistically at par with each other. Leaf Zn (Table 86b), Mn (Table 86c) and Cu (Table 86d) contents were noted higher under treatment T3 (BA 800 ppm) followed by treatment T2 (BA 600 ppm), which was statistically at par with treatment T2. However, minimum micronutrient contents were recorded under heading treatments (T7, T8 and T9) at different heights.

Our results confirm the average opinion in studies that higher micronutrient contents were found under BA treatments (T1, T2 and T3) followed by GA+BA treatments (T4, T5 and T6). It was may be due to more translocation of micronutrients in plants by the application of PGR's, which increased vegetative growth of plant than the control plants. All of these can be accounted for the transport of assimilate devoted to developing laterals and nutrient level increased in treated plants (Magyar and Hrotko 2002). Similarly Tromp (1996) confirmed that important factors in feathering are nutrient availability in plants and similar results are found in our study.

Table 85a: Effect of PGR and heading treatments on N content (%) in leaves of pear plants cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	**BA 400 ppm**	2.26^{bc}	2.18^{b}	2.22	2.27^{b}	2.14^{bc}	2.21
T2	**BA 600 ppm**	2.28^{b}	2.21^{ab}	2.25	2.28^{ab}	2.15^{ab}	2.22
T3	**BA 800 ppm**	2.36^{a}	2.23^{a}	**2.30**	2.30^{a}	2.17^{a}	**2.24**
T4	**GA_3 200 + BA 600 ppm**	2.25^{bc}	2.15^{bc}	2.20	2.24^{cd}	2.12^{cd}	2.18
T5	**GA_3 400 + BA 600 ppm**	2.23^{c}	2.12^{c}	2.18	2.26^{bc}	2.11^{d}	2.19
T6	**GA_3 600 + BA 600 ppm**	2.22^{c}	2.12^{c}	2.17	2.23^{d}	2.12^{cd}	2.18
T7	**Heading at 60 cm**	2.16^{d}	2.07^{d}	2.12	2.16^{e}	2.06^{e}	2.11
T8	**Heading at 75 cm**	2.15^{d}	2.08^{cd}	2.12	2.17^{e}	2.08^{e}	2.13
T9	**Heading at 90 cm** (control)	2.18^{d}	2.06^{d}	2.12	2.16^{e}	2.07^{e}	2.12
LSD		0.040	0.040		0.020	0.020	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 85b: Effect of PGR and heading treatments on P content (%) in leaves of pear plants cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	BA 400 ppm	0.218[ab]	0.207[a]	0.213	0.223[b]	0.216[b]	0.220
T2	BA 600 ppm	0.221[a]	0.210[a]	0.215	0.225[ab]	0.218[b]	0.222
T3	BA 800 ppm	0.224[a]	0.208[a]	**0.216**	0.229[a]	0.224[a]	**0.227**
T4	GA_3 200 + BA 600 ppm	0.216[b]	0.196[b]	0.206	0.222[b]	0.214[bc]	0.218
T5	GA_3 400 + BA 600 ppm	0.215[b]	0.199[b]	0.207	0.221[b]	0.209[cd]	0.215
T6	GA_3 600 + BA 600 ppm	0.214[b]	0.201[b]	0.208	0.224[b]	0.209[cd]	0.217
T7	Heading at 60 cm	0.194[c]	0.185[c]	0.190	0.212[cd]	0.203[e]	0.208
T8	Heading at 75 cm	0.195[c]	0.189[c]	0.192	0.215[c]	0.205[de]	0.210
T9	Heading at 90 cm (control)	0.193[c]	0.188[c]	0.191	0.209[d]	0.206[de]	0.208
LSD		0.006	0.005		0.004	0.005	

[*]LSD indicates the least significant difference test at p<0.05.

[**]Values are means with a common letter are not significantly different at 5% level.

Table 85c: Effect of PGR and heading treatments on K content (%) in leaves of pear plants cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	BA 400 ppm	1.051[d]	1.138[ab]	1.095	1.109[a]	1.109[a]	1.109
T2	BA 600 ppm	1.113[c]	1.151[a]	1.132	1.127[a]	1.116[a]	1.122
T3	BA 800 ppm	1.140[a]	1.150[a]	**1.145**	1.146[a]	1.120[a]	**1.133**
T4	GA_3 200 + BA 600 ppm	1.124[bc]	1.104[c]	1.114	1.077[b]	1.116[a]	1.097
T5	GA_3 400 + BA 600 ppm	1.136[ab]	1.126[b]	1.131	1.057[bc]	1.107[a]	1.082
T6	GA_3 600 + BA 600 ppm	1.049[d]	1.041[d]	1.045	1.024[c]	1.050[b]	1.037
T7	Heading at 60 cm	0.989[e]	0.977[e]	0.983	0.973[d]	0.966[c]	0.970
T8	Heading at 75 cm	0.987[e]	0.987[e]	0.987	0.993[d]	0.931[c]	0.962
T9	Heading at 90 cm (control)	0.953[f]	0.963[f]	0.958	0.986[d]	0.921[c]	0.954
LSD		0.018	0.017		0.052	0.059	

[*]LSD indicates the least significant difference test at p<0.05.

[**]Values are means with a common letter are not significantly different at 5% level.

Table 85d: Effect of PGR and heading treatments on Ca content (%) in leaves of pear plants cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	**BA 400 ppm**	2.19[bc]	2.09[b]	2.140	2.70[a]	2.28[b]	2.490
T2	**BA 600 ppm**	2.24[ab]	2.16[a]	2.200	2.76[a]	2.40[a]	2.580
T3	**BA 800 ppm**	2.26[a]	2.18[a]	**2.220**	2.77[a]	2.43[a]	**2.600**
T4	**GA_3 200 + BA 600 ppm**	2.17[c]	2.08[b]	2.125	2.48[b]	2.25[b]	2.365
T5	**GA_3 400 + BA 600 ppm**	2.15[cd]	2.06[bc]	2.105	2.32[c]	2.18[c]	2.250
T6	**GA_3 600 + BA 600 ppm**	2.11[d]	2.03[c]	2.070	2.34[c]	2.17[c]	2.255
T7	**Heading at 60 cm**	2.05[de]	2.01[cd]	2.030	2.19[d]	2.05[d]	2.120
T8	**Heading at 75 cm**	2.06[e]	2.03[c]	2.045	2.23[d]	2.08[d]	2.155
T9	**Heading at 90 cm** (control)	2.02[e]	1.98[d]	2.000	2.22[d]	2.06[d]	2.140
LSD		0.060	0.050		0.070	0.030	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 85e: Effect of PGR and heading treatments on Mg content (%) in leaves of pear plants cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	**BA 400 ppm**	0.354[b]	0.332[bc]	0.343	0.404[ab]	0.382[b]	0.393
T2	**BA 600 ppm**	0.357[b]	0.336[b]	0.347	0.407[a]	0.397[a]	0.402
T3	**BA 800 ppm**	0.365[a]	0.348[a]	**0.357**	0.406[a]	0.399[a]	**0.403**
T4	**GA_3 200 + BA 600 ppm**	0.347[c]	0.328[c]	0.338	0402[ab]	0.372[c]	0.387
T5	**GA_3 400 + BA 600 ppm**	0.343[c]	0.323[d]	0.333	0.407[a]	0.377[bc]	0.392
T6	**GA_3 600 + BA 600 ppm**	0.336[d]	0.324[d]	0.330	0.398[bc]	0.378[bc]	0.388
T7	**Heading at 60 cm**	0.318[e]	0.302[e]	0.310	0.386[e]	0.363[d]	0.375
T8	**Heading at 75 cm**	0.319[e]	0.306[e]	0.313	0.394[cd]	0.365[d]	0.380
T9	**Heading at 90 cm** (control)	0.318[e]	0.302[e]	0.310	0.388[de]	0.363[d]	0.376
LSD		0.005	0.005		0.007	0.006	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 86a: Effect of PGR and heading treatments on Fe content (ppm) in leaves of pear plants cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	BA 400 ppm	210.98[c]	184.00[d]	197.49	205.70[d]	194.77[d]	200.23
T2	BA 600 ppm	216.35[b]	193.42[c]	204.88	208.84[c]	199.99[c]	204.41
T3	BA 800 ppm	220.34[b]	199.55[ab]	209.94	207.87[c]	203.86[b]	205.86
T4	GA_3 200 + BA 600 ppm	220.24[b]	194.03[bc]	207.13	215.76[b]	202.42[b]	209.09
T5	GA_3 400 + BA 600 ppm	229.10[a]	198.66[ab]	213.88	218.78[a]	204.41[ab]	211.59
T6	GA_3 600 + BA 600 ppm	232.41[a]	203.43[a]	**217.92**	220.53[a]	205.87[a]	**213.20**
T7	Heading at 60 cm	194.63[d]	176.74[e]	185.68	199.24[f]	190.16[f]	194.70
T8	Heading at 75 cm	193.98[d]	176.62[e]	185.30	202.30[e]	192.35[e]	197.32
T9	Heading at 90 cm (control)	195.63[d]	175.55[e]	185.59	200.83[ef]	191.67[ef]	196.25
LSD		5.14	5.33		2.07	2.06	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 86b: Effect of PGR and heading treatments on Zn content (ppm) in leaves of pear plants cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	BA 400 ppm	24.26[a]	22.43[b]	23.34	18.63[bc]	17.85[b]	18.24
T2	BA 600 ppm	25.35[a]	22.50[b]	23.92	18.93[ab]	17.89[b]	18.41
T3	BA 800 ppm	25.72[a]	24.32[a]	**25.02**	19.11[a]	18.76[a]	**18.93**
T4	GA_3 200 + BA 600 ppm	21.73[b]	20.45[c]	21.09	17.97[d]	16.95[de]	17.46
T5	GA_3 400 + BA 600 ppm	21.60[b]	18.60[d]	20.10	18.07[d]	17.09[cd]	17.58
T6	GA_3 600 + BA 600 ppm	20.47[b]	18.53[d]	19.50	18.18[cd]	17.27[c]	17.72
T7	Heading at 60 cm	18.95[c]	15.59[e]	17.27	17.89[de]	16.51[f]	17.20
T8	Heading at 75 cm	19.16[c]	16.38[e]	17.77	17.95[de]	16.64[ef]	17.29
T9	Heading at 90 cm (control)	19.11[c]	16.40[e]	17.75	17.47[e]	16.54[f]	17.00
LSD		1.23	1.28		0.49	0.32	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 86c: Effect of PGR and heading treatments on Mn content (ppm) in leaves of pear plants cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	**BA 400 ppm**	98.84[a]	94.84[b]	96.84	75.61[bc]	67.74[ab]	71.67
T2	**BA 600 ppm**	100.90[a]	99.01[a]	**99.95**	76.72[ab]	68.34[a]	72.53
T3	**BA 800 ppm**	101.41[a]	97.77[ab]	99.59	76.89[a]	68.32[a]	**72.60**
T4	**GA_3 200 + BA 600 ppm**	100.62[a]	91.75[bc]	96.18	72.70[d]	65.34[d]	69.02
T5	**GA_3 400 + BA 600 ppm**	100.76[a]	91.51[bc]	96.13	73.42[d]	66.21[cd]	69.81
T6	**GA_3 600 + BA 600 ppm**	98.66[a]	90.81[c]	94.73	75.39[c]	66.77[bc]	71.08
T7	**Heading at 60 cm**	90.95[b]	86.56[d]	88.75	70.46[e]	59.86[e]	65.16
T8	**Heading at 75 cm**	92.03[b]	86.81[d]	89.42	70.54[e]	60.79[e]	65.66
T9	**Heading at 90 cm** (control)	91.58[b]	86.61[d]	89.09	70.50[e]	60.41[e]	65.45
LSD		4.07	3.81		1.25	1.41	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

Table 86d: Effect of PGR and heading treatments on Cu content (ppm) in leaves of pear plants cvs. Patharnakh and Punjab Beauty

Treatments		Patharnakh			Punjab Beauty		
		2016	2017	Mean	2016	2017	Mean
T1	**BA 400 ppm**	7.39[ab]	6.66[a]	7.02	7.61[ab]	6.74[a]	7.17
T2	**BA 600 ppm**	7.56[a]	6.69[a]	7.12	7.64[ab]	6.91[a]	7.27
T3	**BA 800 ppm**	7.56[a]	6.74[a]	**7.15**	7.72[a]	6.97[a]	**7.34**
T4	**GA_3 200 + BA 600 ppm**	7.35[b]	6.69[a]	7.02	7.56[ab]	6.63[ab]	7.09
T5	**GA_3 400 + BA 600 ppm**	7.47[ab]	6.62[a]	7.04	7.56[ab]	6.80[a]	7.18
T6	**GA_3 600 + BA 600 ppm**	7.43[ab]	6.58[a]	7.00	7.36[bc]	6.79[a]	7.07
T7	**Heading at 60 cm**	6.87[d]	6.05[b]	6.46	6.86[d]	6.25[c]	6.55
T8	**Heading at 75 cm**	7.12[c]	6.12[b]	6.62	7.02[cd]	6.33[bc]	6.67
T9	**Heading at 90 cm** (control)	6.96[cd]	6.08[b]	6.52	6.96[d]	6.34[bc]	6.65
LSD		0.20	0.21		0.35	0.37	

*LSD indicates the least significant difference test at $p<0.05$.

**Values are means with a common letter are not significantly different at 5% level.

CHAPTER V

SUMMARY

Pear is an important fruit crop of temperate and low-chill cultivars can also be cultivated in subtropical climate. Area under this crop is increasing rapidly in the state due to availability of suitable pear cultivars and their developed production technologies. Various factors like climate, availability of cultivars, compatible rootstocks, quality of planting material, advanced cultural practices etc. contribute to the yielding potential of pear plants but planting density is the most important single factor which brings about radical production increased per unit area. Effect of various training systems on plant growth and development also contributed in increasing production efficiency and fruit quality by the modification of plant geometry as dimensional approach. During the present studies, two experiments were conducted on pear plants to achieve the goals of our objectives. In first experiment, pear plants (cvs. Patharnakh, Punjab Beauty and Punjab Soft) were planted during the year 2011 and trained to Espalier, Cordon and Y-trellis training systems. From these plants, results were recorded during the years 2016 and 2017 for our studies regarding effect of various training systems on production and fruit quality of pear. In the second experiment, one-year-old pear nursery plants (cvs. Patharnakh and Punjab Beauty) were planted in the field and were sprayed with plant growth regulators (6-Benzyl adenine and Gibberellic acid) at different concentrations during both the years to achieve respective goals regarding feathering in pear plants. In this experiment, some pear plants were under heading back treatments at different heights (60cm, 75cm and 90cm) to maximize the feathering of plants. The present investigation "Studies on canopy management in pear" was, therefore conducted with the following objectives:

a) To study the effect of different plant canopy structures on growth, productivity and fruit quality in pear.
b) To study the effect of trellis training systems on eco-physiological parameters of pear.
c) To study the effect of heading and plant growth regulators on feathering of pear nursery plants.

The results of this study are summarized below:

5.1 EFFECT OF TRELLIS TRAINING SYSTEMS ON PRODUCTION AND FRUIT QUALITY OF PEAR

- Net photosynthesis rate (Pn) of leaves at different canopy portions was recorded highest in plants trained to Espalier training system followed by Y-trellis system. It was recorded lowest in plants trained to Cordon training system.

- Net photosynthesis rate was recorded highest in upper canopy portions followed by middle canopy and it was noted least in lower canopy portions irrespective of all training systems. The trend of seasonal variation of photosynthesis rate within plant canopies was significantly high during May-June months of both the years.
- Seasonal variation in photosynthesis rate of pear cultivars (Patharnakh, Punjab Beauty and Punjab Soft) was following the alike trend during the entire season of growth. It was observed highest at mature leaf age under the least effect of shade. Photosynthesis rate was decreased after June month frequently to the end of vegetative growth phase. It was associated with increasing effect of shade by upper canopy's growth on the lower canopy portions.
- In pear cv. Punjab Beauty, photosynthesis rate was decreased to least at the end of vegetative growth phase in the month of August. It was associated with leaf falls of pear cv. Punjab Beauty under subtropical conditions of north India.
- Photo-synthetically active radiation (PAR) received by leaves was noted highest in different canopy portions of pear plants, when trained to Espalier training system followed by Y-trellis system. However, it was observed lowest in plants trained to Cordon training system.
- PAR received by leaves was recorded maximum in the upper portion of canopy followed by middle canopy and it was noted minimum in lower canopy portions. PAR interception was recorded highest in the month of April and thereafter follows the decreasing trend to the end of vegetative growth phase. PAR was affected by shade in plant's canopy with the progress of vegetative growth.
- PAR received by leaves was following an analogous trend in all pear cultivars as it was in case of Patharnakh. In pear cv. Punjab Beauty, PAR interception was following an increasing trend during the month of August due to leaf falls under subtropical conditions of north India.
- Stomatal conductance (C) and transpiration rate (E) were recorded utmost in pear (cvs. Patharnakh, Punjab Beauty and Punjab Soft) plants trained to Espalier training system followed by Y-trellis system and these were noted lowest in plants trained to Cordon training system.
- Stomatal conductance and transpiration rate were recorded high in upper canopy portions followed by middle canopy. These parameters were observed least in lower canopy portions irrespective of all training systems during both the years.
- The trend of seasonal variation of stomatal conductance and transpiration rate was following a parallel trend as it was in case of photosynthesis rate. Stomatal conductance

and transpiration rate were significantly high during the May-June months during both the years.

- Photosynthesis rate was directly correlated to stomatal conductance and transpiration rate of leaves. Therefore, an analogous trend was found in these eco-physiological parameters of pear plants trained to various training systems.
- Relative humidity (RH) within plant canopy was highest in the months of July and August. The relative humidity was recorded maximum in plants trained to Y-trellis training system due to dense canopy, when compared to other training systems. It was noted minimum in plants trained to Espalier training system.
- Canopy temperature within plant canopy was recorded highest in the month of June and it was lowest in the month of April during both the years of study. Canopy temperature during the entire season of growth, was found to be most in plants trained to Espalier system and it was recorded lowest in plants trained to Y-trellis training system.
- Soil temperature underneath the plant canopy was found highest in the month of June and it was least in the month of April. However amongst all the training systems, soil temperature underneath the Espalier training system was recorded high and it was directly related to light penetration underneath the plant canopy on ground surface.
- Trend of seasonal variation in micro-climatic factors (RH, canopy and soil temperature) within canopy of plants was alike in all pear cultivars during our studies in both the years.
- Trunk cross sectional area (TCSA) was recorded maximum in plants trained to Y-trellis system intimately followed by Espalier training system. It was noted minimum in plants trained to Cordon training system. However, TCSA was noted highest in pear cv. Patharnakh followed by Punjab Beauty and it was least in pear cv. Punjab Soft during both the years of investigation.
- Shoot diameter was recorded maximum in plants trained to Y-trellis system and it was very much followed by Espalier system. Minimum shoot diameter was obtained under Cordon training systems and it was significantly lesser than the plants trained to Espalier and Y-trellis training systems.
- Spur diameter and length were recorded maximum in plants trained to Espalier system and these were intimately followed by Y-trellis system. However, spur diameter and length were observed minimum in plants trained to Cordon training system.
- Extent of spur formation was significantly high in upper and middle canopy portions, in the plants trained to Espalier and Cordon training systems. In the Y-trellis system, extent of spur formation was highest only in upper canopy portions irrespective of the training

systems. Extent of spur formation in all pear cultivars was noted least in lower canopy portions and it was affected by low PAR interception within inner canopy portions.

- Spur formation was observed highest in plants trained to Espalier system followed by Y-trellis system and it was noted lowest in plants trained to Cordon training system for all three pear cultivars during our studies.
- Chlorophyll content in pear leaves was not significantly affected by the various training systems (Espalier, Cordon and Y-trellis) under different pear cultivars.
- Leaf area was recorded utmost in Cordon system followed by Espalier training system and it was observed smallest in Y-trellis trained plants in pear cvs. Patharnakh and Punjab Beauty. In pear cv. Punjab Soft, leaf area was not affected by various training systems.
- Pruning wood weight was recorded highest in plants trained to Y-trellis training system followed by Espalier system. However, lowest pruning wood weight was recorded under Cordon training system during both the years.
- Flowering period was varied from 2nd week of February to 1st week of March in pear cv. Patharnakh , 1st week of March to 3rd week of March in Punjab Beauty and 1st week of March to end of March in Punjab Soft. Flowering was noted early in Cordon system than plants trained to Espalier and Y-trellis system during both the years of investigation.
- Flower bud density (FBD) was noted high in upper canopy portions as compared to lower canopy portions under all the training systems. In pear cv. Patharnakh, plants trained to Espalier system recorded highest flower bud density in upper canopy portions followed by middle canopy as it was in case of Punjab Beauty.
- Maximum FBD was recorded in plants trained to Espalier system followed by Y-trellis system and it was noted lowest in plants trained to Cordon training system for all three pear cultivars. However, it was recorded maximum in pear cv. Patharnakh and lowest in Punjab Soft.
- Different training systems did not have any significant effect on fruit set in all pear cultivars like Patharnakh, Punjab Beauty and Punjab Soft during both the years of our study.
- Relative pattern of fruiting was recorded maximum in middle canopy portions followed by upper canopy of pear plants trained to Espalier training system and it was regulated by well distribution of light within middle and upper canopy portions under these systems. However, relative pattern of fruiting was noted highest only in upper canopy portions of pear plants trained to Y-trellis training system. It was recorded minimum in lower canopy portions of pear plants trained to various training systems.

- Fruit growth rate (Fruit diameter and length) in pear cv. Patharnakh was increased significantly from 30 DAFS to 150 DAFS, in Punjab Beauty from 30 DAFS to 135 DAFS and in Punjab Soft from 30 DAFS to 120 DAFS under various training systems. Fruit growth rate was recorded high during 45-120 DAFS irrespective of the effect of training systems. Fruit growth rate was less in plants trained to Y-trellis system as compared to other training systems.
- Our results in pear cultivars indicated that simple and complete sigmoid curves existed for growth and development of pear fruits, even despite the fact that the period of each phase of fruit growth was dissimilar in studied pear cultivars.
- Fruit numbers/plant and yield/plant were found maximum in pear cv. Patharnakh plants trained to Espalier training system and it was significantly high than the plants trained to other training systems. In pear cvs. Punjab Beauty and Punjab Soft, fruit numbers/plant and yield/plant were noted maximum in plants trained to Espalier training system followed by Y-trellis system. However, it was recorded lowest in plants trained to Cordon system.
- Yield/hectare was also maximum in plants trained to Espalier system followed by Y-trellis system and it was significantly high than the plants trained to other training systems. Minimum yield/ha was recorded under Cordon training system and it was directly associated with fruit numbers/plant and yield/plant.
- Production efficiency and crop load was recorded highest in pear plants (cvs. Patharnakh and Punjab Beauty) trained to Espalier system and it was significantly high than the plants trained to Y-trellis and Cordon training systems. In pear cv. Punjab Soft, production efficiency and crop load was noted highest in plants trained to Espalier system intimately followed by Y-trellis system. However, it was recorded lowest under Cordon training system in different pear cultivars.
- Highest fruit number/plant, yield /plant, yield/ha, production efficiency and crop load was recorded in pear cv. Patharnakh and it was significantly high than other pear cultivars. It was followed by pear cv. Punjab Beauty. Yield related parameters were found least in pear cv. Punjab Soft during both the years of investigation under subtropical conditions of north India.
- Fruit weight and size was recorded maximum in pear plants trained to Cordon system. It was followed by Espalier training system and it was noted lowest in plants trained to Y-trellis system.
- Upper portion of the plant canopy had significantly high fruit weight and size as compared to lower canopy portions irrespective of the various training systems. However,

maximum fruit weight and size was recorded in pear cv. Patharnakh followed by Punjab Beauty and it was noted lowest in Punjab Soft during both the years.

- Fruit firmness was found highest in fruits harvested from Y-trellis system and lowest fruit firmness was recorded in pear plants trained to Cordon training system. Fruits of lower canopy portion were more firm as compared to upper canopy portions irrespective of the various training systems.
- Total soluble solids (TSS) of fruits were recorded maximum in plants trained to Espalier system and it was noted significantly high than the plants trained to other training systems. Lowest TSS was recorded in fruits harvested from Cordon training system of plants.
- Highest TSS was recorded from the fruits harvested from upper portion of the canopy as compared to lower canopy portions and an analogous trend was found in all three pear cultivars.
- Fruit acidity was recorded highest in fruits harvested from plants trained to Y-trellis system followed by Espalier training system. Lowest fruit acidity was found in plants trained to Cordon system. However, maximum fruit acidity was recorded from the fruits harvested from lower canopy portion as compared to upper canopy portions and it was not affected by various training systems.
- Total sugars content was recorded highest in fruits harvested from Espalier trained plants and it was followed by plants trained to Y-trellis system. Lowest total sugars content in fruits was found in Cordon system plants. Total sugars content was high in fruits harvested from upper portion of the plant canopy as compared to lower canopy portions irrespective of the various training systems.
- Fruit starch content was recorded maximum in plants trained to Y-trellis system followed by Espalier system and it was noted minimum under Cordon system trained plants. Lowest starch content in fruits was recorded in upper canopy portions followed by middle canopy. Higher level of fruit starch content was observed in lower canopy portions and it was directly related to shading effect within plant canopies.
- Foliar nutrient status was also significantly affected by various training systems during the present studies. However, leaf Zn and P contents were not significantly affected by various training systems in all pear cultivars. Leaf N, K, Ca, Mg and Mn contents were found maximum in plants trained to Espalier training system as compared to plants trained to other training systems. Leaf Fe content was found maximum in plants trained to Cordon system. However, leaf nutrient contents were found in the optimum range during both the years of our studies.

From these results, it was concluded that pear plants trained to Espalier system were found to be better in terms of PAR interception and distribution within plant canopies, photosynthesis efficiency, growth and development of plants, yield related parameters, production efficiency and quality of pear fruits as compared to plants trained to Cordon and Y-trellis training systems under subtropical climate of north India.

5.2 EFFECT OF HEADING AND PLANT GROWTH REGULATORS ON FEATHERING OF PEAR PLANTS

- In pear cv. Patharnakh, numbers of feathers/plant were recorded maximum in treatment BA 600 ppm followed by treatment BA 400 ppm. In pear cv. Punjab Beauty, maximum numbers of feathers/plant was recorded in treatment GA 200 ppm + BA 600 ppm followed by treatment BA 800 ppm. It was recorded least in heading treatment at 90 cm (control).
- Mean length and diameter of feathers was recorded maximum in heading treatment at 90 cm followed by treatments BA 600 ppm and BA 400 ppm in pear cv. Patharnakh. Alike results were observed in pear cv. Punjab Beauty. However, mean diameters of feathers was recorded less in all GA+BA treatments.
- Total length of feathers/plant was noted highest in treatment BA 600 ppm followed by treatment BA 400 ppm. It was noted less in heading treatments at 60 cm and 90 cm.
- Height of first feather from ground level was recorded maximum in heading treatment at 90 cm and it was followed by treatment BA 400 ppm. Smallest height of first feather from ground surface was found in treatment GA 600 ppm + BA 600 ppm.
- Stock girth and scion girth was recorded highest in treatment BA 400 ppm. Stock girth and scion girth was noted less in all heading treatments as compared to PGR treatments.
- Crotch angle of feathers with main-axis was recorded highest in treatment BA 400 ppm followed by treatment BA 600 ppm. A narrow crotch angle between feathers and main-axis was found in heading treatments at 90 cm, 75 cm and 60 cm. Alike trends were found in both pear cultivars Patharnakh and Punjab Beauty during both the years of study.
- Spread of plant in both directions was recorded highest in treatment BA 400 ppm followed by treatment BA 600 ppm in pear cv. Patharnakh. In pear cv. Punjab Beauty, mean spread of plant was recorded maximum in treatment BA 600 ppm followed by treatment BA 800 ppm. It was found lesser in all heading back treatments during both the years of investigation.
- Plant height was recorded maximum in heading treatment at 90 cm followed by heading at 75 cm. There was emergence of few elongated shoots (2-3 shoots/plant) in heading treatments on upper portion of the plant. Plant height was observed shorter in all GA+BA treatments and it was decreased with high concentration of PGR’s application.

- Numbers of leaves and buds per 100 cm on lateral shoots were significantly high in all GA+BA treatments followed by application of BA alone in both pear cvs. Pathranakh and Punjab Beauty. However, less numbers of leaves and buds were recorded in heading treatment at 90 cm.
- Leaf area was noted maximum in heading treatment at 90 cm. However, smallest leaf area was noted in treatment GA 600 ppm + BA 600 ppm. A negative correlation was observed between number of leaves and leaf area in our studies.
- Foliar nutrient status was also significantly affected by PGR’s application on pear plants during the present studies. Leaf N, P, K, Ca, Mg, Zn, Mn and Cu contents were found maximum in treatment BA 800 ppm followed by treatment BA 600 ppm. Leaf Fe content was found maximum in treatment GA 600 ppm + BA 600 ppm followed by treatment GA 400 ppm + BA 600 ppm. However, leaf nutrient contents were found lowest in heading treatments as compared to the PGR’s application during our studies. An analogous trend was found in pear cv. Punjab Beauty as was observed in case of Patharnakh.

From these studies, it was concluded that one-year-old nursery pear plants by the application of 6-benzyl adenine at concentration of 400 ppm and 600 ppm were found to be better in terms of number of feathers/plant, total length of feathers/plant, mean crotch angle of feathers with main-axis, spread of plant in both directions, branching zone and foliar nutrient status as compared to other treatments i.e. GA+BA combined application and heading at different heights. These results were more apparent in pear cv. Patharnakh as compared to cultivar Punjab Beauty.

(a)

(b)

(c)

PGR and heading treatments on pear cv. Patharnakh (a) heading at 90 cm (b) BA 400 ppm (c) BA 600 pm

Espalier system (a) Plants after pruning (b) Plants without pruning

Cordon system (a) Plants after pruning (b) Plants without pruning

Y-trellis system (a) Plants after pruning (b) Plants without pruning

Pear plants trained to Espalier system during flowering time

Fruit distribution at lower, middle and upper canopy portions of pear plants trained on Espalier system

Mature fruits (a) Patharnakh (b) Punjab Beauty (c) Punjab Soft

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